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| **SOUTH ASIAN TELECOMMUNICATIONS REGULATOR’S COUNCIL** **(SATRC)** |  |
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SATRC REPORT ON

REGULATORY APPROACHES TO ENHANCE QUALITY OF SERVICE OF MOBILE OPERATORS

**Prepared by**

**SATRC Working Group on Policy, Regulation and Services**

Adopted by

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# CHAPTER-1: INTRODUCTION

## 1.1 Background and Purpose

1.1.1. In general terms, Quality of Service (QoS) refers to the ability of a network or service to satisfy the end user. QoS is defined in ITU-T Recommendation E.800 as ***"the collective effect of service performances, which determine the degree of satisfaction of a user of the service"***. QoS therefore concerns aspects of services that consumers experience directly.

1.1.2. Growing concerns on various QoS parameters specially Call Drop, Call Quality and Data Throughput have been observed recently. With the increase of the subscriber base, customer's dissatisfaction is increasing and complaints against the network are also increasing.

1.1.3. To ensure a level playing field along with a competitive environment and subscriber satisfaction, performance measurement with a common standard regarding QoS is a must. QoS parameters can be measured both from network monitoring terminals and field surveys through Drive Test. Customers' opinion should also be taken into consideration in this regard.

1.1.4. Most of the SATRC member countries adopted 3G and 4G technology. So, it is about time to set some benchmarks/thresholds for Cellular Mobile Operators (CMOs) which they must comply with in order to ensure consumers’ satisfaction.

## 1.2. Scope of Study

1.2.1. Scope of the work item include following:

1. Create conditions for customer satisfaction by making known the quality of service which the Cellular Mobile Operators (CMOs) are required to provide and the user has a right to expect;
2. Measure the Quality of Service provided by the CMOs from time to time and to compare them with the benchmarks so as to assess the level of performance;
3. Protect the interests of local consumers of CMOs; and
4. Promote competition among the CMOs in order to ensure high-quality telecommunication services.

## 1.3. Methodology of the Study

1.3.1. The study has been carried out by the Lead Expert in consultation with the other Experts from Member countries on the subject. Therefore, in order to pursue the study, a questionnaire has been prepared to obtain input (information) on the subject. Based on the inputs of the Member countries, the lead expert has compiled and generated a report based on the best practices for the SATRC regions.

# CHAPTER-2: REGULATORY FRAMEWORK

## 2.1. Quality of Service

2.1.1. International Standardization Organizations such as International Telecommunication Union (ITU), International Organization for Standardization (ISO) and European Telecommunication Standard Institute (ETSI) define Quality of Service as:

1. ITU-T Rec.E.800: ***“Totality of characteristics of a telecommunications service that bear on its ability to satisfy* *stated and implied needs of the user of the service”.***
2. ETSI-TR102157: ***“Quality of Service (QoS): the ability to segment traffic or differentiate between traffic types in order for the network to treat certain traffic differently from others”.***
3. ISO-8402: ***“The totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs”***

## 2.2. Quality of Experience

2.2.1. ITU-T Recommendation P.10/G.100 defines Quality of Experience (QoE) as ***“the overall acceptability of an application or service, as perceived subjectively by the end-user”.***  In 2016, this definition has been modified by ITU-T Study Group 12, as “***Quality of experience (QoE) is the degree of delight or annoyance of the user of an application or service”.***

2.2.2. The psychological profiles and emotional state of a user influences QoE, due to its subjective nature of measurement and customer perception regarding a specific service. In any assessment of the QoE, the description of the influencing factors need to be included.

## 2.3. Network Performance

2.3.1. The performance of any network can be gauged by measuring performance of its network elements one by one, or by measuring the performance of the whole network i.e. the combination of the performance of all single elements. In fact, QoS consists of network performance and non-network performance, as shown in below figure:



## 2.4. Relationship of QoS, NP and QoE

2.4.1. The functions of a service depend on the performance of the network elements and the performance of user terminal equipment. QoS is always end-to-end, i.e. user-to-user or user-to-content. Therefore, QoS measurements are also carried out end-to-end. End-to-end QoS depends on the contributions made by the components, including user, user equipment, access network, IP transport, core network, and the rest of the path end-to-end (e.g. through the Internet). QoE has a broader scope as it is impacted by QoS as well as by user expectations and context.



## 2.5. QoS Regulatory Framework

2.5.1. QoS Regulatory Framework starts with setting Standards defined by International Standardization Organizations such as ITU-T as well as regional bodies e.g. ETSI in Europe. These Standards can be implemented as part of the license conditions as well as regulations or industry guidelines. QoS is defined through a given set of parameters that are measurable. Such quality parameters that are defined for QoS measurements in a given country (or globally) are referred to as Key Performance Indicators (KPIs.) QoS KPIs can be technical and non-technical. Examples of technical KPIs include Call Setup Success Rate, Call Drop Rate and Call Setup Time etc. Non-technical KPIs are customer centric, and may include parameters such as billing accuracy, network outage, etc. After defining QoS KPIs, different measurement methods can be used, which may differ from one country to another. National Regulatory Authorities (NRA) as well as Network Service Providers (NSPs) monitor QoS KPI.

2.5.2. Different approaches exist in the monitoring of technical and customer centric KPIs. Technical monitoring of KPIs can be performed by network auditing, drive tests, probe stations on selected locations, etc. The customer focused KPIs are monitored by consumer surveys. The purpose of monitoring the values of the defined KPIs is to detect degradation of the QoS when it appears, and to apply appropriate actions to enforce QoS. Such QoS enforcement can be performed by publishing KPI monitoring results on a public website, through press releases, via directives etc., with the aim of informing consumers. However, if such enforcement approaches are not enough to enforce QoS, then more drastic QoS enforcement should be undertaken through financial penalties or through dispute resolution mechanisms. This QoS Regulatory Framework is as shown in the figure below.



2.5.3. A harmonized and common approach to regulate QoS is necessary to enable greater quality prospects for consumer, irrespective of their locations. ITU-T Rec.G.1000 define terms which provide the general QoS Framework divided into seven QoS criteria as specified below:

1. Speed (refers to all service functions)
2. Accuracy (e.g. speech quality, call success ratio, bill correctness, etc.);
3. Availability (e.g. coverage, service availability, etc.);
4. Reliability (e.g. dropped call ratio, number of billing complaints, etc.);
5. Security (e.g. fraud prevention);
6. Simplicity (e.g. ease of software updates, ease of contract termination, etc.); and
7. Flexibility (e.g. ease of change in contract, availability of different billing methods such as online billing, etc.).

# CHAPTER-3: MONITORING, COMPLIANCE & ENFORCEMENT

## 3.1. Selection of KPIs and Target Values

3.1.1. QoS Key Performance Indicators (KPIs) characterize the level of the service quality and customer satisfaction. QoS parameters represent subjective and abstract user perception of quality in terms of numeric values. QoS KPIs are essential for effective QoS management. They should be simple to use, provide accurate representation of customer perception, and be commonly accepted as standards. It should be possible to distinguish between parameters for specific service types.

3.1.2. While defining QoS KPIs involvement of operators is beneficial and desirable. The factors need to be considered are the practicability for operators to measure the parameter, practicability for regulator and independent third party to audit the results and the measurement should retain the customer experience aspect.

3.1.3. QoS Regulation is based on the definition of QoS KPIs that will be monitored for the purposes of QoS enforcement. A target is defined as a potential value for a parameter that must be reached if quality is to be regarded as satisfactory. Three (3) classes of KPIs determine the user experience i.e. a) Customer Interface, b) Network Infrastructure KPIs and c) Service Functionality KPIs. The Service functionality KPIs are organized according to service type (such as Voice, SMS, etc.) rather than by operator type (fixed wireless, mobile, etc.) to ensure comparability between countries and consistency in the treatment of operators.

3.1.4. KPIs targets are set by the Regulator based upon consultation, keeping in view current KPIs values obtained through monitoring operators’ data. Aggregated performance targets involve number of different observations that can be formulated in two different ways:

a. Percentage of events that exceed or fail to meet a target level of performance (e.g. % Calls established in less than X seconds). In this case, X indicates a target level.

b. Number of hours within which 90 percent of SIMs were activated. In this case, no target level is indicated. If compensation is going to be given, then the measurement must have a simple pass or fail criterion for each individual customer.

## 3.2. Data Collection and Monitoring

3.2.1. The purpose of QoS Monitoring is to verify the QoS experienced by consumers and to compare the results (from audit exercises) against license obligations. The methods of auditing telecommunication operators include:

1. Drive Testing
2. Consumer Surveys
3. Data Submission by Operators (typically on quarterly basis)

3.2.2. Internationally active testing is the most commonly adopted methodology to measure QoS KPIs. Active testing has high implementation cost and sampling methodology is very critical, therefore, QoS monitoring tools have to be deployed to replicate a like-for-like QoS performance comparison of service providers.

3.2.3. Consumer surveys can effectively pinpoint the weakest elements of service quality, providing good feedback to operators, while allowing consumers to compare their views on performance of various operators with other people. It is also a good addition to the indicator-based method of measurement. Comparing the two sets of data can determine whether a weakness identified by consumers also falls among the low-levels of relevant indicator data or it is just consumer’s perception.

3.2.4. Crowdsourcing is another method of data collection from large number of consumers. ITU-T P.912 defines crowdsourcing as ***“Obtaining the needed service by a large group of people, most probably an on-line community”.*** ITU-T Rec.E.802 covers the end-to end QoS assessment of fixed and mobile Internet access using the crowdsourcing approach. A wide range of data can be collected from mobile devices when using crowdsourcing solutions that is useful for the QoS assessment of fixed and mobile broadband connection. They may include, but are not limited to and can provide relevant QoS indicators for broadband networks, such as throughput, latency, jitter and packet loss etc. Crowdsourcing is categorized into two types i.e. Active and Passive. Active data collection methods create artificial traffic with the intention to assess end-to-end QoS parameters. For example, intentional file transfer with the aim to measure the throughput, ping tests, among others. Passive data measurements do not inject artificial traffic or test payload into the network for QoS assessment. Instead, they act more as an observer of radio parameters, the end-user's transferred data, and collect information regarding the actual traffic.

## 3.3. Compliance and Enforcement

3.3.1. QoS Results are published by the Regulator in order to carry out comparisons between operators’ performance. The main purpose of publishing information on QoS is to better inform consumers. Regulators should publish information on performance on their websites while requiring operators to send this information periodically to consumers, along with their bills. QoS information examples that should be published include the QoS results from the network audit campaign (drive test, consumer survey, etc.). This information should be made available as soon as possible.

3.3.2. Ensuring compliance is highly recommended in QoS regulation. There are two (2) approaches in implementing QoS regulations i.e. Encouragement Approach and Enforcement Approach. For the regulator to proceed with the enforcement approach, it may start with recommendations and move towards obligations. The regulator can adopt a range of techniques, starting from naming-and-shaming strategies to tighter regulation, financial penalties and finally more drastic legal enforcements. However, doing so can involve extensive legal processes and may take a long time. A schedule of penalties may be announced publicly to ease implementation.

3.3.3. As a general principle, it is recommended that both encouragement and enforcement should be graduated and proportional. Whenever feasible, the regulator should engage in constructive dialogue with operators on quality problems. This should not be seen as a process of telling the operator how to run their business, but of asking targeted questions that can trigger the operators to review and reconsider their approach in areas with specific problems.

# CHAPTER-4: QUALITY IN MOBILE NETWORKS

## 4.1. Mobile Network Architecture

4.1.1. The development of the mobile network architectures has direct influence on the QoS
in all-IP mobile networks such as 4G. The reason is that in Circuit Switched (CS) mobile networks the end-to-end delay is typically limited with the propagation delay of signals which travel approximately at the speed of light, which provides a delay of up to 100ms between any two points on Earth connected with terrestrial connection. Therefore, the requirement for end-to-end delay for voice below 150ms can be satisfied in CS mobile networks. However, Packet Switched (PS) networking principles result in increased total delay and delay variation due to packetization, coding/decoding, buffering at networks nodes. Therefore mobile network architectures have also evolved to accommodate specific characteristics of IP transfer end-to-end, which is always higher than in CS networks for the same distance.

4.1.2. Mobile network evolution started during the 3G era, which transformed
the hierarchical mobile architecture with a Radio Network Controller (RNC) between the Base Stations, i.e. eNodeBs, and Serving GPRS Support Node (SGSN) into a flat architecture, with Universal Mobile Telecommunication System Radio Access Network (UTRAN) which consisted only of NodeBs and centralized core network nodes i.e.3G-SGSN and 3G-Gateway GPRS Support Node (3G-GGSN), together with subscribers database, the Home Subscriber Server (HSS)). This was referred to as System Architecture Evolution (SAE).The main reason was the QoS in the mobile networks based on IP, including UTRAN and the mobile core network, i.e. for provision of lower delay in the mobile network which is needed for real-time services over all-IP mobile networks as well as emerging critical services over a mobile network.

4.1.3. 4G mobile network from 3GPP is LTE/LTE-Advanced. LTE was standardized initially with 3GPP Release 8, together with the common Internet Protocol Multimedia Subsystem (IMS) for signaling based on Session Initiation Protocol (SIP) and Diameter for communication with the users’ database HSS as well as with Evolved Packet Core (EPC). Evolution of 3GPP mobile standards is shown in figure below:



 4.1.4. 4G mobile network architecture for LTE/LTE-Advanced is shown in below, whereas, overall 3GPP has standardized three segments:

a. High-speed access, which refers to radio access technology.

b. IP core network, which includes all controllers/gateways and databases in the mobile networks as well as their mutual interfaces.

c. Services, which include service overlay network implemented over a given mobile network, with IMS as the central node in the services part.



## 4.2. QoS in UMTS / LTE

4.2.2. Mobile broadband access in fact started with 3G mobile networks. However, these networks were based on a hybrid approach, that is circuit-switching used for voice and packet-switching (IP connectivity) used for Internet access service. However, the main representative of 3G mobile networks, the UMTS, had well-defined QoS support from the beginning. For the packet-switching traffic (i.e. IP traffic) in UMTS, four different traffic (i.e. QoS) classes are defined in the table.

|  |  |
| --- | --- |
| Class | Features |
| Conversational | Characterized by a low transfer time and preserved time variation between information entities of the stream. The most well-known use of this scheme is voice over IP (VoIP) and video conferencing tools. |
| Streaming | Characterized by the preserved time variation between information entities within a flow, although it does not have any requirements on low transfer delay. It is suitable for transfer of streaming audio and video. |
| Interactive | Characterized by the request response pattern of the end user. Examples are: web browsing, data base retrieval, server access, polling for measurement records and automatic database enquiries. Low round trip delay time and low bit error rate are one of the key attributes. |
| Background | Examples are background delivery of E-mails, Short Message Service (SMS) and download of databases and reception of measurement records. The scheme is more or less delivery time insensitive, but requires low data error rates. |

4.2.2. The QoS support in mobile networks standardized by 3GPP is accomplished by the definition of bearers. UMTS bearer is a service that provide transmission of information signals between given entities in the network, with certain QoS attributes, capacity (bitrate), and traffic flow characteristics. There are three main bearers in UMTS. The number of bearers in the LTE/LTE-Advanced mobile networks is similar to that in UMTS. QoS impact in UMTS is shown in the figure and the bearers’ are defined as under:

a. Radio Bearer. Radio bearer service (RAB) between the mobile terminals and NodeB (base stations in UMTS), i.e. UTRAN

b. Iu Bearer. Iu bearer service between UTRAN and core network gateway, which is SGSN in UMTS.

c. Backbone Bearer. Backbone bearer services between the core network main gateways, i.e. SGSN and GGSN.





4.2.3. A bearer is set up when an application in a mobile terminal initiates connections. When QoS support is needed the connection is established between the mobile terminal and certain Application Server (AS) on the operator’s side. The main goal of bearer set up and existence is minimization of QoS knowledge and configuration in mobile terminals. Regarding the QoS identification System Architecture Evolution (SAE) uses QoS Class Identifiers (QCIs), which are based on three QoS parameters: priority, loss probability and delay. Each bearer is assigned a scalar value called QCI.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| QCI | Resource Type | Priority | Delay Budget | Loss Rate | Example Application |
| 1 | GBR | 2 | 100ms | 10-2 | VoIP |
| 2 | 4 | 150ms | 10-3 | Video Call |
| 3 | 6 | 300ms | 10-6 | Video Streaming |
| 4 | 3 | 50ms | 10-3 | Real-Time Gaming |
| 5 | Non-GBR | 1 | 100ms | 10-6 | IMS Signaling |
| 6 | 7 | 100ms | 10-3 | Voice, Live Video, Interactive Gaming |
| 7 | 6 | 300ms | 10-6 | TCP Applications (Web, E-mail, P2P File Sharing, Http Video, Chat, Buffered Video Streaming etc.) |
| 8 | 8 |
| 9 | 9 |

## 4.3. QoS for 5G

4.3.1. The QoS support in 5G mobile networks started with 3GPP Release 15, is based on further evolution of QoS support defined for LTE/LTE-Advanced mobile networks. While in UMTS and LTE/LTE-Advanced, the QoS support is based on bearers, the 5G mobile core is designed to have flow based QoS rather than bearer-based one. Similar to LTE, the 5G QoS supports two (2) resource types i.e. i) QoS flows that require Guaranteed Bit Rate (GBR), and ii) QoS flows that do not require GBR (i.e., non-GBR).

4.3.2. QoS Flow ID (QFI) is used to identify a QoS flow in 5G systems. Such QFI can be assigned dynamically or they can be equal to standardized 5QIs (5G QoS Indicators). Such QFI can be assigned dynamically or they can be equal to standardized 5QIs (5G QoS Indicators).

4.3.3 The main novelty (regarding the 3GPP mobile networks) in 5G QoS approach is possibility for differentiation of data flows which provides means for differentiation of traffic from different applications or services with diverse QoS requirements while at the same time maximizing the resource utilization in the Access Network (AN).

## 4.4. New QoS type in 5G

4.4.1. The new resource type in 5G is delay critical GBR, which has requirement for very low delays (up to 20ms) as well as low jitter (up to 20ms), targeted to critical services such as control of automatic processes or transportation vehicles via the mobile network thus excluding the need for building separate network for such delay-critical services.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 5QI | Resource Type | Priority | Delay Budget | Packet Loss Rate | Default Maximum Data Burst Volume | Targeted Services |
| 10 | Delay Critical GBR | 11 | 5ms | 10-5 | 160 Bytes | Remote Control |
| 11 | 12 | 10ms | 10-5 | 320 Bytes | ITS  |
| 12 | 13 | 20ms | 10-5 | 640 Bytes | Other Delay Critical Services |
| 16 | 18 | 10ms | 10-4 | 255 Bytes | Discrete Automation |
| 17 | 19 | 10ms | 10-4 | 1358 Bytes | Discrete Automation |

## 4.5. Expectations from 5G

4.5.1. Human users will be one user class amongst others. Main popular applications will remain but evolve. New application areas and use cases will be launched and used. OTT services will become fully equivalent or even superior to VoLTE (because of wider functionality). Data applications in 5G are in vast majority. These include:

a. **Existing Applications & Use Cases.** Current use cases will remain popular (HTTP browsing, video streaming, OTT messaging, etc.)

b. **Evolving Applications & Use Cases.**4K/8K video, HDR, 360° video, virtual reality, live broadcasting, real-time gaming. Similar to today’s video streaming, just more bandwidth, more reliable; shorter latency. Rendering will move from device to core, in interaction with device

c. **New applications & Use Cases.** Augmented reality and AR gaming, Remote control, VR Retail shopping. Highly adaptive to network conditions by Machine Learning and Artificial Intelligence techniques.

# CHAPTER-5: CURRENT PRACTICES IN SATRC COUNTRIES

## 5.1. Questionnaire

5.1.1. A questionnaire was designed to obtain information about existing QoS regulatory framework of SATC countries, KPIs being measured along-with measuring methodologies, enforcement mechanism and challenges being faced by the SATRC countries.

## 5.2. QoS Regulatory Framework

5.2.1. QoS Regulations exist in most SATRC countries. The Regulations are being updated from time to time in order to cover new features resulting from technology upgrades. Sometimes, license conditions also needs to be revised to incorporate new KPIs.

a. In Pakistan, the license conditions can only be amended through mutual consent of regulator and licensee. Whereas the QoS Regulations can be amended through consultation.

b. In India, several amendments have been made through consultations in the QoS regulations which were originally promulgated in 2000, the most recent being done in 2019. The process for amending regulations, as being followed in India, is as follows:

1. A public consultation paper is issued soliciting comments and counter comments on it from public, Service Providers, consumer advocacy groups, inter-alia.
2. Open house discussions are held after giving wide publicity of the event.
3. Based on the comments and counter-comments TRAI firms up the action to be taken and if needed, further inputs are taken.
4. Thereafter modification in Regulation through amendment, if need be, is issued.

c. Some countries including Bhutan and Maldives are enforcing QoS through terms and conditions of mobile licenses but Bhutan is in the process of developing QoS regulations as well.

## 5.3. QoS KPIs

5.3.1. ITU has specified seven (7) QoS criteria i.e. Speed, Accuracy, Availability, Reliability, Security, Simplicity and Flexibility. The first four (4) include technical KPIs while the last three (3) cover non-technical aspects. While all SATRC countries cover technical KPIs for Voice, SMS & Data in their regulations and license conditions, some countries do not have specific non-technical KPIs as part of QoS regulations.

5.3.2. Many SATRC countries have either updated their regulations / license conditions to include QoS KPIs for VoLTE or are in the process of doing so.

a. In order to capture the VoLTE parameters, 6th amendment to regulations was issued in India wherein UL and DL Packet Drop Rate benchmarks were notified.

b. Iran has defined MOS, CS Drop Rate and CS CSSR for VoLTE.

c. Studies are on-going in Nepal regarding new KPIs for VoLTE and OTT services.

d. Sri Lanka has defined VoLTE E-RAB Setup Success Rate, Call Drop Rate, Intra-frequency HO Success rate, Inter-Frequency HO Success Rate and CSFB Success Rate.

e. Pakistan also plans to include VoLTE Drop Call Rate, Call Setup Success Rate, SRVCC Handover Success Rate (During On-going Call plus During Setup), Call Setup Time, and MOS in its QoS Regulations.

5.3.3. Generally, the QoS Regulations are technology agnostic. However, no specific KPI have been defined yet in SATRC countries for 5G. Some countries, including Pakistan, are conducting 5G trials. Iran and Nepal are in the process of developing a Regulatory Framework for 5G services.

## 5.4. QoS Enforcement Mechanism

5.4.1. In SATRC countries, either regulator or operator itself is the stakeholder responsible for measurement of QoS data.

1. In Afghanistan, Bangladesh, Iran and Pakistan, the regulator is responsible for QoS data measurements.
2. In Nepal & Bhutan, both the regulator and operator are responsible for data measurements.
3. In India, Maldives and Sri Lanka, the measurement data is provided by operators while the regulator performs regular inspections and network audits.

5.4.2. Field Testing, also known as Drive Testing is the preferred method for measuring QoS KPIs in the SATRC countries. However, in some countries there exist other approaches as well. Some of the detail is as under:

 a. Bangladesh, India, Iran, Nepal, Maldives and Sri Lanka also use KPIs extracted from the Core Network / Network Management System (NMS).

 b. Crowd sourced data is also being used in India for assessing wireless network speeds which is driven by subscribers’ devices.

 c. Nepal is also developing mobile applications to utilizing crowd sourced data related to QoS and QoE.

5.4.3. Few regulators in SATRC countries are exploring new techniques and methodologies for QoS monitoring.

1. Bangladesh is in the process of establishing a Telecom Monitoring System which will enable generation of QoS reports independently.
2. Iran has already deployed performance measurement tool which fetches raw data / counters from operator’s network. Other regulators rely upon operators to provide such data / reports.
3. In India, TRAI has been collecting data about upload and download speeds of different service providers for different wireless technologies through crowd sourced ‘My Speed’ application. The reports are made available to the public. Customers can also rate the quality of calls using the ‘My Call’ application on a scale of 1 to 5. The aggregated results can be viewed on My Call analytical dashboard.
4. Iran has tested a centralized benchmarking system which contains five (5) modules: Performance Measurements, Active Probes, Mobile Applications, Drive Test and Customer Relationship Management (CRM).
5. Nepal is also making use of Probes and planning to introduce Mobile Applications for measuring QoE.

5.4.4. Most SATRC countries, except Iran, do not have provision available to monitor QoS KPIs on real-time basis. However, there are few exceptions as well.

 a. According to license conditions of operators in Iran, they have offer online and real-time access to raw counters for performance measurement module in order to calculate major QoS KPIs.

 b. Bangladesh is also planning to implement Telecom Monitoring System which will enable real-time QoS KPI monitoring.

5.4.5. Most SATRC countries publish QoS testing results on the regulator’s official websites. Maldives is also planning to do so while in Sri Lanka, ‘Comparative Reports’ are shared with operators on quarterly basis.

5.4.6. In most SATRC countries, there exists a three (3) step enforcement mechanism: i) instruction to operator for improving QoS KPIs, ii) issuance of show-cause notice for repeated non-compliance, followed by iii) legal proceedings including fine and operational sanction. The reports are often published for public’s awareness as well.

a. In Afghanistan, the operators are penalized in case of shortcoming in meeting the QoS thresholds, based upon a pre-defined formula which automatically calculates the amount of penalty to be paid by the operators.

b. Bhutan has signed MoU with operators for QoS KPI improvement.

c. In Maldives, the regulator notifies the operator to improve KPIs and resolve issues in case of customer complaints.

d. In Sri Lanka, QoS KPI comparison reports are prepared on monthly basis and circulated among operators for information.

## 5.5. Quality of Experience (QoE)

5.5.1. All of the SATRC countries measure QoS KPIs. However, few countries are using different means, such as crowd sourced data and surveys to ascertain Quality of Experience (QoE) as well.

a. Bangladesh is in the process of introducing crowdsourcing.

b. India & Iran are studying the KPIs that can be monitored based on QoE.

c. Maldives conducts nationwide phone survey to determine general perception of coverage and quality of mobile and data services in the country.

d. Nepal is developing mobile application to measure QoE.

e. Sri Lanka has also initiated QoE measurement process.

# CHAPTER-6: INTERNATIONAL BEST PRACTICES

## 6.1. Choosing QoS KPIs

6.1.1. There is a degree of flexibility allowed when deciding which QoS KPIs are to be chosen and measured by the Regulator. The Regulators in consultation with stakeholders are free to choose among the QoS KPIs that are appropriate, taking into account national circumstances and other factors, such as, the meaningfulness and usefulness of KPI, the underlying costs, time needed to implement the measurement and possible monitoring systems, changes required to adapt and modify current methodologies and allowing for the possibility of comparing new results with previous records. The minimum QoS KPIs for Voice and Internet Services in mobile networks are mentioned in the following table:

|  |  |  |
| --- | --- | --- |
| Service | KPI | Definition |
| Voice | Call Setup Success Rate | Probability that the end-user can access the mobile telephony service. |
| Call Setup Time | Time period between sending of complete address information by the originating user and call establishment or receiving alerting message. |
| Call Drop Rate | Probability that a successful established attempt is ended unintentionally. |
| Speech Quality | Represents the quantification of the end-to-end speech transmission quality. |
| Service Coverage Area | Coverage are of the mobile network where received signal strength at mobile terminal allows making a voice call. |
| Internet | Download / Upload Speed | Download/Upload Speed is the speed that information on the Internet/Mobile (e.g., text and graphics) is transferred to Mobile/Internet. |
| Packet Delay | The time difference between the occurrences of two corresponding IP packet reference events. |
| Packet Delay Variation | The difference between the one-way delay of IP packet and reference IP packet transfer delay. |
| Packet Loss Ratio | The ratio of total number of lost IP packets to the total number of transmitted IP packets in a given measurement |

## 6.2. 3GPP QoS KPIs

6.2.1. 3rd Generation Partnership Project (3GPP) unites Seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as [“Organizational Partners”](https://www.3gpp.org/Partners) and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies. 3GPP has defined technical specifications regarding QoS KPIs for UMTS and GSM in 3GPP TS 132 410 and QoS KPIs for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) in 3GPP TS 132.450 i.e. Definitions and 3GPP TS 132.451 i.e. Requirements. In these technical specification, six major categories are defined i.e. 1) Accessibility, 2) Retainability, 3) Integrity, 4) Availability, 5) Mobility and 6) Utilization.

6.2.2. ETSI TS 128 554 presents 5G end to end KPI concept and overview. It covers QoS KPIs i.e. Accessibility, Integrity and Utilization. Whereas the future update of the document will also include the remaining QoS KPIs i.e. Retainability, Availability and Mobility. Also, one more option is adopted recently in 5G: Energy Efficiency. The KPIs mentioned in these documents for 3G, 4G and 5G are as under:

| Technology | Category | Key Performance Indicators |
| --- | --- | --- |
| TS 132 410 |
| 3G | Accessibility | RAB Establishment Success Rate  |
| RAB Establishment Success Rate for Speech  |
| RAB Establishment Success Rate for Video telephony |
| 2G | RRC Connection Establishment Success Rate  |
| 3G | UTRAN Service Access Success Rate |
| 2G | GERAN Service Access Success Rate for CS Domain |
| 3G | UMTS PDP Context Activation Success Rate |
| 3G | UMTS Switched Call Success Rate |
| 3G | Retainability | RAB Abnormal Release Rate  |
| 2G | GERAN Service Abnormal Release Rate |
| 2G/3G | Combined 2G 3G Call Drop Ratio |
| 3G | Mobility | Soft Handover Success Rate  |
| 3G | Outgoing Intra-system Hard Handover Success Rate  |
| 2G/3G | Outgoing Inter RAT Handover Success Rate for CS Domain |
| 2G/3G | Outgoing Inter RAT Handover Success Rate for PS Domain |
| 2G | Handover Success Rate (BSC and Cell) |
| 3G | Utilization | Percentage of Established RABs, CS Speech  |
| 3G | Percentage of Established RABs,CS 64kbps(Video telephony) |
| 3G | Percentage of Established RABs, Total PS |
| 3G | Availability | UTRAN Cell Availability |
| TS 132 450 |
| 4G | Accessibility | E-RAB Accessibility  |
| Retainability | E-RAB Retainability |
| Integrity | E-UTRAN IP Throughput  |
| E-UTRAN IP Latency  |
| Availability | E-UTRAN Cell Availability  |
| Mobility | E-UTRAN Mobility  |
| TS 128 554 |
| 5G | Accessibility | Registered Subscribers of Network and Network Slice Instance through AMF" (Authentication Management Field). |
| Registered Subscribers of Single Network Slice Instance through UDM"(Unified Data Management) |
| Registration success rate of one single network slice instance |
| Integrity | End-to-end latency of 5G network |
| Downlink latency for IP packets through gNB in split scenario |
| Upstream throughput for network and network slice instance |
| Downstream throughput for network and network slice instance |
| Upstream GTP data throughput at N3 interface |
| Downstream GTP data throughput at N3 interface |
| RAN UE Throughput |
| Utilization | Mean number of PDU sessions of Single Network Slice Instance |
| Virtualized resource utilization of single network slice instance |
|  |
| 5G | Energy Efficiency | E-UTRAN data Energy Efficiency |

## 6.3. BEREC QoS KPIs & Measurement Method

6.3.1. The QoS, as perceived by the end-user, is a crucial factor for both customers and service providers and with the profusion of ever evolving technologies, networks and services with different levels of QoS, it is becoming increasingly more complex to manage, measure and regulate QoS. Indeed, quality can be impacted by many factors at the network level and along the value chain, including the device, hardware, infrastructure, service and applications. Body of European Regulators for Electronic Communications (BEREC) suggested a list of QoS parameters, definitions and measurement methods shown in table to be used, where appropriate.

| QoS KPI | Definition | Measurement Method |
| --- | --- | --- |
| Supply time for initial connection | ETSI EG 202 057-1 (clause 5.1) The duration from the instant of a valid service order being received by a direct service provider to the instant a working service is made available for use. This should exclude cancelled orders.  | ETSI EG 202 057-1 (clause 5.1.3) It is measured by: a) The times by which the fastest 50%, 95% and 99% of orders are completed; b) The percentage of orders completed by the date agreed with the customer and, where the percentage of orders completed by the date agreed with the customer is below 80%, the average number of days, for the late orders, by which the agreed date is exceeded.  |
| Call setup time | ETSI EG 202 057-2 (clause 5.2) The call set up time is the period starting when the address information required for setting up a call is received by the network and finishing when the called party busy tone or ringing tone or answer signal is received by the calling party. Where overlap signaling is used the measurement starts when sufficient address information has been received to all the network to begin routing the call.  | ETSI EG 202 057-1 (clause 5.2.3) It is measured by: a) The mean value in seconds for national calls; b) The time in seconds within which the fastest 95% of national calls are set-up; c) The mean value in seconds for international calls; d) The time in seconds within which the fastest 95% of international calls are set-up; e) the number of observations performed for national and international calls.  |
| 3GPP TS 32.454 clause 5.1.2Session setup time Applicable for IMS (VoLTE KPI) | 3GPP TS 32.454 clause 5.1.2 It is measured by the mean value |
| Bill correctness complaints | ETSI EG 202 057-1 (clause 5.11) The proportion of bills resulting in a customer complaint about the correctness of a given bill per service.  | ETSI EG 202 057-1 (clause 5.11.3) It is measured by a percentage. |
| Voice connection quality | ETSI EG 202 057-2 (clause 5.3) ETSI TR 102 506 Evaluation of speech quality per call. The end-user perceived voice quality.  | ETSI EG 202 057-2 (clause 5.3.2) Statistics for: Mobile to Fixed Calls Mobile to Mobile Calls  |
| ITU-T G.1020: Performance parameter definitions for quality of speech and other voice band applications utilizing IP networks; |
| ITU-T G.1028: End-to-end quality of service for voice over 4G mobile networks; |
| ITU-T P.863: Perceptual objective listening quality prediction |
| Dropped call ratio | ETSI EG 202 057-3 (clause 6.4.2) The proportion of incoming and outgoing calls which, once they have been correctly established and therefore have an assigned traffic channel, are dropped or interrupted prior to their normal completion by the user, the cause of the early termination being within the operator's network.  | ETSI EG 202 057-3 (clause 6.4.2.2) When using the measurements based on network element counters, the following statistics should be provided: the percentage of dropped calls, calculated from all the calls in the period. When using test calls, the following statistics should be provided: the percentage of dropped calls, together with the number of observations used and the absolute accuracy limits for 95% confidence calculated from this number |
| 3GPP TS 32.454 clause 5.2.1 Call drop for IMS session Applicable for IMS (VoLTE KPI)The number of dropped sessionsdivided by the number of successfulsession establishments. | 3GPP TS 32.454 clause 5.2.1 It is measured by a percentage. |
| Unsuccessful call ratio | ETSI EG 202 057-2 (clause 5.1) ETSI EG 201 769-1 (clause 5.4) Unsuccessful call ratio is defined as the ratio of unsuccessful calls to the total number of call attempts in a specified time period.  | ETSI EG 202 057-2 (clause 5.1.3) ETSI EG 201 769-1 (clause 5.4.2) It is measured by: a) The percentage of unsuccessful calls for national calls; b) The percentage of unsuccessful calls for international calls; c) The number of observations used for national and international calls together with absolute accuracy. |
| Call set up failure probability | ETSI TS 102 024-9 (clause 4.1.1) The ratio of total call setup attempts that result in call setup failure to the total call setup attempts in a population of interest. | ETSI TS 102 024-9 (clause 4.1.1) |
| Call signaling delays | ETSI TS 102 024-9 (clause 4.2) It involves three different scenarios: call setup, call answer and call release. The Call Setup Delay (CSD) is thetime between the calling terminal providing sufficient addressinformation to set up the call, and the calling party receiving a confirmation from the called terminal that the called party is being alerted.The Call Answer Signal Delay(CASD) is the time between thecalled terminal indicating that it isready to initiate the call and receiptof that indication by the callingterminal.The Call Release Delay (CRD) isthe time between the clearingterminal initiating a call clear down,and its receipt of clearingconfirmation by the called terminal. | ETSI TS 102 024-9 (clause 4.1.1) |
| Response time for operator services  | ETSI EG 202 057-1 (clause 5.6.1) Time elapsed between the end of dialing to the instant the human operator answers the calling user to provide the service requested. Applicable to both fixed and mobile services. | ETSI EG 202 057-1 (clause 5.6.3) It is measured by: a) mean time to answers; b) percentage of calls answered within 20 seconds. |
| Frequency of customer complaints | ETSI EG 202 057-1 (clause 5.9.1) ETSI EG 202 843 The number of complaints logged per customer per data collection period. | ETSI EG 202 057-1 (clause 5.9.3) ETSI EG 202 843 Statistics: Number of customer requests to - technical support - commercial support Number of customer complaints related to - repair services - network/service management by the customer - cessation Number of customer complaints of any kind. |
| Customer complaints resolution time | ETSI EG 202 057-1 (clause 5.10.1) The duration from the instant a customer complaint is notified to the published point of contact of a service provider and is not found to be invalid to the instant the cause for the complaint has been resolved. | ETSI EG 202 057-1 (clause 5.10.3) It is measured by: a) the time by which the fastest 80% and 95% of complaints have been resolved (expressed in clock hours); b) the percentage of complaints resolved any time stated as an objective by the service provider. |
| Successful SMS Ratio | ETSI EG 202 057-2 (clause 5.6.1) Probability that a user can send a Short Message successfully from a terminal equipment to a Short Message Center | ETSI EG 202 057-2 (clause 5.6.1.3) The percentage of successfully sent short messages, together with the number of observations used and the absolute accuracy limits for 95% confidence calculated from this number. |
| SMS delivery time | ETSI EG 202 057-2 (clause 5.6.3) The end-to-end delivery time for SMS is the period starting when sending a SMS from a terminal equipment to a Short Message Center and finishing when receiving the very same SMS on another terminal equipment. ETSI EG 102 250-2 (clause 7.4.5) | ETSI EG 202 057-2 (clause 5.6.3.3) It is measured by: a) the mean value in seconds for sending and receiving short messages; b) the time in seconds within which the fastest 95 % of short messages are sent and received; c) the number of observations performed. ETSI TR 102 529 |
| Latency | ITU-T Y.2617The time between the first bit of a packet of a source entering anetwork, being received by the destination, which immediately sent a bit back to the source, andthen the last bit of the packet arriving at the source across the network (round trip delay). | It is recommended that delay is measuredusing:• UDP with ICMP or TCP as fall back option,• at least 10 measurements, and• calculated as an average of recorded roundtrip time values (typically expressed inmilliseconds).The measurement server should return anyUDP packet payload immediately, allowing the client to calculate delay. The Unix echo service could be used for this function. Themeasurement setup should be insensitive to (user) clock changes during the measurement. |
| Jitter | ITU-T Y.2617The difference between the delay of the selected packets. | It is recommended that the delay variation (jitter) is calculated as mean deviation based on the samples collected for the delaymeasurement. |
| Packet Loss Ratio | ITU-T Y.2617The total number of packets failing to deliver through the networkdivided by the total number of transmitted packets within a specifictime window. | If a packet is not received back within a certain timeout (e.g. 3 seconds), it is considered as lost for the purpose of packet loss measurements. Recommended to send a large number of IP packets (e.g. at least 1000). Delay and packet loss measurements are typically performed over a longer period of time in order to allow for the time varying nature of network performance in packet-switched networks. |

## 6.4. Network Benchmarking

6.4.1. Network Benchmarking is carried out to find best performing network with respect to consumer experience as it is the ultimate goal to assess the performance of a mobile network. It is easy to compare network performance on individual KPI levels (Drop Rate, Call Setup Time, single file download speed, etc.). However, the real problem is losing the bigger picture of what is best for the end users while comparing and optimizing so many KPIs. There are many different scores in the market for benchmarking network quality. Few of the examples are Connect Score/P3 Score, Chip Score, Ookla and RootMetrics Score etc.

6.4.2. The benchmarking and scoring of networks covering large geographic areas require careful consideration of number of factors which include deployed technology, extent of coverage, customer device population, customer population distribution and network usage and tariff offerings. While scoring the networks, following steps needs to be observed:

 a. **Fair Play**. Benchmarking outcomes can be significantly influenced by specific targeting of test devices for superior performance. In such cases the results obtained no longer reflect the experience of a customer using that network. Steps should be taken to ensure that the measured results are truly representative of the real customer experience.

 b. **Coverage**. Often networks are built with differing coverage objectives. Network rollout often varies between operators. This is often an important differentiator for consumers making decisions about which network is best for them. Benchmarking should be performed in such a way that it highlights coverage differences in the results. From a scoring perspective, operators should never be penalized for providing coverage where other operators do not. In fact, they should instead be rewarded in the scoring system. It should be the intention of any comprehensive mobile benchmark to include coverage comparison as a differentiating factor in the scoring.

 c. **Deployed Technology**. Network evolution and the adoption rate of new technologies often varies between operators. Benchmarking should be performed in such a way that it incorporates the use of the latest technology available. This is to reflect the network capability and customer experience available with the latest devices. Benchmark scoring should account for Operators who offer performance differentiation through early adoption of new technologies by way of a 'bonus' for such deployment.

## 6.5. Network Performance Score

6.5.1. Network Performance Score is a single metric that characterizes the overall network performance. NPS compares the quality of mobile networks and visualizes The Quality of Experience (QoE) that the end users perceive when using common applications. ETSI has released its technical report in August 2019 i.e. TR 103 559 on NPS.

6.5.2. NPS considers and weights the Key Performance Indicators (KPIs) for a wide range of services that are essential for and representative of the service quality and combines them into an overall performance score. This score can be calculated for individual regions such as cities, towns and highways. The scores of the individual regions are then aggregated in an overall network performance score.

6.5.3. The structure of the network performance score is highly transparent and consists of different layers of weighting and accumulation. NPS score is based on telephony and data services sub scores, each of which is scaled separately from 0 to 100 %. Each of these two sub scores consists of a set of comprehensive KPIs or contributors. Today, the sub scores have weightings of 40 % telephony and 60 % data services and form a complete network score. It is possible to apply an additional intermediate weighting layer that gives different weightings for individual regions and categories such as cities, connecting roads, hotspots and rural areas. The weighted and cumulative scores for the sub-region have again range from 0 to 100 %.

6.5.4. The KPIs of NPS for Voice Services are broadly categorized into Accessibility/ Sustainability, Setup Time and Speech Quality. Whereas in case of Data Services, KPIs are measured for HTTP Transfer, Video Streaming, Browsing and Social Media. All the KPIs are shown in below table.

|  |
| --- |
| INTEGRAED NETWORK PEROFRMANCE SCORE |
| **VOICE (40%)** | ***DATA (60%)*** |
| **Accessibility / Sustainability** | ***Http Transfer*** |
| * Call Setup Success Ratio – CSSR
* Call Drop Ratio
 | * Single File Download/Upload Success Rate
* Multi-Connection Download / Upload Throughput
 |
| **Call Setup Time** | ***Video Streaming*** |
| * Average Call Setup Time
* Call Setup Time > 15 Seconds
* 10 Percentile Call Setup Time
 | * Success Ratio
* Time to Transfer First Picture
* Video Quality – MOS
 |
| **Speech Quality** | ***Browsing & Social Media*** |
| * Average MOS – Super Wide Band
* MOS < 1.6
* 90 Percentile MOS - SWB
 | * Browsing Popular Websites
* Posting to Social Media
 |

## 6.6. Network Coverage

6.6.1. Many countries face difficulties meeting the increasing demand from users and local
authorities for a mobile connectivity available in rural areas and in constrained areas such as
indoor locations, subways, tunnels, hot spots, etc.

## 6.7. Factors Affecting Indoor Coverage

6.7.1. Consumers increasingly expect wireless devices of all kinds to provide seamless coverage, both outdoors and indoor, which requires a more dense radio network. Radio wave propagating in the atmosphere when impinges on a dielectric material such as a wall or window, phenomena of refraction occurs which results into reflection of some part of it whereas the other part is transmitted through the material into the building. The portion of wave reflected outside the building represent loss to a mobile present inside the building. An additional loss occurs due to the fact that the building material is lossy. This gives rise to attenuation of the transmitted wave as it propagates through the material due to absorption. At corners and edges of the building where two or more walls/ceilings meet and at the edges of window and doors where wood or glass panels meet walls, another phenomenon of diffraction of radio waves occurs. Further the radio wave scatters when it impinges on a rough surface. Building “clutter”, such as furniture and people, can often modelled as scatter sources because their dimensions are much greater than the roughness of building materials.

6.7.2. ITU-R Recommendation P.1406 defines Building Entry Loss (BEL) as, ***“The difference between the signal measured outside the building at street level and that measured inside the building”.*** ITU-R Recommendation P.2019-1 then models the BEL. It classifies building into two categories i.e. “thermally-efficient” & ”traditional”. In modern, thermally-efficient building methods are used (metallized glass, foil-backed panels) building entry loss is generally significantly higher than for ‘traditional’ buildings without such materials.

## 6.8. Correction Factors in Indoor Coverage

6.8.1. Ensuring reliable indoor coverage in buildings is a challenge facing any mobile network operator. Furthermore, an acceptable level of indoor service is difficult to define as different consumers have different priorities on the level of indoor service. The correction factors defined by different European Countries are as under:

a. OFCOM estimates between 10 and 18 dB of loss can represent reasonable average values for frequencies between 800 to 2600 MHz and for the vast majority of existing UK housing stock.

b. In Romania, ANCOM placed indoor coverage obligations on all licenses i.e. a 95% probability of indoor reception is required. To verify the compliance with this requirement, ANCOM leads outdoor field measurements and then adds a correction factor to the results in order to obtain the indoor signal. Regarding the indoor coverage, the correction factor relating to the indoor propagation attenuation is stipulated in the licenses as follows:

i. 6 dB for radio signals in the frequency ranges 800 MHz and 900 MHz.

ii. 8 dB for radio signals in the frequency ranges 1800 MHz and 2600 MHz for coverage in rural areas and coverage on national and European roads, as well as on highways.

iii. 12 dB for radio signals in the frequency ranges 800 MHz and 900 MHz, and 16 dB for radio signals in the frequency ranges 1800 MHz and 2600 MHz for mobile coverage in urban areas.

c. In Austria, the coverage obligation of the Multiband-Auction 2013 includes also indoor coverage requirements (for data services in the 800 MHz band for dedicated communities) with an extra attenuation of 20 dB considering building loss.

d. In France, there is no indoor requirement placed on licenses; however in order to reflect users’ experience (concerning voice and SMS services) ARCEP has defined a correction factor to the outdoor strength field measurements. Mobile operators have to publish mobile coverage maps with several levels of coverage.

i. “Satisfying coverage”: a certain strength field level is measured. It corresponds to the case where mobile coverage is generally available outside of buildings;

ii. “Good coverage”: a correction factor of -10 dB has been applied in order to reflect the locations where the coverage is available most of the time outside of buildings and sometimes inside of the buildings;

iii. “Very good coverage”: a correction factor of -20 dB has been applied in order to reflect the locations where the coverage is available outside of buildings and most of the time inside of the buildings.

e. In Sweden there are no particular indoor requirements in the licenses. However, the operators have an agreement with the NRA how to present their coverage on their coverage maps. The signal is measured or predicted outdoors and a margin of 16 dB penetration loss applied. Very good coverage is defined as an area where one probably can both make phone calls and use mobile broadband outside and inside. Indoor coverage depends on the walls, windows and doors and where in the building one is.

## 6.8. Solution of Indoor Coverage

6.8.1. Finding an appropriate solution to indoor service problems is also complicated by the fact that different consumer groups will have different priorities such as home users are very sensitive to cost and disruption during installation whereas in large public offices there may be a willingness to trade off these against more reliable service levels. The type of solutions that exists in the market and the selection of these solutions are influenced by the cause of the existing poor indoor coverage level. Different type of In-Building Solutions (IBS) include Wi-Fi, Carrier Wi-Fi, Repeaters, Femtocell, Picocell and Distributed Antenna System (DAS). However, BEREC and RSPG in its joint report on Facilitating mobile connectivity in “challenge areas” states that depending on the in-building solution implemented, the Quality of Experience (QoE) provided to end users may not be on a like-for-like basis compared with outdoor coverage provided over the microcell network.

## 6.9. Signal Repeaters

6.9.1. United State of America (USA) and United Kingdom (UK) has allowed use of Signal Repeaters / Amplifiers by the consumers to improve signal and hence service quality inside building.

6.9.2. OFCOM has made **“Wireless Telegraphy (Mobile Repeater) (Exemption) Regulation 2018”** on 12th April, 2018. Prior to these Regulations, the use of mobile phone repeaters, other than those supplied directly by the CMOs, was unlawful. Under these Regulations, two case of usage are allowed in UK, which are **Indoor Use** and **Motor Vehicle Use**. In this regard, OFCOM also published **“UK Interference Requirement 2102”** on 27th February, 2018. It contains the requirements of the use of (i) **static mobile phone repeaters for indoor use** and (ii) **low gain mobile phone repeaters for in-vehicle use** in specified frequency bands. These requirements taken together with the ‘essential requirements’ detailed in Article 3.2 of Directive 2014/53/EU constitute the minimum requirements for the use of the spectrum by the repeaters within the UK.

6.9.3. FCC issued a Report and Order on 20th February, 2013, wherein the Commission amended Parts 1, 2, 20, 22, 24, 27, and 90 of its Rules to adopt new technical, operational, and registration requirements for Signal Boosters, which came into effect on 1st March, 2014. The new Rules created two classes of Signal Boosters i.e. Consumer Signal Boosters and Industrial Signal Boosters. Consumer Signal Boosters have been authorized under provider licenses subject to certain requirements. Specifically, subscribers must:

1. Obtain provider consent to operate the booster;
2. Register the booster with their provider;
3. Limit booster use to certain frequencies used for the provision of subscriber-based services;
4. Use an appropriately labeled booster with manufacturer-specified antennas, cables, and/or coupling devices;
5. Use a booster that meets the Network Protection Standards and is FCC certificated;
6. Operate the booster on a secondary, non-interference basis and shut it down if it causes harmful interference; and
7. Not deactivate any booster features that are designed to mitigate harmful interference.

6.9.4. FCC directed Wireless Providers for provision of consent and maintenance of registration mechanism and also issued Network Protection Standards. Consumer Signal Boosters must meet the Network Protection Standard with the following requirements:

1. Comply with existing technical parameters (e.g., power and unwanted emissions) for the applicable spectrum band;
2. Automatically self-monitor certain operations and shut down if not in compliance with FCC new technical Rules;
3. Automatically detect and mitigate oscillations in the uplink and downlink bands;
4. Power down or shut down automatically when a device is not
needed, such as when the device approaches the base station with which it is communicating;
5. Be designed so that these features cannot be easily defeated; and
6. Incorporate interference avoidance for wireless subsystems.
7. In addition, Consumer Signal Boosters must comply with current RF exposure requirements. Consumers may continue to use existing signal boosters provided they have (i) the consent of their serving provider; and (ii) register the booster with that provider.

# CHAPTER-7: RECOMMENDATIONS FOR KEY QUALITY PROBLEMS

## 7.1. Key Quality Problems

7.1.1. Key challenges being faced by the SATRC countries can be broadly classified into following categories:

1. **Network Coverage Issues**

i. In-adequate mobile coverage in remote/un-served/ under-served areas (Nepal, Sri Lanka). Coverage and Service Quality in Difficult Terrains e.g. mountainous or forests etc., or non-profitable areas i.e. with sparse population is a challenge faced by SATRC countries.

ii. Poor indoor coverage (Maldives, Pakistan). Indoor coverage is badly affected from varying Building Entry Loss (BEL) due to challenging construction material utilized in modern day building. This compels consumers to buy sub-standard boosters /repeaters which creates interference in entire spectrum band. (Afghanistan, Pakistan)

b. **Network Optimization Issues**

i. KPIs with major concerns include less throughput / actual speed against Advertised Speed, Call Drop Rate.

ii. Development of new KPIs such as VoLTE KPIs.

iii. Methodologies for measurement of new QoS KPIs.

iv. Mute VOLTE calls on 4G, not captured in KPIs (India)

v. Slow internet speeds (Afghanistan, Bhutan, Nepal, Sri Lanka)

vi. Network congestion (Bhutan)

**c. Quality of Experience Issues**

i. Un-authorized activation of VAS without user consent (Sri Lanka)

d. **Regulatory Issues**

i. Illegal Jammers causing interference in the network (Afghanistan)

ii. Locking of sites due to security concerns causing coverage degradation (Afghanistan).

iii. Lack of competition (Nepal)

iv. Inadequate Spectrum (Bangladesh, Nepal)

v. Interference due to seasonal ducting effect (Sri Lanka)

## 7.2. Key Recommendations

7.2.1 Following measures are recommended for:

**a. Improving Network Coverage:**

**i. Network Densification:**

Coverage holes at specific locations housing multiple structures can be filled by deploying outdoor micro multi operator sites, also called ‘Small Cells’. It is an umbrella term for low-powered radio access nodes operating in licensed / unlicensed spectrum, with range of 10 meters up to several hundred meters. It covers Femto Cells, Pico Cells, Micro Cells and Metro Cells based upon coverage requirements. They are typically installed on building walls or street furniture (e.g. lampposts and CCTV poles).

**ii. Indoor Coverage:**

For improving indoor coverage, USA and UK have permitted use of indoor repeaters (signal boosters). SATRC countries can also look in to it. Good quality, type approved, low power, band-specific repeaters can be offered to users with operator’s consent, provided they do not cause interference in the network.

A 20 dB loss in indoor performance can be predicted based on outdoor measurements. So if an adequate margin is built in outdoor coverage thresholds, it will help in addressing indoor coverage.

1. **Improving Network Quality:**

**i. Network Capacity:**

If adequate spectrum is not available, the network capacity will degrade with rise in traffic. And capacity on access side won’t benefit much if backhaul is choked. Focus on improving back-haul connectivity and capacity, preferably by shifting on fiber, wherever possible. Most often, this is the reason for slow network speeds.

1. **Effective QoS / QoE Monitoring Mechanism:**

The QoS and QoE Monitoring System should utilize all available methods & Performance Measurement Tools based upon raw counters, drive-test data, probes (if feasible), crowd-sourced data and surveys. All modules to be integrated and reports to be correlated in order to check and compare performance of operators in terms of QoS and QoE KPIs.

For Mobile Broadband Services, the Regulator needs to monitor whether operators are offering advertised speeds or otherwise.

Any testing scenario needs to include social media apps (i.e. YouTube, Facebook, etc.) both in drive-testing and static point testing.

1. **Effective QoS / QoE Enforcement Mechanism:**

Penalties for non-conforming QoS KPIs push operators to improve network quality up to a certain limit. A better way is to let them compete over better network quality by virtue of ranking their performance in different geographic regions through Network Performance Score (NPS).

QoS reports / scores should be regularly published on both, regulators’ and operators’ web sites.

**c. Improving Quality of Service & Experience (QoS & QoE):**

**i. Customer Perception:**

Keeping in view that users perceive very good performance very positively, therefore, the QoS Regulations at least include all those QoS KPIs of a particular service, which affects the consumers’ perceptions directly.

Example of few of such QoS KPIs for Voice Services are Service Accessibility which include Call Setup Success Ratio, Call Setup Time, Call Drop Rate and End-to-End Speech Quality / Mean Opinion Score (MOS). In case of Data Services, User Data Throughput, Browsing Speed, Video MOS, Latency etc. Whereas, example of QoS KPIs which are not directly perceived / experienced by users may include: RxQual, Ec/No, RSRQ, RxLev Sub, RAB Setup Success Rate (Data), Session Abnormal Release Rate, Inter System Handover, etc.

**ii. Non-Network Performance KPIs:**

Non-technical or non-network performance KPIs include Service provisioning, Restoration / Repairing, Service reliability, Billing, Complaint handling, etc. These KPIs are very important from overall user perception point of view. Any QoS Regulation should also include such KPIs.

**iii. New KPIs:**

With development of new services in different verticals, based on Internet of Things (IoT) and 5G, the QoS / QoE aspects also shift to new services. New QoS / QoE KPIs are to be introduced in regulations from time to time either through amendments in regulations or by revising license conditions.

**iv. Ensuring Customer Consent:**

Ensure Value Added Service (VAS) packages are only activated with customer consent. A dual consent One Time Pin (OTP) code based activation method can be used for this purpose.

1. **Regulatory Interventions**

**i. Spectrum Availability:**

Additional spectrum is the key for improving network quality. Left-over spectrum in all IMT bands should be released, preferably with staggered payment option to operators.

**ii. Roll-out Obligations:**

Additional roll-out obligations can be included at the time of spectrum auctions / license renewals to cover more population. Also enhanced QoS requirements can be introduced at that time.

**iii. Infrastructure Sharing / Spectrum Trading & Sharing / National Roaming:**

Some SATRC countries, offer separate licenses for facilities based operators. Permitting them to deploy active equipment and offering it for sharing as well (Active Sharing), will increase the pace of network deployment, thus improving network quality.

Also, provisions in regulations for spectrum trading, sharing and national roaming allows operators to expand its coverage while reducing cost of network deployments.

**iv. Right of Way:**

Right of Way refers to the right to lay a cable or to install a tower. This may be through or in a municipal area, or it may be on a private property. There are rules and procedures already laid down, but these rules haven’t totally solved the problem. And, therefore, fresh ideas are needed to improve this situation.

Technical specification should be in place for in-building telecommunication cabling, the use of physical utility infrastructure for granting rights of way, and for ducts and associated access points to be provided in new roads, footpaths and railway tracks.

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# 9. LIST OF ACRONYMS

|  |  |
| --- | --- |
| AMF | Authentication Management Field |
| BEREC | The Body of European Regulators for Electronic Communications  |
| CDN | Content Delivery Network |
| CN | Core Network |
| CSSR | Call Set-up Success Rate |
| DN | Data Network |
| ETSI | European Telecommunications Standards Institute |
| gNB | gNodeB - 5G wireless base stations |
| GNSS | Global Navigation Satellite System |
| GTP | GPRS Tunneling Protocol |
| ISP | Internet Service Provider |
| ITU | International Telecommunications Union |
| MOS | Mean Opinion Score |
| N3 | Interface between the RAN (gNB) and the (initial) UPF. |
| N4 | Interface between the Session Management Function (SMF) and the UPF |
| N6 | Interface between the Data Network (DN) and the UPF |
| N9 | Interface between two UPF’s (i.e., the Intermediate I-UPF and the UPF Session Anchor) |
| NRF | Network Repository Function |
| NSSF | Network Slice Selection Function |
| PCF | Policy Control Function |
| PCH | Paging Channel |
| PDU | Protocol Data Unit |
| RAN | Radio Access Network |
| RSPG | Radio Spectrum Policy Group |
| RTT | Round Trip Time |
| SMF | Session Management Function  |
| SWB | Super Wide Band |
| TN | Transport Network |
| UDM | Unified Data Management |
| UE | User Equipment |
| UPF | User Plane Function |

# 10. ANNEXURE-I

**Questionnaire for Work Item on**

 **“REGULATORY APPROACHED TO ENHANCE QoS OF MOBILE OPERATORS”**

Q1. Please provide the details of the existing regulatory framework for Quality of Service (QoS) in your country? In addition, also share the relevant documents and their web addresses.

Q2. Keeping in view these Seven (7) QoS criteria mentioned above, what Key Performance Indicators (KPIs) are measured in your country related to specific services i.e. Voice, SMS and Data?

Q3. Describe the methodologies for measuring QoS KPIs. What tools are being used for measurement of QoS KPIs?

Q4. Who are the responsible stakeholders for QoS data measurements (e.g., Operator, Regulator, Consumer, Third Party, joint arrangement among multiple stakeholders, etc.)?

Q5. What is the QoS enforcement mechanism and how is it implemented in your country?

Q6. Is Quality of Experience (QoE) measured in your country? If yes, explain the procedure of measuring the QoE along with its parameters?

Q7. Do you have any specific requirements for indoor coverage testing? Is there any requirement to provide mandatory emergency service connectivity indoor or outdoor?

Q8. Has any work been initiated in defining QoS criteria for 5G?

Q9. How is the QoS testing result being published or communicated to Operators / Consumers?

Q10. Do you have any regulations for OTT applications? If so, is OTT to licensed network call permitted and its QoS monitored?

Q11. What is the mechanism for revision of QoS KPIs? Is it through Regulation, Revised License Conditions, any other?

Q12. Are there any new techniques or methodologies for QoS monitoring such as, Autonomous Benchmarking Solutions, Active Probes, Mobile Apps, Reconciliation of Regulator and Operator collected data, being tested in your country?

Q13. Is there any provision available to monitor real-time QoS KPIs? If so, how it is managed between Regulator and the Operator.

Q14. Are there any plans for introducing new QoS parameters? Please specify, if any? *(e.g., KPIs for App based user experience; KPIs for VoLTE, etc.)*

Q15. What are the key quality problem being faced in your country? In your opinion, what measures should be taken to address that problem? *(e.g., releasing more spectrum, increasing mandatory Data DL speeds for 3G / 4G, etc.)*