DEVELOPMENT OF A QAULITY OF SERVICE (QOS) POLICY FRAMEWORK FOR MOBILE BROADBAND SERVICES IN SRI LANKA

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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ABSTRACT

Development of a QoS Policy Framework for Mobile Broadband Services in Sri Lanka

Quality of Service (QoS) has become an important aspect of regulation as part of industry monitoring and consumer protection objectives. The statutory framework that exists currently in Sri Lanka for mobile broadband QoS regulation is elementary, outdated and no proper monitoring mechanism in relation to the telecommunications environment today. Therefore, the current regulations falls short of driving improvements in quality of service in the telecommunications industry, promoting investment and innovation in the provision of services, and empowering consumers to make informed decisions about the choice of services and service providers.

This research is mainly focused to identify the most suitable parameters required to measure the broadband QoS in mobile telecommunication; define target values for those parameters; define the procedures to get the measurements and define the auditing procedures for the regulator. There are few steps used to gather information for the policy framework. A survey was conducted among the professional in mobile telecommunication industry in Sri Lanka as the premier step. Then a study was done about the already implemented broadband policy frameworks in other countries. And also, it was thoroughly followed the definitions and standard introduced by ITU and ETSI.

Finally seven QoS parameters were identified which are suitable for the proposed QoS policy framework and defined their target values. The measurements for three parameters have to get from live tests and remaining four can be calculated from the network tools already used by the operators. Therefore first three measurements should be taken by the regulator and remainings should be taken by the operator and required to send them to the regulator. It is proposed to do these testings once a month and the regulator should do an audit once a quarter for each and every operator.

Keywords: *QoS, Broadband, Mobile telecommunication, Policy*

DEDICATION

To my loving wife Anusha and my little princess - daughter Sethuli

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LIST OF ABBREVIATIONS

Abbreviation	Description
3G	3rd Generation
BER	Bite Error Rate
BOI	Board of Investment
CE	Channel Element
CQI	Channel Quality Indicator
DL	Downlink
ETSI	European Telecommunications Standards Institute
GDP	Gross Domestic Product
GGSN	Gateway GPRS Support Node
HSPA	High Speed Packet Access
IMF	International Monetary Fund
Inter-RAT	Inter Radio Access Technology
IT	Information Technology
ITU	International Telecommunication Union
KPI	Key Performance Indicator
KQI	Key Quality Indicator
LAN	Local Area Network
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
NBCC	National Broadband Consultative Committee
NTA	Nepal Telecommunication Authority
PDP	Packet Data Protocol
PS	Packet Switching
QoE	Quality of Experience
QoS	Quality of Service
RAB	Radio Access Bearer
RF	Radio Frequency

RNC	Radio Network Controller
RRC	Radio Resource Control
RTWP	Received Total Wideband Power
SGSN	Serving GPRS Support Node
SINR	Signal to Interference plus Noise Ratio
SNDR	Signal to Noise plus Distortion Ratio
SNR	Signal to Noise Ratio
TRAI	Telecom Regulatory Authority of India
TRCSL	Telecommunications Regulatory Commission of Sri Lanka
UAE	United Arab Emirates
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRAN	Universal Terrestrial Radio Access Network
WCDMA	Wideband Code Division Multiple Access
WLL	Wireless Local Loop

CHAPTER 1: INTRODUCTION

1.1 Requirement of Broadband

Timely available of accurate information is an essential requirement for the socioeconomic development of a country. The development goes along with competition and people need a lot of information to decide the best option. With the development of technology people tend to use the available electronic information and requirement of information gradually increases for better decision making. Information technology tremendously contributing to maintain enormous amount of data in electronic data centres. In order to transport such information to the individuals, economical and affordable broadband connectivity should be provided. [1]

The broadband technologies can minimize the gap between urban and rural communities. For instance e-health is an electronic heath care practice which produce Telemedicine, virtual heath care teams, evidence based medicine, electronic media records and many more. Distance education using internet will provide the facility to less privileged school children in rural areas to learn with modern techniques. These are only two applications and almost all applications can use such techniques to improve the standard of service. Another important application is the working from home. According to this concept some jobs can be done from home (virtual office). It can be a solution even for the prevailing transport problem. Once a proper low cost IT infrastructure and economical broadband access technologies are implemented in Sri Lanka, all government institutions can have their own networks or a common network for the dissemination of information. This will enable the government servants and public to access the accurate information timely, get the required services and also reduce the paperwork.

1.2 History of Broadband in Sri Lanka

Telecommunication sector reforms in Sri Lanka began in 1980 with the de-linking of government owned posts and telecommunications services. From then on, the sector experienced fundamental changes with the restructuring and partial privatization of the state-owned incumbent operator; permitting market entry in the mobile telephony market; competition in the fixed wireless local loop (WLL) segment of the fixed market; and the establishment of a five-member regulatory commission with its own fund and with relatively more workable independence than a typical government department in Sri Lanka. These policy initiatives, at least up to the late 1990s, reflected a commitment on the part of policy makers to pro-competitive reforms, with Sri Lanka's telecommunication sector being seen as one of the more open among developing countries in the Asia Pacific region, with a huge potential for growth.

With the end of the civil war in 2009 Sri Lanka entered what is referred to as a 'post-conflict' phase. There were positive signs of a general improvement in the country's social and economic well-being by 2013/2014. And, although still facing challenges, the telecom sector in particular was starting to enter a new development phase. Over the past few years the Sri Lankan economy has rebounded from the difficult state it was experiencing back in 2009. The country had been hit by a balance of payments crisis in that year and needed a US$2.6 billion IMF loan to bail it out. Since then, however, the US$65 billion economy has been reporting strong economic growth – more than 7% GDP growth in 2013 - and the unemployment rate had hit a record low. The IMF forecast annual growth of 6%-7% in the short term.

The generally improving market environment has seen the country's telecom sector well positioned for continuing vigorous growth. The already modern and progressive telecommunications sector is certainly high on the list of priorities for further expansion and development. This also fits well with the government's wider agenda for national development. The government has been promoting such initiatives as the e-Sri Lanka project. It has also established the National Broadband

Consultative Committee (NBCC), a special committee appointed to accelerate and promote the availability of affordable high speed broadband internet in the country.

A good start has been made on expansion and provision of infrastructure that is capable of providing a sophisticated level of telecommunications service to the population throughout the whole country. Extending infrastructure into the North and Eastern provinces, those parts of the country most affected by the long-running war has been given high priority. It is well recognized that the growth and development of any country's telecom sector is necessary to provide, among other things, an impetus for national economic activity. Nevertheless, much still needs to be done to complete the build-out of the necessary national infrastructure. After a five-year period of strong growth the fixed-line subscriber market flattened out and then entered into a decline. Considerable uncertainty hangs over this segment of the telecom market. The widespread application of the Wireless Local Loop (WLL) platform was for some time a positive element in this struggling sector. However, even the WLL subscriber numbers are now in decline. There is also large concentration of fixed services in the capital Colombo (penetration of 35%) which makes the national figure look better than it is.

In the meantime, the country's mobile telephone services have continued on a positive growth path. As an effective and efficient alternative to the fixed-line networks, the mobile phone quickly became a popular and essential service. The Sri Lankan mobile market was still growing at an annual rate of around 50% in 2009 in as it headed towards the 60% penetration mark. However, since then subscriber growth has moderated to less than 10% per annum. The country's four competing mobile operators – Dialog Axiata, Mobitel, Etisalat Sri Lanka and Hutchison Lanka – have been joined by a fifth operator, Bharti Airtel Lanka, adding vigour to an already highly competitive market. In 2013, first Dialog and then Mobitel launched Fourth Generation (4G) LTE services in a move that effectively lifted the countries standing as a telecom market in the region.

The development of the internet remains of particular concern for Sri Lanka. In a country whose population is increasingly undeniably internet savvy and the

government rhetoric positively supporting the nation going online, the estimated user penetration remained relatively low coming into 2014. Despite signs of an enthusiastic user market, coverage and accessibility have continued to be limited and the sophistication of the available services generally low. The level of broadband access has been of particular concern. By 2013/2014, however, fixed broadband internet services were being supplemented by a rapidly expanding mobile broadband segment.

1.3 Future of Broadband in Sri Lanka

The telecommunication sector is a key element in Sri Lanka's development plans to emerge as an important regional hub in the maritime, aviation, energy, knowledge, commercial and tourism sectors. Telecommunications are therefore a vital sector that the BOI has targeted since it is central to the economy, being connected to all the other areas of economic activity. The policy of the Government of Sri Lanka is reflected in the government policy, the economic and social blueprint for the country. Facilities will be also provided to streamline the services offered by the public administration structure of the country, utilizing telecommunication and information technology. A network of infrastructure facilities will put on place to facilitate the utilization of telecommunication services and IT services.

Liberalized telecommunication market Sri Lanka has a liberalized telecommunication market which has a huge impact on economic and social development of the country. The telecommunications sector is well developed and considered by some experts as South Asia's most advanced telecom industry. This is because new technologies which offer the public a faster service have been introduced in the country and also the island is well connected by fibre optic cables. An advanced telecommunications industry is necessary for a country which is opened and indeed an integral part of the global economy. It will also help the country develop her tourism industry, impacting favourably on the future plans to achieving 2.5 million arrivals by 2015. For the BOI, telecommunications, which is

identified at present as part of the infrastructure sector, is one of the Board's most important target sectors, representing a cumulative investment of US$ 3.7 billion in 2013.

Sri Lanka's main investors in the telecommunication sector are Malaysia, the UAE, China, the Netherlands, India, Hong Kong and Singapore. Through these investments, the Sri Lankan population has benefited considerably through foreign exchange earnings, creation of new employment opportunities and also the technical how that has been brought into the country. What is clear is that thanks to their investments through the BOI, the telecommunication industry has transformed the landscape of Sri Lanka both economically and socially. In the past landlines were very difficult to obtain and the waiting list was very long, but today any private citizen has access to a mobile phone. In fact, mobile phones subscriptions represent a staggering 20 million compared to a mere 2.7 million landline subscribers.

What this really means that a significant number of citizens of Sri Lanka does own a mobile phone with which he or she can communicate or use as a tool for doing business. As a result of this high level of mobile penetration in Sri Lanka, there is an immense potential to exploit this opportunity in favour of the country's growth. When it is used by the financial sector, it saves a large amount of man hours as well as offering a secure service. At the same time mobile penetration can be used to uplift the living standards of the rural people. Through mobile applications the farmers can be educated on market price trends. This will limit the involvement of middlemen in the business and make the individual farmers more financially viable. All these automations will change the landscape of Sri Lanka and promote her as a commercial hub.

The internet has transformed our society radically and added to our lives a new dimension with seemingly endless possibilities. The number of internet users in Sri Lanka has grown rapidly since it emerged in the late 1990s. Internet penetration of the country reached 18% in 2012 (source: ITU). Though internet penetration remained less than 25%, there was a high growth in penetration level. The importance of the internet as a strategic tool is a factor in determining customer

loyalty. The information revolution which has been made possible through internet is vital to the country. No company can escape from its effects. It has changed the way business is done. It has led to creating a global village through the provision of a vast pool of information and the expansion of e-commerce. As well it may also emerge in future as the means by which Sri Lanka will bridge the technological gap. Sri Lanka can access research and knowledge from all over the world through the internet. This will create vast improvements in the efficiency of all the economic activities across a wide variety of sectors.

1.4 Research Problem

Mobile telecommunication systems by nature have finite resources. Radio spectrum and transport (backhaul) resources are limited, expensive, and shared between many users and services. Mobile broadband networks must support multiple applications of voice, video, and data on a single IP-based infrastructure. These converged services each have unique traffic handling and Quality of Experience (QoE) requirements. Such issues cannot be economically solved by overprovisioning the network. A positive user experience must be obtained through efficient partitioning of the available wireless network resources.

Quality of Service (QoS) has become an important aspect of regulation as part of industry monitoring and consumer protection objectives. Many regulatory bodies around the world ensure quality of service through appropriate regulatory instruments e.g. regulations/directives. These regulations/directives usually require operators to measure and report the quality of the services they provide, which are then accordingly published by the regulators. The latter may further set performance targets for operators.

The statutory framework that exists currently in Sri Lanka for QoS regulation is elementary and outdated in relation to the telecommunications environment today.

Ensuring compliance even within this framework has not been possible for the regulator due to the absence of a proper monitoring mechanism.

Therefore, the current regulations falls short of driving improvements in quality of service in the telecommunications industry, promoting investment and innovation in the provision of services, and empowering consumers to make informed decisions about the choice of services and service providers.

Telecommunications operators consider QoS to be very important for their competitiveness in the market. They believe that in a floor-rated market such as Sri Lanka, quality is the key to retaining their customer base. Quality improvement is a continuous exercise for the operators. However, they are concerned that there are no established QoS indicators, definitions and methods of measurement, resulting in non-uniformity in evaluation of QoS across the industry.

1.5 Objectives

"The TRCSL, in response to public opinion that HSPA services do not provide the speeds advertised, commenced a process of monitoring and found that such opinion is justified and has introduced new guidelines on advertising speeds of mobile broadband services." The above phrase is abstracted from the website of Telecommunication Regulatory Commission of Sri Lanka. This is not a bad decision but the problem is that, whether they have a policy regarding broadband speed check. Otherwise this process will not be fair for each and every operator. So in this research project, it was decided to research for a new policy framework to address these issues.

This research project describes how to develop an appropriate regulatory framework for Quality of Service for mobile broadband services. The main objective of this project is to develop a policy framework for the QoS measurement in mobile broadband in Sri Lanka. During this project, following sub objectives are also addressed;

- Identify and define the QoS parameters need to be monitored for the above policy.
- Identify the procedures how to calculate the target values for the above identified QoS parameters and define those values.
- Define the measurement methodologies which are required to measure the above QoS parameters.
- Define the methods of reporting and publication of results of those QoS parameters.
- Define mechanisms for ensuring compliance of these QoS measurements.

1.6 Scope

The scope of this project can be elaborated in following manner. This proposed policy framework is to cover the QoS parameters related to mobile broadband and it covers the end to end steps of a policy. Normally, there are few factors that should be considered under a policy framework. They can be summarized as;

- Customer service
- Network coverage
- Network availability
- Service accessibility and retainability

The technical QoS parameters are associated with service accessibility and retainability. Therefore it is planned to address only the broadband QoS parameters in mobile technology within this research project scope. But these QoS parameters are considered by covering following scenarios;

- All 5 mobile operators
- All broadband technologies used in Sri Lanka (3G and LTE)
- All the types of equipment used in Sri Lanka (Huawei, ZTE, Alcatel, Ericsson)

All the QoS parameters which are related to broadband performance are analyzed to identify the required parameters for the policy. (Ex: RRC success rate, RAB success rate, PS drop rate) Then it is required to study the policy frameworks introduced by other countries to identify these kinds of related QoS parameters which are already used. After this, the procedures should be defined which can be used to define the target values for the above identified QoS parameters and then, it is planned to define the measurement methodologies and related equations for each and every mobile broadband operator in Sri Lanka considering their equipment type.

CHAPTER 3: ANALYSIS ON STRUCTURE OF THE POLICY FRAMEWORK

3.1 Review of Quality of Service Standards in Sri Lanka

Telecommunications services in Sri Lanka are governed by the Sri Lanka Telecommunications Act No. 25 of 1991 as amended by the Sri Lanka Telecommunications Amendment Act No. 27 of 1996. Telecommunications Regulatory Commission of Sri Lanka (TRCSL) has the power to take such regulatory measures including the issue of directives as may be deemed necessary to monitor the quality of services provided by operators and to ensure that these services conform to standards relating to quality of service specified by rules made under this Act. [2]

Recent findings by the TRCSL indicate the following regarding the QoS monitoring practices of the telecommunications service providers.

- Operators consider QoS to be very important for their competitiveness in the market. They believe that in a floor-rated market such as Sri Lanka, quality is the key to retaining their customer base.
- Operators are not fully aware of the existing QoS regulatory environment.
- Operators have a large number of KPIs at the core of their operations. The KPIs are strongly linked to employee performance assessment and corresponding rewards. The KPIs are also aligned with vendor-provided tools.
- Operators engage in continuous quality improvement. They also carry out regular tests for quality monitoring as well as benchmarking themselves against competitors.
- Operators are concerned that there are no established QoS indicators and definitions for methods of measurement. Different indicators and definitions are used.

- Power supply unreliability, RF interference and administrative/social issues related to site acquisition are seen as obstructions to maintaining service quality by operators.

3.2 Quality of Service: The ITU Framework

The ITU-T's E-series Recommendations address the quality of telecommunication services as summarized in following table.

Terms and definitions related to the quality of telecommunication services	E.800 – E.809
Models for telecommunication services	E.810 – E.844
Objectives for quality of service and related concepts of telecommunication services	E.845 – E.859
Use of quality service objectives for planning of telecommunication networks	E.860 – E.879
Field data collection and evaluation on the performance of equipment, networks and services	E.880 – E.899

Table 3.1 - ITU Recommendations

(Source: ITU)

ITU-T E.800 Recommendation, QoS is defined in ITU-T E.800 as "Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service". The Quality of Experience (QoE) is defined as "The overall acceptability of an application or service, as perceived subjectively by the end-user" by ITU-T P.10/G.100. QoE is a consequence of a user's expectations, including customer support, pricing, Service Level Agreement as defined by operators, users' behavior, contents and context within which the service is experienced. QoE is affected by technical (QoS) and non-technical aspect of service. [3]

Service provided by a mobile operator can be measured by the service provider and perceived by the customer. These two views: the service providers' perspective and customers' perspective can be different and complimentary. These viewpoints are essential for the concept of QoS to be meaningful, useful and practical as illustrated in following figure. The closer the 4 viewpoints are in a given service, the better the QoS delivered. During this research project, it was getting focused only a part of this cycle.

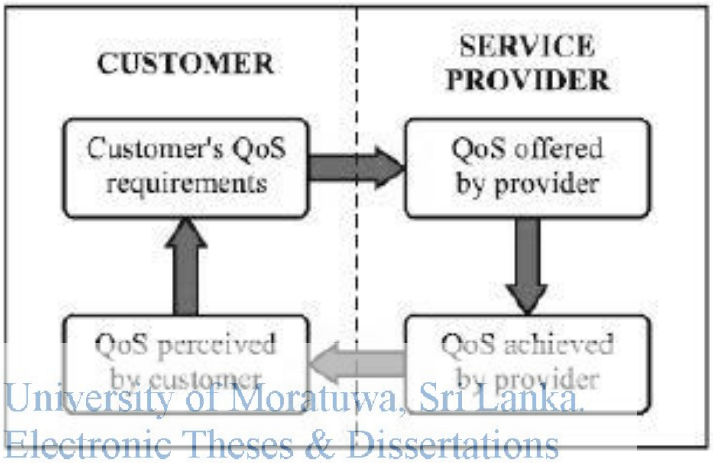

Figure 3.1- QoS cycle

They define set of guidelines to be used when introduce regulations for QoS measurements to the mobile broadband operators.

- The measurements made should be important to customers, practical for operators and comparable between operators.
- The measurements published should be accessible and helpful to customers, fair to operators.
- They should be made available in ways appropriate to the culture of the intended users.
- Any targets set should be useful to customers and realistic for operators.
- Monitoring should entail regularly examining, and understanding the basis for the measurements.

3.3 QoS and User Experience Mapping

The Quality of Experience (QoE) is defined in following manner by ITU, "The overall acceptability of an application or service, as perceived subjectively by the end-user." So this is the measurement of how well that network is satisfying the end user's requirements including the complete end-to-end system effects (client, terminal, network, services infrastructure, etc.). The QoS and QoE can be mapped according to the following diagram.

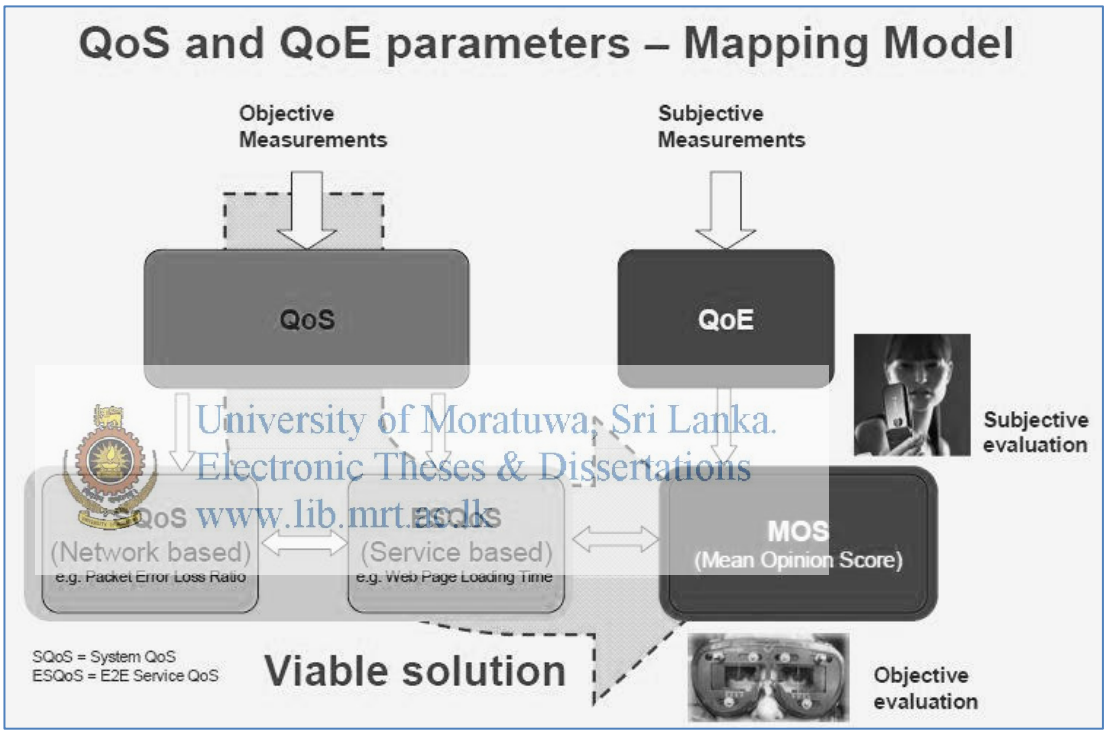

Figure 3.2- QoS and QoE mapping model

Therefore it is required to identify and maintain the QoS parameters in certain levels since they reflect the quality of the user experience. So firstly the relevant QoS parameters should be identified and then their target values should be defined. There are hundreds of QoS parameters in mobile broadband and most of them are directly related to the user experience. So it is a big task to identify how the user experience will differ according to their variations. Following table shows how some of these parameters values will be changing according to the user experience.

QoS class* (i)	Resource Type	Packet Delay Budget (PDB)[a]	Packet Error Loss Rate (PERL)[b]	Data Rate (DR)	Example Services
1	GBR	100 ms	10^{-2}	4-25 kb/s	Conversational Voice
2		150 ms	10^{-3}	32-384 kb/s	Conversational Video (Live Streaming)
3		50 ms, 250 ms	10^{-3}	60 kb/s, 30 kb/s	Real Time Gaming, Telemetry
4		300 ms	10^{-6}	20-384 kb/s	Non-Conversational Video (Buffered Streaming)
5	Non-GBR	100 ms	10^{-6}	4-13 kb/s	IMS Signalling
6		300 ms	10^{-6}	< 384 kb/s, < 128 kb/s	Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		100 ms	10^{-3}	4-13 kb/s, < 384 kb/s, < 60 kb/s	Voice, Video (Live Streaming), Interactive Gaming
8		300 ms	10^{-6}	< 384 kb/s, < 64 kb/s	Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)

Table 3.2 – Target values of QoS parameters vs. user experience

3.3 Identification and Definition of QoS Parameters

The principle of this is to first identify the different functions experienced or performed by the customers when using the communication service; then the second step is to list the criteria used by the customer to judge the quality with which each of these functions is performed. [4]

- QoS parameters should be easily understood by the public, and be useful and important to them.
- All parameters are applicable at the network termination point. Where measurements are possible, they should be made on the customer's premises, using in-service lines. They should be as realistic as possible, real traffic rather than test calls should be used as a basis of the measurements, wherever possible.

- Parameters should be capable of verification by independent organizations. This verification might be made by direct measurements or by audit of the operator's measurements.
- The accuracy of QoS parameter values should be set to a level consistent with cost effectively available measurement methods.
- The parameters are designed for both statistical and individual application. The statistical values should be derived by the application of a simple statistical function to the individual values. The statistical function should be specified in the standard. The standard should also contain guidelines on how statistically significant samples should be selected.

Once QoS parameters are identified, they should be defined in measurable terms. Each regulator could have its own definition for a particular QoS parameter. Therefore while proposing a definition of measurement for a QoS parameter, the following factors, among others, should generally be taken into consideration;

- The practicability for operators to make the required measurements
- The practicability for regulators or any independent entity to audit the results
- The measurement being made should retain the customer experience aspect

3.4 Set the Target Values

Once Quality of Service parameters have been defined in measurable terms, targets may be set. Target setting is generally the responsibility of the regulator. While setting target values, regulators generally take into consideration references that have already been worked out by standards bodies. However, there are instances of target setting by other parties such as operators, groups of operators with or without consultation with the regulator, independent organizations etc.

3.5 Get the Measurements

Measurement methodology can be looked at in two aspects; how measurements are made and who makes the measurements. The three main methods of

measurement are through Key Quality Indicators (KQIs), through live tests or through consumer surveys. These measurement methodologies are summarized in following table. [5]

Measurement method	Description
Key Quality Indicators (KQI)	• Different sets of indicators are introduced for different services after a series of public consultations. These relate to both customer service and technological issues. • These indicators make the results comparable across time periods and service providers. • To make it less prone to measurement biases, the method requires gathering of data under a specified, recurrent period.
Live Tests	• Due to the costs involved, only a few countries have adopted this for measurement of quality of mobile services and Internet connections. • For mobile services, this is done with drive tests with a custom vehicle having dedicated equipment. The vehicle adheres to a specific route, usually covering the biggest cities and most crowded travel routes.

Consumer Surveys	• This type of measurement can identify the weakest elements of service quality, and is a good method for providing feedback to operators. • This complements the indicator method. Contrasting the two sets of data can determine whether a weakness identified by consumers can also be identified by the relevant indicator data. If not, proper revision of both activities can be performed.

Table 3.3 - QoS measuring methods

Parameters may be measured either objectively via technical means such as KQIs or subjectively via surveys amongst the users. Subjective measurement is a time-consuming and expensive procedure. Therefore, objective measurements are often used where specific network related QoS parameters measured can be correlated to the user's perception of QoS.

Objective measurements are made by measuring physical attributes of circuits, networks and signals. These measurements can be made either on real traffic or on artificially generated traffic.

- **Intrusive measurement:** is performed on artificially generated traffic (such as established test calls) and the traffic can be tailored to check almost everything.
- **Non-intrusive measurement:** is performed on real traffic conditions and therefore is expected to give a more realistic vision of the QoS, however not all possibilities are checked.

Subjective measurements are used to assess aspects of QoS that cannot be measured easily by technical means or that may be missed out due to a limited

number of measurement points. They are used to assess the quality of a service with respect to audio i.e. speech and video quality, and are also used as reference for objective measurement methods.

3.6 Responsibility of Getting the Measurements

Measurements may be made by the regulator, the operators themselves or a third party. Some measurements (such as fault repair times) are best made by operators. Others are best made by external measurement agencies, because doing so makes them more comparable between different operators and sometimes, less costly. In particular, drive tests are more comparable and less costly if they are done at similar times, between similar places and in similar circumstances for all mobile operators. The merits and demerits in a general sense of each party making measurements are summarized in following table. [6]

Party making measurements	**Advantages**	**Disadvantages**
Regulator	Independent and fully under regulator control.	Requires trained and up-to-date staff, tools and expensive. Disputable by operators.
Operators	Minimum workload and costs for the regulator.	Difficult to demonstrate independence.
Third party	Independent and under regulator control. No need for regulator to maintain tools and measurement teams.	Choosing a third party can be expensive and time consuming.

Table 2.4 - QoS measuring responsibility

Calculating and allocating the costs of measurements can be contentious. Measurements can raise the costs of all operators, including those that already make similar measurements. In principle the measurements made could characterize the quality of many aspects of services for different market segments in different geographic areas. However, the costs are related to the number and variety of the

measurements made and can be reduced by concentrating on few particularly useful measurements.

Where measurements are made by an operator or are audited for an operator the costs are usually carried by the individual operator. In other cases the costs may be recovered from license fees by the regulators or from all the operators in an industry group sharing an external measurement agency, perhaps in proportion to subscriber numbers, coverage or revenue.

3.7 Audit and Publish the Measurements

The measurements submitted by operators may be independently audited for accuracy by the regulator. However, it may be inconvenient and costly to audit of all measurements. The regulator may therefore audit only part of the measurements either at random or upon complaints of accuracy. The definitions of measurements themselves, as well as the subsequent measurements, require auditing both before the definitions are implemented and thereafter. Though the definitions may be intended to be precise enough to achieve comparability, they may remain open to slightly different interpretations. Prior to auditing, the following issues need to be addressed;

- Determine the main QoS parameters to be audited for the services of interest.
- Define in details the methodology for auditing.
- Determine the sampling methodology for auditing.

Measurements from operators should be published at regular intervals by the regulators. Many of the published measurements are often unlikely to interest many potential customers, but they may help to demonstrate that the regulator is fair and open. Publishing measurements is also central to achieving some of the aims of QoS regulation.

CHAPTER 4: LITERATURE SURVEY ON EXISTING BROADBAND QOS REGULATIONS

Some of the countries are already implemented policies for broadband QoS measurements. Not only the European countries, some Asian countries are also introduced this kind of policy frameworks. During the literature survey, it was able to go through several policy frameworks of few European and Asian countries to gather the information to make a more efficient broadband QoS policy framework for Sri Lanka. Some countries have been elaborated the information related to QoS measurements thoroughly, but some countries haven't been described them deeply. Followings are some examples of broadband QoS policy frameworks introduced by several countries. [7], [8]

4.1 India

The Broadband Policy issued by the Indian Government in October, 2004 provides for fixation of the Quality of Service standards for Broadband Service by Telecom Regulatory Authority of India (TRAI). At the time of issue of the Broadband Policy, Broadband connections in India were of the order of 50,000 only. This has crossed 17 lakhs connections by August, 2006. Along with the increase in the numbers of customers, the numbers of consumer complaints pertaining to Broadband Services are also increasing. The analysis of complaints received by the Authority indicates the customers concern for fault repair, service provisioning, and network and billing related problems. To address customers' concern and to create conditions for consumer satisfaction, a need is, therefore, felt to fix the Quality of Service benchmarks for Broadband. [9]

The objective of laying down Quality of Service parameters for Broadband service is to;

- Create transparency and monitorable standards in services through predetermined Quality of Service norms for broadband which the service provider is required to provide and the user has a right to expect.

- Measure the Quality of Service for broadband provided by the service providers from time to time and to compare them with the norms so as to assess the level of performance.
- Protect the interests of consumers of Broadband service and thus enhance consumer satisfaction.

Every Cellular Mobile Telephone Service provider is required to meet the following Quality of Service benchmarks for the wireless data services in respect of each specified parameter.

Name of Parameter	**Benchmarks**	**Averaged over a period**
Service Activation /Provisioning	Within 4 hrs with 95% success rate.	One Month
Successful data transmission download attempts	>80%	One Month
Successful data transmission upload attempts	>75%	One Month
Minimum download speed	To be measured for each plan by the service provider and reported to TRAI	One Month
Average Throughput for Packet data	>75% of the subscribed speed.	One Month
Latency	Data <250ms	One Month
PDP Context Activation Success Rate	≥95%	One Month
Drop rate	≤5%	One Month

Table 3.1 - Parameter summary of Indian policy

(Source: Telecom Regulatory Authority of India)

The Authority may, from time to time, through audit and objective assessments of quality of service conducted either by its own officers or employees or through an agency appointed by it, verify or assess the performance of the service provider with respect to the Quality of Service benchmarks for the wireless data services.

Every service provider is required to maintain documented process of collection of data for each Quality of Service parameter specified by the Authority in the regulation and submit to the Authority, within thirty days of notification of these regulations, the documented process of collection of data of each Quality of Service parameter indicating the correlation with the primary data which are derived from system counters or codes in Operation and Maintenance Centre or Network Management System or Mobile Switching Centre, along with record keeping procedure.

Every service provider is required to maintain complete and accurate records of its compliance of benchmark of each Quality of Service parameter specified in the regulation in such manner and in such formats, as may be specified by the Authority from time to time by an order or direction. The Authority may, if it considers it expedient so to do, at any time, direct any of its officers or employees or an agency appointed by the Authority to inspect the records maintained under these regulations or to get such records audited. The results of the audit and objective assessment of the Quality of Service undertaken by the Authority or its authorized agency will be published through its website or through press releases or through advertisements in the newspapers, for the information of the general public.

Every service provider shall publish at its website the details of all data services, being offered by it, along with their tariff, indicating the cities and towns to which such data services and tariff plans are applicable and do not make any change in the existing data services and their tariff or offer new data services to the consumer without their prior publication at its website.

4.2 Nepal

According to the broadband policy of Nepal, quality of service refers to the ability of a network or service to satisfy the end user. So the ultimate aim of QoS regulations and enforcement is to promote consumer interests and to encourage service providers to invest in their networks for the benefit of consumers. QoS regulation and enforcement is of particular importance to Nepal because of the significant growth it has experienced in the last few years, and will most likely continue to experience, in take-up of telecommunications services by consumers, and because of the decentralized nature of Nepal, with a significant proportion of consumers living in rural or remote areas. [10]

The regulation defines key parameters of QoS which should be measured, and that the Nepal Telecommunication Authority (NTA) has set clear and achievable minimum standards for each of them. In general, these standards should be applied universally in general regulations. Finally, this guideline is circulated by the NTA for industry and general stakeholder consultation and finalization in order to ensure that it represents the best possible advice based on all possible information about the telecommunications sector in Nepal. Such an approach would be in keeping with global best practice.

Service parameter	Definition	Measurement	Benchmark
Service activation and provisioning	Activation of new data services or reactivation of existing data services.	Measured as a percentage of successful activations based on the total number of requested activations over a one-month period.	Successful acivations should be > 95% of all requested activations. Activation to occur within 4 hours of request.
Data download	Download attempts that result in the successful transmission of data.	Measured as a percentage of successful downloads based on the total number of attempted downloads over a one-month period.	Successful downloads should be > 80% of all attempted downloads.
Data upload	Upload attempts that result in the successful transmission of data.	Measured as a percentage of successful uploads based on the total number of attempted downloads over a one-month period.	Successful downloads should be > 75% of all attempted uploads.
Throughput	Throughput of [illegible]	Measured as a percentage of the subscribed network speed averaged over a one-month period.	Throughput should be > 75% of the subscribed network speed.
Data latency	The time taken for a message to be sent via an exchange to the intended terminal.	Measured as the number of milliseconds taken for the successful transmission of data to the intended terminal on average over a one-month period.	Data latency should be < 250 ms.

Table 4.2 – Parameter summary of Nepal policy

(Source: Nepal Telecommunication Authority)

For each quality of service standard that is reportable for a service, and for each reporting period, the service provider performs the following measurements, reporting and record keeping;

- To monitor the quality of telecommunication service being provided by the mobile operator and adherence to the criteria laid down in the License

and Regulations, each mobile provider shall conduct end-to-end drive tests and surveys at intervals as required by the Authority. They can procure the test instruments and equipment as and when required for the purpose.

- The tests and surveys are so designed as to give the overall as well as a detailed picture of the network, and of the Quality of Service provided by the mobile operator with fifteen days prior intimation to the Authority.
- The Authority may specify the nature and procedure of quality tests and surveys, and may issue directions in this respect, to which the mobile operator shall comply. The mobile operator is required to furnish the results of the quality tests and surveys to the Authority, for each quarter, in such form and manner as the Authority may specify, provided that the information for the applicable quarter is submitted by the operator within thirty days after the close of the reporting quarter.

The Authority conducts inspections, surveys and tests, or carries out surprise checks, through its designated officers, or conduct performance audits for Quality of Service of the operator from time to time, to ensure that users of telecommunications services get such Quality of Service standards as laid down in these Regulations and the License. The inspections may be carried out with or without a representative of the operator. The mobile operator should extend full co-operation and provide all assistance to the inspecting officers in carrying out the tests and surveys, including provision of test instruments, technical support and should make available network management system and records, whether electronic or manual or both, whenever required by such officers. The Authority may engage, if circumstances so require, third parties or consultants to conduct quality of service auditing. The inspecting officer prepares an inspection report for the quality of service inspection, also comprising the shortfalls, if any, observed during such inspection. The operator should immediately take all remedial measures to remove the shortfalls identified in the inspection report and shall submit a compliance report within thirty days of the issuance of the inspection report, in confirmation that all stated shortfall have been removed, provided that the Authority has provided the opportunity to remove the shortfalls identified in the inspection report for the same city.

4.3 Singapore

According to the broadband QoS regulations in Singapore, they mainly consider three parameters; network availability, bandwidth utilization and network latency. They define them according to the following equations.

$$\text{Network Availability} = \frac{(\text{Up time} - \text{Down time}) \times 100\%}{\text{Up time}}$$

The target value for this parameter is; should be more than 99%.

$$\text{Bandwidth Utilisation} = \frac{\text{Peak utilisation} \times 100\%}{\text{Available bandwidth}}$$

The target value for this parameter is; should be less than 90%. If it exceeds 90% for 3 consecutive months, the provider needs to expand.

Network Latency: Round Trip Time (RTT) taken by packets to reach a given destination and return. The target values are 85ms for local network latency and 300ms for international network latency.

Parameter	Singapore
Network Availability	> 99%
Latency (Local)	< 85ms
Latency (Intl)	< 300ms
Bandwidth Utilisation	90% during peak time
Broadband Connection Speed (download)	Not Specified
Service Activation	Not Specified
Customer Support	Not Specified

Table 4.3 - Parameter summary of Singapore policy

(Source: Infocomm Development Authority of Singapore)

CHAPTER 5: METHODOLOGY

There should be a clear mechanism to gather the information required for any kind of policy framework. In this research project, it was required to consider few subcategories as mentioned in the earlier chapters. The first point is to identify the most suitable parameters required to measure the broadband QoS in mobile telecommunication. Then the second subcategory is to define target values for those parameters. After that, define the procedures to get the measurements. Finally, define the auditing procedures for the regulator.

5.1 Research Methodology

Research is a process of collecting, analyzing and interpreting information to answer questions. Data Collection is an important aspect of any type of research study. Inaccurate data collection can impact the results of a study and ultimately lead to invalid results. A formal data collection process is necessary as it ensures that data gathered are both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid. Generally there are three types of data collection and they are;

1. Surveys: Standardized paper-and-pencil or phone questionnaires that ask predetermined questions.

2. Interviews: Structured or unstructured one-on-one directed conversations with key individuals or leaders in a community.

3. Focus groups: Structured interviews with small groups of like individuals using standardized questions, follow-up questions, and exploration of other topics that arise to better understand participants.

It was chosen the first method to gather the data for the research. The methods involved in survey data collection are any of a number of ways in which data can be collected for a statistical survey. The important factors to be considered in this kind of surveys are;

1. Selecting a correct sample of resource persons to give the set of questions
2. Define the correct set of questions

After gathering all the required data, it is possible to analyze them and come to a conclusion. Finally I include those results to the proposed policy framework and finalize it with clear procedures.

5.2 Select the Resource Persons to Produce the Set of Questions

It is very important to select a correct set of resource persons to produce the predefined set of questions. Therefore I took every possible action to choose them by covering the almost all part of the mobile telecommunication industry. The sample of resource persons can be categorized in to two major groups.

1. Professionals from the mobile telecommunication industry
2. Professionals from the broadband equipment vendors

Summary of the sample group can be shown by the following table.

Company/ Institute	Type of business
Mobitel (Pvt) Ltd	Operator
Dialog Axiata PLC	Operator
Etisalat Lanka (Pvt) Ltd	Operator
Huawei Technologies Lanka Co.,(Pvt) Ltd	Equipment vendor
ZTE Lanka (Pvt) Ltd	Equipment vendor
Ericsson Telecommunications Lanka (Pvt) Ltd	Equipment vendor
Alcatel-Lucent	Equipment vendor

Table 5.1 - Survey sample

5.3 Define the Set of Questions

A set of questions were prepared to give to above mentioned professionals to get their ideas and that was covered the all required fields wanted to fulfill the data collection. The set of questions can be listed as following;

1. What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?
2. What are the target values you propose for the above mentioned parameters?
3. Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.
4. What are the parties you propose to measure those QoS parameters?
5. How frequently should an audit be carried out by TRCSL?
6. Do you have any other suggestions or comments?

CHAPTER 6: RESULTS AND ANALYSIS

6.1 Results

The next step of this research is to summarize and analyze the results obtained through the survey and convert those data to valuable information. The one of the main thing that I want to find out from the survey is to identify the QoS parameters which should include to the policy framework to measure the broadband quality. Therefore the suggested QoS parameters can be summarized in following manner.

1. Download Speed
2. Latency
3. Average Throughput
4. Service Availability
5. PS Service Drop Rate
6. Handover Success Rate (Soft handover/ Inter-frequency handover/ Inter-RAT handover)
7. PS RAB Setup Success Rate
8. RRC Connection Setup Success Rate
9. RTWP
10. Utilization (Power/ CE/ IUB/ Code)
11. Web Page Loading Time
12. PDP Context Activation Success Rate
13. CQI Average
14. Jitter
15. BER

Then it is required to choose the most suitable QoS parameters for the broadband quality measurements. Because when we analyze the above mentioned parameters; it is possible to understand that some parameters are covered by another parameter. Another important thing is that, as we mentioned in an earlier chapter, those selected parameters should fulfill the following requirements.

- QoS parameters should be easily understood by the public, and be useful and important to them.
- All parameters are applicable at the network termination point. Where measurements are possible, they should be made on the customer's premises, using in-service lines. They should be as realistic as possible, real traffic rather than test calls should be used as a basis of the measurements, wherever possible.
- Parameters should be capable of verification by independent organizations. This verification might be made by direct measurements or by audit of the operator's measurements.
- The accuracy of QoS parameter values should be set to a level consistent with cost effectively available measurement methods.
- The parameters are designed for both statistical and individual application. The statistical values should be derived by the application of a simple statistical function to the individual values. The statistical function should be specified in the standard. The standard should also contain guidelines on how statistically significant samples should be selected.

So we have to deeply analyze the above mentioned QoS parameters to check whether they satisfy the required conditions.

1. Download Speed

This parameter can be measured on a sample basis by the user and service provider. The service providers need to install download speed measurement software in the Server at ISP Node to facilitate the user to measure independently the download connection speed through a web link.

2. Latency

Latency is the amount of time taken by a packet to reach the receiving endpoint after being transmitted from the sending point. This time period is termed the "end-to-end delay" occurring along the transmission path. Latency

generally refers to network conditions, such as congestion, that may affect the overall time required for transit.

3. Average Throughput

It is defined as the rate at which packets are transmitted in a network. In a mobile network the download speed varies depending on the number of users in a particular location. Even though a service provider may be advertising certain speed, the actual speed may vary as per the number of users in the network and there could be customer dissatisfaction on account of relatively slow speed. Hence, there is a need to prescribe an average throughput to protect the interest of consumers. The service providers need to constantly upgrade their network to meet average throughput benchmark.

4. Service Availability

Service availability/ uptime is the measure of the degree to which the broadband access network including ISP Node is operable and not in a state of failure or outage at any point of time for all users. It also includes the upstream connectivity uptime. Therefore, it measures the total downtime of the network for all users, including the LAN Switches, Routers, Servers, e-mail facilities etc at ISP Node and connectivity to upstream service providers.

5. PS Service Drop Rate

It measures the inability of Network to maintain a connection and is defined as the ratio of abnormal disconnects with respect to all disconnects (both normal and abnormal). An abnormal disconnect may happen because of Radio Link Failures, Uplink (UL) or Downlink (DL) interference, bad coverage, unsuccessful handovers or any other reason. The drop rate is to be measured for all generations of the technologies separately.

6. Handover Success Rate (Soft handover/ Inter-frequency handover/ Inter-RAT handover)

Handover concept is an essential for the mobile telecommunication since the data session connectivity depends on this parameter. In the broadband context, there are three major types of handovers are there. The first one is the soft handover which is related to the handovers occurred between cells which are operated in same frequency. The second type of handover is inter-frequency handovers and the third one is the handover between different technologies. The Successful Soft Handover procedure is complete when the RNC receives an ACTIVE SET UPDATE COMPLETE message from the UE during the soft handover procedure. The attempt procedure is complete when the RNC sends an ACTIVE SET UPDATE message to the UE. The PS Inter-RAT Outgoing Handover successes procedure is complete when the RNC sends the RANAP IU RELEASE COMPLETE message after receiving the IU RELEASE COMMAND message with the cause of "Successful Relocation", "Normal Release" or "Network Optimization." In this case, the PS outgoing inter-RAT handover succeeds.

7. PS RAB Setup Success Rate

The PS RAB Setup Attempt Procedure is complete when the RNC receives an RAB ASSIGNMENT REQUEST message from the SGSN in the PS domain; the message contains information about one of the following service types: Conversational services, Streaming services, Interactive Services, Background Services. The PS RAB Setup Success Procedure starts when the RNC receives a RADIO BEARER SETUP COMPLETE message from the UE. This procedure is complete when the RNC sends an RAB ASSIGNMENT RESPONSE message to the SGSN in the PS domain.

8. RRC Connection Setup Success Rate

The RRC Connection Attempt for service Procedure is complete when the RNC receives an RRC CONNECTION REQUEST message from the UE. The

message contains information about one of the following service types requested by the UE: Conversational Call, Streaming Call, Background Call, Interactive Call, Originating Subscribed Traffic Call, Emergency Call, High Priority Signaling, Low Priority Signaling, Cause Unknown, Call Re-Establishment. The RRC Setup Success for Service Procedure is complete when the RNC receives an RRC CONNECTION SETUP COMPLETE message from the UE.

9. RTWP

RTWP represents a measure of UMTS technology: the total level of noise within the UMTS frequency band of any cell. RTWP is related to uplink interference and it has importance in the capacity management, as it provides information for the Congestion Control regarding Uplink Interference. In UMTS, the uplink interference may vary due to several factors, such as the number of users in the cell, the Service, Connection Types and Conditions of Radio, etc..

10. Utilization (Power/ CE/ IUB/ Code)

The resource utilization is also an important factor in broadband quality measurement. The man resource types in broadband are Power, Channel Element, Transmission resources and Code.

11. Web Page Loading Time

The time consumed to load a web page is also a proposed QoS parameter to use to measure the broadband quality.

12. PDP Context Activation Success Rate

A Packet Data Protocol (PDP) context specifies access to an external packet-switching network. The data associated with the PDP context contains information such as the type of packet-switching network, the Mobile Station PDP (MS PDP) address that is the IP address, the reference of Gateway GPRS Support Node (GGSN), and the requested QoS. A PDP context is handled by the MS, Serving GPRS Support Node (SGSN) and GGSN and is identified by a

mobile's PDP address within these entities. Several PDP contexts can be activated at the same time within a given MS.

13. CQI Average

CQI stands for Channel Quality Indicator. As the name implies, it is an indicator carrying the information on how good/bad the communication channel quality is. CQI is the information that UE sends to the network and practically it implies the following two

i) Current Communication Channel Quality
ii) UE wants to get the data with this-and-that transport block size, which in turn can be directly converted into throughput

In HSDPA, the CQI value ranges from 0 ~ 30. 30 indicates the best channel quality and 0, 1 indicates the poorest channel quality. Depending which value UE reports, network transmit data with different transport block size. If network gets high CQI value from UE, it transmits the data with larger transport block size and vice versa. What if network sends a large transport block even though UE reports low CQI, it is highly probable that UE failed to decode it (cause CRC error on UE side) and UE send NACK to network and the network have to retransmit it which in turn cause waste of radio resources. What if UE report high CQI even when the real channel quality is poor ? In this case, network would send a large transport block size according to the CQI value and it would become highly probable that UE failed to decode it (cause CRC error on UE side) and UE send NACK to network and the network have to retransmit it which in turn cause waste of radio resources. How UE can measure CQI ? This is the most unclear topic. As far as I know, there is no explicit description in any standard on the mechanism by which the CQI is calculated, but it is pretty obvious that the following factors play important roles to CQI measurement.

i) signal-to-noise ratio (SNR)
ii) signal-to-interference plus noise ratio (SINR)
iii) signal-to-noise plus distortion ratio (SNDR)

14. Jitter

Packet Jitter is the variation in the delay of received packets. At the sender they are sent evenly spaced intervals, but due to traffic congestion, improper queuing or configuration errors they come at unequal intervals.

15. BER

In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent. A BERT (bit error rate test or tester) is a procedure or device that measures the BER for a given transmission.

6.2 Analysis on Selecting QoS Parameters

After analyzed all the suggested QoS parameters, now it is required to finalize the list of QoS parameters which are going to include the policy framework. The first QoS parameter is Download Speed and it is highly subscriber concerned parameter and it should include to our policy framework. Because almost all the broadband subscribers are expected to have a good data speed to their connection. And also other countries are already used this parameter as one of their QoS parameter which is used to measure the broadband service quality. Even though a service provider may be advertising certain speed, the actual speed may vary as per the number of users in the network and there could be customer dissatisfaction on account of relatively slow speed. Hence, there is a need to prescribe an average throughput to protect the interest of consumers. Therefore Average Throughput should also to include to the proposed policy framework.

The second QoS parameter mentioned in the above list is Latency. This parameter is also very useful to measure the user experience in broadband services since round trip time is directly connected to the quality of the broadband service. The fourth QoS parameter is service availability and this is one of the main parameter can be used to measure the availability of the network resources. But it is better to pass this parameter to another category since here it is possible to consider only the QoS parameters for this policy. [11]

The next parameter is PS Drop Rate, which is the main parameter related to the retainability. This parameter can be measured from the tools which are used by the mobile network operators. Therefore it is required to include this parameter to our policy framework. The next parameter is Handover Success Rate and it is mainly contributed to the network performance related to the mobility. Even though this parameter is a very important one, it is not directly affect to the customer's experience. Because the actual effect of handover failures are related to the performance if the download/ upload speed is decreased or data session is dropped. But those factors are already captured under data download/ upload speed testings and PS service drop rate parameters. Therefore it is not required to include handover success rate to this parameter list. Another parameter suggested was PS RAB setup success rate; and it is much related QoS parameter under network accessibility. The purpose of a Radio Access Bearer is to provide a connection segment using the WCDMA Radio Access Network for support of a UMTS bearer service. The WCDMA RAN can provide Radio Access Bearer connections with different characteristics in order to match requirements for different UMTS bearers. So its setup success rate is also very prominent factor in broadband performance monitoring. [12]

Another QoS parameter related to the network accessibility is RRC connection setup success rate. During the connection establishment procedure, the WCDMA RRC configures the layers Layer-1 and Layer-2 using the parameters received from the UTRAN network. Once the configuration is complete the RRC of the UE initiate the RLC signaling link. Once the RRC connection establishment is successful, the signaling connection establishment will be resumed. Once the signaling connection is

established there will be higher layer peer-to-peer signaling data transfer.The UE enters connected mode once the WCDMA RRC connection is established. Within the connected mode the level of UE connection to UTRAN will be determined by the QoS requirements of the active radio access bearers and the characteristics of the traffic on those bearers. Mainly the RRC connection set up success rate and RAB setup success rate are correlated with the network accessibility. Since this is very important factor for broadband, it is required to include this parameter also to the policy framework.

The next parameter is RTWP level. RTWP is the total level of noise within the UMTS frequency band of any cell. It is related to uplink interference and because of uplink interference the data session disconnections, data speed reductions can be happened. Again since we have included the data speed measurements and connection drops to our parameter list, it is possible to eliminate RTWP level from this list. Another suggested parameter is utilization and it also will address under data speed measurements. Therefore there is no requirement to include RTWP parameter to this list since the data speed is there. In addition to that it is very difficult to define target values for this kind of parameters, because it depends upon the number of users attached. Therefore it is not suitable to include this kind of parameters to a policy framework to measure the broadband quality. Web page loading time is our next parameter which was proposed through the survey, but since we are going to include latency, there is no additional requirement to include this parameter to the proposed QoS parameter list. [13]

The next QoS parameter is PDP context activation success rate. The PDP addresses are network layer addresses and GPRS systems support both X.25 and IP network layer protocols. Therefore, PDP addresses can be X.25, IP, or both. Each PDP address is anchored at a Gateway GPRS Support Node (GGSN) and all packet data traffic sent from the public packet data network for the PDP address goes through the gateway (GGSN). The public packet data network is only concerned that the address belongs to a specific GGSN. The GGSN hides the mobility of the station from the rest of the packet data network and from computers connected to the public packet data network. Statically assigned PDP addresses are usually anchored at a

GGSN in the subscriber's home network. Conversely, dynamically assigned PDP addresses can be anchored either in the subscriber's home network or the network that the user is visiting. When a MS is already attached to a SGSN and it is about to transfer data, it must activate a PDP address. Activating a PDP address establishes an association between the current SGSN of mobile device and the GGSN that anchors the PDP address. The record kept by the SGSN and the GGSN regarding this association is called the PDP context. It is important to understand the difference between a MS attaching to a SGSN and a MS activating a PDP address. A single MS attaches to only one SGSN, however, it may have multiple PDP addresses that are all active at the same time. Each of the addresses may be anchored to a different GGSN. If packets arrive from the public packet data network at a GGSN for a specific PDP address and the GGSN does not have an active PDP context corresponding to that address, it may simply discard the packets. Conversely, the GGSN may attempt to activate a PDP context with a MS if the address is statically assigned to a particular mobile device. So this parameter is one of the essential parameter which is required to include this policy framework.

Another suggested parameter is CQI average. Channel quality information (CQI), respectively, tells the base station scheduler the data rate the terminal expects to be able to receive at a given point in time. The CQI value that the terminal reports does not just correspond to the Ec/N0 or the signal to interference ratio (SIR) the terminal is experiencing. When the terminal is close to the base station and assumes high HS-DSCH power allocation (based on the value given by the network), a high CQI value is reported. Respectively, when the terminal is closer to the cell edge (the lowest curve) then the reported CQI is much lower, especially if the expected HSDPA Node B power allocation is low as well. When at or close to the cell edge; most of the interference comes from other cells. So the CQI average is also related to the data speed and no need to include it again to the parameter list. [14]

The last two suggested QoS parameters are jitter and BER. Jitter is the variation in latency as measured in the variability over time of the packet latency across a network. A network with constant latency has no variation. The jitter is expressed as an average of the deviation from the network mean latency. But unfortunately there

is no proper method to measure the network jitter. Currently network operators measure jitter only between two nodes. But it is not recommended to insert this parameter for policy since we don't have a well-defined measuring method. The last parameter is BER and it also has a link between the broadband experience. But there is no any clear method to measure the BER. Hence it is not suitable to include to a policy framework. Therefore finally we can list down the selected QoS parameters for policy framework through the survey done among the mobile network experts in following manner.

1. Download Speed
2. Latency
3. Average Throughput
4. PS Service Drop Rate
5. PS RAB Setup Success Rate
6. RRC Connection Setup Success Rate
7. PDP Context Activation Success Rate

6.3 Analysis on Defining Target Values for QoS Parameters

The next step is to define the target values for the above selected QoS parameters. First of all we'll define target values for Download Speed and Average Throughput. There are three main resources which can be used to get help for the process of defining the target values for above two QoS parameters.

1. Proposed values by the network experts through the survey
2. The advertise speeds by the network operators
3. The target values defined in other countries' policy frameworks

The proposed target values through the survey can be summarized in following way. The network experts have suggested average throughput should be between 600kbps and 15Mbps. But majority of them suggested a value around 2Mbps. For the upload data speed, they have suggested values between 300kbps and 2Mbps. When we check the advertised data speeds by the operators, it is like this. Airtel has

advertised their download data speed is possible up to 3.6Mbps. Dialog has advertised their download data speed as speed up to 7.2Mbps and Mobitel and Etisalat also advertise the same value. Hutch has advertised their download data speed is possible up to 3.6Mbps. In other countries, they have defined a percentage value of the operators' advertised data speed. For an example Indian has defined it as average throughput should be greater than 75% of the advertised data speed.

The following diagrams show the 3G and LTE data speed test results collected from speedtest.net web site. These results are made according to the data speed measurements of the subscribers who use this web site to check the data speeds. The following figure shows the data speeds of all five operators for 3G download from November, 2014 to May, 2015.

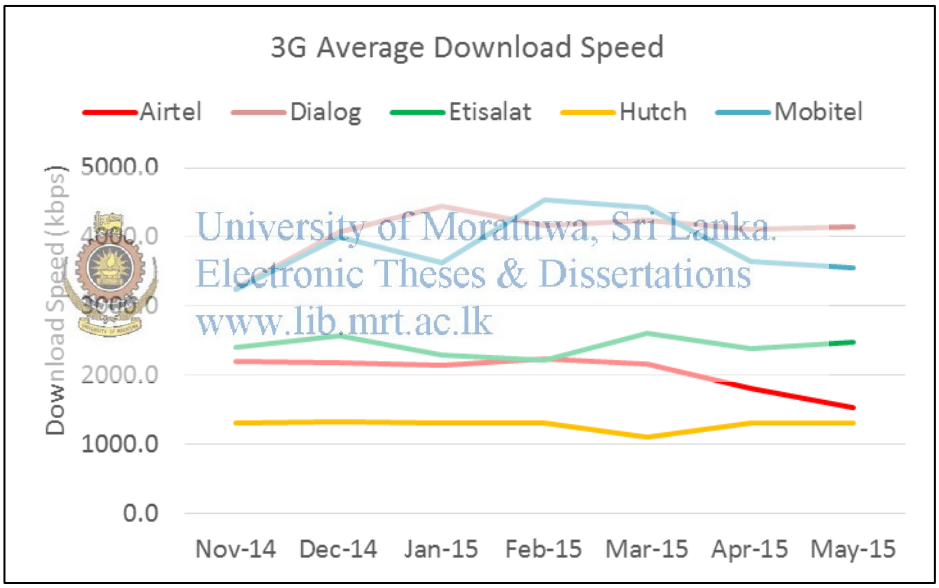

Figure 6.1 - 3G download data speed results of speedtest.net

Then it is necessary to check the 3G upload speeds for all five operators during earlier mentioned time period.

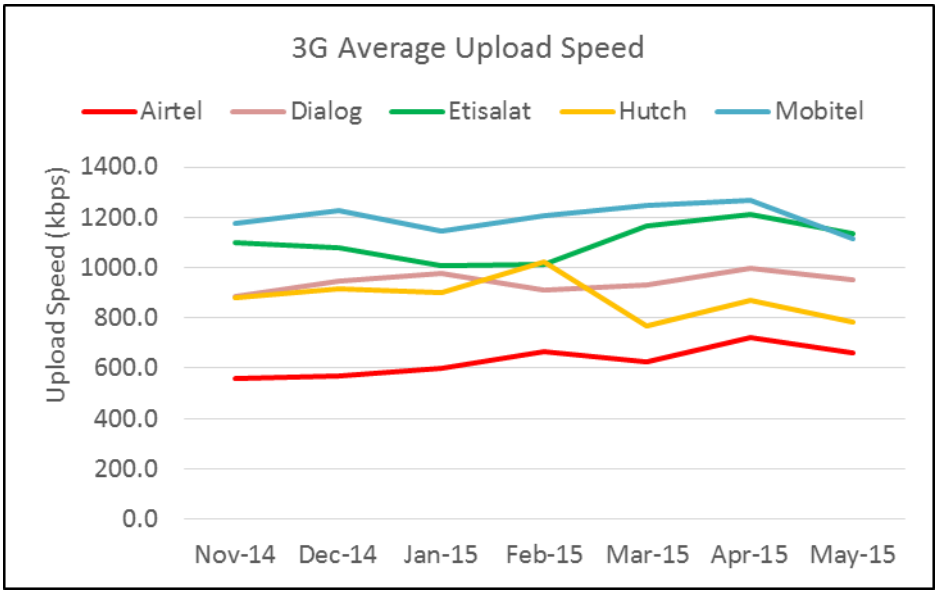

Figure 6.2 - 3G upload data speed results of speedtest.net

All above results are for 3G networks and different operators are used different technologies. But all of them are currently using a technology higher than HSPA. The theoretical download speed for HSPA is 7.2 Mbps and HSPA+ with Dual Carrier has a theoretical download speed of 42Mbps. From analyzing the all above criterias and facts mentioned above, the suggestion is the average throughput for this policy framework should be 2Mbps for 3G networks.

But when considering about LTE, the data speed is mainly depends on the bandwidth used for LTE and MIMO type used. As mentioned above, the test results obtained from speedtest.net web site can be displayed according to following diagram.

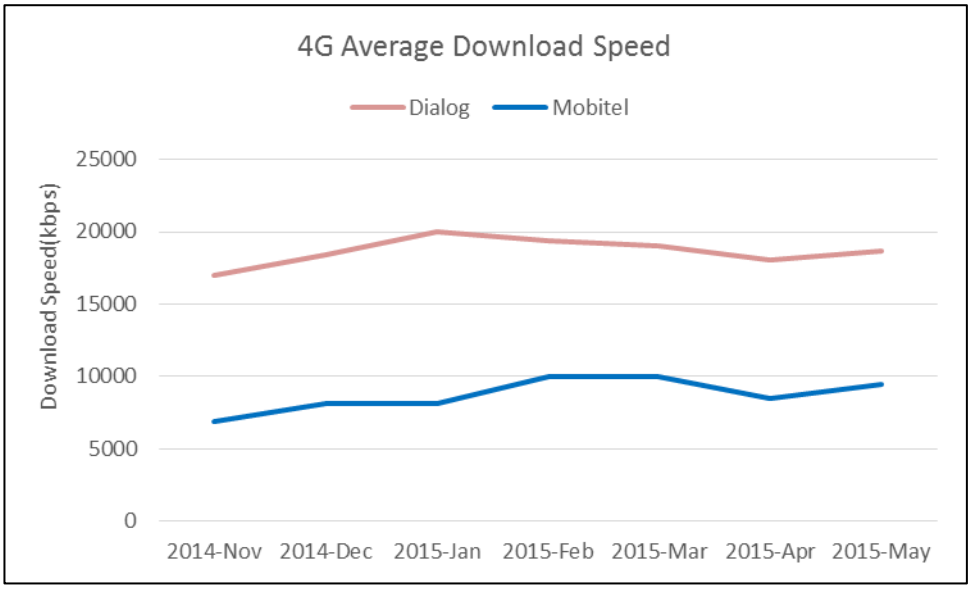

Figure 6.3 - LTE download data speed results of speedtest.net

The theoretical download data speed for LTE from 5MHz with 2x2 MIMO is 22Mbps. Since TRCSL is still not auctioned the free frequency bands, it is not ethical to define the bandwidth limit which should be used for LTE. Therefore the final suggestion is to use 5Mbps as the target value for average throughput for LTE networks. [15]

For this parameter TRCSL should done a test to download a test file from a local server and an international server. The test procedure will be discussed in next few subsections of this chapter. But one additional condition is applied for this testing. It is the signal level in 3G or LTE should be better than -90dBm. This value is already defined by the TRCSL. Then the download speed of the test should be published and there is no any threshold for the speed.

The next selected QoS parameter is Latency. According to the survey carried out, they have suggested the value from 50ms to 200ms for the latency and other countries which are already implemented the QoS policy frameworks have defined this value as should be less than 250ms. Therefore the proposed value is the latency should be less than 200ms. The next QoS parameter is PS Service Drop Rate. Normally all the operators in Sri Lanka consider this parameter as a basic KPI

parameter in broadband and try their best to keep in a very low level. But when we define a target value for this kind of parameter;

1. It should be an achievable target
2. It should fair value for all operators

Therefore the suggested target value should be taken through the survey. The network experts, who participated for the survey, had suggested the target value should be between 1% and 5%. So the proposed value for PS service drop rate should be less than 5%. Then we have to consider the PS RAB Setup Success Rate and RRC Connection Setup Success Rate. When consider the target values proposed by the survey, the final values can be defined as PS RAB setup success rate should be greater than 95% and RRC Connection Setup Success Rate should be greater than 95%.

Another very important QoS parameter which is included to the policy framework is PDP Context Activation Success Rate. India has defined the target value as 95% and every operator should maintain this success rate greater than the threshold value. In our survey also the proposed value for this QoS parameter is 95%. Finally we can summarize the target values for the proposed QoS parameters in following manner.

No.	QoS Parameter	Target Value
1	Download Speed	Test results
2	Latency	Less than 200ms
3	Average Throughput	2Mbps(3G)/5Mbps(LTE)
4	PS Service Drop Rate	Less than 5%
5	PS RAB Setup Success Rate	Greater than 95%
6	RRC Connection Setup Success Rate	Greater than 95%
7	PDP Context Activation Success Rate	Greater than 95%

Table 6.1 - Proposed target values

6.4 ETSI Recommendations on Selected QoS Parameters

ETSI is an international body who supports for defining the standards for different fields. Therefore it is better to check the definitions made by ETSI for the above mentioned QoS parameters. Since first three parameters are related to field testings, it is required only to consider the last four parameters. So the fourth selected QoS parameter is PS service drop rate. In ETSI standards it is defined as RAB abnormal release rate. This KPI describes the ratio of number of RAB release requests to number of the successful RAB establishments and it reflects service retainability across UTRAN. This KPI is obtained by the number of RAB release requests divided by the number of successful RAB establishments. ETSI has defined this parameter for both CS and PS to calculate the overall service drop rate. [16]

$$RARR = 1 - \frac{\begin{array}{l} RAB.RelReqCS.sum + \sum_{cell/RNC} RAB.NbrIuRelReqCS.sum + \\ RAB.RelReqPS.sum + \sum_{cell/RNC} RAB.NbrIuRelReqPS.sum \end{array}}{\sum_{type} \left\{ \begin{array}{l} RAB.SuccEstabCSNoQueuing.[type] + \\ RAB.SuccEstabCSQueuing.[type] + \\ RAB.SuccEstabPSNoQueuing.[type] + \\ RAB.SuccEstabPSQueuing.[type] \end{array} \right\}}$$

type∈{Conv, Strm, Intact, Bgrd}

CS:

- RAB.SuccEstabCSNoQueuing.Conv
- RAB.SuccEstabCSNoQueuing.Strm
- RAB.SuccEstabCSNoQueuing.Intact
- RAB.SuccEstabCSNoQueuing.Bgrd
- RAB.SuccEstabCSQueuing.Conv
- RAB.SuccEstabCSQueuing.Strm
- RAB.SuccEstabCSQueuing.Intact
- RAB.SuccEstabCSQueuing.Bgrd
- RAB.RelReqCS.sum

- RAB.NbrIuRelReqCS.sum

PS:

- RAB.SuccEstabPSNoQueuing.Conv
- RAB.SuccEstabPSNoQueuing.Strm
- RAB.SuccEstabPSNoQueuing.Intact
- RAB.SuccEstabPSNoQueuing.Bgrd
- RAB.SuccEstabPSQueuing.Conv
- RAB.SuccEstabPSQueuing.Strm
- RAB.SuccEstabPSQueuing.Intact
- RAB.SuccEstabPSQueuing.Bgrd
- RAB.RelReqPS.sum
- RAB.NbrIuRelReqPS.sum

Therefore it is required to remove the CS compositions of above equation to calculate the PS service drop rate.

The next parameter is PS RAB setup success rate. This KPI describes the ratio of all successful RAB establishments to RAB establishment attempts for UTRAN network and is used to evaluate service accessibility across UTRAN. This KPI is obtained by the number of all successful RAB establishments divided by the total number of attempted RAB establishments.

$$RabEstabSR = \frac{\sum_{type}\left\{\begin{array}{l} RAB.SuccEstabCSNoQueuing.[type] + \\ RAB.SuccEstabCSQueuing.[type] + \\ RAB.SuccEstabPSNoQueuing.[type] + \\ RAB.SuccEstabPSQueuing.[type] \end{array}\right\}}{\sum_{type} RAB.AttEstabCS.[type] + RAB.AttEstabPS.[type]}$$

type∈{Conv, Strm, Intact, Bgrd}

CS:

- RAB.AttEstabCS.Conv

- RAB.AttEstabCS.Strm
- RAB.AttEstabCS.Intact
- RAB.AttEstabCS.Bgrd
- RAB.SuccEstabCSNoQueuing.Conv
- RAB.SuccEstabCSQueuing.Conv
- RAB.SuccEstabCSNoQueuing.Strm
- RAB.SuccEstabCSQueuing.Strm
- RAB.SuccEstabCSNoQueuing.Intact
- RAB.SuccEstabCSQueuing.Intact
- RAB.SuccEstabCSNoQueuing.Bgrd
- RAB.SuccEstabCSQueuing.Bgrd

PS:

- RAB.AttEstabPS.Conv
- RAB.AttEstabPS.Strm
- RAB.AttEstabPS.Intact
- RAB.AttEstabPS.Bgrd
- RAB.SuccEstabPSNoQueuing.Conv
- RAB.SuccEstabPSQueuing.Conv
- RAB.SuccEstabPSNoQueuing.Strm
- RAB.SuccEstabPSQueuing.Strm
- RAB.SuccEstabPSNoQueuing.Intact
- RAB.SuccEstabPSQueuing.Intact
- RAB.SuccEstabPSNoQueuing.Bgrd
- RAB.SuccEstabPSQueuing.Bgrd

Here also, ETSI has defined this parameter for both CS and PS to calculate the overall service drop rate and it is required to remove CS compositions from the above equations to calculate the RAB setup success rate.

The next QoS parameter is RRC connections establishment success rate. This KPI describes the ratio of all successful RRC establishments to RRC establishment

attempts for UTRAN network, and is used to evaluate UTRAN and RNC or cell admission capacity for UE and/or system load. This KPI is obtained by the number of all successful RRC establishments divided by the total number of attempted RRC establishments. The equation is for this parameter is defined as follows.

$$RrcEstabSR = \frac{\sum_{cause} RRC.SuccConnEstab.[cause]}{\sum_{cause} RRC.AttConnEstab.[cause]}$$

The next QoS parameter is PDP context activation success rate. This KPI describes the ratio of the number of successfully performed PDP context activation procedures to the number of attempted PDP context activation procedures for UMTS PS core network and is used to evaluate service accessibility provided by UMTS and network performance to provide GPRS. This KPI is obtained by successful PDP context activation procedures initiated by MS divided by attempted PDP context activation procedures initiated by MS.

$$UPDPCASR = \frac{\sum_{sgsn} SM.SuccActPdpContext}{\sum_{sgsn} SM.AttActPdpContext}$$

So the next step is to define the QoS parameters which are already selected for mobile broadband QoS measurements by using the above ETSI definitions.

6.5 Analysis on Getting Measurements of QoS Parameters

In Chapter 03, we have discussed all the steps of a policy framework required to follow. The first step is to identify the most suitable QoS parameters which have to be selected for the policy framework. Therefore we have selected seven parameters as discussed earlier in this chapter. The next step is to identify the target values for the above parameters. This step is also completed defining the target values by using the survey results. The third step is to

The first parameter is Download Speed and the method we have to use to get the measurements is doing a live test. The Average Throughput and Latency also can be measured from this test. The test location can be selected by TRCSL, but the only condition is that the target values can be achieved if the signal level is better than -90dBm. The measurement setup to be used to conduct testings for measuring download data speed, average throughput and latency is given in following figure. The basic measurement set-up consists of a Test-Device and a Test-Server with specified software and hardware. Test data sessions have to be established between the Test-Device and Test-Server and measurements must be made for the respective QoS parameters. These parameters shall be measured in a stationary mode. To assess the quality of the connection between an end user and an Internet Service Provider (ISP), ideally the Test-Server should be placed as near as possible to the gateway providing the interconnection between access network and ISP network. The location of the test-server as near as possible to the gateway providing the interconnection between access network and ISP network implies that the measurements will not reflect the influence in the QoS of the ISP network, between that gateway and the gateway interconnecting with the Internet.

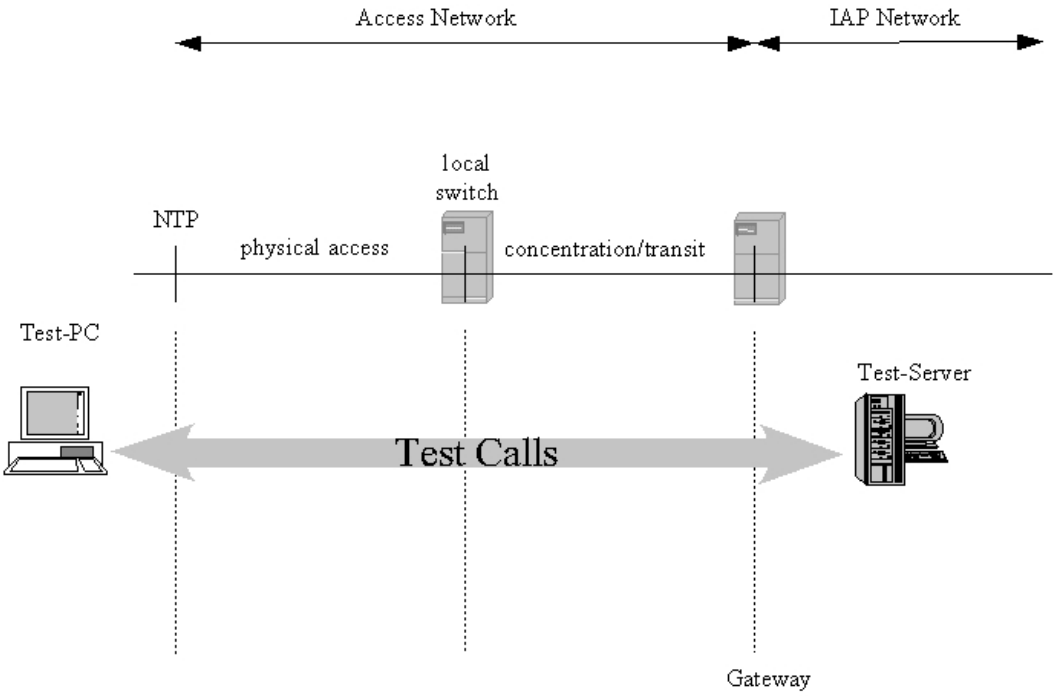

Figure 6.4 - Testing methods

(Source: Telecom Regulatory Authority of India)

For all tests, a dedicated test server should be used as a well-defined reference. The test server may be located centrally for all the licensed service areas (LSA). Under no circumstances a commercial server (e.g.www.google.com) should be used, since the test conditions for such a server may change over time making later reproduction of the results impossible. The test server should be identified by an IP address and not by its Fully Qualified Domain Name (FQDN) in order to avoid issues with Domain Name Server (DNS) lookup and including the DNS caching strategies of the used operating system into the measurement. The Transmission Control Protocol (TCP) settings of the server tested against should also be recorded. Since the number of host operating systems for internet servers is larger than on the client side, no detailed recommendation concerning the TCP settings of the server is given. However, the TCP stack of the reference server should at least be capable of the following:

- Maximum Segment Size between 1380 Bytes and 1460 Bytes
- TCP RX Window Size > 4096 Bytes

- SACK (Selective Acknowledgement) enabled
- TCP Fast Retransmit
- TCP Fast Recovery enabled
- Delayed ACK enabled (200ms)

The test file should consist of incompressible data i.e. a data file that is already compressed, e.g. like a zip or jpg file. The test file should have at least twice the size (in Kbit) of the theoretically maximum data transmission rate per second (in Kbit/s) of the Internet access under consideration.

PS Service Drop Rate, PS RAB Setup Success Rate, RRC Connection Setup Success Rate, PDP Context Activation Success Rate can be calculated from the network tools owned by the mobile network operators.

There are five mobile broadband operators in Sri Lanka and each of them has different equipment in their broadband networks. Therefore it is required to define common equations to calculate those QoS parameters. Following table describes what are the technologies used by each mobile operator in Sri Lanka to provide broadband.

Mobile Network Operator	Technology
Mobitel	UMTS, HSPA, HSPA+, DC-HSPA+, 4G LTE
Dialog	UMTS, HSPA, HSPA+, DC-HSPA+, 4G LTE
Etisalat	UMTS, HSPA, HSPA+, DC-HSPA+
Airtel	UMTS, HSPA, HSPA+
Hutch	UMTS, HSPA, HSPA+

Table 6.2 - Technologies used by network operators

In order to give these services above operators use one or more following vendor type equipment for access network side. So we can categorize the equipment vendors according to what technology equipment and tools they have already deployed in the mobile broadband networks Sri Lankan market.

- Huawei for UMTS, HSPA, HSPA+, DC-HSPA+
- ZTE for UMTS, HSPA, HSPA+, DC-HSPA+
- Alcatel for UMTS, HSPA, HSPA+, DC-HSPA+
- Ericsson for UMTS, HSPA, HSPA+, DC-HSPA+

- Huawei for 4G LTE
- ZTE for 4G LTE

And followings are used for core network side for same scenario.

- Alcatel
- Huawei
- ZTE

The next step of the policy framework is to define the common set of equations to calculate the above mentioned four QoS parameters which should be calculated by the each operator. The first one is PS Service Drop Rate. Actually this is for the UMTS broadband networks and similar parameter in LTE is E-RAB Drop Rate. The equation that I suggest to calculate the PS Service Drop Rate is;

$$\text{PS Call Drop Ratio} = \frac{\text{Number of PS RAB Abnormal Releases}}{\text{Total Number of PS RAB Releases}} * 100\%$$

This parameter provides the ratio of the PS RAB Abnormal Releases to the total PSRAB Releases (Normal Release + Abnormal Release) and is used to check the retainability of PS Service within the UTRAN networks. The RNC initially sends an IU RELEASE REQUEST/RAB RELEASE REQUEST message to the CN due to exception. If the RNC receives an IU RELEASE COMMAND/RAB ASSIGNMENT REQUEST message with any one of the following information: "User Inactivity", "Normal Release", "Successful Relocation", "Network Optimization", the RNC measures the items according to the service types in the best cell that the UE camps on if the released RABs belong to PS domain.

In LTE networks, following equation is using to calculate the E-RAB Drop rate which equivalent to the PS Service Drop Rate in UMTS.

$$\text{E} - \text{RAB Drop Rate} = \frac{\text{Number of E}-\text{RAB Abnormal Releases}}{\text{Number of E}-\text{RAB Abnormal Realeases} + \text{Number of E}-\text{RAB Normal Realeases}} * 100\%$$

The QoS parameter is PS RAB Setup Success Rate. This is also related to broadband UMTS networks and E-RAB Setup Success Rate is the equivalent QoS parameter in LTE networks.

$$\text{PS RAB Setup Success Ratio} = \frac{\text{Number of PS RAB Setup Successes}}{\text{Number of PS RAB Setup Attempts}} * 100\%$$

This parameter is used to check the RAB Setup Success Ratio of all PS services in an UMTS network. The PS RAB Setup Attempt Procedure is complete when the RNC receives an RAB ASSIGNMENT REQUEST message from the SGSN in the PS domain; the message contains information about one of the following service types: Conversational services, Streaming services, Interactive Services, Background Services. The PS RAB Setup Success Procedure starts when the RNC receives a RADIO BEARER SETUP COMPLETE message from the UE. This procedure is complete when the RNC sends an RAB ASSIGNMENT RESPONSE message to the SGSN in the PS domain.

The equivalent LTE parameter for this parameter can be defined in following formula to use in the LTE networks.

$$\text{E} - \text{RAB Setup Success Rate} = \frac{\text{Number of E} - \text{RAB Suceessful Establishments}}{\text{Number of E} - \text{RAB Attempt Establishments}} * 100\%$$

The next QoS parameter is RRC Connection Setup Success Rate and it can be defined according to the following equation for UMTS broadband networks.

$$\text{RRC Setup Success Ratio} = \frac{\text{Number of RRC Setup Successes}}{\text{Number of RRC Connection Attempts}} * 100\%$$

The RRC Connection Attempt for service Procedure is complete when the RNC receives an RRC CONNECTION REQUEST message from the UE. The message contains information about one of the following service types requested by the UE: Conversational Call, Streaming Call, Background Call, Interactive Call, Originating

Subscribed Traffic Call, Emergency Call, High Priority Signaling, Low Priority Signaling, Cause Unknown, Call Re-Establishment. The RRC Setup Success for Service Procedure is complete when the RNC receives an RRC CONNECTION SETUP COMPLETE message from the UE. The equivalent equation for LTE can be defined according to following formula.

$$\text{RRC Connection Success Rate} = \frac{\text{Number of RRC Suceessful Connections}}{\text{Number of RRC Attempt Connections}} * 100\%$$

The final proposed QoS parameter is PDP Context Activation Success Rate. Even though all three parameters we have discussed so far are access related parameters. So they have to calculate by using the network tools which are in access network. But the next parameter, PDP Context Activation Success Rate is in the core network. A PDP context is handled by the MS, Serving GPRS Support Node (SGSN) and GGSN and is identified by a mobile's PDP address within these entities. Several PDP contexts can be activated at the same time within a given MS. The equation which is required to calculate this can be written in following way.

$$\text{PDP Context Activation Success Rate} = \frac{\text{Number of Successfully Completed PDP Context Activations}}{\text{Number of Total Attempts of Context Activations}} * 100\%$$

Normally we can categorize the failed PDP context activations in to two parts; one is network related failures and other part is charging related failures. Normally network operators are considered only to the PDP context activation success rate which is calculate by considering the charging failures also to the equation as PDP failures. But it is essentially required not to consider failures which are happened due to charging (Online Charging System – OCS related issues in prepaid customers and authentication failures due to credit issues in postpaid customers) as failures for this calculation.

6.6 Analysis on Responsibility of Getting Measurements

In earlier three subsections of this chapter, we have discussed and finalized; what should be the QoS parameters considered for the mobile broadband policy framework; what should be their target values and how should be got their measurements. Now it is required to finalize the responsible parties for getting those parameters. It is possible to divide those seven parameters in to two parts; the parameters related to live networking testings and parameters related to network tools. The live testing should be done by the regulator. So TRCSL should select a place to do the testing and required to do it according to the prescribed test procedure. But when we consider the second part, those measurements should be taken from the live network tools. Those tools are with the operators. Therefore regulator should instruct the operators to get the relevant measurements according to the earlier defined formulas and send to the regulator. Then it is required to verify those values by the regulator from audits.

6.7 Analysis on Auditing and Publishing Results

Normally auditing function is done by the regulator. So in our policy framework also, it is required to do the audits by TRCSL. According to our survey results the measurements should have to be taken for monthly basis and an audit should be carried quarterly basis. Then finally TRCSL should publish the verified results of the proposed policy framework in monthly basis. It is better if they can publish the results on their web site. But the very important factor is to verify the results before publishing.

CHAPTER 7: CONCLUSION

The main objective of this research project is to prepare a policy framework to measure mobile broadband quality for all mobile operators. The structure of a policy framework related to broadband QoS can be divided into few identical steps. Those steps can be summarized in following manner.

1. Identify and define the QoS parameters
2. Set the target values for those parameters
3. Define the procedures for getting the measurements of those parameters
4. Identify the responsible parties to get the measurements
5. Define the proper ways to audit and publish the results

There was a requirement to do a survey among the mobile network experts to colloect some information which are required to finalize the above steps in the process of policy framework preparation. Then I analyzed the responses received through the survey and following QoS parameters were finalized as required paramters for this policy framework.

1. Download Speed
2. Latency
3. Average Throughput
4. PS Service Drop Rate
5. PS RAB Setup Success Rate
6. RRC Connection Setup Success Rate
7. PDP Context Activation Success Rate

The next step was, to find out the target values for those parameters. For this task I used the results of the survey, the values used by other countries for their policies and the standard values defined by ITU. After the analysis following target values were finalized.

No.	QoS Parameter	Target Value
1	Download Speed	Test results
2	Latency	Less than 200ms
3	Average Throughput	2Mbps(3G)/5Mbps(LTE)
4	PS Service Drop Rate	Less than 5%
5	PS RAB Setup Success Rate	Greater than 95%
6	RRC Connection Setup Success Rate	Greater than 95%
7	PDP Context Activation Success Rate	Greater than 95%

Table 7.1 - Proposed target values

The responsibility of measuring the first three parameters is with the regulator through conducting the live tests and remaining four parameters should be measure by the network operators and should send the results to the regulator. These tests should be done monthly basis and the regulator should do an audit to verify their test results by every quarter. Finally the regulator should publish the verified results in their web site to access to the general public. The proposed policy framework for QoS measurement in mobile broadband was prepared by including the above mentioned information. The proposed policy framework is attached to thesis as annexure 2.

7.1 Further Research Opportunities

There are few opportunities can be identified to continue this research in future to fulfill all the regulatory aspects related to broadband QoS. Since this research is focused only to the mobile broadband, it is possible to do a same kind of research for the fixed networks based on the conclusion made in this thesis. In addition to that, it is required to do a research to define a clear method to verify the target values proposed for every two years. The broadband technologies are growing in a rapid way according to the data requirement in the modern world and the networks are also expanded quickly by the operators to face the competence. Therefore it is essential to do the researches to find the validity of these target values and it is required to inform the new target values to the operators and to the general public by the TRCSL in every two years.

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Appendix A: Survey Responses

Survey Response 01

Resource Person : Technical Manager

Company : ZTE Lanka (Pvt) Ltd

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**
   Speed (Throughput), web page loading time, latency
2. **What are the target values you propose for the above mentioned parameters?**
   Speed : above 15Mbps, web page loading time < 5 secs, latency <50ms
3. **Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.**
   No but, it should strictly maintained in CBD and urban areas
4. **What are the parties you propose to measure those QoS parameters?**
   Corporate offices - Data should be collected in collective basis, Students
5. **How frequently should an audit be carried out by TRCSL?**
   Every 3 months, or else if an operator make major change then they needs to inform to TRSL and let them check the improvement
6. **Do you have any other suggestions or comments?**
   - Since back haul network plays a major role, government should invest to maintain a back haul network (country wide fiber network)
   - Operators should provide GBR

Survey Response 02

Resource Person : Manager - Core Network Planning

Company : Mobitel (Pvt) Ltd

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**

Avg. Download Speed, Avg. Upload Speed, Avg. Latency

2. **What are the target values you propose for the above mentioned parameters?**

Avg. Download Speed (3G→ 4 Mbps, 4G→10 Mbps), Avg. Upload Speed (3G→ 1 Mbps, 4G→4 Mbps), Avg. Latency (less than 200ms)

3. **Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons**.

Avg. Download Speed (Yes) → based on the geographical RAT, Avg. Upload Speed (Yes) → based on the geographical RAT, Avg. Latency (No)

4. **What are the parties you propose to measure those QoS parameters?**

NOC, Planning, SQ

5. **How frequently should an audit be carried out by TRCSL?**

Monthly

6. **Do you have any other suggestions or comments?**

Benchmark with international networks

Survey Response 03

Resource Person : Specialist - BSS

Company : Dialog Axiata PLC

1. What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?

User throughput, Service Availability (Downtime), Service Retainability (Service drop rate), Mobility (e.g. Handover success rate)

2. What are the target values you propose for the above mentioned parameters?

Based on the target Cx segment/Data package/Technologies used e.g. DCHSDPA

3. Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.

Not only the GEO, but the Cx segment wise since they expect different user experience

4. What are the parties you propose to measure those QoS parameters?

Not clear meant by parties

5. How frequently should an audit be carried out by TRCSL?

As frequently as they can without biasing any operator

6. Do you have any other suggestions or comments?

Personnel feeling is that the scope is too large, if we take one QOS parameter, User throughput only for an example can dig deep

Survey Response 04

Resource Person : Assistant Manager - BSS

Company : Dialog Axiata PLC

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**

Primary QoS parameters,

- HSDPA/HSUPA Data throughput (Per User)
- HSDPA/HAUPA/R99 RAB setup success rate (RAB – RAdio Bearer)
- HSDPA/HAUPA/R99 drop rate
- RRC connection setup success rate (RRC – Radio Resource Controller)
- RTWP of the serving cell (RTWP – Received Total Wideband Power)

Secondary QoS Parameters

- Power/CE/IuB/HS-Code Utilization

2. **What are the target values you propose for the above mentioned parameters?**

QoS Parameter	Value (For Daily Granularity)
HSDPA/HSUPA Data throughput (Per User)	Avg – 2.5 Mbps
HSDPA/HAUPA/R99 RAB setup success rate (RAB – RAdio Bearer)	99.90%
HSDPA/HAUPA/R99 drop rate	1.0%
RRC connection setup success rate (RRC –	99.90%

Radio Resource Controller)	
RTWP of the serving cell (RTWP – Received Total Wideband Power)	< -105 dBm
Power Utilization	< 60% of Max Power configured

3. **Do you think the target values should differ region wise? If yes, please identify such parameters and give your reasons.**

Yes,

HSDPA/HSUPA Data throughput (Per User) – Applications and customer orientation to use the connection vary region to region

4. **What are the parties you propose to measure those QoS parameters?**

- Network Planning Group
- Network Operation Group
- Network Quality Assurance Group
- Senior Management (Technical) – Higher level monitoring

5. **How frequently should an audit be carried out by TRCSL?**

By Quarterly

6. **Do you have any other suggestions or comments?**

No

Survey Response 05

Resource Person : Director – Network Performance Service

Company : Huawei Technologies Lanka Co., (Pvt) Ltd

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**

CS: There should be one index which can indicate the overall experience, the index need to be derived from call accessibility/retainability/voice quality

PS: There should be one index which can indicate the overall experience, the index need to be derived from data session setup success, retainability, & service specific metrics like page response delay, throughput & etc….

2. **What are the target values you propose for the above mentioned parameters?**

   a. This depends on operators' strategy and regulatory constraints. For an example a call drop below 0.2 will be good to have but if the ARPU is low it is not cost effective to invest heavily on such high target.

3. **Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.**

   a. Technically no reason to have different targets. But considering rural coverage it is accepted that even with low QoS it is required to provide service. So this can be considered as reason for having lower targets for rural coverage

4. **What are the parties you propose to measure those QoS parameters?**

   a. Should be measured by operator routinely and audits should be performed by regulator

   b. There should be third party benchmark also to measure current position comparatively

5. **How frequently should an audit be carried out by TRCSL?**

   a. Quarterly

6. Do you have any other suggestions or comments?

a. QoS need to be considered hand in hand with business economics. Otherwise it will not be practical

Survey Response 06

Resource Person : Engineer – Radio Network Optimization

Company : Etisalat Lanka (Pvt) Ltd

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**
    - DL/UL Throughput
    - Latency/Ping delay
    - FER
    - RSCP&Ec/Io
    - Browsing speed
    - Video buffering
2. **What are the target values you propose for the above mentioned parameters?**
    - DL/UL Throughput – 2-3 Mbps DL
    - Latency/Ping delay –
    - FER
    - RSCP&Ec/Io - -85/-8
    - Browsing speed-300kbps
    - Video buffering - Benchmarking

3. Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.

4. What are the parties you propose to measure those QoS parameters?

Operators/TRCSL

5. How frequently should an audit be carried out by TRCSL?

Once a month

6. Do you have any other suggestions or comments?

Survey Response 07

Resource Person : Technical Service Manager – Radio Network Planning

Company : Huawei Technologies Lanka Co., (Pvt) Ltd

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**

Suggest to have metrics that can measure QoS for combined services like CS+PS, Video Phone. Should consider accessibility and retain ability based on User behavior as smart phone usage as grown significantly. Considering Video Phone, most applications like skype have mobile applications so response time, delay and jitter metrics could be introduced to reflect actual user experience

2. **What are the target values you propose for the above mentioned parameters?**

This will have to be decided based on lab tests

3. **Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.**

Coverage and backhaul transmission may cause values to differ in different regions

4. **What are the parties you propose to measure those QoS parameters?**

Mainly Operator and Telecom Regulator. But consultancy firms who have field experience in South East Asia region would be able to give further insight for the benchmark

5. **How frequently should an audit be carried out by TRCSL?**

Based on Network growth and new technology implementation

6. **Do you have any other suggestions or comments?**

Latest and comprehensive tool setup is needed to capture the QoS in accurate and usable format

Survey Response 08

Resource Person : Assistant Manager - Radio Access Planning

Company : Mobitel (Pvt) Ltd

1. What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?

PS connection setup success rate/ PS connection drop rate/Average data throughput in a selected routes/latency for selected webservers / service availability

2. What are the target values you propose for the above mentioned parameters?

3. Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.

Average data throughput in a selected routes to be differ

4. What are the parties you propose to measure those QoS parameters?

Operator

5. How frequently should an audit be carried out by TRCSL?

Quarterly

6. Do you have any other suggestions or comments?

Survey Response 09

Resource Person : Assistant Manager - Broadband Access Planning

Company : Mobitel (Pvt) Ltd

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**
    a. Average file DL speed to a test server located locally and internationally (with single thread and multiple thread activation)
    b. Average file UL speed to a test server located locally and internationally
    c. Average web page loading time with a server located locally and internationally
    d. Average delay in loading video/ no. of buffering occurred in video streaming
2. **What are the target values you propose for the above mentioned parameters?**
    a. Single thread DL speed of 1Mbps
    b. UL speed of 400 kbps
    c. Page loading time depends on time. A standard simple page such as google loading within 2s and yahoo within 10s.
    d. Delay in playing video up to 5s and no buffering
3. **Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.**
    a. no
4. **What are the parties you propose to measure those QoS parameters?**
    a. Reporting by operators
    b. TRC
    c. Independent benchmark test party
5. **How frequently should an audit be carried out by TRCSL?**
    a. Every quarter of year

6. Do you have any other suggestions or comments?

ISP bandwidth, terminating location, link quality will have a significant impact on BB quality but would likely difficult to adjust easily.

Survey Response 10

Resource Person : Senior Engineer – Radio Network Planning & Optimization

Company : ZTE Lanka (Pvt) Ltd

1. **What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?**

Speed, web page loading time & should available in all the places

2. **What are the target values you propose for the above mentioned parameters?**

More than 10 Mbps always & less than 4 seconds

3. **Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.**

No

4. **What are the parties you propose to measure those QoS parameters?**

Customers who visited arcade, survery can be carried out after the customer service provided if they wish to answer & intitution/school/university students

5. **How frequently should an audit be carried out by TRCSL?**

By quarterly

6. **Do you have any other suggestions or comments?**

Guaranteed speed should be provided

Survey Response 11

Resource Person : Group Answer

Company : Alcatel-Lucent

1. What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?

It depends on the Mobile Technology and the services provided by each operator. Please find the attached doc with few KPI's for different technologies (GSM, WCDMA, and LTE).

2. What are the target values you propose for the above mentioned parameters?

Target values also Vendor and Operator specific. When any project starts mobile vendor should give there KPI's commitments and it will adjust by the operator according to their requirements, then at the end of the project vendor should achieve the KPI's targets to get the acceptance. This is for initial KPI's, but later on Operator will adjust the KPI's targets for periodic monitoring and Network maintainers.

WCDMA

Item	Service	KPI Target
Accessibility		
Call Setup Success Rate	Voice AMR 12.2	MOC: ≥ 97%
PDP Context Activation Success Rate	PS HSxPA	≥ 97%
Retainability		
CS Call Drop Rate	Voice AMR 12.2	≤ 0.5%
PS Call Drop Rate	PS HSxPA	≤ 0.5%
Mobility		
Soft handover Success Rate	Voice AMR 12.2	≥ 99%
Inter RAT handover Success Rate (3G/2G)	Voice AMR 12.2	≥ 98%
	PS HSxPA	≥ 98%

Integrity		
Call Setup Time	Voice AMR 12.2	MOC: 95% of successful calls ≤ 5 sec;
	PS HSxPA	PDP : 95% of successful calls ≤ 7secs;
Throughput		
Average FTP throughput UL	PS HSxPA	+ ≥ 300kbps
Average FTP throughput DL	PS HSxPA	+ ≥ 600bkps

LTE

KPI	KPI Target
(service) RRC setup success rate	>98%
ERAB Establishment success rate	>98%
(Service) dropped call rate	<3%
Ping round trip Delay – (32 bytes)	>50ms
Single user DL peak throughput at 30MHz (DL: UL=3:1)	120Mbps
Single user UL peak throughput at 30MHz (DL: UL=3:1)	6Mbps
Single user DL peak throughput at 20MHz (DL: UL=3:1)	80Mbps
Single user UL peak throughput at 20MHz (DL: UL=3:1)	6Mbps
Tracking Area update Success rate	>98%
E-UTRAN Mobility	>98%
E-UTRAN IP Latency	<30ms

3. Do you think the target values should differ regionwise? If yes, please identify such parameters and give your reasons.

Yes, Because If you take two regions like Dens and Rural, There is a huge difference in the carried traffic (Sites in dense carries high traffic and Rural area low traffic) and rate of Successful calls and the dropped calls. But when you come to KPI's you will see high call drop rate in Rural sites due to low number of generated calls. From The example you will see that for the Rural area, even for only one call drop you will get 20% of Call drop rate due to less number of calls. Therefore it's better to use regions wise KPI targets.

4. What are the parties you propose to measure those QoS parameters?

As I mentioned before for Initial KPI's commitment is from the Vendor and Operator negotiate it to get the best network from the Vendor, later on for network maintainers activities operator define new KPI's or they will maintain the initial KPI's from the Vendor.

5. How frequently should an audit be carried out by TRCSL?

As a Networks quality maintainer, TRC should perform frequent network Benchmarks among operators for different technologies and different services (Data Throughput). At least they should perform this kind of a activity for every six months time and acknowledge mobile operators and show their issues and ways to improve network.

6. Do you have any other suggestions or comments?

Survey Response 12

Resource Person : Group Answer

Company : Ericsson Telecommunications Lanka (Pvt) Ltd

1. What are the QoS parameters you propose to measure, to ensure the customer satisfaction in mobile broadband?

a. If the idea is to ensure Customer Satisfaction (i.e. QoE : Quality of Experience), more forcus should give to end-user performance.

b. Eg . Data Throughput, Call Setup Success Rate, CQI average, PS Drop Rate, RTT : Round-trip-time, Latency & Jitter, BER, Re-Transmissions

2. What are the target values you propose for the above mentioned parameters?

a. Rough values are given for happy Customers

b. Data Throughput (> 2 Mbps), Call Setup Success Rate (99%), CQI average (>25) , PS Drop Rate (<5%), RTT : Round-trip-time (<100 ms), Latency & Jitter (lowest), BER (<10%)

3. What are the parties you propose to measure those QoS parameters?

a. Depends on the requirement :

4. How frequently should an audit be carried out by TRCSL?

a. Refer the earlier attachments

5. Do you have any other suggestions or comments?

a. QoS/QoE measurements are heavily subjective. Their accuracy depends on the way of collecting data, time of data collection, area of data collection, sample size, collection method (Drive Test Vs Network QoS) and often have to use statistical methods for analysis. Better to refer “QoS and QoE Management in UMTS Cellular Systems” book for more details.

Appendix B: Proposed Policy Framework

Quality of Service Parameters and Target Values for Broadband

Mobile Telephony

Definition	Measurement (Periods of measurement –one month and one quarter)	Proposed Target
QoS_1. Download Speed		
It is required to install download speed measurement software in the Server at ISP Node to facilitate to measure independently the download connection speed through a web link.	The regulator shall measure the download speed.	No target specified at this stage.
QoS_2. Latency		
This is the amount of time taken by a packet to reach the receiving endpoint after being transmitted from the sending point.	The regulator shall measure the latency using the test defined in QoS_1.	Less than 200ms
QoS_3. Average Throughput		
It is defined as the rate at which packets are transmitted in a network.	The regulator shall measure the average throughput using the test defined in QoS_1.	3G: 2Mbps LTE: 5Mbps

<table>
<tr><th colspan="3">QoS_4. PS Service Drop Rate/ E-RAB Drop Rate</th></tr>
<tr><td>It measures the inability of Network to maintain a connection and is defined as the percentage of abnormal disconnects with respect to all disconnects.</td><td>Computational Methodology:

In UMTS;

$$PS\ Call\ Drop\ Rate = \frac{Number\ of\ PS\ RAB\ Abnormal\ Releases}{Total\ Number\ of\ PS\ RAB\ Releases} * 100\%$$

In LTE;

$$E-RAB\ Drop\ Rate = \frac{Number\ of\ E-RAB\ Abnormal\ Releases}{(Number\ of\ E-RAB\ Abnormal\ Realeases + Number\ of\ E-RAB\ Normal\ Realeases)} * 100\%$$

Note: These values are measured from Access Network.</td><td>Less than 5%</td></tr>
<tr><th colspan="3">QoS_5. PS RAB Setup Success Rate/ E-RAB Setup Success Rate</th></tr>
<tr><td>It is defined as the percentage of PS RAB/E-RAB failures with respect to all PS RAB/E-RAB attempts.</td><td>Computational Methodology:

In UMTS;

$$PS\ RAB\ Setup\ Success\ Ratio = \frac{Number\ of\ PS\ RAB\ Setup\ Successes}{Number\ of\ PS\ RAB\ Setup\ Attempts} * 100\%$$

In LTE,

$$E-RAB\ Setup\ Success\ Rate = \frac{Number\ of\ E-RAB\ Suceessful\ Establishments}{Number\ of\ E-RAB\ Attempt\ Establishments} * 100\%$$

Note: These values are measured from Access Network.</td><td>Greater than 95%</td></tr>
<tr><th colspan="3">QoS_6. RRC Connection Setup Success Rate</th></tr>
</table>

It is defined as the percentage of RRC Connection Setup failures with respect to all RRC Connection Setup attempts.	Computational Methodology: In UMTS; $\text{RRC Setup Success Ratio} = \frac{\text{Number of RRC Setup Successes}}{\text{Number of RRC Connection Attempts}} * 100\%$ In LTE; $\text{RRC Connection Success Rate} = \frac{\text{Number of RRC Suceessful Connections}}{\text{Number of RRC Attempt Connections}} * 100\%$ **Note:** These values are measured from Access Network.	Greater than 95%
QoS_7. PDP Context Activation Success Rate		
It is defined as the percentage of PDP Context Activation failures with respect to all PDP Context Activation attempts.	Computational Methodology: $\text{PDP Context Activation Success Rate} = \frac{\text{Number of Successfully Completed PDP Co}}{\text{Number of Total Attempts of Context}} * 100\%$ **Note:** These values are measured from Core Network. It is required not to consider failures which are happened due to charging (Online Charging System – OCS related issues in prepaid customers and authentication failures due to credit issues in postpaid customers) as failures for this calculation.	Greater than 95%