2020 APT Expert Mission for Brunei Darussalam

Technical Assistance Final Report for Enhancement of 'Code of Practice Standard of Performance on Quality of Service' for the Telecommunications Sector

December 2020

Disclaimer

This study has been prepared for the Brunei Darussalam Authority of Infor-Telecommunications Industry (AITI) by the Expert Mission Programme of the Asia-Pacific Telecommunity (APT) in collaboration with the National Information Society Agency (NIA) of the Republic of Korea.

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List of Abbreviations

CoP QoS	Code of Practice on Quality of Standard
AITI	Authority of Info-Communications Technology Industry
UNN	United National Networks Brunei
TA	Technical Assistance
APT	Asia-Pacific Telecommunity
NIA	National Information society Agency, Republic of Korea
GSMA	Global System for Mobile Communications Association
ITU	International Telecommunication Union
FTTH	Fiber To The Home
ASEAN	Association of Southeast Asian Nations
UN	United Nations
GNI	Growth National Income
MOS	Mean Opinion Score
PESQ	Perceptual Evaluation of Speech Quality
POLQA	Perceptual Objective Listening Quality Analysis
SLA	Service Level Agreement
NER	Network Efficiency Ratio
QoE	Quality of Experience
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
CSFB	Circuit Switch Fallback
CPE	Customer Premises Equipment
FTP	File Transfer Protocol
USSD	Unstructured Supplementary Service Data
SMS	Short Messaging Service
MMS	Multimedia Messaging Service
KPI	Key Performance Indicators
KQI	Key Quality Indicators
GSM	Global System for Mobile Communications
RSSI	Received Signal Strength Indication
PDP	Preferred Provider

ICMP	Internet Control Message Protocol
UE	User Equipment
EPS	Evolved Packet System
GPS	Global Positioning System
TCP	Transmission Control Protocol
RTT	Round Trip Time
TTFF	Time to First Fix
NP	Network Provider
PoP	Point of Presence
RSRP	Reference Signal Received Power
MNO	Mobile Network Operator
CA	Carrier Aggregation
WB	World Bank
AfDB	African Development Bank
IDB	Inter-American Development Bank
ADB	Asia Development Bank
WeGO	World Smart Sustainable Cities Organization
UNPOG	United Nations Project Office on Governance
UNDP	United Nations Development Plan
KOICA	Korea International Cooperation Agency
SNU ITPP	Seoul National University International IT Policy Program
KAIST ITTP	Korea Advanced Institute of Science & Technology Information & Telecommunication Technology Program
OECD KPC	Organization for Economic Cooperation and Development Korea Policy Centre

Executive Summary

Brunei Darussalam introduced the Quality of Service Code of Practice (QoS Code) in March 2014, with the aim of ensuring the delivery of telecommunications services of good and acceptable quality to all users in Brunei. The QoS Code contributed to strongly encouraging local telecom operators to provide services at standards somewhat higher than those prescribed. However, many things have changed recently in the landscape of the telecommunications sector in Brunei.

Most significantly, Brunei's telecom infrastructure was regrouped in 2019 under a single entity, namely the Unified National Networks (UNN), whereby the networks of the three "Telcos" (Telekom Brunei, Datastream Technology, and Progresif Cellular) were incorporated within the UNN. Now, each telco provides retail services with equal access to the national network. Furthermore, when the QoS Code was first introduced, it included parameters only for fixed lines based on copper and fiber optics and mobile networks based on 2G, 3G and pre 4G (IMT-2000).

Therefore, the QoS Code should incorporate the already launched 4G and the planned 5G, because one of the current trends in next-generation solutions for mission critical users is the use of commercial 4G, followed by 5G networks. Brunei is preparing for the introduction of 5G, and one of the key issues here is the Quality of Service of the 5G network. In this ever-changing environment, now is the most relevant moment for the Authority of Infor-Communications & Technology Industry (AITI) to review the existing standards and to identify those in need of revision in accordance with emerging services and technological advancements.

With technical assistance (TA) through Expert Mission of Asia-Pacific Telecommunity (APT), APT and NIA intend to help the AITI revise Regulatory Framework on QoS for telecommunication. As requested, this report mainly focuses on the analysis of current regulatory framework inclusive of gap analysis to be measured and monitored in telecommunication service. This TA report is about supporting the planning of the 'Revised Regulatory Framework on QoS for telecommunication inclusive of 5G', not about establishing the revised framework itself on behalf of AITI.

This report is organized into four parts. It begins with an introductory chapter that provides an overview of the background of the TA and the policy context of Brunei. Chapter 2 assesses the current status of broadband and ICT in Brunei. An assessment of the current status of broadband and ICT in a country is critical to revising the code, especially considering 5G services introduction plan and emerging mobile services. The evaluation of current status of broadband in Brunei mainly relies on AITI's internal reports and international studies conducted by different institutes to measure

development of the broadband sector and identify weaknesses and strengths, largely due to insufficient data on some of the broadband related sectors in Brunei. An assessment of the current status of the telecommunication sector in Brunei will deepen understanding of the market structure, patterns of usage, performance of networks, and business environment, thus providing a strong impetus for determining what should be done in the future.

Chapter 3 reviews current CoP QoS Performance Parameter. This section deals with the mandatory performance parameters in the context of the respective infrastructure and services. The critical performance parameters identified in the succeeding subsections have been grouped in the form of different tables to establish scope, benchmarks, and significance in the respective cases. This may help not only help to maintain reasonable uniformity across the technologies, but may also impart the necessary flexibility required to manage any modifications without any structural alterations of this section.

Chapter 4 presents Korea's wired and wireless communication quality evaluation framework as an example. Testing method and equipment for each communication service, related acts, implementation procedures and assessment parameter are explained in detail. As Korea is the first country in the world to introduce 5G, Korea’s telecommunication quality measurement system inclusive of 5G may be the reference for Code revision. In addition, a brief training plan to ensure the effective implementation of Brunei's revised framework is also described. Training plan is divided into basic course, advanced course, and overseas training course.

1. Introduction

This document is a final report within the scope of technical assistance to analyse and update Brunei Code of Practice Standard of Performance on Quality of Service (CoP QoS). The technical assistance aims at providing guidelines and recommendations on Quality of Service inclusive of 5G in Brunei Darussalam.

1.1 Background of the Project

Almost every Bruneian is now online. When connecting online, however, they encounter problems with the quality of service. Quality of Service (QoS) consists of a set of parameters related to the performance of traffic on the telecommunication network. According to the ITU-T, QoS is defined as 'the collective effect of service performance which determines the degree of users' satisfaction with a given service.'[1] In other words, QoS in the field of telecommunication is a set of specific requirements provided by a network to users, which are necessary in order to achieve the required functionality of the service in question. Therefore, the quality of a service is an important point to consider when selecting services offered by different service providers.

Ensuring the QoS is becoming an increasingly important and complex issue in today's highly competitive and challenging digital environment. In this digitally connected world where all functions and aspects of life are being transferred to telecommunication networks and services, citizens everywhere are heavily reliant on ICTs to conduct their everyday socio-economic activities. Using the internet in a way that improves one's everyday life requires a reliable connection with sufficient bandwidth. Under the current circumstances, quality of service is critical to ensuring the consistency of application performance and optimal end-user experiences. A harmonized and up-to-date approach to keeping up with technological progress so as to guarantee QoS would greatly help with improving the services, irrespective of the location of the subscriber or the service provider.

The project aims to provide the technical assistance required to help the Authority of Info-Communications Technology Industry (AITI) prepare for revision of the CoP QoS. The report mainly focuses on assisting with analyzing Brunei's current CoP QoS as established by AITI, as well as on identifying the gaps between the current QoS and the desired level of QoS, along with recommendations on the parameters and metrics in the CoP QoS,

[1] ITU-T Recommendation E.800: Definitions of the terms related to the quality of service.

including the 5G network. In addition, by benchmarking Korea's QoS testing method based on its global practice, appropriate testing equipment and methods relevant to Brunei are also recommended.

The AITI introduced the Quality of Service Code of Practice (QoS Code) in March 2014, with the aim of ensuring the delivery of telecommunications services of good and acceptable quality to all users in Brunei. The QoS Code contributed to strongly encouraging local telecom operators to provide services at standards somewhat higher than those prescribed. However, many things have changed recently in the landscape of the telecommunications sector in Brunei. Most significantly, Brunei's telecom infrastructure was regrouped in 2019 under a single entity, namely the Unified National Networks (UNN)[2], whereby the networks of the three "Telcos" (Telekom Brunei, Datastream Technology, and Progresif Cellular) were incorporated within the UNN. Now, each telco provides retail services with equal access to the national network. Furthermore, when the QoS Code was first introduced, it included parameters only for fixed lines based on copper and fiber optics and mobile networks based on 2G, 3G and pre 4G (IMT-2000). Therefore, the QoS Code should incorporate the already launched 4G and the planned 5G, because one of the current trends in next-generation solutions for mission critical users is the use of commercial 4G, followed by 5G networks. Brunei is preparing for the introduction of 5G, and one of the key issues here is the Quality of Service of the 5G network. In this ever-changing environment, now is the most relevant moment for the AITI to review the existing standards and to identify those in need of revision in accordance with emerging services and technological advancements.

In an effort to revise and update the QoS Code, the AITI has requested technical assistance from the APT. This technical assistance (TA) with the QoS Code has been performed under the Expert Mission Programme of the Asia-Pacific Telecommunity (APT) in collaboration with the National Information Society Agency (NIA) of the Republic of Korea.

2. Current State of Broadband in Brunei Darussalam

2.1 State of ICT/Broadband

Although a relatively small market, Brunei Darussalam benefits from a high penetration rate of telecommunication services. The country achieved total digitalization of the phone network in 1995, while the mobile penetration rate exceeded the 100 percent mark much later, in 2008. An assessment of the current status of the telecommunication sector in

[2] The Unified National Networks (UNN) is a 100% equity-owned organization of the Brunei government. Founded as a government subsidiary on December 4, 2018, it is a digital communication service based in Brunei whose purpose is to provide inexpensive communication services to domestic and foreign customers. The UNN is working with Deutsche Telecom to receive support for technology related to network integration.

Brunei will deepen understanding of the market structure, patterns of usage, performance of networks, and business environment, thus providing a strong impetus for determining what should be done in the future. Thus, an assessment of the current state is a systematic method of where a country is at present, and could be regarded as an integral part of any strategic planning. The methodology used to analyze the current state of affairs is a combination of desk research based on the data provided by the AITI and web-based information collection relevant to the telecommunications sector in Brunei Darussalam.

2.1.1 Telecommunication

2.1.1.1 The Mobile Connectivity Index 2020

- The Mobile Connectivity Index is designed to measure the performance of mobile connectivity of countries, focusing specifically on mobile connectivity. It is an input index to measure a set of major enabling characteristics, rather than an output index that measures Internet take-up and usage.

- The Index measures the performance of 170 countries, accounting for 99 percent of the world's population, against the four key enablers of mobile Internet connectivity. The four key enablers for the Index are[3]:

  - Infrastructure – the availability of high-performance mobile internet network coverage;

  - Affordability – the availability of mobile services and devices at price points that reflect the level of income across a national population;

  - Consumer readiness – citizens with the awareness and skills needed to value and use the internet, and a cultural environment that promotes gender equality;

  - Content and services – the availability of online content and services accessible and relevant to the local population.

- The index consists of twelve dimensions in four enablers. And fourteen dimensions are built up through 35 indicators. As an output of these measurements, it groups countries in clusters according to the strength of the enabling environment for mobile connectivity allowing comparisons and contrasts to be drawn between groups of nations.

3. GSMA Intelligence

< Table 1> Mobile Connectivity Index 2020 for Brunei: Scores of Enablers (Score/100)

	Index score	Infrastructure	Affordability	Consumer Readiness	Content & Services
2020	67.4	59.6	69.6	74.6	66.4

Source: GSMA, 2020

< Table 2 > Mobile Connectivity Index

Infrastructure	Affordability	Consumer Readiness	Context
- Mobile Infrastructure - Network Performance - Other Enabling Infrastructure - Spectrum	- Mobile Tariffs - Handset Price - Income Inequality - Taxation	- Basic Skills - Gender Equality	- Local Relevance - Availability
39 Indicators			

Source: GSMA

- Brunei scored 67.4 in the Mobile Connectivity Index 2020, being evaluated as 'advanced.' According to the Index 2020, consumer readiness is somewhat satisfactory, but infrastructure and availability of relevant content and services need to be improved further. Brunei has certain demographic advantages, including a high level of literacy and strong per-capita consumption of ICT products and services.

< Table 3 > Mobile Connectivity Index 2020 for Brunei: Scores of Fourteen Dimensions

Enabler	Dimension	Score 2020
Infrastructure	Network Coverage	82.3
	Network Performance	44.8
	Other Enabling Infrastructure	76.3
	Spectrum	31.3
Affordability	Mobile Tariffs	59.7
	Handset Price	71.0
	Inequality	54.6
	Taxation	97.5
Consumer Readiness	Mobile Ownership	89.7
	Basic Skills	63.2
	Gender Equality	78.5
Content & Services	Local Relevance	75.9
	Availability	59.0
	Online Security	62.4

Source: GSMA, 2020

- Among the fourteen dimensions, Brunei performs most strongly in taxation (97.5), mobile ownership (89.7), and network coverage (82.3), while network performance (44.8) and spectrum management (31.3) need to be greatly improved.

- As shown in the table below, the coverage of 2G and 3G mobile services is at an acceptable level, while the coverage of 4G should be expanded to unserved areas. Furthermore, additional steps should be taken to improve the performance of mobile download (22.0) and upload (32.1) speeds.

- Improving the mobile broadband user experience is critical to enabling Bruneians to realize the various benefits offered by the Internet and applications. Since the quality of service offered through mobile broadband has significant economic and social impacts, it is important to review the quality of the mobile broadband service and to take steps to improve the quality of the service, based on data on mobile connections speeds.

< Table 4 > Mobile Connectivity Index 2020 for Brunei:
Scores of Network Performance and Network Coverage Indicators

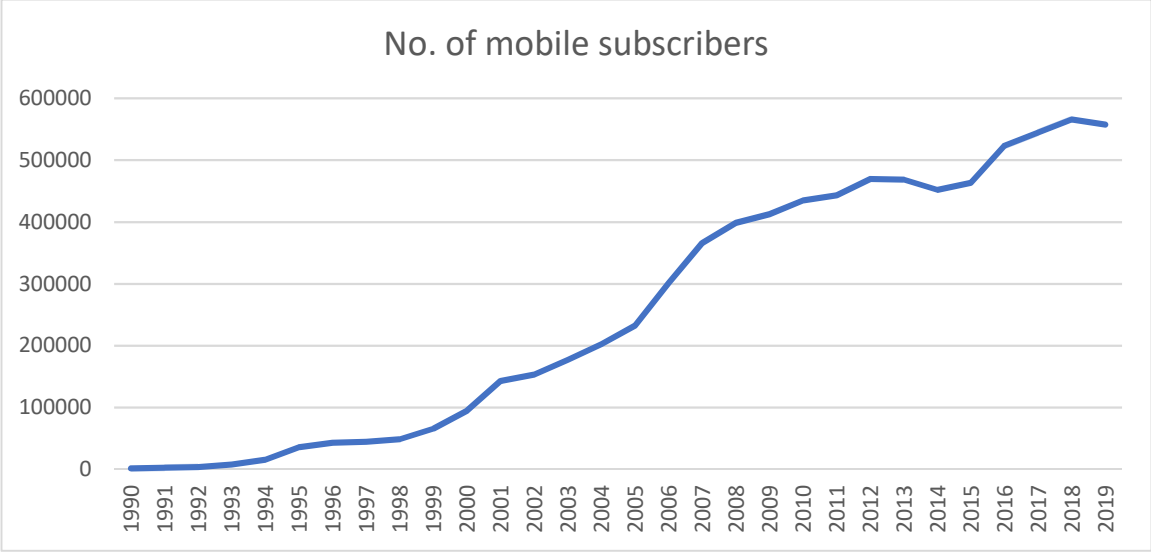
Dimension	Indicator	Score(2020)
Network Performance	Mobile download speed	22.0
	Mobile latencies	80.3
	Mobile upload speeds	32.1
Network Coverage	2G	99.1
	3G	95.9
	4G	85.0
	5G	0

Source: GSMA, 2020

2.1.1.2 Mobile subscribers

- Mobile subscriptions reached 55,700 in 2019, equivalent to a 128.6 percent penetration rate. According to the ITU, mobile-cellular subscriptions per 100 inhabitants was 131.9 at the end of 2018, whereas it decreased by 3.3 percent in 2019.

< Figure 1 > Mobile-cellular subscriptions: 1990-2019



Source: ITU

- The mobile penetration in Brunei continued to grow strongly until 2007, reaching a penetration of 105.12 percent by early 2008. Overall, the number of mobile subscribers was increasing steadily, but the growth rate of mobile subscribers began slowing down after 2008 as the Brunei mobile market appeared to reach saturation point.

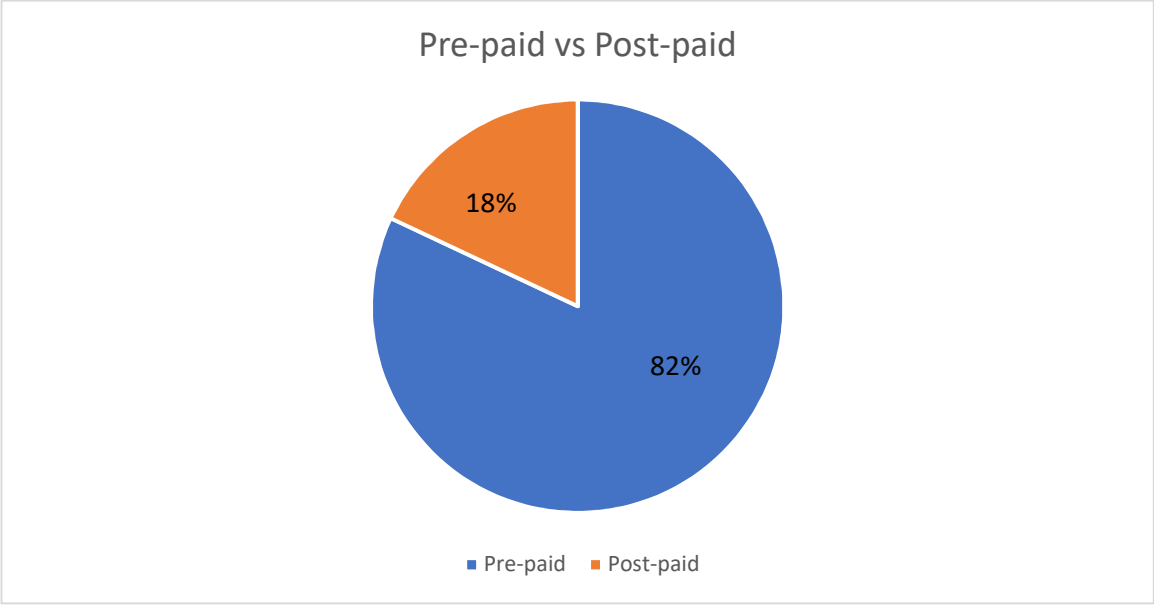
< Table 5 > Mobile-cellular subscriptions in Brunei: 2018-2019

Mobile Subscriptions (Year)	%
Mobile-cellular subscriptions per 100 inhabitants (2018)	131.9
Mobile-cellular subscriptions per 100 inhabitants (2019)	128.6

Source: ITU

- Pre-paid mobile connections account for 82 percent of subscriptions, while the remaining 18 percent are post-paid. As in many other countries, the pre-paid service is by far the most popular mobile phone service in Brunei, accounting for 82 percent of all mobile phone subscribers.

< Figure 2> Mobile connections by payment plan



Source: Digital 2020

- Seventy-six percent of mobile connections were broadband (3G & 4G) as of January 2020.

2.1.1.3 Fixed subscribers

- In 2018, the number of fixed telephone lines in Brunei Darussalam stood at 86,590, which is equivalent to almost 20 percent of the total population. However, the

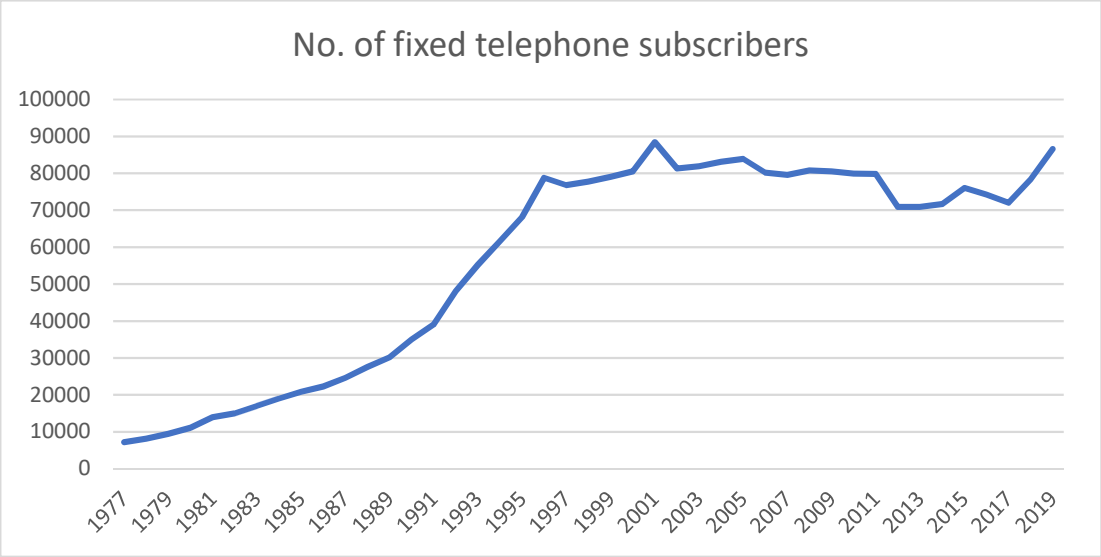
number of fixed telephone subscribers has been in decline since reaching a peak in 2001. Although it has fluctuated in recent years, it tended to decrease marginally throughout the period 2002-2018, hitting 78,322 in 2018.

< Table 6> Fixed subscriptions in Brunei: 2018-2019

Fixed Subscriptions	%
Fixed-telephone subscriptions per 100 inhabitants (2018)	18.26
Fixed-telephone subscriptions per 100 inhabitants (2019)	19.98

Source: World Development Indicators, The World Bank

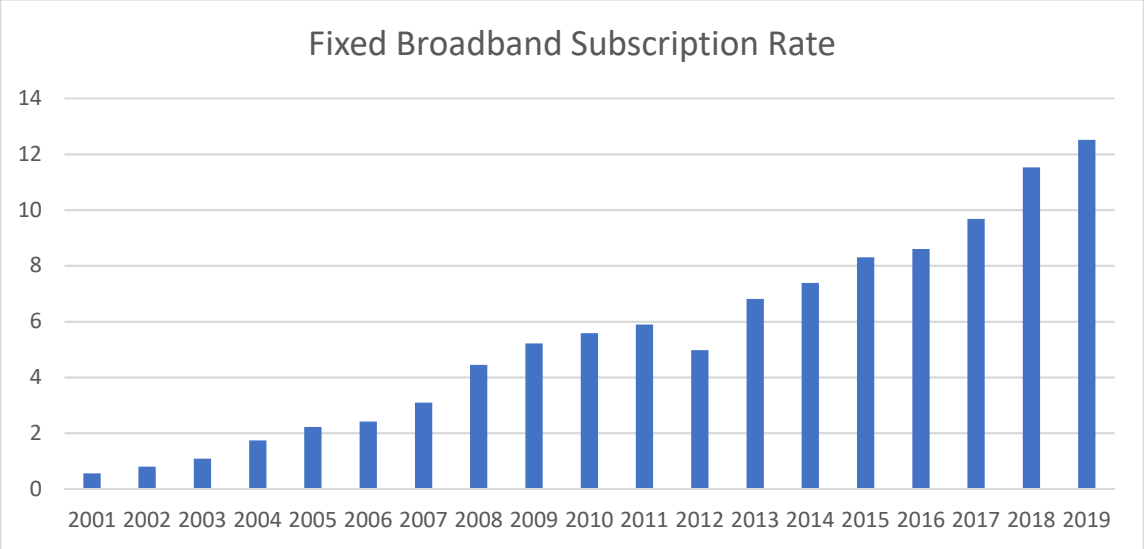
< Figure 3> Fixed telephone penetration: 1977-2019



Source: ITU

- Brunei is a small but extremely wealthy country with a population of about 437,000. The national telecommunications infrastructure is maintained to a generally high standard, supported by considerable investment in networks. However, due to the country's limited ability to achieve economies of scale, the fixed-line market is not well developed. The fixed infrastructure sector is traditionally characterized by huge fixed and sunk investment.

< Figure 4> Fixed broadband subscribers in Brunei: 2001-2019



Source: WB

- The up-to-date value for fixed broadband subscriptions per 100 inhabitants in Brunei was reported at 54,195, corresponding to 12.51 percent in 2019.[4] As seen in Figure 4, except for 2012, the trend of fixed broadband has continued to increase slowly from a relatively low base of subscribers. It is analyzed that this slow growth in fixed broadband is due to mobile broadband acting as the driver of growth in the market.

- As of 2019, about 93 percent of fixed broadband subscribers is connected via FTTH in Brunei. ADSL connections continued to decline, from 16.3 percent in 2017 to 7 percent in 2019, while FTTH connections increased by 9.3 percent in the same period.

< Table 7> Fixed broadband subscription by connection type: 2017-2019

	2017	2018	2019
xDSL	6,705 (16.3%)	6,708 (13,3%)	3,814 (7.0%)
FTTH	34,367 (83.7%)	43,394 (86.7%)	50,381 (93.0%)

Source: AITI, 2020

2.1.2 Internet

2.1.2.1 Internet users

- Number of Internet users helps measure how widespread Internet use is within a country. Internet penetration in Brunei has been maintained at 95 percent since 2017,

[4] https://data.worldbank.org/indicator/IT.NET.BBND?locations=BN

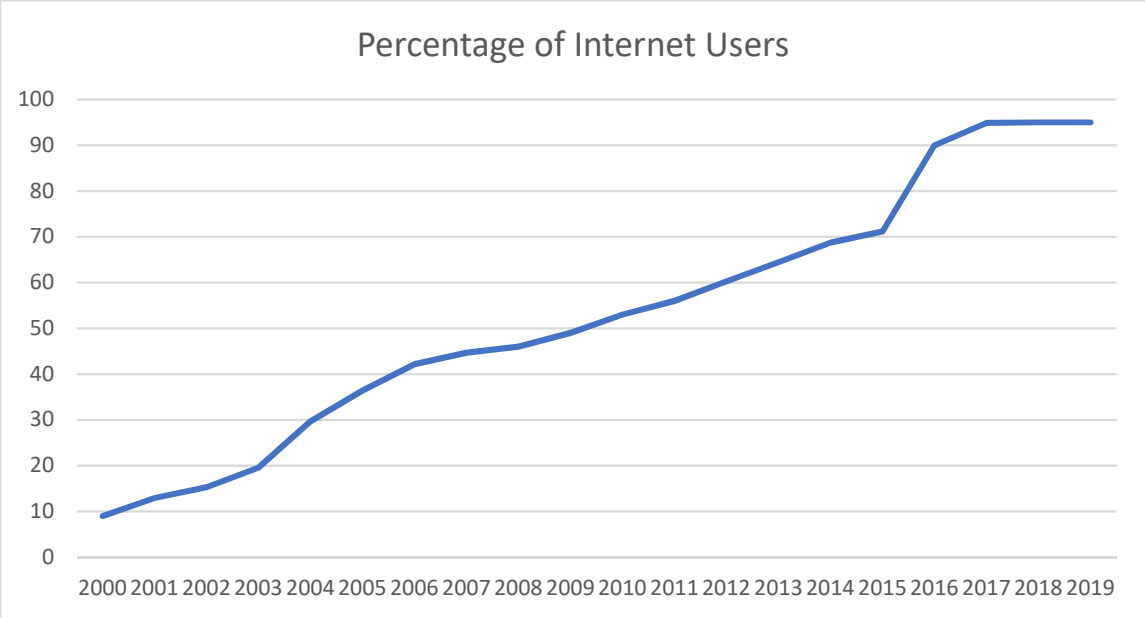
while the global average for 2019 was around 76.74 percent. In terms of Internet penetration, Brunei ranked 9th in the world and 1st among the ASEAN member states in 2019.[5] Besides, about 53.6 percent of all households in Brunei had access to the Internet in 2019.

< Table 8> Internet users and household in Brunei in 2019

Internet users and households	%
Individuals using the Internet (%)	95
Households with Internet access at home (%)	53.59

Source: ITU

< Figure 5 > Internet penetration in Brunei: 2000-2019



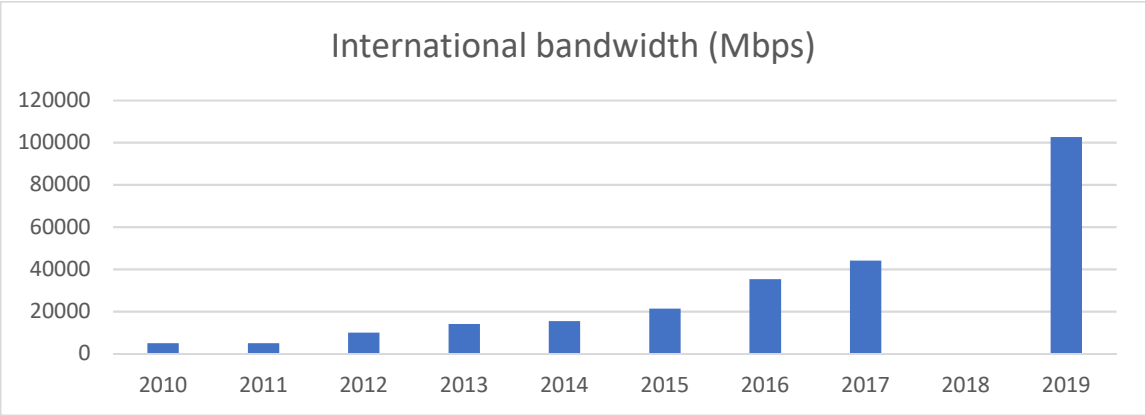
Source: ITU

2.1.2.2 International bandwidth

- International Internet bandwidth is the contracted capacity of international connections between countries for transmitting Internet traffic. Brunei has made steady improvements in international bandwidth since 2011. According to ITU, international bandwidth amounted to 102.5 Gbps in 2019. Brunei experienced a year-on-year average growth rate of more than 200 percent for the time period 2011 to 2019.

[5] https://www.theglobaleconomy.com/rankings/Internet_users/

<Figure 6> International Bandwidth for Brunei 2010-2019



Source: ITU (Data is not available for 2018.)

- As of January 2020, Brunei was connected to four active submarine cable systems, with a potential bandwidth capacity of 10 Tbps. These four systems are landed in two cable landing sites in Brunei, namely the Tungku landing site and the Telisai landing site.[6]

2.1.2.3 Broadband speed

- Unlike the way a regular speed test 'snapshot' is captured, the Internet speed test, in which physical equipment is used to constantly measure the speed available on specific lines across a long period of time, is often performed to track broadband speed.

- The Worldwide Broadband Speed League, which tracked broadband speed measurements in 221 countries and territories over a 12-month period (from May 2018 to May 2019), found that the mean download speed for Brunei was 8.97 Mbps in 2019, thus ranking 116th out of 221 countries and territories. The mean download speed should be regarded as a realistic reflection of the real-world user experience rather than the actually available bandwidth.

- In 2018, Brunei ranked 112ndamong 207 countries with an average speed of 4.78 Mbps. Despite a significant increase in speed, Brunei slipped four places in the annual league table of global broadband speeds due to the continuous rise in the global average speed. The average global broadband speed in 2018 was 9.1 Mbps, while the average speed measured in 2019 was 11.03Mbps - an increase of 20.65% over the previous year. Thus, Brunei's average broadband speed fell short of the global average broadband speed.

[6]. https://www.submarinenetworks.com/stations/asia/brunei

<Figure 7> Broadband speed in Brunei 2019

Source: Broadband Speed League 2020

2.1.3 Affordability

- Based on the criterion set by the UN Broadband Commission, both fixed and mobile data in Brunei satisfy the affordability threshold.[7] The fixed-broadband price basket was just 0.7 percent of the GNI (USD 5.86) per capita in 2019. Hardly differing from the fixed broadband price, mobile data on average represented 0.6 percent of GNI per capita, while mobile data and voice basket amounted to 1.3 percent.

< Table 9> Key affordability indicators for Brunei 2019

Key affordability indicator	Brunei (% GNI per capita)	USD	Rank
High consumption mobile data and voice	1.3	32.99	44
Fixed broadband	0.7	18.53	8
Mobile-data	0.6	14.83	25

Source: ITU, Measuring Digital Development: ICT Price Trends 2019

- Brunei ranked 196th out of 206 countries for fixed broadband Internet tariffs in the 2020 Global Pricing League.[8] These high costs can be attributed mainly to the small population, making it difficult from a commercial perspective to provide services at affordable prices.

[7] According to the UN Broadband Commission, entry-level broadband services should be made affordable in developing countries at less than 2 percent of the monthly Gross National Income (GNI) per capita by 2025. This lowers the Commission's existing affordability threshold target, from less than 5 percent by 2020 to less than 2 percent, which is expected to make broadband services (fixed or mobile) more affordable to a much higher number of people.

[8] https://www.cable.co.uk/broadband/pricing/worldwide-comparison/

- According to the Broadband Pricing League, Brunei's average cost of fixed broadband per month was USD 157.02 in early 2020, with the average cost of broadband decreasing year on year by USD 11.61 from USD 168.63. The ranking was fell 23 places compared with the previous year.

- The significant difference between the results of the ITU and the Broadband Pricing League is due to the consideration of the ability to pay, whether GNI per capita is considered or not.

2.1.4 Popular websites

- Google is the most popular website among Bruneians, followed by YouTube and Wikipedia, according to Alexa, based on such factors as estimated daily time on site, daily page views, and volume of traffic together with total site linking in.

< Table 10> Top 10 popular websites in Brunei: November 2020

Rank	Website	Category
1	Goole.com	Search Engine
2	youtube.com	TV and Video
3	wikipedia.org	Dictionaries and Encyclopedia
4	Kissasian.sh	Drama online
5	yahoo.com	News and Media
6	Google.com.bn	Search Engine
7	Xm.com	Online Trading
8	Live.com	email
9	Aliexpress.com	Online Retail
10	facebook.com	Social Network

Source: Alexa (https://www.alexa.com/topsites/countries/BN)

2.1.5 Social media users

- In January 2020, the number of active social media users was estimated to reach 410,000 in Brunei (94 percent of the population), of which over 99 percent were mobile users.[9] The number of social media users is increased by 1.2 percent between April 2019 and January 2020. As of January 2020, Facebook users accounted for more than two-fifths of SNS, followed by Instagram and Twitter.

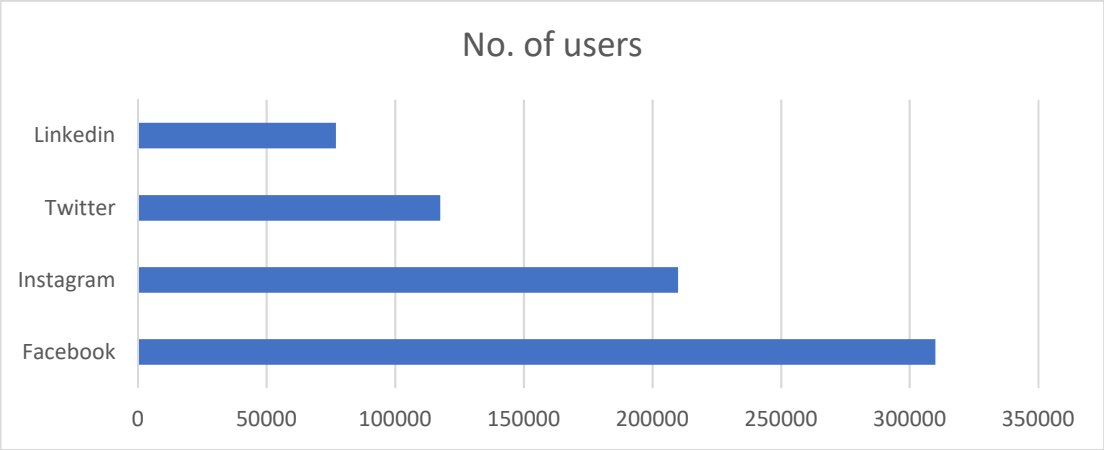
[9] Digital 2020: Brunei Darussalam, https://datareportal.com/reports/digital-2020-brunei-darussalam

< Table 11> Social media statistics in Brunei

Social Media	No. of users (Thousands)
Facebook	310
Instagram	210
Twitter	117.5
Linkedin	77

Source: https: //datareportal.com/reports/digital-2020-brunei-darussalam

< Figure 8> Number of Social Media Users

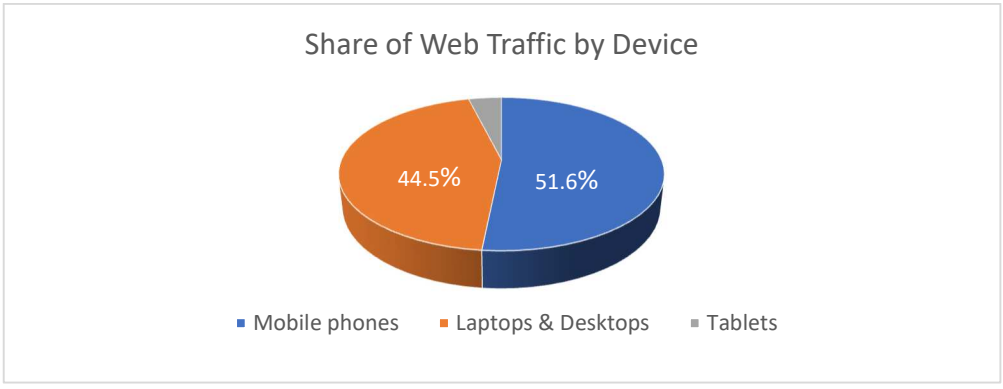


Source: https://datareportal.com/reports/digital-2020-brunei-darussalam

2.1.6 Share of Web traffic by device

- As of January 2020, around 51.6 percent of Web traffic in Brunei was accessed with mobile phones, whereas web traffic from laptops and desktop computers accounted for 44.5 percent, and tablets for the remaining 3.9 percent.[10]

<Figure 9> Share of Web traffic by device as of January 2020

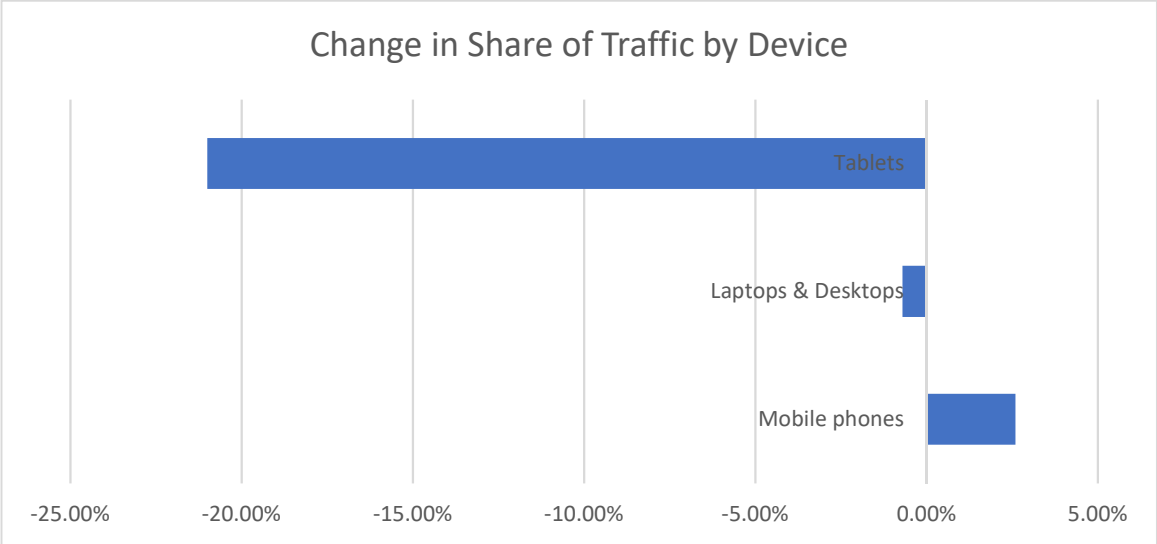


Source: Digital 2020 Brunei Darussalam, https://datareportal.com/reports/digital-2020-brunei-darussalam

[10] Digital 2020: Brunei Darussalam, https://datareportal.com/reports/digital-2020-brunei-darussalam

- The rate of smartphone ownership in Brunei is 88 percent, and the proportion of households with laptops is around 61 percent,[11] yet mobile account for 51.6 percent and laptops or desktops for 44.5 percent of Internet traffic, respectively, indicating that the volume of web traffic is almost proportional to the ownership of devices.

<Figure 10> Change in the Share of Web traffic by Device from December 2018 to December 2019



Source: Digital 2020, https://datareportal.com/reports/digital-2020-brunei-darussalam

- Looking at the change in the share of traffic by device from December 2018 to December 2019, the share of mobile phones increased by 2.6 percent, while that of laptops & desktops decreased slightly.

2.1.7 Coverage Information (2019)

<Table 12> Population, Households, Quarters, Area In Hectares by District and Coverage Strength

District	Population	Households	Quarters	Area In Hectares	DST GSM (2G)	DST UMTS (3G)	DST LTE (4G)	PSCB (3G)
Brunei-Muara	282,124	50,345	49,704	50,614	0	9	6	2
					61	52	154	81
					92	114	18	91
					20	3	0	3
					1	0	0	0
					6	2	2	2

[11] AITI, ICT Household Report 2019. According to the ITU, 64 percent of households possessed a computer in 2019.

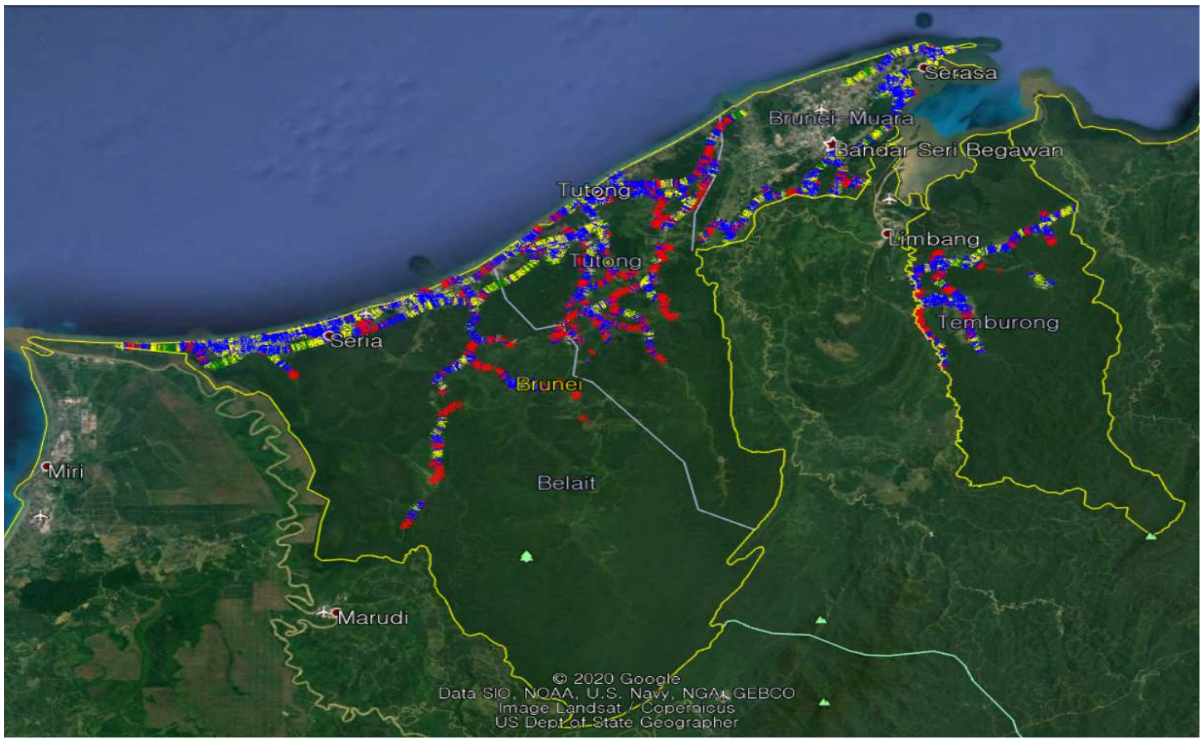
Belait	1411	418	374	121395	2	5	10	9
					21	18	37	11
					15	26	2	28
					2	1	0	0
					17	7	9	10
					3	3	2	2
Tutong	41,599	7,305	7,233	104,114	4	24	23	22
					32	22	43	29
					26	22	3	19
					7	2	0	0
					1	0	1	0
					6	6	6	6
Temburong	8,801	1,693	1,583	43,461	7	12	22	15
					20	23	22	22
					16	10	3	8
					3	3	1	0
					5	4	4	7
					7	6	6	6

<Table 13> Coverage color palette

Excellent	Good	Fair	Bad	No Signal	No Data

In Brunei Darussalam District, Rural Covered is 82.63% for DST2G, 62.64% for DST3G, 53.16% for DST4G, and 53.75% for PSCB 3G. In Brunei Muara District, Percentage Covered is 99.99% for DST2G, 98.34% for DST3G, 98.31% for DST4G, and 99.79% for PSCB 3G. In Tutong District, Percentage Covered is 97.73% for DST2G, 80.41% for DST3G, 77.85% for DST4G, and 81.22% for PSCB 3G. In Kuala Belait District, Percentage Covered is 98.10% for DST2G, 98.99% for DST3G, 98.07% for DST4G, and 96.81% for PSCB 3G. In Temburong District, Percentage Covered is 87.17% for DST2G, 78.00% for DST3G, 65.98% for DST4G, and 65.58% for PSCB 3G.

<Figure 11> DST 3G Data RSCP



<Figure 12> RCSB Voice RSCP

3. Telecommunication Service Quality Evaluation in Brunei Darussalam

3.1 Quality of Service Major Standard Specification

Among the various elements of quality measurement, MOS, the voice quality experienced by the user, is an important quality evaluation index and is defined in ITU-T P.800. As a method of quantifying and measuring the cognitive processes related to the quality of human speech, ITU-T P.862 proposes and uses MOS quality measurement as a quality called PESQ. In addition, with the development of voice service quality, wideband voice is commercialized and serviced, and ITU-T P.863 recommends measuring wideband voice quality by POLQA.

< Table 14 > QoS Standard Specification

Section	Standards	Org	comments
Service Classification	G.114	ITU-T	Specification for one-way delay required by PSTN
	G.109	ITU-T	Five quality grades on end-to-end voice quality using R value of E model
	TIPHON standard	ETSI	A standard for voice quality standards led by companies in Europe.Complies with ITU-T standards
	G.1010	ITU-T	Type classification and type-specific performance for multimedia services from a user's perspective
	Y.1540/1541	ITU-T	QOS Types and Performance Specifications for IP QOS Service in IP Networks
	P.800	ITU-T	Level 5 Regulation for Voice Quality (MOS)
	P.862	ITU-T	PESQ MOS Quality
	P.863	ITU-T	POLQA MOS Quality
	TS 23.107	3GPP	Radio Communication Based Application Service Classification
	S.P0079-A	3GPP2	Radio Communication Based Application Service Classification
QOS class	Y.CACPriority	ITU-T	Definition of Priority class level in IP Networks
	Y.RestPriority	ITU-T	Definition of restore priority class level in IP network

Source: KNISA's Service Quality Management Technology and Policy, 2007

< Table 15 > Quality Evaluation Items

items	unit	comments
call success rate	%	Rate of successful calls during call attempts (except for cases of disconnection, no connection, or poor sound quality)
data transmission speed	Mbps	Data transmission speed between the terminal and the measurement server in the operator's network
data transmission delay	ms	Data transmission delay time between the terminal and the measurement server in the operator's network
loss rate	%	Loss rate between the terminal and the measurement server in the operator's network
connection success rate	%	The percentage of successful calls attempting to connect to the measurement server
Web connection delay	%	Time until all web screens are displayed after accessing the web address (Except when connection is not available or transmission status is bad)

Source: MSIT's Communication Service Quality Evaluation Criteria, 2019

There are various standards for not only voice quality but also for call service quality. The call success rate is defined as the percentage or ratio of calls that are actually connected among the attempts made by a sender to connect to a called party. When a separate quality measurement software is installed in the sending-receiving terminal, the number of request messages transmitted for call connection and the number of successfully connected messages can be measured immediately. In addition, there are methods of measuring network quality by measuring data transmission speed, delay, loss rate, and connection success rate in an operator network, as well as a method of measuring web connection delay which measures the internet connection delay time. Brunei has a high MOS value of 3.83 or more and a transmission speed of 10.95 Mbps or more.

3.2 Overview of AITI Code of Practice Quality of Service

The Code may be cited as the Code of Practice and Standards of Performance relating to Quality of Services for the telecommunications sector in Brunei Darussalam (the 'Code'). The Code, or parts thereof, took effect on 1 March 2014 and will remain in force until further notification. Any amendments will enter into effect as and when notified.

3.2.1 Goals of the Code

- Promote delivery of telecommunications services at performances standards that reasonably meet the social, industrial and commercial needs of Brunei Darussalam.
- Promote efficiency, domestic and international competitiveness in evolving telecommunications, sector by making quality an inherent part of network infrastructure and services delivery
- Promote transparency and self-regulation to pave the way for maintaining the best possible customer interface along with optimal resource utilization
- Establish a baseline by specifying quality benchmarks for varied nature of telecommunication networks and services that are existing or evolving
- AITI shall endeavour to achieve these goals by exercising the powers and duties as provided in the Code.

3.2.2 Scope and Application of the Code

The following sub-section defines the scope and application of the Code in the context of the subscribed network Infrastructure and Services.

- Unless otherwise stated, the provisions of the Code shall apply to all Licensees under AITI's COP on Quality of service, 2014 as amended.
- The Code or any part thereof may apply to the Market Players as determined by AITI from time to time

- The Code or part thereof may assume the intended effect from different dates as determined by AITI for the given class of the Licensees. Similarly the specified sections may be revoked, exempted or modified with prospective effect as per the prevailing legislations. In all cases, AITI shall release the public notice on the website (http:// www.aiti.gov.bn) after seeking consultation with the stakeholders if necessary.
- The Code may be used as a baseline for the Telecommunications Infrastructure, Services or Applications that have not been explicitly mentioned or performance standards have not been mandated in the succeeding sections of the Code. AITI encourages the Licensees and Customers to use the Code as per the principle of similarity to reduce any uncertainty in the incidental matters.
- The Code allows for Service Level Agreements (SLAs) where Customer has a specific set of needs that are different from the general performance standards adopted herein. The agreement may be drawn mutually only with the bonafide Licensees without requiring prior notification or approval from AITI. The same applies for the instances where Market Players also act as the providers through the bonafide Licensees.
- The Code does not apply to the Content or Program as carried through network infrastructure but may apply to terms of carriage of the Content.
- The Code does not ensure consumer protection in the event of any direct transactions between Consumer and sole entity that does not possess any valid license.

3.2.3 Regulatory Principles

The following regulatory principles provide the foundation for the Code, and guide its implementation:

- Equitable proportionate regulation for the evolving sector.
- Increased transparency for stakeholders especially to help customers to make informed choices and to understand the limitations, if any.
- Reliance on self-regulation to enhance resource optimization.
- Harmonious alignment with other regulatory instruments and legislations.
- Adherence to technical neutrality in consonance with technical interoperability and feasibility.
- Simultaneous regard to public safety, emergency communication and rights of other stakeholders.

3.2.4 Use of Information by AITI

3.2.4.1 Purpose, Audit and Disclosures

- All contextual information including reports etc. as provided to AITI shall ordinarily be used for securing consumer interest, regulatory administration, improved consumer awareness, and enabling policy related inputs for development of ICT industry at national, regional or international levels.
- AITI reserves to right to undertake independent or joint technical audit, sampling surveys and use of standard measurement techniques for verification, compliance assessment and other related purposes.
- The information made available to AITI shall not be entirely disclosed to any other party without a valid reason. Notwithstanding this position, it shall not bind AITI from undertaking disclosure of quality-related information in consumer or national interests

3.2.4.2 Advisory Guidelines

AITI may publish Advisory Guidelines on specific matters as related to this Code in accordance with AITI's COP on Quality of service, 2014 as amended.

3.2.5 Requirements for Compliance

3.2.5.1 Related to Reporting

- The compliance towards submission of periodic reports shall be in accordance with Schedule D of the licensing terms and conditions.
- Any partial submission or non-submission shall be considered as non-compliance against reporting requirements. AITI reserves the right to issue notice to the concerned Licensee to submit the details or explanation within 21 days from the last date of submission due.

< Figure 13 > Instructions of QoS Quarterly Reporting to AITI

Quality of Service (QoS) Reporting to AITI

Instructions:

Structure	1	The given template may be used for submission of information relating to requirements under QoS Code of Practice and Standards of Peformance.
	2	The template has been structured into different portions ie. worksheets for convenience of making and compiling entries alongwith additional room for growth in future.
	3	For the information fields that are repeated in the respective worksheets, separate or combined values may be provided with suitable indications.
	4	The irrelevant fields may be provided with "Not Applicable". The common fields may be provided "Available at ____" as appropriate. Blank fields may be interpreted as no information.
Information	5	All relevant information should be consolidated and submitted in one instance only (say, "Q1:Original").
	6	Any subsequent modifications in the original information shall be as per request in writing.
	7	The date of making subsequent modifications shall be recorded in the final version (say, Q1: "Revised 1") for a particular term.
	8	The pre-revised entries shall have "***pink***" background and the modified ones shall have "***brown***" background.
	9	No modifications shall be ordinarily permitted after a lapse of 30 days of original submission.
	10	In case of information discrepancy between physical and electronic format, the former set shall prevail.
Submission	11	For online submission and any related queries etc., email_ID : **qos.report@aiti.gov.bn** may be used.
	12	Any problems while submiting the report should be immediately reported to AITI by other means.
	13	At least one complete set of physical copies in print shall be submitted to Chief Executive, AITI.
	14	Any related depictions, graphs, tables, links, general updates etc. may also be submitted alongwith the report.

Source: AITI QoS Report

3.2.5.2 Related to Performance Parameter

1) Performance Parameters for Voice Call

< Figure 14 > Technical Information Performance Parameter

	PART- B	INFORMATION RELATED TO PERFORMANCE	
		Performance Parameter	**Reference to the Code**
Technical Information	B.1	Time Consistent Busy Hour ("Busy Hour")	Section 4 & 6
	B.2	Grade of Service	Section 4 & 6
	B.3	Network Effectiveness Ratio	Section 4 & 6
	B.4	Network Availability (Core and Access)	Section 4 & 6
	B.5	Service Availability	Section 4 & 6
	B.6	Call Drop Rate (Urban;Rural)	Section 4 & 6
	B.7	Service Coverage Area	Section 4 & 6
	B.8	Voice Quality	Section 4 & 6
	B.9	Call Set-up Time	Section 4 & 6

Source: AITI QoS Report

< Figure 15 > Servicing and Maintenance Performance Parameter

Servicing and Maintenance	B.10	Percentage of installations, re-installations and service activation completed beyond 07 working days (for fixed access only)	Section 7
	B.12	Percentage of installations, re-installations and service activation completed beyond 30 working days (for fixed access only)	Section 7
	B.13	Percentage of reported cases where service was not activated as per Subscription with in 01 working day (for cellular mobile)	Section 7
	B.14	Percentage of cases for curative maintenance that took beyond 03 working days	Section 7
	B.15	Percentage of cases for curative maintenance that took beyond 07 working days	Section 7
	B.16	Percentage of subscriber requests processed beyond 02 working days	Section 7
	B.17	Percentage of subscriber requests processed beyond 07 working days	Section 7

Source: AITI QoS Report

< Figure 16 > Service Channel and Complaints Performance Parameter

Service Channel	B.18	Specified Service Channel(s) - Telephone number, Postal address, Fax number, E-mail_ID	Section 7
	B.19	Percentage of calls handled after 50 seconds on Customer Care Number(s)	Section 7
	B.20	Percentage of calls handled after 90 seconds on Customer Care Number(s)	Section 7
Complaints	B.21	Number of complaints received through all Specified Service Channels	Section 7
	B.22	Percentage of complaints acknowledged	Section 7
	B.23	Percentage of acknowleged complaints resolved beyond 10 working days	Section 7
	B.24	Percentage of acknowledged complaints resolved beyond 30 working days	Section 7

Source: AITI QoS Report

< Figure 17 > Undertaking Information related to Voice Performance

Undertaking	B.25	The following is hereby certified: (i) That contents are based on system-generated information, (ii) required disclosure to customers is complied, (iii) emergency call routing is efficiently maintained, and (iv) radio emissions have been found within the permitted measurement limits	Section 2

Source: AITI QoS Report

2) Performance Parameters for Broadband

< Figure 18 > Technical Information Performance Parameter

PART- B INFORMATION RELATED TO PERFORMANCE			
		Performance Parameter	**Reference to the Code**
Technical Information	B.1	Busy Hour	Section 4 & 6
	B.2	International Bandwidth Capacity and Peak-utilisation Value	Section 4 & 6
	B.3	Concentation Ratio (for fixed access)	Section 4 & 6
	B.4	Network Availability (Core and Access)	Section 4 & 6
	B.5	Service Availability	Section 4 & 6
	B.6	Service Coverage Area	Section 4 & 6
	B.7	Average Download Speed (user-level)	Section 4 & 6
	B.8	Average Upload Speed (user-level)	Section 4 & 6
	B.9	Latency	Section 4 & 6
	B.10	PDP-context Activation Success Ratio	Section 4 & 6
	B.11	Packet Loss Ratio (and/or Media Loss Rate)	Section 4 & 6

Source: AITI QoS Report

< Figure 19 > Servicing and Maintenance Performance Parameter

Servicing and Maintenance	B.12	Percentage of installations, re-installations and service activation completed beyond 07 working days (for fixed access only)	Section 7
	B.13	Percentage of installations, re-installations and service activation completed beyond 30 working days (for fixed access only)	Section 7
	B.14	Percentage of reported cases where service was not activated as per Subscription with in 01 working day (for cellular mobile)	Section 7
	B.15	Percentage of cases for curative maintenance that took beyond 03 working days	Section 7
	B.16	Percentage of cases for curative maintenance that took beyond 07 working days	Section 7
	B.17	Percentage of subscriber requests processed beyond 02 working days	Section 7
	B.18	Percentage of subscriber requests processed beyond 07 working days	Section 7

Source: AITI QoS Report

< Figure 20 > Service Channel and Complaints Performance Parameter

Service Channel	B.19	Specified Service Channel(s) - Telephone number, Postal address, Fax number, E-mail_ID	Section 7
	B.20	Percentage of calls handled after 50 seconds on Customer Care Number(s)	Section 7
	B.21	Percentage of calls handled after 90 seconds on Customer Care Number(s)	Section 7
Complaints	B.22	Number of complaints received through all Specified Service Channels	Section 7
	B.23	Percentage of complaints acknowledged	Section 7
	B.24	Percentage of acknowleged complaints resolved beyond 10 working days	Section 7
	B.25	Percentage of acknowledged complaints resolved beyond 30 working days	Section 7

Source: AITI QoS Report

< Figure 21 > Undertaking Performance Parameter

Undertaking	B.26	The following is hereby certified: (i) That contents are based on system-generated information, (ii) required disclosure to customers is complied, (iii) required disclosure to AITI about traffic shaping having a bearing on subscriptions is complied,and (iv) radio emissions have been found within the permitted measurement limits.	Section 2

Source: AITI QoS Report

3) Performance Parameters for Leased Lines

< Figure 22 > Performance Parameters for Leased Lines

	PART- B	INFORMATION RELATED TO PERFORMANCE	
		Performance Parameter	**Reference to the Code**
Technical & Service Information	B.1	Network Availabiltity	Section 4 and 6
	B.2	Service Avalability	Section 4 and 6
Service Channel	B.19	Specified Service Channel(s) - Telephone number, Postal address, Fax number, E-mai_ID	Section 7
Other Information	B.12 to B.18	Relevant information (on the lines of earlier Worksheets may be appended, if not provided already).	Section 7
Undertaking		The following is hereby certified: (i) That contents are based on system-generated information, (ii) required disclosure to customers is complied, (iii) required disclosure to AITI about traffic shaping having a bearing on Managed-IP subscriptions is complied	Section 2

Source: AITI QoS Report

- The contextual information contained in the report as submitted to AITI shall be regarded as statement of compliances for a specific period.
- The statement of compliance towards respective performance parameters and standards of practice shall be read together and be construed as composite performance
- In the event of non-compliance or partial compliance against specific performance parameters, AITI shall take into accounts all material facts made available before observing it as an act of non-compliance. The explanations may include reasons identified and proposed action-plans for the improvement or mitigation. The operational lapses shall be not construed as force majeure conditions unless justified.
- AITI shall reserves the right to take appropriate action in any event related to non-disclosure of essential information in consumer interest after a due notice period of 21 days.

3.2.6 Review of the Code

AITI by its own determination or on request made by primary stakeholders i.e. consumers, Licensees, and Government bodies may undertake the review of the Code to retain its instrumentality and significance.

3.3 Review of CoP QoS Performance Parameter

3.3.1 Performance Parameters

This section deals with the mandatory performance parameters in the context of the respective infrastructure and services, as mentioned above.

The critical performance parameters identified in the succeeding subsections have been grouped in the form of different tables to establish scope, benchmarks, and significance in the respective cases. This may help not only help to maintain reasonable uniformity across the technologies, but may also impart the necessary flexibility required to manage any modifications without any structural alterations of this section.

3.3.1.1 Core Network Infrastructure and Services

The following shall apply to subscription-based voice infrastructure and services, notwithstanding force majeure exemptions. The time period for the averaging of measured performance results should not exceed one quarter of three complete months, unless otherwise specified.

Busy Hour

Parameter	Busy Hour
Scope	All related public network infrastructure
Benchmark	To be continuously recorded on daily basis for a minimum period of 90 days to generate the valid average. Provided any voice access that is carried as IP data is included.
Significance	It determines the busiest hour during each day when the Broadband traffic through the network is recorded to be the highest with respect to the installed capacity. During the day, there may more than one peak at different times. For any network, busy-hour registered for voice and broadband access may differ in respective cases.

International Bandwidth capacity and peak utilization value

Parameter	International Bandwidth capacity and peak utilization value
Scope	At International Gateway that deals with packet data traffic (Autonomous System)

	or its Downstream equivalent
Benchmark	Aggregate installed capacity in terms of international bandwidth.and Registered peak utilization of above capacity not to exceed 75% during busy- hour.
Significance	It determines the current availability of aggregate international bandwidth and its peak utilization level in relative terms.

Contention Ratio

Parameter	Contention Ratio (Concentration Ratio)
Scope	Public Fixed broadband
Benchmark	Not to exceed 10:1
Significance	It determines the maximum estimated number of concurrent users that may be sharing one unit of the international bandwidth at any time.

Network Availability

Parameter	Network Availability
Scope	All related public network infrastructure
Benchmark	Round the clock availability with the following notes; Scheduled outage for maximum of 1 day on aggregated basis per year in case of core network part Scheduled outage for maximum of 2 days on aggregated basis per year in case of a local access part Standard power back-up arrangements for minimum 08 continuous hours
Significance	It determines the state of Availability of respective network infrastructure to extend services to users. “Core” here refers to all essential centralized parts of the network without which the services may be affected for good number of customers beyond a particular location. “Access” here refers to essential parts of the network which serve a particular location. Each instance of scheduled outage shall be aggregated and recorded per month. Advance notice to respective customers shall be provided whenever outage may exceed 2 hours in continuity.

Service Availability

Parameter	Service Availability
Scope	For all identified services that require broadband access part
Benchmark	Round the clock availability with the following notes: Intermittent aberrations and transient degradations not to exceed 01 hour per month on aggregate basis
Significance	Based on the state of the serving networks, it further determines the state of the service Availability when Network infrastructure remains available.

Service Coverage Area

Parameter	Service Coverage Area

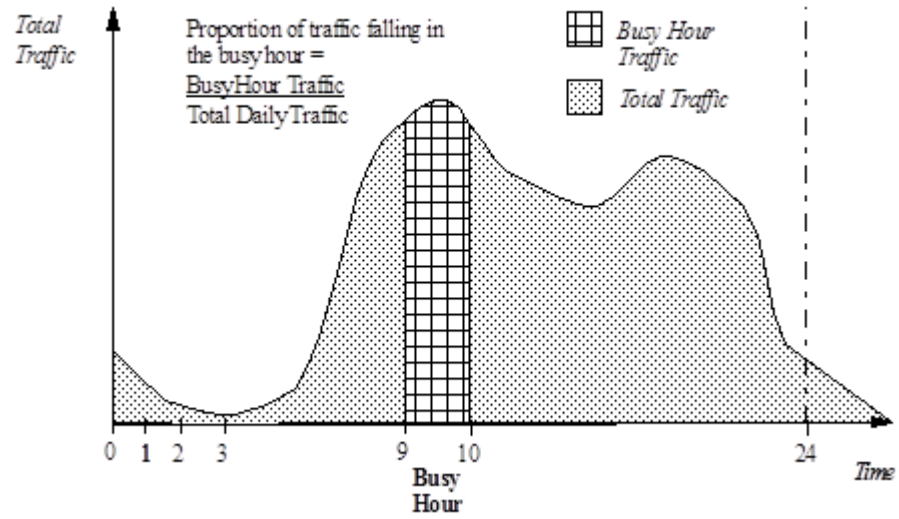
Scope	For all type of public broadband access including Fixed and, Cellular mobile “3G” Cellular mobile “near-4G” and “4G”
Benchmark	Graphical depictions or area-wise listing of mukim/kampongs where fixed broadband access is available for xDSL and; FTTx <3G mobile network> Same as in case of voice services for “3G” level cellular mobile services on independent basis. <LTE and 5G mobile network> Same as declared or estimated with respect to “4G” level for voice according to the given criteria. For clarity, it may be shown separately in each case.
Significance	For each type of class of broadband access, this provides the current status of Availability and reach across all populated and developing areas. Any modifications during the course of time may be incrementally reflected at the end of each quarter.

3.3.1.2 Mobile Network and Services

The following shall apply to subscription-based voice Infrastructure and Services notwithstanding force majeure exemptions. The time period for averaging of measured performance results shall not exceed one quarter of three complete months unless specified otherwise.

Busy Hour

Parameter	Time Consistent Busy Hour (“Busy Hour”)
Scope	Fixed Line, Mobile Network
Benchmark	To be continuously recorded on daily basis for a minimum period of 90 days to generate the valid average.
Significance	It determines the busiest hour during each day when the traffic through the network is recorded to be the highest with respect to the installed capacity. During the day, there may more than one peak at different times. Busy hour should be monitored for each trunk lines for below traffic types - Voice traffic - Data traffic Busy hour should be monitored for below network - Fixed trunk line - Mobile radio network
Method	1. Gather statistics for each minute from network monitoring system for more than 6 months. 2. Analyze daily traffic trend for monitored duration 3. Decide the busiest 60-minute period of the day.

Note	Below figure shows busy hour example of the day  It's recommended to plan to perform benchmarking test including busy hour, so that QoS and QoE should be measured including worst (heaviest traffic) case.

Grade of Service

Parameter	Grade of Service
Scope	Fixed Line, Mobile Network
Benchmark	Not to exceed 1% for fixed line and 2% for cellular mobile on average basis during busy hour when point-of interconnect interfaces are also included.
Significance	It determines the level of possible congestion that may be experienced by a user during busy hour. The higher degree of congestion would require repeated call-attempts by a user.
Method	Gather statistics from network monitoring system

Network Effectiveness Ratio

Parameter	Network Effectiveness Ratio
Scope	Fixed Line, Mobile Network, VoIP
Benchmark	Not below 95% on average basis
Significance	It determines the success ratio per 100 attempts at the user-level to digitally connect a calling party to the called party.
Method	Gather statistics from network monitoring system

Network Availability

Parameter	Network Availability
Scope	For all related public network infrastructure in each respective case
Benchmark	Round the clock availability with the following notes; Scheduled outage for maximum of 1 day on aggregated basis per year in case of core network part Scheduled outage for maximum of 2 days on aggregated basis per year in case of a

	local access part Standard power back-up arrangements for minimum 08 continuous hours
Significance	It determines the state of Availability of respective network infrastructure to extend services to users. "Core" here refers to all essential centralized parts of the network without which the services may be affected for good number of customers beyond a particular location. "Access" here refers to essential parts of the network which serve a particular location. Each instance of scheduled outage shall be aggregated and recorded per month. Advance notice to respective customers shall be provided whenever outage may exceed 2 hours in continuity.
Method	Gather statistics from network monitoring system

Service Availability

Parameter	Service Availability
Scope	All interconnected voice services - fixed, cellular mobile and Vo-IP that can support access to emergency numbers
Benchmark	Round the clock availability with the following notes: Intermittent aberrations and transient degradations not to exceed 01 hour per month on aggregate basis
Significance	Based on the state of the serving networks, it further determines the state of the service Availability when Network infrastructure remains available.
Method	Gather statistics from network monitoring system

Voice Call Drop Rate

Parameter	Call Drop Rate
Scope	All interconnected voice services - fixed, cellular mobile and Vo-IP that can support access to emergency numbers
Benchmark	Not to exceed 2% on average basis for a fixed base station cell-site serving "urban" locations as identified. Not to normally exceed 3% on average basis for a fixed base station cell-site serving "island" location as identified. The values remain same for independent networks as well as combination of overlay networks. Exemptions related to scheduled outage remain applicable and such reported periods may be excluded.
Significance	In case of wireless networks, it determines the tolerable level of un-intentional call drop events when measured at each respective network-end. AITI shall maintain an updated indicative classification of "urban" and "island" locations in the context of public communication through wireless networks. The service licensee shall continue to list out the base station cell-sites where recorded call drop rate exceeds the given limits on month to month basis.
Method	Measured from Active Call test by Measurement System

Service Coverage Area

Parameter	Service Coverage Area

Scope	Each of mobile network (GSM, 3G, LTE, 5G)
Benchmark	<2G and 3G mobile network> Not below 80% of populated areas under “urban” locations on aggregate basis; Not below 60% of the populated areas under “island” locations on aggregate basis; The values remain the same for independent networks as well as combination of overlay networks. Provided the received radio signal level remains better than -95 dBm When measurement is carried out using a test –device mounted in a vehicle moving with speed not exceeding 60 kilometers per hour. Further provided that carrier to noise ratio as measured below -12 dBm and -15 dBm shall continue to be classified as fair and weak respectively. <4G and 5G mobile network> Service Coverage Area to be declared on the basis of RSRP >= -115 dBm and RSRQ >= -11 dB. RSRP and RSRQ will be measured by scanner in vehicle with antenna mounted on outside top of vehicle roof. <Fixed Line> As reported by the licensee in terms of area based listing.
Significance	It determines the availability of adequate signal strength for a voice call in stationary as well as nonstationary mode. For any interpretations, official Census Report and Maps may be used.
Method	Measured by Scanner during benchmark test

Voice Call Setup Time

Parameter	Call Setup Time
Scope	Mobile network
Benchmark	<GSM, 3G, and LTE to 3G CSFB > Not to exceed 07 seconds when dialing information has been completely keyed-in for all domestic calls. <VoLTE and VoNR> Not to exceed 03 seconds for voice call originating mobile.
Significance	It determines the maximum time to establish the voice call on end-to-end basis by means of interconnected networks within the country

Download Throughput

Parameter	Average Download Speed (user-level)
Scope	For all type of broadband access including fixed, fixed-wireless and mobile network
Benchmark	Under normal conditions, the download speed as measured for the domestic section between CPE and serving network by using the local speed measurement server shall be as follows: For copper-line based broadband access: at least 80% of the subscribed value For fiber-based broadband access:

	at least 90% of the subscribed value. For wireless broadband access: no less than 100 kbps for nonstationary user during at least 80% of the measuring instances in the declared or estimated Service Coverage Area. and depiction of slab-wise distribution of measured application level (i.e. FTP) throughput samples during Service Drive test as appropriate: % samples <100 kbps % samples <500 kbps % samples <1Mbps % samples <5 Mbps % samples <10 Mbps % samples < 20 Mbps
Significance	It determines the extent to which any promise made during the subscription is fulfilled by the service licensee at typical user-level. Even under dynamic conditions, the services should retain the advertised character and remain close to the promises made during subscription. All values given here apply to domestic traffic only.

Upload Throughput

Parameter	Average Upload Speed (user-level)
Scope	For all type of public broadband access including fixed and mobile network
Benchmark	In continuation from above: For fixed broadband access through copper and fiber lines: at least 30% of the subscribed or download speed value For “3G” based broadband access: at least 10% of the subscribed or download speed value on shared basis For “near 4G” and “4G” based broadband access: at least 30% of the subscribed or download speed value on shared basis The supported upload values must be disclosed to the customers at least slab-wise: - less than 100 kbps - between 100 kbps to 500 kbps - between 500 kbps to 1.5 Mbps - over 1.5 Mbps - beyond 5 Mbps
Significance	It determines the bandwidth support for different services or applications may require adequate value in the upload direction. Even under dynamic conditions, the services should retain the advertised character and remain close to the promises made during the subscription. All values given here apply to domestic traffic only. The licensee may voluntarily provide the information about kind of services or applications that can be supported at given data rates in download and upload directions.

Latency

Parameter	Latency (or Round Trip Delay)
Scope	For all type of public broadband access including fixed and mobile network
Benchmark	Under normal conditions, the latency as measured for the domestic section between CPE and serving network by using the local speed measurement server shall be as follows: For terrestrial broadband access, latency at any time on end to end basis shall not normally exceed: 50 milliseconds for any reachable domestic location for best-effort class of broadband traffic 400 milliseconds for any reachable location for best effort class of broadband traffic 300 milliseconds for any reachable location for end-to-end real-time voice call, video call, telemetry, e-transactions and online gaming 200 millisecond for IP-TV services with Delay Factor(i.e. jitter) less than 50 milliseconds For non-terrestrial access, it shall not normally exceed 800 milliseconds in case of a Geostationary orbit satellite 300 milliseconds in case of a Medium or Low Earth-orbit satellite
Significance	It determines the maximum time delay for the completed roundtrip transmission for an IP packet under dynamic conditions. Each Service or Application may different user requirements and thus, technical values need to be differentiated.

PDP context activation success ratio

Parameter	PDP context activation success ratio
Scope	For all type of public broadband access including fixed and mobile network
Benchmark	Not below 95% on average basis for the total attach requests registered
Significance	It determines the success ratio of activated packet data calls per 100 activation requests.

Packet Loss

Parameter	Packet loss (or Media Loss Rate for multimedia video)
Scope	For all type of public broadband access including fixed and mobile network
Benchmark	Average packet loss for a session not to exceed: 1% for all class of broadband access, domestic 3% for best effort class, any location 3% for voice call, any location 1% for video call, any location For multimedia video, Media Loss Rate shall not exceed the following averages: 0.4% for Standard Definition video and video on-demand or equivalent; 0.05% for High Definition videos or equivalent.
Significance	It is a measure of acceptable level of loss of information packets before receiving

	them at given destination. Different Services or Applications have different values of loss tolerance. In case of multimedia videos, the Media Loss Rate is the number of media packets lost over a certain time interval (typically one second).

Message Delivery Failure Rate

Parameter	Message Delivery Failure Rate
Scope	Mobile network
Benchmark	Not to exceed 1% on daily average basis for USSD support. Not to exceed 2% on daily average basis for SMS and MMS support. Any valid messages remaining undelivered for over a period of 24-hours shall be included for delivery in the next 24-hours period and so on.
Significance	It determines the average rate of failure of delivery of messages when measured at the source network end in a 24-hours period. USSD support features are inherently essential for customer servicing and thus shall be provided higher priority. The licensee may declare their own respective policies towards maximum number of attempts or numbers of days before the undelivered messages are wiped off.

3.4 QoS/QoE List and Measurement Methods

The following section specifies list of QoS(Quality of Service) and QoE(Quality of Experience), and measurement method. QoS represents quality of service, which means network level performance. QoE represents quality of experience, which means quality of user view, for various type of services including voice call, data service, messaging service.

KPI means key performance indicator, which means QoS parameter to be checked or measured. KQI means key quality indicator, which means QoE parameter to be measured based on active call test. From benchmark test, both of KPI and KQI will be measured from passive monitoring and active call test by measurement system.

Some of KPIs will be measured at the network node. For example, “busy hour” and “grade of service” is not tested by benchmarking system, but monitored in network node during certain duration. Those data will be used for statistical analysis and used for final report.

3.4.1 KPI from System Monitoring

Busy Hour

Parameter	Time Consistent Busy Hour (or Busy Hour)
Measured by	System monitoring
Unit of measurement	Time interval in hours: minutes / quarter of 90 days (“quarter”) when Busy Hour is recorded daily.
Measurement	Average of daily busy-hour report for minimum 90 days in continuity.

& recording	
Remarks	Measurement at network point that deals with heaviest traffic during 24-hour interval. e.g. Gateway Switch, Packet Core Network, Access Point From network traffic usage amount during certain duration, we can decide busy hour like (for example); 9:30 am to 10:30 am is busy hour

Grade of Service

Parameter	Grade of Service
Measured by	System monitoring
Unit of measurement	In percentage averaged for one quarter when measurements are recorded daily.
Measurement & recording	Ratio of total calls failures due to congestion during Busy Hour of the day to that of total call attempts registered in the network for the corresponding period.
Remarks	Measurement at network point that deals with heaviest traffic during Busy Hour e.g. Gateway Switch, Access Point

Network Effectiveness Ratio

Parameter	Network Effectiveness Ratio
Measured by	System monitoring
Unit of measurement	In percentage averaged for one quarter
Measurement & recording	Ratio of total calls Successfully connected through switching system to total call attempts registered in the network for the corresponding period.
Remarks	Measurement at network point that deals with heaviest traffic during 24-hour interval. e.g. Gateway Switch, Access Point

Network Availability

Parameter	Network Availability
Measured by	System monitoring
Unit of measurement	In number of hours: minutes in one quarter
Measurement & recording	Total period of outage for Core and Access network parts respectively. Provided nature of incidental outages – scheduled, unscheduled and due to force majeure shall be clearly specified.
Remarks	Measurement for ‘Core’ is at network point that deals with the heaviest traffic during 24-hour interval. Measurement for ‘Access’ part is at each Access Point. e.g. Cabinet, Cell-site.

Service Availability

Parameter	Service Availability
Measured by	System monitoring

Unit of measurement	In number of hours: minutes in one quarter.
Measurement & recording	Total period of degraded provisioning for each subscribed service while network facility remains available. Provided nature of Incidental degradations – scheduled, unscheduled and due to force majeure shall be clearly specified.
Remarks	At any suitable point(s) according to the nature of service under broad classification - voice, broadband, messaging, multimedia.

3.4.2 KPI and KQI from Benchmark Test

Service Coverage Area

<table>
<tr><td>Parameter</td><td colspan="3">Service Coverage Area</td></tr>
<tr><td>Measured by</td><td colspan="3">Scanner</td></tr>
<tr><td>Unit of measurement</td><td colspan="3">In percentage when averaged results are drawn from sampled data collected during drive test.</td></tr>
<tr><td>Measurement & recording</td><td colspan="3">Using scanner in a vehicle to take samples as per standard procedure in the outdoor environment.
<Condition to decide as ‘in-coverage’ and ‘out-of-coverage’>
- All sampling will be done by tile size of 75x75 meter in geography
- If there is more than one detected cell site in a tile, with quality higher than threshold, that tile(area) will be decided as ‘in-service’
- If there is no detected cell, or quality is lower than threshold, that tile(area) will be decided as ‘out-of-service’
<Quality threshold for each technology>
- GSM: RSSI is used
RSSI
<table>
<tr><td>>= -70 dBm</td><td>Excellent</td><td>Strong signal with maximum data speeds</td></tr>
<tr><td>-70 to -85 dBm</td><td>Good</td><td>Strong signal with good data speeds</td></tr>
<tr><td>-86 to -100 dBm</td><td>Fair</td><td>Fair but useful, fast and reliable data speeds may be attained, but marginal data with drop-outs is possible</td></tr>
<tr><td>< -100 dBm</td><td>Poor</td><td>Performance will drop drastically</td></tr>
<tr><td>-110 dBm</td><td>No signal</td><td>Disconnection</td></tr>
</table>
- 3G: RSSI, Ec/Io, and RSCP is used
RSSI
<table>
<tr><td>>= -70 dBm</td><td>Excellent</td><td>Strong signal with maximum data speeds</td></tr>
<tr><td>-70 to -85 dBm</td><td>Good</td><td>Strong signal with good data speeds</td></tr>
<tr><td>-86 to -100 dBm</td><td>Fair</td><td>Fair but useful, fast and reliable data speeds may be attained, but marginal data with drop-outs is possible</td></tr>
<tr><td>< -100 dBm</td><td>Poor</td><td>Performance will drop drastically</td></tr>
<tr><td>-110 dBm</td><td>No signal</td><td>Disconnection</td></tr>
</table>
Ec/Io
<table>
<tr><td>0 to -6</td><td>Excellent</td><td>Strong signal with maximum data speeds</td></tr>
<tr><td>-7 to -10</td><td>Fair</td><td>Strong signal with good data speeds</td></tr>
</table></td></tr>
</table>

	-11 to -20	Fair to poor	Reliable data speeds may be attained, but marginal data with drop-outs is possible. When this value gets close to -20, performance will drop drastically

RSCP

-60 to 0	Excellent	Strong signal with maximum data speeds
-75 to -60	Good	Strong signal with good data speeds
-85 to -75	Fair	Fair but useful, fast and reliable data speeds may be attained
-95 to -85	Poor	Marginal data with drop-outs is possible
-124 to -95	Very poor	Performance will drop drastically, closer to -124 disconnects are likely

- LTE and 5G: RSRP, RSRQ, SINR is used

RSRP

>= -80 dBm	Excellent	Strong signal with maximum data speeds
-80 to -90 dBm	Good	Strong signal with good data speeds
-90 to -100 dBm	Fair	Reliable data speeds may be attained, but marginal data with drop-outs is possible. When this value gets close to -100, performance will drop drastically
-100 to -120 dBm	Poor	Performance will be lower
<= -120 dBm	No signal	Disconnection

RSRQ

>= -10 dB	Excellent	Strong signal with maximum data speeds
-10 to -15 dB	Good	Strong signal with good data speeds
-15 to -20 dB	Fair	Reliable data speeds may be attained, but marginal data with drop-outs is possible. When this value gets close to -20, performance will drop drastically
-20 dB	Poor	Performance will be lower

SINR

>= 20 dB	Excellent	Strong signal with maximum data speeds
13 to 20 dB	Good	Strong signal with good data speeds
0 to 13 dB	Fair	Fair but useful, fast and reliable data speeds may be attained
<= 0 dB	Poor	Performance will be lower

As described above, there can be multiple KPIs for coverage decision. Final decision will follow worst KPI – for example, if one KPI is “poor” and others are “fair”, that tile will be decided as “poor” area.

Remarks	The sample collected shall be analyzed using standardized tool. Information about test set-up, procedure, tool and duration of tests shall be made available.

PDP context activation success ratio

Parameter	PDP context activation success ratio
Unit of measurement	In percentage averaged during whole benchmark test.
Measurement & recording	Ratio of total successful PDP context activations to total PDP context activation attempts. Test will be performed on mobile. PDP context activation can be tried through airplane mode on and off on the mobile.
Remarks	PDP context activation will be performed at the beginning of each loop of active call test scenario.

Voice Call Drop Rate

Parameter	Voice Call Drop Rate
Measured by	Active Call Test by Measurement System
Unit of measurement	In percentage for whole benchmark test
Measurement & recording	Ratio of total call setup fail basis to total call trials Details will be explained in “Measurement Method” section.
Remarks	Statistics can be generated for each of voice call service types if needed; - GSM CS - 3G CS - LTE to 3G CSFB - LTE VoLTE - 5G to LTE EPS Fallback - 5G VoNR

Voice Call Setup Time

Parameter	Voice Call Setup Time
Measured by	Active Call Test by Measurement System
Unit of measurement	In seconds average for whole benchmark test
Measurement & recording	Measurement of time delay during each call after call trial start till the call is finally connected for conversation Details will be explained in “Measurement Method” section.
Remarks	Statistics can be generated for each of voice call service types if needed; - GSM CS - 3G CS - LTE to 3G CSFB - LTE VoLTE - 5G to LTE EPS Fallback - 5G VoNR

Speech Quality

Parameter	Speech Quality
Measured by	Active Call Test by Measurement System
Unit of measurement	MOS(Mean Opinion Score) averaged over a scale of 1.00 to 5.00 during whole benchmark test using POLQA
Measurement & recording	MOS test will be performed only for the mobile to mobile voice call. Each mobile will be configured to use different voice call types (GSM CS, 3G CS, LTE to 3G CSFB, LTE VoLTE, 5G VoNR, etc.). POLQA will be used for MOS test standard. NB(narrow band) or SWB(supper wide band) reference speech will be used for each service type; - GSM CS, 3G CS, LTE to 3G CSFB: NB speech - VoLTE, VoNR: SWB speech <Good/Bad Decision> - For NB, 95 percent of calls are expected to have average MOS higher than 3.20. - For SWB, 95 percent of calls are expected to have average MOS higher than 3.60. Details will be explained in “Measurement Method” section.
Remarks	Percentage of calls and MOS value threshold described above can be adjusted following local environment of Brunei.

Mouth to Ear Delay

Parameter	Mouth to Ear Delay
Measured by	Active Call Test by Measurement System
Unit of measurement	In milliseconds averaged during whole benchmark test using POLQA
Measurement & recording	Measurement system will provide mouth ear delay, as well as MOS. Mouth-to-Ear (M2E) latency describes the time it takes speech input in a voice communication transmit device to be output from a receiving device, and has been identified as a key component of quality of experience (QoE) in communications. Details will be explained in “Measurement Method” section.
Remarks	M2E statistics should be generated for each network and service types; - GSM CS - 3G CS - LTE to 3G CSFB - LTE VoLTE - 5G to LTE EPS Fallback - 5G VoNR

Average Download and Upload speed

Parameter	Average Download and Upload speed
Measured by	Active Call Test by Measurement System
Unit of measurement	In Kbps(GSM, 3G) or Mbps(LTE, 5G)
Measurement & recording	Average on sampling basis during whole benchmark test. Throughput test will be done based on iPerf. Throughput test will be performed on mobile. Details will be explained in “Measurement Method” section.
Remarks	iPerf server should be located in core network, and should not connected through internet – to prevent any influence from internet congestion.

Latency

Parameter	Latency (Round Trip Time)
Measured by	Active Call Test by Measurement System
Unit of measurement	In milliseconds averaged for whole drive test
Measurement & recording	Latency test will be done based on ping test with ICMP. If ICMP is blocked from network node, TCP echo or UDP echo can be used. Latency test will be performed on mobile. Details will be explained in “Measurement Method” section.
Remarks	ICMP server will be located in core network, and should not connected through internet – to prevent any influence from internet congestion.

Packet Loss Ratio

Parameter	Packet Loss Ratio
Measured by	Active Call Test by Measurement System
Unit of measurement	In percentage averaged for whole benchmark test
Measurement & recording	It’s ratio of total packets lost before successful delivery (to a destination) to that of total number of packets transmitted (towards that destination) in successive attempts. Packet loss ratio will be calculate from latency test, where we will get “ping request count” and “ping response count”. Timeout response will be counted as “received” response, therefore not counted as “loss”. Details will be explained in “Measurement Method” section.
Remarks	Packet loss ratio test will be performed on mobile

Streaming Service Freeze Count

Parameter	Streaming Service Freeze Count
Measured by	Active Call Test by Measurement System
Unit of	In count averaged for whole benchmark test

measurement	
Measurement & recording	For streaming VOD service or live streaming service, freeze count means number of times that video frozen during each test. Test should be performed on mobile. Details will be explained in “Measurement Method” section.
Remarks	Statistics can be calculated for each serving network; - GSM - 3G - LTE - 5G

Streaming Service Freeze Duration Sum

Parameter	Streaming Service Freeze Duration Sum
Measured by	Active Call Test by Measurement System
Unit of measurement	In milliseconds averaged for whole benchmark test
Measurement & recording	For streaming VOD service or live streaming service, freeze duration sum means sum of all freeze durations during each test. Test should be performed on mobile. Details will be explained in “Measurement Method” section.
Remarks	Statistics can be calculated for each serving network; - GSM - 3G - LTE - 5G

Web Page Load Success Ratio

Parameter	Web Page Load Success Ratio
Measured by	Active Call Test by Measurement System
Unit of measurement	In percentage averaged for whole benchmark test
Measurement & recording	Web page load success ratio can be calculated by $$\text{Web page load success ratio (\%)} = 100\ x\ \frac{Number\ of\ web\ page\ load\ complete\ within\ load\ timeout}{Number\ of\ web\ page\ load\ trials}$$ Web page load test will be performed on mobile. Details will be explained in “Measurement Method” section.
Remarks	Statistics can be calculated for each serving network; - GSM - 3G - LTE - 5G

Message Delivery Failure Rate

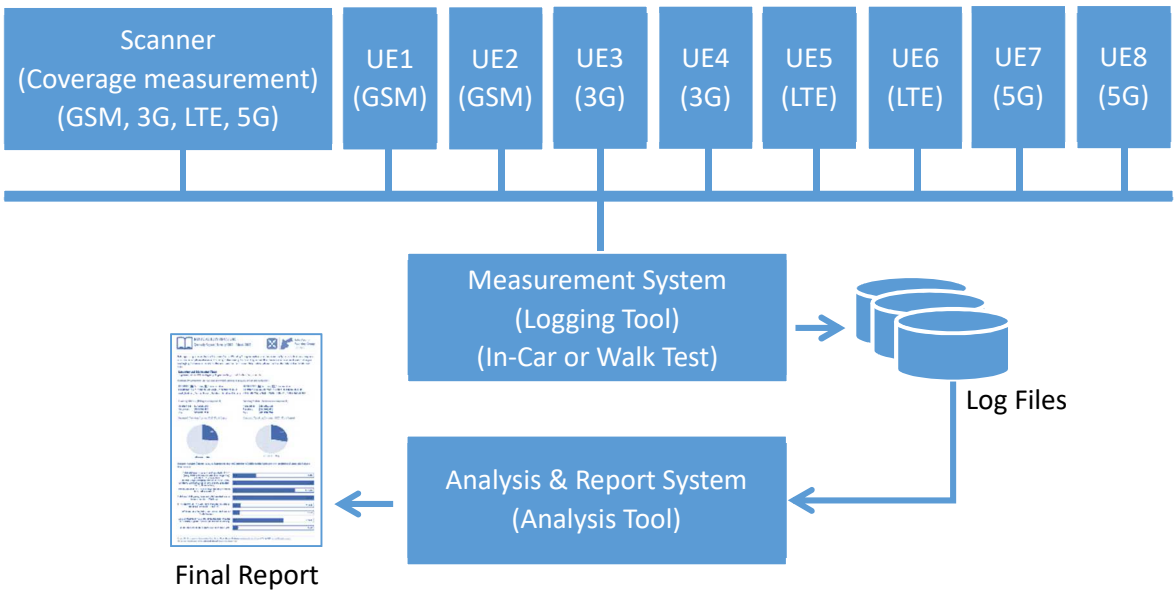
Parameter	Message Delivery Failure Rate
Measured by	Active Call Test by Measurement System
Unit of measurement	In percentage averaged for whole benchmark test
Measurement & recording	For messaging services and applications, it is ratio of messages transmitted successfully in intra- and internetwork mode to total messages meant for transmission during benchmark test. Details will be explained in "Measurement Method" section.
Remarks	The measurement shall apply separately to the following: (i) SMS (mobile to mobile delivery) (ii) MMS (mobile to mobile delivery)

3.4.3 Measurement Method

3.4.3.1 Measurement system configuration

The measurement system consists mainly of the measurement system, scanner, and mobile phones. However, there should also be accessory devices for use in the drive test and walk test.

<Figure 23> Measurement system configuration



<Table16> List of devices in measurement system

Scanner x1	• 1 scanner is required to scan available cell list and quality for all technologies and all frequencies served in Brunei • Scanner is used to measure coverage of GSM, 3G, LTE and 5G in nationwide • PCTEL MXflex(in-car test) or IBflex(walk test) is recommended
UE x8	• 8 mobiles are required for benchmark test

	• UE is used to measure user experience quality for GSM, 3G, LTE and 5G in nationwide • For each technology, 2 mobiles are required for active call test including mobile to mobile voice call and various data services - 2 mobiles for GSM Mobiles should be configured to use GSM only - 2 mobiles for 3G Mobiles should be configured to use 3G only - 2 mobiles for LTE Mobiles should be configured to use LTE only, or Mobiles should be configured to use 3G and LTE only (for CSFB test) - 2 mobiles for 5G Mobiles should be configured to use 5G only, or Mobiles should be configured to use LTE and 5G only (for EPS Fallback test) • Single mobile model can be selected (e.g., Samsung Galaxy S20 Plus) and each mobile can be configured to use specific network (e.g., GSM, 3G, LTE, or 5G)
Measurement System x1	• 1 measurement system is needed to control 1 scanner and 8 mobiles simultaneously on a single platform • All raw data gathered from scanner and mobile should be saved to log file, so that it can be used for further analysis and report
Vehicle x1	• Vehicle should have DC inverter to provide power to measurement system and scanner • All mobiles should be mounted in similar location inside the vehicle • Mobile mounting panel should not use metal materials, and should use plastic of wood so that there is no RF interference or degradation • Scanner antenna should be mounted on outside top of vehicle roof • GPS should be installed, and antenna should be mounted on outside top of vehicle roof • In-car test (or drive test) can be done for main road, highway, etc. • Drive speed should be managed to be speed of 80 km/h if possible, but can be changed based on test area situation
Walk test kit x1	• Backpack to mount below devices - 1 scanner - 8 mobiles - 1 measurement system - 1 GPS - Batteries to provide power to each device • All mobiles should be mounted in outside of backpack • Walk test can be done for in-building, street, mountain, ship, etc.

<Figure 24> Drive test vehicle and mobile installation

<Figure 25> Walk test usage example

<Figure 26> PCTEL IBflex and MXflex scanner

3.4.3.2 Measurement features

Network Coverage	• Coverage of GSM, 3G, LTE, 5G network will be measured using scanner • Scanner will measure pure RF quality and available cells information of each network, for all registered frequencies in Brunei
QoE	• QoE (Quality of Experience) • QoE will be measured using mobiles • For QoE measurement of various service types, measurement system will perform various active call tests repeatedly using mobiles - Detach from network, and attach to network This will be used to calculate; ✓ Network accessibility ✓ Network availability - Voice call test with MOS measurement between two mobiles

	Various types of voice call should be configured and tested; ✓ GSM voice call between two mobiles (UE1 – UE2) ✓ 3G voice call between two mobiles (UE3 – UE4) ✓ LTE to 3G CSFB call between two mobiles (UE5 – UE6) ✓ LTE VoLTE call between two mobiles (UE5 – UE6) ✓ 5G EPS Fallback voice call between two mobiles (UE7 – UE8) ✓ 5G VoNR call between two mobiles (UE7 – UE8) - Throughput test on mobile - Latency test on mobile - YouTube streaming test on mobile - Web browsing test on mobile - SMS and MMS test between two mobiles
QoS	• QoS (Quality of Service) • QoS will be measured based on RF quality information from mobiles • During active call test, mobiles will provide radio quality continuously, and measurement system will show radio KPIs and save to log files • During test, measurement system will check "serving network" of each mobile, which can be used for usage ratio of each GSM, 3G, LTE and 5G network in view of mobile. This will be compared with network coverage data from scanner in the report phase, to provide "network is available, but mobiles don't use" type of report.

3.4.3.3 Active call tests

Active call test means "active voice or data call generation test" with mobile phone, to measure real user's quality of experience (QoE). During benchmark test, measurement system will repeatedly perform active call test for various service types on mobile. This section defines active call test types, and details of each test.

Detach & Attach test

Detach & attach test provides network availability and network accessibility information during test. Mobile will detach from network, and wait for certain duration, and try attach to network. This attach will success or fail, and it'll take time to attach. Measurement system will check this result and time duration, and calculate "network availability" and "network accessibility" and "attach time".

Depending on the network status, attach might success after several failures, and it'll take quite long time. This might happen even if coverage is enough and you can see multiple cells available in near. This detach and attach test will be performed repeatedly during test.

Voice Call test (with MOS test)

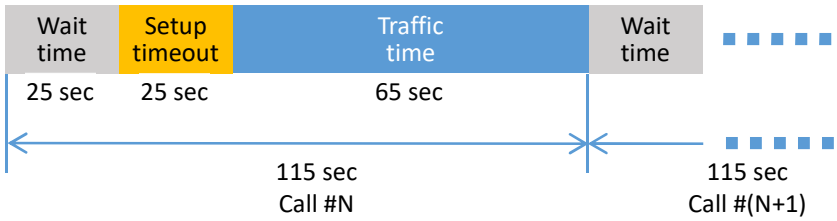
Voice call can be originated from mobile, and other mobile will receive incoming call. If both

mobiles can't enter into conversation within certain duration (setup time), origination mobile will cancel call and repeat next call test after some duration (wait time). Once entering conversation, both mobiles will keep call during certain duration (traffic time) and release call. This can be repeated many times, to measure nation-wide statistics.

Call plan for voice call test will be as below. Each time duration can be changed reflecting usage statistics of real mobile users in Brunei.

- Wait time: 25sec
- Setup timeout: 25sec
- Traffic time: 65sec

<Figure 27> Voice Call Plan

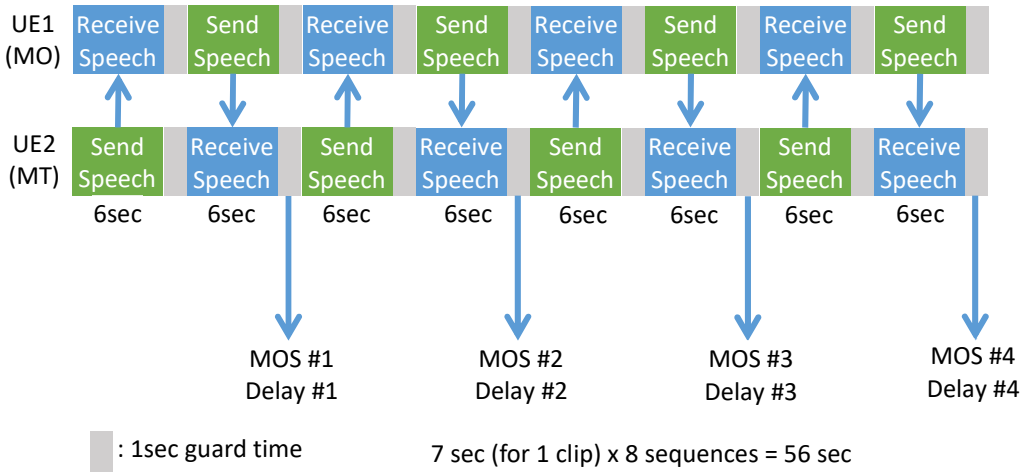


During conversation time, MOS test will be performed simultaneously, with different configuration for voice call type;

- MOS algorithm: POLQA (ITU-T P.863)
- Reference speech
  - ✓ reference: ITU-T P.Supplement 23 (coded-speech database)
  - ✓ AM_Engligh_NB for GSM, 3G, and CSFB
  - ✓ AM_Engligh_SWB for VoLTE and VoNR

Reference speech has 6 second duration, and mobile 1 will send reference speech through voice channel to mobile 2. Mobile 2 will receive degraded speech (over voice channel) and calculate MOS based on POLQA algorithm. Then mobile 2 will send reference speech again, and mobile 1 will receive speech. This will be repeated during conversation time. Below diagram shows repetition of send speech and receive speech during traffic time. During 65sec conversation time, four times of MOS calculation can be done for each of received speech, by repeating four times of send speech and receive each. There should be 1sec guard time considering speech transmission delay and POLQA calculation delay.

<Figure 28> MOS test during voice conversation time



For the CSFB test, LTE mobile should be configured not to use VoLTE service. Also for VoLTE test, LTE mobile should be configured to use VoLTE service.

Voice call test will provide below KQIs.

- **Voice call origination success ratio (%)**

$$\text{MO success ratio } (\%) = 100\ x\ \frac{Number\ of\ calls\ with\ origination\ success}{Number\ of\ calls\ tried}$$

- **Voice call setup success ratio (%)**

$$\text{Setup success ratio } (\%) = 100\ x\ \frac{Number\ of\ calls\ with\ setup\ success}{Number\ of\ calls\ tried}$$

where “setup success” means “successfully entering into conversation state with peer mobile”

- **Voice call complete ratio (%)**

$$\text{Call complete ratio } (\%) = 100\ x\ \frac{Number\ of\ calls\ not\ terminated\ until\ traffic\ timeout}{Number\ of\ calls\ with\ setup\ success}$$

- **Voice call fail ratio (%)**

$$\text{voice call fail ratio } (\%) = 100\ x\ \frac{Number\ of\ calls\ with\ setup\ fail}{Number\ of\ calls\ tried}$$

- **Voice call drop ratio (%)**

$$\text{Call dro ratio } (\%) = 100\ x\ \frac{Number\ of\ calls\ dropped\ before\ traffic\ timeout}{Number\ of\ calls\ with\ setup\ success}$$

- **Voice quality**
  - ✓ MOS avg
  - ✓ MOS max

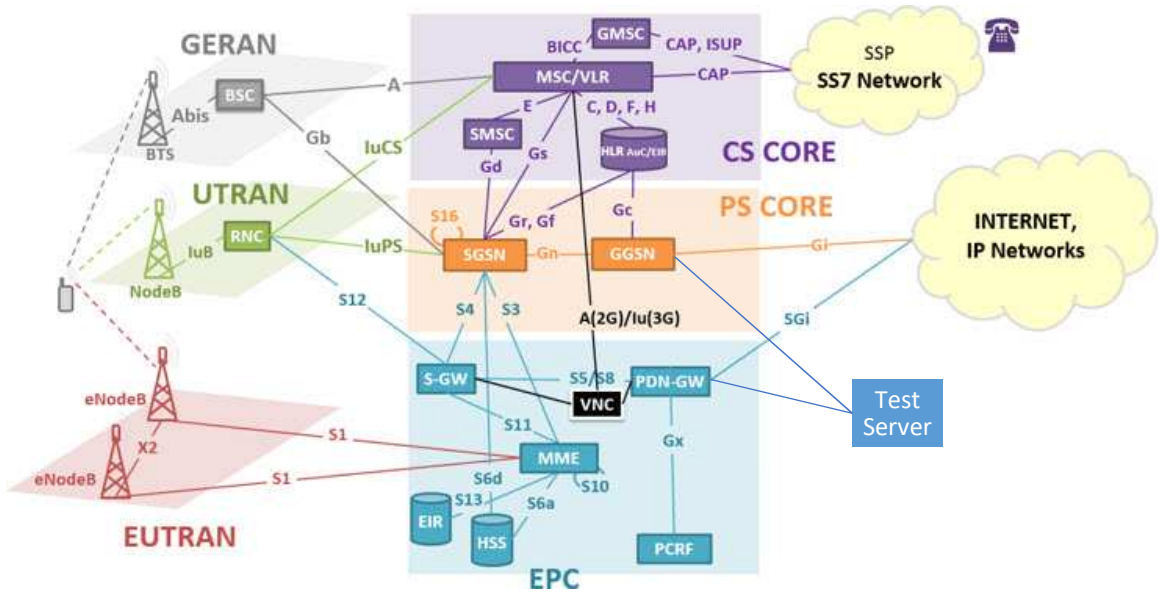
✓ MOS min

- **Voice call setup time (sec)**

Data throughput test

Data throughput test will be made using iPerf with TCP, and the server should be located in core network, not to be affected by internet traffic. This server will also run ICMP server for the latency test. TCP based iPerf with multi session is recommended to reduce throughput degradation due to latency delay, and also slow start duration should be considered for throughput calculation.

<Figure29> Throughput and Latency test server location



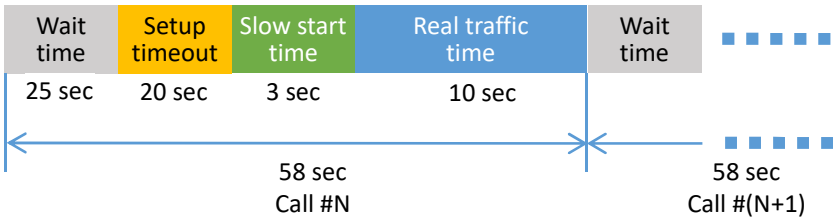
Call plan for throughput test will be as below. Each time duration can be changed reflecting usage statistics of real mobile users in Brunei.

- Test method: TCP based iPerf
- Number of sessions: 4 sessions
- Wait time: 25sec
- Setup timeout: 20sec
- Traffic time: 13sec

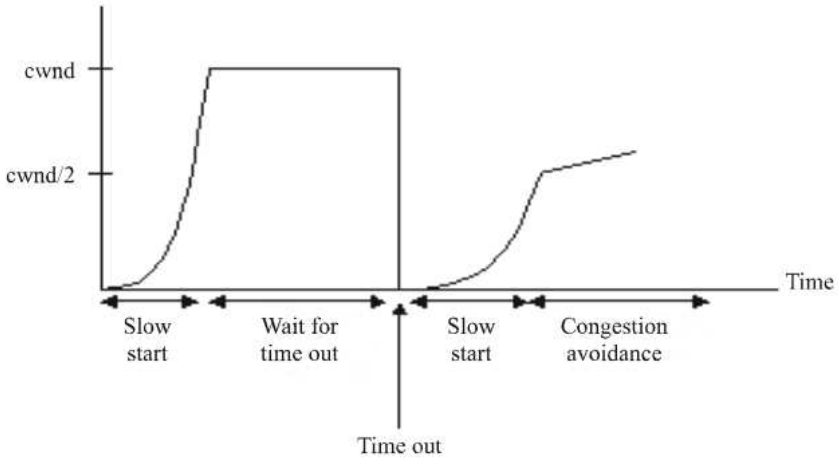
✓ Slow start time: 3sec

✓ Real traffic time: 10sec

<Figure 30> Throughput test call plan



<Figure 31> Slow start duration in TCP throughput measurement



Throughput test based on best effort method using TCP has a “slow start” characteristic. To measure exact data throughput, slow time should be eliminated from the throughput calculation. For this, measurement system should enable user to define “slow start” duration in milliseconds unit, together with “traffic time” or “real traffic time”. Throughput will be calculated for “real traffic time” only.

Also, for the upload throughput test, this slow start time can be used to eliminate high throughput duration due to buffered traffic by operating system. This will provide more correct upload throughput measurement for network quality.

If measurement system can’t start (download or upload) transmission within “setup timeout”, call will be counted as “data call fail” and continue next call.

Latency test

From the Latency test, we can get latency and loss ratio. Call plan for latency test will be as below.

- Test method: Ping test based on ICMP
- Packet size: 24byte
- Timeout: 2000msec
- Ping count: 100 times
- Interval: 100msec
- TTL: 256
- Wait time: 20sec
- Traffic time: 15sec (100 times x 100msec interval = 10sec)

Smaller packet size will give lower RTT(round trip time) delay, and it's recommended to use 24byte packet for ping test. Also, smaller interval will give lower delay in wireless network, therefore it's recommended to use 100msec interval, to make network subsystems keep the traffic flow in active state.

Latency test will provide below KQIs.

- RTT avg (msec)
- RTT max (msec)
- RTT min (msec)
- Number of timeout: Number of replied received after timeout
- Number of no reply: Number of requests not acknowledged with any reply
- Loss ratio (%)

$$\text{Loss ratio } (\%) = 100\ x\ \frac{Number\ of\ no\ reply}{Number\ requests}$$

YouTube Streaming test

Even network provides high speed data and low latency, it doesn't mean that usage quality of real service will be 100% good. Real service will suffer variation of network quality during service usage period, and QoE might be affected due to unstable QoS.

YouTube is one of mostly used service in mobile network, and it should be possible to measure

QoE of YouTube Streaming service. Target video can be both of stored video, or live streaming video like live new, etc. In many countries, public broadcasting system usage is decreasing every year, but on-demand video streaming service usage is growing consistently. This is also one of reason for YouTube Streaming test.

YouTube Streaming test plan will be as below. Each time duration can be changed reflecting user's usage statistics in Brunei. However, it's recommended to use Full HD(1920x1080) video URL, so that maximum throughput can be measured during test.

- Video URL
- Wait time: 20sec
- Setup time: 25sec
- Traffic time: 300sec

During test, measurement system should provide below KQIs.

- TTFF (sec): (Time To First Frame): Test start to the first frame on UE screen
- TTLF (sec): (Time To Last Frame): Test start to the last frame on UE screen
- TTLF ratio (%): TTLF / media duration
- Setup duration (sec): Test start to video URL query complete
- Freeze Count (Buffering count)
- Freeze Duration Sum (sec)
- Freeze and Resume Events
- Playback Time (sec)
- Average Download Throughput (Mbps)
- Inst. Download Throughput (Mbps) (per sec)
- Download Bytes (bytes)
- Time ratio of each status
  - ✓ Time ratio of played at 1080p (%)
  - ✓ Time ratio of played at 720p (%)
  - ✓ Time ratio of played at 480p (%)
  - ✓ Time ratio of played at 360p (%)
  - ✓ Time ratio of played at 240p (%)

- ✓ Time ratio of played at 144p (%)
- ✓ Time ratio of freeze (%): at the beginning of video load, or during video play

Web Browsing test

Web surfing is one of the most common service used in public broadband network and mobile network both, and it's QoE should be measured during benchmark test.

Web pages will be public web sites served through internet, therefore QoE might be affected by internet congestion or web server congestion situation.

Web browsing test plan will be as below. This can be changed depending on the internet and web page performance of each sites.

- URLs to load
  - ✓ e.g., www.google.com, www.yahoo.com, www.amazon.com, www.gov.bn, etc.
- Wait time: 25sec
- Setup timeout: 5sec (setup timeout for each URL)
- Load timeout: 10sec (load timeout for each URL)

During web browsing test, below KQIs will be measured.

- **Page load success ratio (%): statistical page load success ratio**

$$\text{Page load success ratio (\%)} = 100\ x\ \frac{Number\ of\ web\ page\ load\ complete\ within\ load\ timeout}{Number\ of\ web\ page\ load\ trials}$$

- **Page load timeout ratio (%)**

$$\text{Page load timeout ratio (\%)} = 100\ x\ \frac{Number\ of\ web\ page\ load\ timeout}{Number\ of\ web\ page\ setup\ success}$$

- **Page load fail ratio (%)**

$$\text{Page load fail ratio (\%)} = 100\ x\ \frac{Number\ of\ web\ page\ connection\ fail}{Number\ of\ web\ page\ load\ trials}$$

- **Page load time (sec)**

  "Page load start" to "page load complete" duration

- **Page setup time (sec)**

  "page load start" to "page connection success and 1st packet received" duration

- **Web page size of each URL (bytes)**

- **Average download throughput of each page (Mbps)**

SMS and MMS test

Short message service (SMS) and multimedia messaging service (MMS) measurements can be executed without forcing the mobile terminal equipment to a particular access technology to simulate a similar scenario when the end user mobile terminal equipment is continually changing access technology.

Measurements consist of sending an SMS with a fixed number of alphanumeric characters and fixed size for MMS from a mobile probe simulating a mobile subscriber to a fixed one simulating another mobile subscriber belonging to the same operator. The SMS/MMS is considered as received if the delivery time is less than the maximum time established.

Below figure shows SMS test timeline example defined in ITU-T E.806. There should be guard time between each call test, to allow mobile to go to idle state.

<Figure 32> Timeline for SMS test

SMS and MMS test plan will be as below.

- Service type: SMS or MMS
- Message length to send (bytes)
- Phone number to send to
- Wait time (sec)
- Setup timeout (sec)
- Send/Recv timeout (sec)

During SMS and MMS test, below KQIs will be measured.

- Service type: SMS or MMS
- Message length (bytes)
- Send result: Success, Timeout
- Recv result: Success, Timeout

- Send duration (sec): “Send start” to “Send complete”
- Recv duration (sec): “Message available notification” to “Recv complete”
- Delivery duration (sec): “Send start at mobile 1” to “Recv complete at mobile 2”
- Network duration (sec): “Delivery duration” – (“send duration” + “recv duration”)

3.4.2.4 Repeating multiple types of active call tests

During field measurement, all of various active call tests can be performed in sequence. Below figure shows sample of one cycle consisted by multiple active call tests.

Detach & Attach	Wait	Voice MO	Wait	Voice MT	Wait	SMS Send	Wait	SMS Recv	Wait
plan1		plan2		plan3		plan4		Plan5	

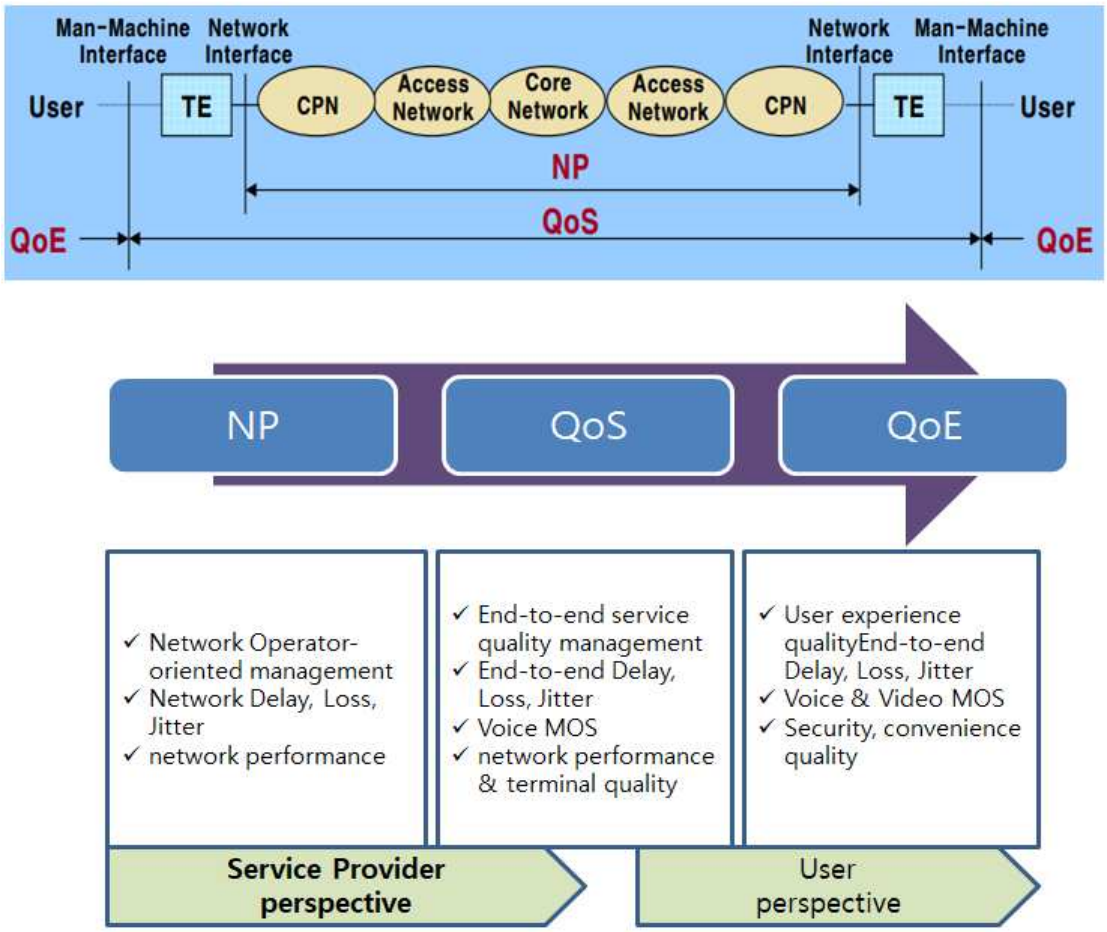
Ping	Wait	iPerf DL	Wait	iPerf UL	Wait	YouTube Streaming	Wait	Web Page	Wait
Plan6		Plan7		Plan8		Plan9		Plan10	

4. Guideline for Revised CoP QoS Regulatory Framework

4.1 QoS, QoE Gap Analysis

4.1.1 QoE Test

<Figure 33> NP, QoS and QoE Comparison



Source: KNISA's Service Quality Management Technology and Policy, 2007

Those related to service quality can be classified into three major categories. It is NP (Network Performance), QoS (Quality of service) and QoE (Quality of Experience).

NP is an area managed by the network providers. As regards quality factors, performance is measured through delay and loss jitter.

QoS means end-to-end service quality. Therefore, the performance factors measure end-to-end delay, loss, jitter, and voice quality. The measurement factors include network performance and terminal performance.

QoE is the quality of the user's experience. The following factors are measured: jitter, delay, and loss, all of which are related to end-to-end service quality, like QoS. In 5G, voice and video quality are also measured by the MOS.

The success of 5G (the fifth generation of mobile communications), and to some extent that of 4G, depends on its ability to seamlessly deliver applications and services with a good Quality of Experience (QoE). Along with the user, QoE is important to network operators, product manufacturers (both hardware and software), and service providers

4.1.2 Gap Analysis

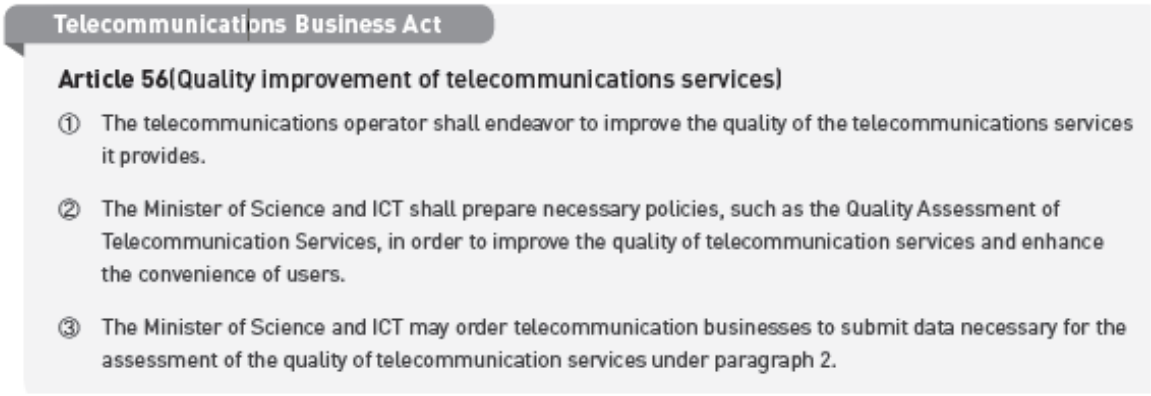
Scopes	As-is	To be
Technology	▷ 3G & 4G ▷ Maximum transfer rate - 1Gbps ▷ User experience transmission speed - 10 Mbps ▷ High speed mobility :- 350km/h ▷ Transmission delay – 10ms ▷ Maximum number of device connections – 100,000 /km^2 ▷ Data processing capacity per area - 0.1 Mbps/m^2	▷ 5G ▷ Maximum transfer rate - 20Gbps ▷ User experience transmission speed - 1Gbps ▷ High speed mobility :- 500km/h ▷ Transmission delay – 1ms ▷ Maximum number of device connections – 1,000,000 /km^2 ▷ Data processing capacity per area - 10 Mbps/m^2
Network	▷ Individual Network ▷ Competitive network management ▷ Differentiation of network quality ▷ Duplicate investment	▷ Integrated network by UNN ▷ Easy maintenance ▷ Consistent installation and upgrade ▷ Focus on service quality
QoS & QoE	▷ QoS ▷ Indoor testing & Outdoor testing ▷ Short and multimedia message measurement ▷ Broadband data measurement ▷ *Voice Call test (with MOS test)* ▷ Call service test ▷ *Data throughput test* ▷ *Network Availability* ▷ SMS and MMS test	▷ QoE ▷ Indoor testing & Outdoor testing ▷ Short and multimedia message measurement ▷ Broadband data measurement ▷ *Voice Call test (with MOS test)* ▷ Call service test ▷ *Data throughput test* ▷ *Network Availability* ▷ Drive testing and Walk testing ▷ Quality of video experience ▷ Video Transmission test ▷ Web-browsing measurement ▷ File transfer measurement

4.2 Korea's Communication Service Quality Assessment Enforcement

4.2.1 Rationale for Quality Assessment and its Progress

The Quality Assessment of Telecommunication Services helps users select reasonable communication products by providing them with objective quality information. It aims to induce improvements in quality by expanding voluntary investment on the part of operators in areas with poor quality through the disclosure of the assessment results for each business operator. The Quality Assessment of Telecommunication Services is carried out annually pursuant to Article 56 of the Telecommunications Business Act.

<Figure 33> Telecommunications Business Act of Korea



Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

4.2.2. Progress on the Quality Assessment

The Quality Assessment of Telecommunication Services has been conducted on fixed-line telephone, 2G voice calls, and super high-speed Internet since 1999. In 2011, information was provided through the quality assessment of mobile phone services, super high-speed Internet, wireless Internet (2G, 3G, WiFi, WiBro), and paid digital broadcasting (IPTV, DCATV, and satellite).

In 2012, the quality of wireless Internet services that are currently and most commonly in use, such as LTE, 3G, WiFi, WiBro, mobile phone voice calls, and super high-speed Internet services, was assessed. The same year, the quality of paid digital broadcasting services, which have a stable quality, and LTE and 3G services was newly assessed.

In 2013, the quality of wireless Internet (broadband LTE, LTE-A, 3G, Ev-Do reA, WiFi, WiBro) services, mobile communication voice calls, and super high-speed Internet services was assessed. In 2014, the quality of wireless Internet (broadband LTE-A, broadband LTE, 3G, Ev-Do reA, WiFi, and WiBro), mobile communication voice calls, and super high-speed Internet services was assessed.

In 2014, the quality of wireless Internet and mobile communication voice calls in vulnerable

areas was assessed for the first time since the Ferry Sewol accident. Information was recorded on the quality of communication services in vulnerable areas provided by telecom operators for hiking routes, sea routes, islands, and coastal roads.

In 2015, the overall average speed information for LTE services was provided, and the quality of giga-level wired Internet services was assessed for the first time.

In 2016, the overall average speed of LTE services was provided, wireless Internet services such as 3G, WiFi, and giga-level wired Internet services were evaluated, and the government evaluated voice call (2G, 3G, and VoLTE) services for mobile communication. WiBro service was introduced for the first time as a means of self-evaluation for operators. Super high-speed Internet (100Mbps) and mobile communication voice call (2G, 3G, and VoLTE) services for administrative dongs were evaluated.

In 2017, the quality assessment of telecommunication service was expanded to include assessments of wireless Internet such as LTE, 3G, and WiFi. Additional assessments were conducted to analyze the quality of Wi-Fi that was open for all citizens besides each company's customers, in addition to the existing commercial and public Wi-Fi. 500M and 1G on the giga-level wired Internet service were assessed. The quality of voice call (2G, 3G, and VoLTE) services was also assessed. The coverage information disclosed by telecommunication businesses was verified in 2017 through an accuracy check and the results of the regular quality measurement, measured directly by the users, were also disclosed.

In 2018, the quality of mobile video services was assessed. Users were asked to measure the quality of the video by giving scores, and a quality assessment was conducted on items that can be measured quantitatively, such as video loading and advertisement time. Assessment was expanded to thematic areas where the population is concentrated, such as public transportation, buildings, and traditional markets, to measure and disclose results on the quality while also reflecting the users' actual service environment.

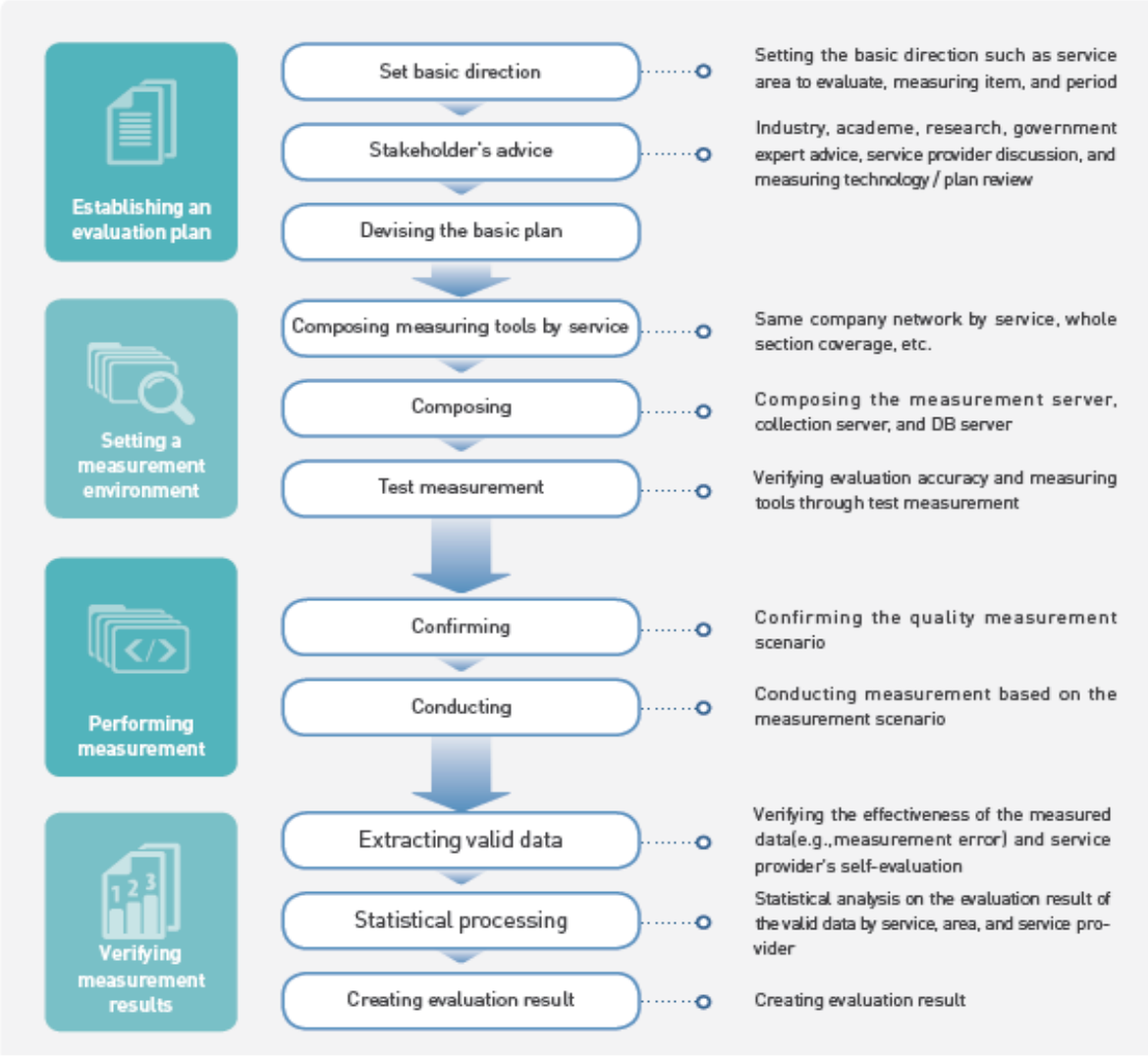
In 2019, assessments were conducted with a different method, wherein the quality of the 500M and 1G-level wired Internet services, which were deemed to have stabilized, were measured directly by the users themselves. The quality of the 10G-level wired Internet and 5G services, commercialized in October 2018 and April 2019 respectively, were investigated on a trial basis and tool verification was carried out for a formal evaluation in the future.

In 2020, the quality of telecommunication services will be assessed for wireless Internet (5G, LTE, 3G, and WiFi), wired Internet (1G, 500M, and 100M), voice call (VoLTE, and 3G), and mobile video (major video streaming) services. 5G service, which has been commercialized only recently and is gaining more subscribers, will be evaluated separately in the first and second half of the year to check the changes in the quality and trends in the expansion of coverage.

4.2.3 Procedure for the Telecommunication Service Quality Assessment

The telecommunication services quality assessment involves four stages: establishment of an assessment plan, construction of the measurement environment, measurement, and verification of the measurement results.

<Figure 34> Telecommunication Service Quality Assessment Procedure of Korea



Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

In the assessment planning stage, basic directions are prepared, such as services and areas to be assessed, items to be measured, and frequency of measurement. Detailed discussions are held with experts in related fields, including telecommunication businesses, academia, research circles, and civic groups, on methods and procedures for measurement, etc. Through this process, a basic plan for quality assessment is established each year and assessment is conducted according to the basic plan.

In the measurement environment construction stage, assessment tools such as hardware and

software that can measure communication services are prepared and a measurement system is constructed. After a joint verification with telecommunication businesses, the measurement tools are finalized.

In the measurement phase, the measurement scenario is finalized and the measurement is carried out in accordance with the assessment plan, while also taking detailed measurement indicators, evaluation methods, etc., into account. Quality assessment areas are largely divided into administrative areas such as large, small, and medium-sized cities, farming and fishing villages, and thematic areas such as large shopping malls with large crowds, major streets, festivals, highways, subways, and railways (KTX, Saemaeul, Mugunghwa, etc.). Areas where quality is expected to be weak, such as islands, hiking trails, coastal roads, and sea routes, are selected separately. Administrative areas such as large, small, and medium cities, and farming and fishing communities are selected with due consideration for the floating population and the amount of traffic used. The thematic areas are selected bearing the floating population in mind. Vulnerable areas are identified by taking the number of residents (islands), hikers (hiking routes), and passengers (sea routes) into account.

In the measurement verification phase, the explanatory materials submitted by the carrier are reviewed in accordance with the measurement equipment errors and predetermined statistical processing rules in order to derive effective data. The statistical processing of the assessment results are carried out by service, region, and carrier.

Once the statistics are processed, a report showcasing the results is prepared and made public. The results of the detailed assessments by type, including regional, business, and service areas, are disclosed through Smart Choice(http://www.smartchoice.or.kr).

4.2.4 Methods Used for Measuring the Quality of Telecommunication Services

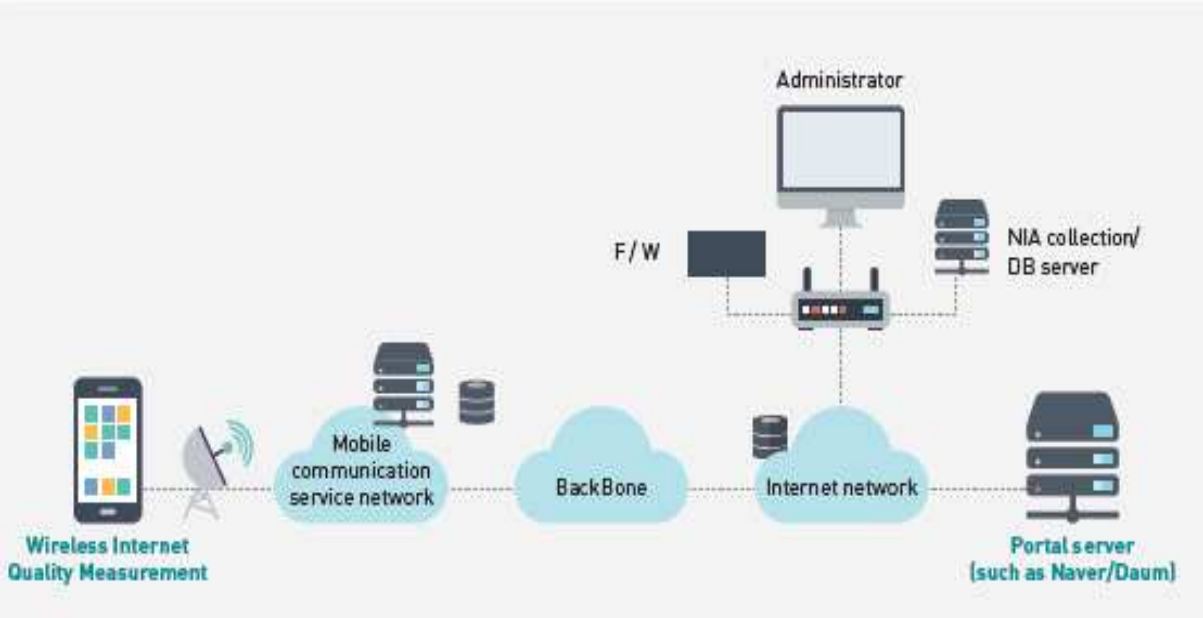
1) Wireless Internet Service

Building a Quality Measurement Environment

The quality of wireless Internet services is assessed by measuring various indicators through data transmission between the measured server and device. A measurement server is installed directly in the national office of a domestic telecommunication service provider and a sufficient capacity line is connected to the server to verify the accurate quality information of the service network section. The installation of measurement servers is carried out every year with the cooperation of the three mobile carriers. The objective measurement of communication quality is made possible by such active cooperation.

Measurement devices are selected and evaluated based on their ability to reflect all the qualities of wireless Internet services established by telecommunication businesses. Every year, devices that can accommodate all three mobile carriers' quality are identified through a consultation. The evaluation was conducted using Samsung Electronics' Galaxy S8 in 2017, Samsung Electronics' Galaxy Note 8 in 2018, and Samsung Electronics' Galaxy Note 9 in 2019.

<Figure 35> Wireless Internet Service Quality Measurement Section of Korea



Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

Quality Measurement Index

The wireless Internet service quality assessment measurement index comprises quantitative indicators for users to make objective comparisons. Through data transmission between measured server and device, the transmission speed, the transmission and connection success rates, latency, packet loss rate, web surfing time, etc., are measured.

The transmission speed is measured by separating the download and upload speeds, and the transmission success rate is the proportion of successful transmission above the minimum speed by connecting to the measurement server. By 2016, the minimum transmission speed for evaluating the transmission success rate of LTE services was set to 4 Mbps for download. After the LTE quality improved, the transmission success rate has been evaluated since 2017 by raising it to 6 Mbps.

Connection success rate refers to the proportion of households that attempted to connect to the server and succeeded, and latency refers to the time until the response signal is received after sending a signal to the measurement server. Packet loss ratio refers to the ratio of data that has not been transmitted between the measurement server and device. Finally, web surfing time measures the time taken for the entire web page to be displayed on the device once a frequently accessed website is selected and accessed.

<Table 17> Wireless Internet Service Quality Measurement Index of Korea

Assessment metrics	Description
Transmission speed	Data transmission speed between device and carrier measurement server
Transmission success rate (%)	Proportion of households that accessed the measurement server and succeeded in transmitting at minimum speed
Connection success rate (%)	Proportion of households that attempted to access the measurement server and succeeded
Latency	The time taken for the incoming response signal to arrive after sending a signal to the measurement server
Packet loss rate	The quantity of data not received while transmitting data between the device and the operator's measurement server
Web surfing time	Time taken from the time the user enters the website address until the entire web page is displayed on screen

Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

In the 2019 quality assessment, websites for measuring wireless Internet web surfing time were selected based on those that represented web portals, social networking sites, and shopping malls such as Naver, Daum, Google, YouTube, Facebook, T-Story, Wi-Gosoo, G-Market, Kakao, and 82cook.

<Table 18> 5G quality of service Performance Parameter

Performance Parameter	Parameter definition
Connection success rate	Rate of successful calls by attempting to connect to the measurement server(%)
Transmission success rate	The rate of calls that have successfully transmitted over a certain speed (12Mbps) by connecting to the measurement server(bps)
Delay Time	Time until signal is transmitted to measurement server and received response signal arrives(ms)
Packet Loss	The ratio of the amount of data that was not received when transmitting and receiving data between the terminal and the measurement server (%)
Transmission Speed	Data transmission/reception speed between terminal and business measurement server
Web access time require	The time from when the user enters the website address until all the web page screens are displayed on the terminal(ms) (Select and measure the top 10 sites with high utilization rates)
LTE conversion rate	Rate of network conversion to LTE among 5G services (%)
Connection time	Time when the terminal attempts to connect to the network and connects successfully(ms)

Source: Ministry of Science and ICT, Republic of Korea

In case of 5G evaluation, the connection success rate, transmission success rate, delay time, data loss rate, transmission speed, and web access time that can be objectively compared.

- New evaluation of LTE conversion rate and Access time
- The minimum video transmission rate (constant speed), which is the criterion for determining the transmission success rate of 5G service, is raised to 12 Mbps, taking into account the high-speed transmission characteristics of 5G service (LTE 6 Mbps)

Quality Measurement Method

The quality of wireless Internet is measured by installing a quality measuring tool (app) on the measuring device. Professional personnel conduct the measurement while traveling by car or on foot in the measurement area. In the case of administrative dongs and highways, the quality is measured by tightly monitoring a wide area so that quality can be reflected evenly. In the case of large shopping malls, major streets, and festival areas where floating populations are concentrated, the quality is measured while traveling on foot. In the case of transportation such as subways, railways, buses, etc., quality is measured while commuting by the relevant vehicle. Vulnerable areas such as hiking trails, sea routes, and coastal roads are also measured while traveling on foot, by car, or ship, based on the environment.

<Figure 36> Measurement while traveling by car / Measurement while traveling on foot (left) and by ship (right)

Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

2) Wired Internet Service

Building a Quality Measurement Environment

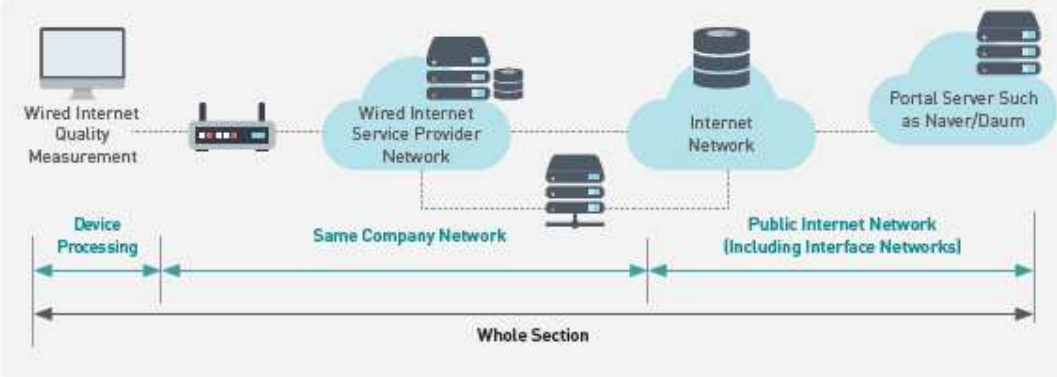
The quality measurement of wired Internet service is also a method of measuring various indicators by sending and receiving data between the measurement server and the device, just like it is in the case of wireless Internet service. In the past, measurement servers were installed in IDC centers in cooperation with business operators to conduct evaluations. It is currently assumed that the quality of super high-speed (100M) and giga-level (500M, 1G) Internet used by most people has stabilized sufficiently.

The government conducts assessments by utilizing quality results directly measured by operators (super high-speed) or users (giga-level) rather than measuring them directly. However, the government continues to measure the entire section and international section.

Quality Measurement Index

The quality assessment of wired Internet service is based on transmission speed. Web surfing time is also measured for the entire section. Transmission speed refers to the rate of data transmission between the measurement server and device. Web surfing time measures the time taken for the entire screen of the web page to be displayed on the device once the user selects and accesses the website.

<Figure 37> Wired Internet Service Quality Measurement Section of Korea



Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

<Table 19> Wired Internet Service Quality Measurement Index of Korea

Assessment Metrics		Description
Network and International Segments	Transmission Speed	Data transmission speed between device and carrier measurement server
All Segments	Transmission Speed	Transmission speed of the entire section when a user uses the Internet to send data to the portal service provider
	Web Surfing Time	Time taken from the time the user enters the website address until the device displays the initial screen

Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

In the 2019 quality assessment, websites selected to measure wired Internet web surfing time included those that represented web portals, social networking sites, and shopping malls such as Naver, Daum, Google, YouTube, Facebook, MSN, Kakao Service, Zoom, Coupang, and G-Market.

Quality Measurement Method

The quality of the wired Internet service network section is evaluated based on the results of

autonomous measurements by operators and users. In the case of operators' autonomous measurement, the measurement tools are installed and verified jointly by the operators and the National Information society Agency of Korea (NIA). The results are analyzed by NIA to ensure the reliability of the assessment. The quality of the international section is measured by installing measurement servers directly in the overseas PoP centers of the three mobile carriers and transmitting data with domestic measurement devices.

Finally, the quality of the entire section is assessed using large-volume email service. Large files are sent via email on Naver and Daum, Korea's leading portal sites, and download and upload speeds are measured. As use patterns are diversified (cloud, etc.) through portal sites, the quality of the entire section will be measured in different ways in the future.

3) Voice Call Service

Building a Quality Measurement Environment

Unlike wireless Internet quality measurement, voice call service quality measurement is carried out using separate hardware measurement equipment. Vehicle-type equipment that can be mounted on a vehicle and walking-type equipment that can be used while traveling on foot are prepared separately to measure different types of areas, and are used flexibly according to the area of measurement. Before beginning measurement, the verification of quality measurement equipment and inspection of consistency between equipment and devices are carried out to ensure the reliability of the results.

Quality Measurement Index

The measurement index of voice call service is the success rate of calls. Call success rate has three sub-categories: connection success, disconnection, and poor sound quality. Connection success determines whether a connection is successful within 20 seconds of pressing the call button. Disconnection is considered a success if the connection is not lost for 65 seconds. For poor sound quality, the MOS sound quality is assessed using a measuring instrument, and if the sound quality is less than 2.2 points on average or less than 1.9 points twice in a row, it is considered poor. ITU International Standards recommend using the MOS method, which evaluates the quality of video and voice on a five-point scale. A score of 2.2 points is considered "hard to understand," and a score below 1.9 points is considered "impossible to understand."

<Table 20> Index for Voice Call Service Quality Measurement of Korea

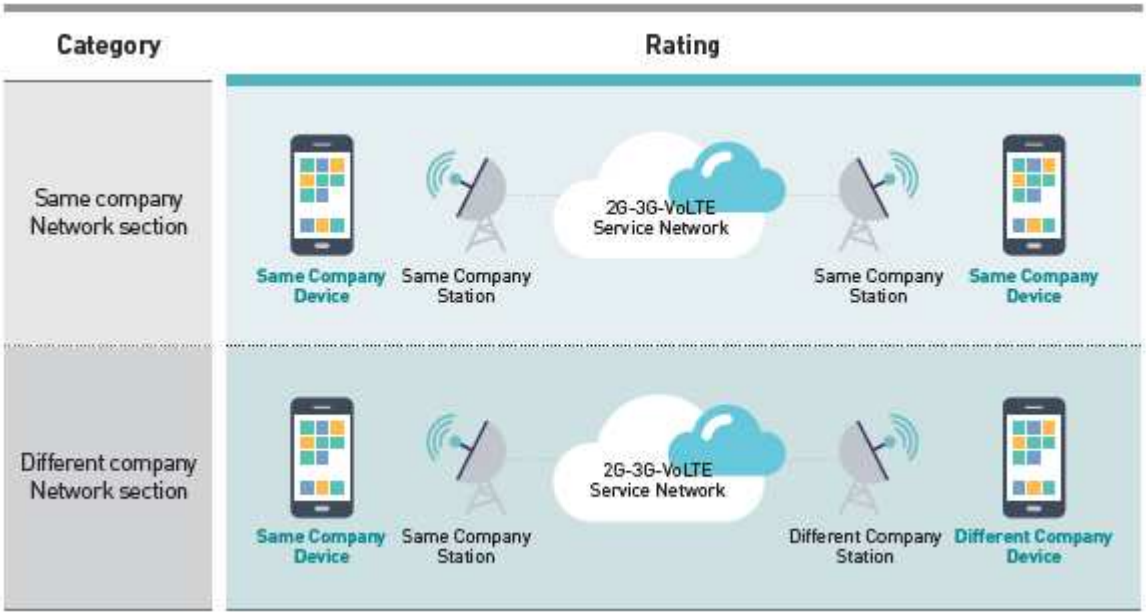
Assessment metrics		Description
Call Success rate	Connection successful	Successful if connected within 20 seconds of pressing the call button
	Call disconnected	Dropped out of call time (65 seconds)
	Poor sound quality	Sound quality value (1-5 points) of below 2.2 on average or below 1.9 twice in a row (2.2: Hard to understand, 1.9: Impossible to understand)

Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

Quality Measurement Method

The quality measurement of voice call services can be divided into the measurement of a company's own section, which measures calls between the same carriers, and the measurement of third-party segments, which measures calls between different carriers. The quality of voice call service has stabilized in sections for the company's own section and for third-parties in urban areas. Thus, operators measure the quality autonomously. For quality vulnerable areas, NIA carries out direct measurements.

<Table 21> Division of Voice Call Quality Measurement Sections of Korea



Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

Voice call quality is measured in the same way as wireless Internet. To measure the call success rate, one travels by foot, any other vehicle, ship, etc. according to the type of area to be measured.

3) Checking Wired and Wireless Internet Coverage

Coverage Inspection Index

Indices for checking the reliability of coverage information disclosed by telecom operators are the over-representation and information match ratios. Over-representation ratio refers to the extent to which the coverage information disclosed by the carrier exceeds the actual coverage inspection results. This is an inspection index for 5G, LTE, and 3G, where coverage is expressed in area units. Information match rate determines whether the coverage information disclosed by the carrier is consistent at a particular point (address, etc.). It is used as an inspection index for WiFi and wired Internet services that provide coverage information based on specific points.

<Table 22> Wired and Wireless Internet Coverage Inspection Index of Korea

Assessment items		Judgment criteria
5G, LTE, 3G	Over-representation ratio	Ratio of areas where coverage released by carriers is exaggerated when compared to the actual inspection coverage information
WiFi, Wired Internet	Information match ratio	Ratio of areas where the actual coverage inspection results match the coverage information released by the carrier

Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

Criteria for Evaluation Area Selection

<Table 23 > Overview of 5G service coverage and quality evaluation

Division	Target service	Target area
Coverage check	Outdoor (administrative building) 5G service coverage	Seoul·6 metropolitan cities outdoor (administrative-dong) 50 areas
	Multi-use facilities and transportation infrastructure 5G service coverage	Seoul·6 metropolitan cities multi-use facilities and transportation infrastructure 119 areas
Quality valuation	Outdoor (administrative building) 5G service	33 outdoor areas in Seoul and 6 metropolitan cities (administrative-dong)
	Multi-use facilities and transportation infrastructure 5G service	Seoul·6 metropolitan cities multi-use facilities and transportation infrastructure 84 areas

Source: Ministry of Science and ICT, Republic of Korea

- Coverage Check

Distribution of the number of evaluation areas and random extraction of coverage check areas in consideration of the number of population and administrative district distribution by region

- Outdoors (administrative-dong): Random extraction of 50 areas from Beopjeong-dong in Seoul and 6 metropolitan cities
- Multi-use facilities and transportation infrastructure: Randomly extract 119 areas from the multi-use facilities and 5G-building facilities* of the three mobile operators

- Quality evaluation

- The number of evaluation areas is distributed in consideration of the number of populations and administrative districts by region, and about 30% for outdoor

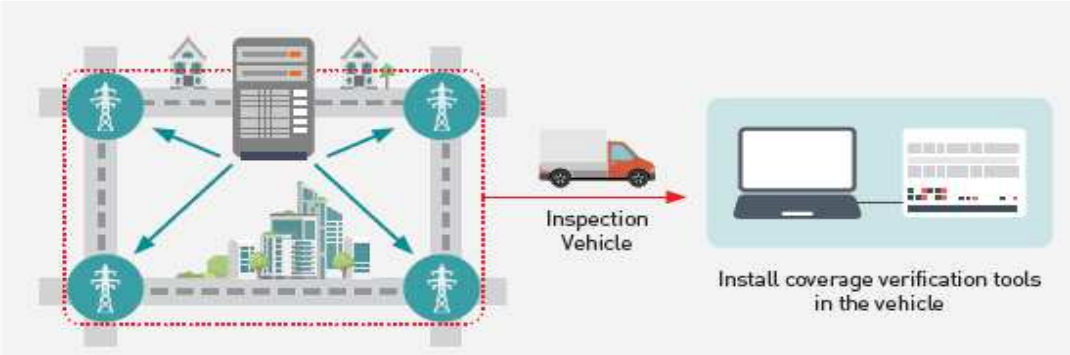
(administrative buildings) and 70% for major multi-use facilities and transportation infrastructures

- Outdoor (administrative dong): Random extraction of 33 regions among administrative dongs in Seoul and 6 metropolitan cities
- Multi-use facilities and transportation infrastructure: Randomly extract 84 regions from the 3 mobile communication companies' multi-use facilities and 5G construction facilities

Coverage Inspection Method

The coverage inspection method depends on the inspection index per service. In the case of 5G, LTE, and 3G services, the inspection personnel installs measuring tools on a vehicle to carry out checks on all roads that are accessible to the vehicle. The RF Scanner is used as a coverage check tool to check the propagation environment of wireless Internet. It is installed on the vehicle and the inspection results are recorded based on GPS coordinates. After the inspection, the results are calculated in a manner identical to the grid on the coverage map released by the provider. Over-representation ratio is calculated by comparing whether service is provided within the grid (75m×75m). 1 Samsung Galaxy S20+ terminal, 1 LG V50S terminal, 2 terminals in total, capable of 5G technology quality measurement are used for evaluation terminal.

<Figure 38> How to Check Coverage



Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

<Table 24> 5G Service availability

Performance Parameter	Criteria
5G Service availability	The ratio of 5G service availability in which the 5G signal strength (RSRP*) value collected every second in the actual inspection area is more than a certain standard (-105dBm) * RSRP: Reference Signal Received Power

Source: Ministry of Science and ICT, Republic of Korea

As WiFi and wired Internet have narrow ranges, operators provide coverage information in the form of branches. Accordingly, for WiFi and wired Internet, the availability of services and subscription to products at the relevant branch are checked to calculate the match rate by comparing actual survey results with information disclosed by the provider.

4) Mobile Video Service

Quality Measurement Background

With the activation of smartphone distribution and the continuous development of communication technology following the emergence of LTE services, wireless Internet users use wireless Internet services for various reasons, including information search, watching videos, and file transmission. The NIA conducted a pilot evaluation in 2017 on the quality of mobile video services used by most citizens in addition to the technical quality of telecommunication services, and has been conducting official evaluations since 2018.

Quality Measurement Index

Experienced image quality and network and video transmission speeds were selected as indices to evaluate mobile video services, and to reflect the items with which users encountered difficulty while using these services.

<Table 25> Index for Mobile Video Service Quality Measurement

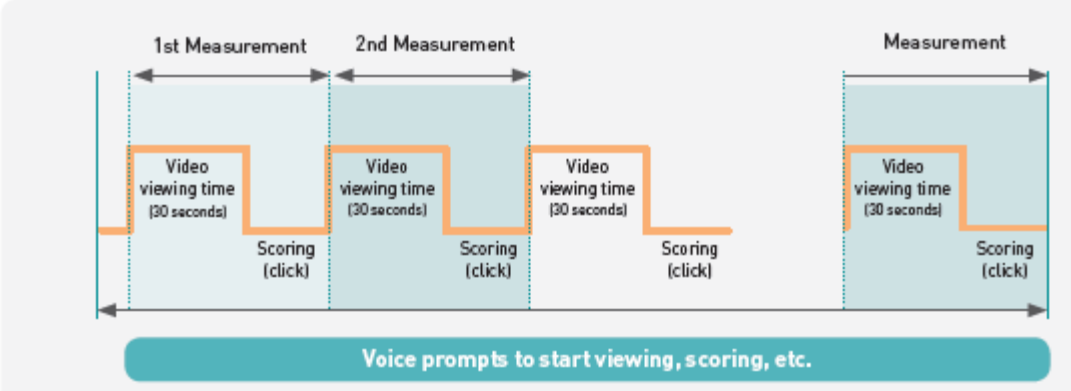
Assessment index	Description	Unit
Quality of Video Experience	The overall quality value of the video, which includes various quality elements, such as breaks, distortions, blurs, or stops for videos on devices	Five-point scale (1 to 5 points)
Network Transmission Speed	Transmission speed of the line between the provider's network and the user's device	Mbps
Video Transmission Speed	The rate at which data are transmitted from the video service provider's content server to the user's device	Mbps

Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

Quality Measurement Method

The quality of the video experience is based on a score that reflects breaks, distortions, and blurs on screen while watching the video. A user evaluation team is selected to measure the quality of the video directly on a scale ranging from 1 to 5 points.

<Figure 39> Procedure for Mobile Video Service Quality Measurement



Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

Network transmission speed refers to the transmission speed between the server of the three domestic mobile telecommunication businesses and the user's device in the context of the user's mobile video service. Video transmission speed refers to the speed at which data are transmitted from the video service provider's content server to the user's device. With mobile video services in use, the measurement compares the speed of the company's network with the transmission speed of the video providers to see if the networks of the three domestic mobile carriers have enough capacity to watch the mobile video service, after which the results are published.

Assessment is conducted on three operators, namely YouTube, Kakao, and Naver, considering the service usage rate of Korean users.

5) User's Regular Assessment

Owing to limited time and budget, the government's quality assessment cannot conduct a survey of more than 3,500 administrative dongs across the country. Thus, it samples and surveys administrative dongs across the country at about 10% level to measure the quality and present the results.

Users' regular assessment is a complementary tool that compensates for the limitations in the government's evaluations. Using the quality measurement system operated by the NIA (wired: wired Internet speed measurement website, wireless: wireless Internet speed measurement app), quality data measured directly by users are collected for a year. The results are then calculated by type, such as region, service, and business operators.

Until 2018, the results of the users' regular assessment were released only for wireless Internet services. From 2019 onward, results have been released for both wired and wireless Internet.

The results may vary based on the type of communication services and devices used by the actual user. Thus, wireless Internet service divides measurement devices (smartphones) into five types for LTE and publishes the results. For wired Internet, the results are released according to the types of subscription products such as 500M and 1G.

<Figure 40> Wired (Let, Web) and Wireless (Right, App) Internet Users' Regular Measurement System

Source: 2019 Telecommunication and Broadcasting Service Quality Assessment, NIA

4.3 Measurement methodologies of ITU-T Standards

This Recommendation describes a baseline framework of best practices for measuring quality of service (QoS) throughout the industry, and covers mobile network QoS measurement campaigns, the characteristics and requirements for monitoring systems, post-processing scenarios, the sampling methodologies used by regulators, test equipment vendors, and companies that deliver network measurements, data analysts and service providers, in order to monitor QoS at the national level.

4.3.1 Measurement environment

For mobile networks, measurement environments can be divided into two main categories: indoor and outdoor. Measurements can include both indoor and outdoor, stationary and mobile scenarios thus covering all the different environments in which end users make use of their mobile service. Currently, there is a high rate of mobile traffic generated from indoor environments; hence, it is advisable to measure indoor QoS performance, in addition to outdoor.

1) Indoor testing

The following recommended methodologies can help the users of the monitoring system to identify the indoor QoS status:

- Walk testing;
- Unattended probes;
- Crowdsourced data collection.

2) Outdoor testing

The following recommended methodologies can help the users of the monitoring system to identify the outdoor QoS status:

- Drive/walk testing;
- Unattended probes;
- Crowdsourced data collection.

Clause 4.5.2 to 4.5.3 provides a high-level description of the four different measurement methodologies which a monitoring system user can perform with regard to indoor and outdoor testing.

4.3.2 Walk testing

Locations such as train stations, underground train platforms, airports, sports stadiums, shopping malls, university campuses and pedestrian zones are becoming hotspots for wireless communication. In outdoor measurements, walk testing is normally employed where vehicles cannot be used. Multi-device, carry-on testing equipment provides a convenient way to work when benchmarking multiple operators or testing coverage for multiple services and radio access technologies.

However, walk testing measurement campaigns have limitations in terms of the number of samples, mobile network operator (MNO), and service due to certain physical parameters such as spatial dimensions, equipment weight, and technical requirements such as antenna isolation, which can influence sample resolution. The following actions are recommended before initiating a walk testing measurement.

- Draft blueprints of the building layouts in the case of an indoor location.
- Schedule and draft a list of targeted spots or locations.
- The targeted sample size per service or MNO depends on the number of smartphones that can be accommodated by the equipment. However, the sample size and distribution should be chosen according to, among other things, the type of variable under consideration and the statistical representation being targeted. For example, covering a wider area or measuring over a longer period could provide more statistically representative results. See Annex A and [ITU-T E.840] for references.
- Adopt and conduct a general routine procedure to check the functionality of hardware or software.
- Consider using a light portable control unit to report real-time results or the status of the measurement equipment.

- The automatic network selection feature should be blocked and set to the on-net feature.

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4.3.3 Drive testing

Drive testing measurement campaigns involve preplanning procedures designed to satisfy the goal and scope of the campaign. Targeted services, demographic distribution and socio-economic factors can entail different campaign design parameters. Essentially, a successful drive testing campaign should consider the sample size in such a way that the measured data are representative of the targeted region's population.

In order to perform drive testing measurement campaigns, the users of monitoring system should consider the following recommendations:

- The sample size should be chosen so that the results are representative of the behaviour of the mobile networks in the area under study. For this purpose, the users of monitoring system must define a sampling methodology. References can be found in Annex A and [ITU-T E.802].
- An initial radio coverage footprint or MNO/technology is required for planning.
- The antennas used to perform the measurements should be installed at the average human height.
- In the case of a regulator's benchmarking, measurements should be performed randomly for all access technologies and for all MNOs simultaneously.
- Measurement profiles should be established. (Technical references can be found in [ITU-T E.804])
- The routes should cover areas with human activity, avoiding route repetition if drive testing is used to derive the KPIs for a wide area.
- For services that are evaluated in movement, the speed of the vehicle should be set by considering that one device can be located at a fixed point while another device will be in motion.
- The automatic network selection feature should be blocked and set to the on-net feature.
- The targeted region's population distribution should be studied prior to the campaign to guarantee that:

  A. The collected sample considers residential and commercial concentrations;

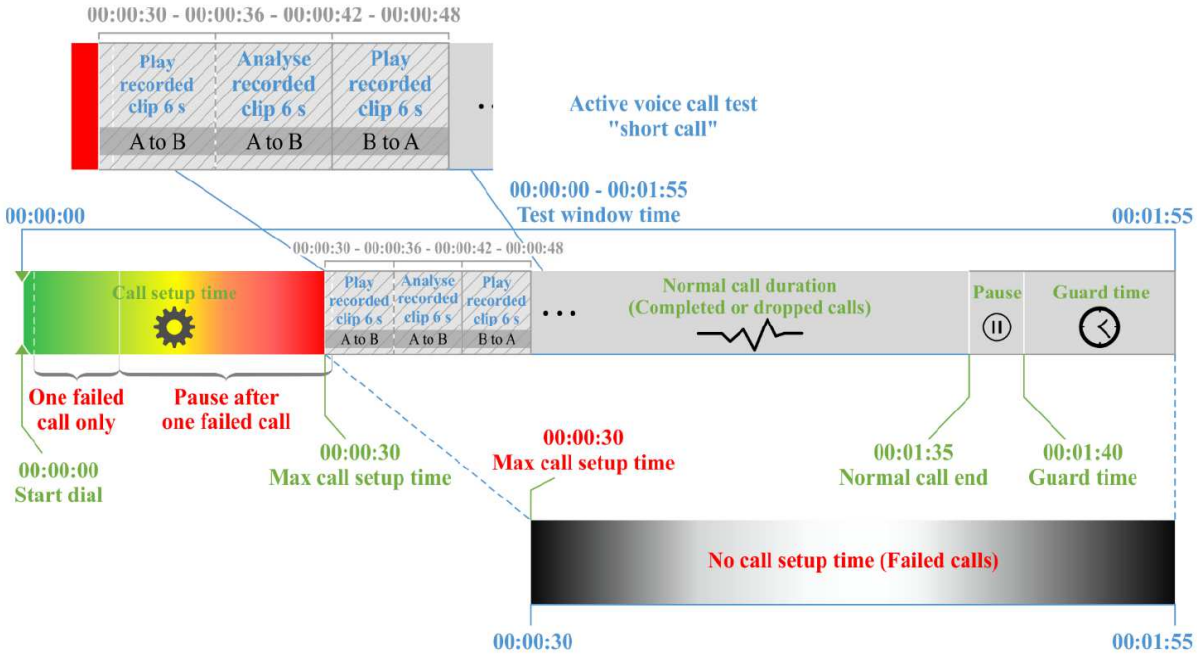
  B. The development factors of the sub-regions may be considered.
- Business days and daytime testing intervals should be considered preferentially.

4.3.4 Voice call measurement

Voice service measurements include the launch of a series of call attempts for the automatic selection of radio access technologies. Call attempts are generated from different scenarios, and can be mobile to mobile, fixed line to mobile, or mobile to fixed line. An appropriate sample for voice measurements should be chosen according to the scenario. Information can be found in [ITU-T P.863.1] and [ITU-T E.807].

The timeline scenario shown in Figure 1 for an active voice call test is just an example and does not set forth the required specifications. Furthermore, the radio network characteristics, the associated time interval parameters, and the overall window test time will affect the total acquired number of samples.

<Figure 41> Timeline for call measurements



Source: ITU-T-REC-E.806

The scenario depicted above represents an example of a voice call testing procedure. While the normal call duration may vary depending on the purpose of the test (short call, long call), almost all other properties are the same for each case faced during the measurement test.

Additionally, specific characteristics per country behaviour should be considered as they can impact the scenario design; for example, if, statistically, the average call time for country A is 2 minutes while that for country B is 4 minutes, the minutes of usage per dropped call will be higher.

Before the test starting point, the calling party (A) starts dialing the preconfigured called party (B), in which case a window of fixed duration is allowed as the maximum call setup time to establish a connection to party B, in which the test is waiting for party B to answer the test call. If party B does not answer or the calling party has problems during the test call setup

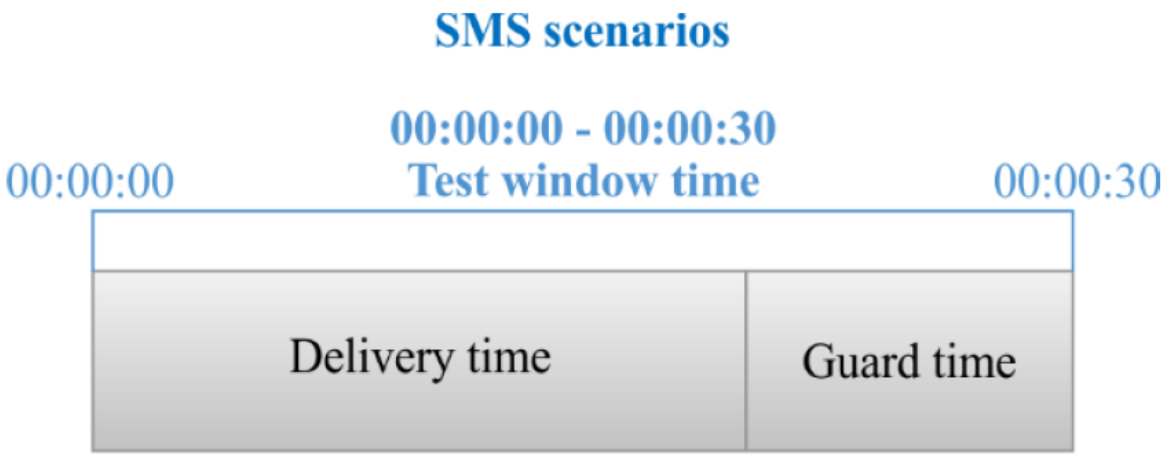
phase, the test call procedure enters the ''no call setup time'', where the test call will be flagged as a ''failed call''.

4.3.5 Short and multimedia message measurement

Short message service (SMS) and multimedia messaging service (MMS) measurements can be executed without forcing the mobile terminal equipment to a particular access technology to simulate a similar scenario when the end user's mobile terminal equipment is continually changing access technology.

The method of measurement consists in sending an SMS with a fixed number of alphanumeric characters and a fixed size for MMS from a mobile probe simulating a mobile subscriber to a fixed one simulating another mobile subscriber belonging to the same operator. The SMS/MMS is regarded as having been received if the delivery time is less than the maximum time established. The diagram in Figure 4.4 below shows a reference timeline for an SMS measurement.

<Figure 42> Timeline for short message service measurements



Source: ITU-T-REC-E.806

4.3.6 Broadband data measurement

Broadband data measurement campaigns should be balanced on different monitoring systems to reduce the window test frame and increase the number of samples, as this will enable greater coverage of the testing map area.

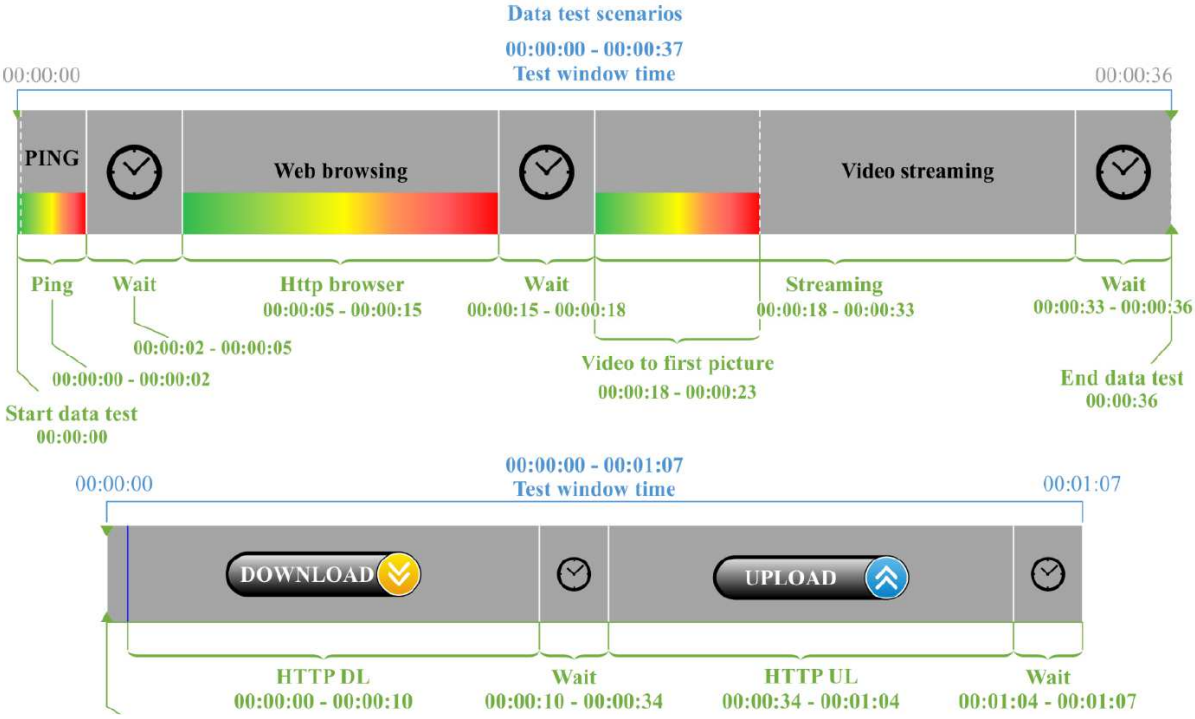
The setup for the scenarios will depend on the service application being measured. The diagram in Figure 3 below shows an example of a timeline for the evaluation of data services. Further information can be found in [ITU-T Y.1540], [ITU-T Y.1545.1].

NOTE: When measurements involve specific server resources, user equipment or unattended probes, or multiple networks to reach the desired content or test server, then their

contribution to the results cannot be distinguished from the mobile network performance. See [ITU-T G.1031] for an example list of influence factors that contribute to the results.

Clauses 4.5.7 to 4.5.9 are examples of broadband data measurements.

<Figure 43> Example of broadband data measurements



Source: ITU-T-REC-E.806

4.3.7 Web-browsing measurement

Measurements related to web browsing can be characterised, among other things, by measuring the performance of navigation in terms of page load time and the overall success rate for page download. Web-browsing tests, with an average fixed duration, are launched from mobile equipment or a probe simulating a mobile subscriber in a static or mobile situation to a predetermined set of recommended websites. Access attempts are randomly distributed between the different sites tested.

4.3.8 File transfer measurement

File transfer measurement consists in sending and receiving files of a fixed size for the uplink and downlink channels between mobile devices or a probe simulating a mobile subscriber in a fixed location and a server having resources dedicated to this measurement. KPIs, such as download session success rate, mean download time or mean upload time, can be measured (with limits placed on the time allowed for completion in either direction).

4.3.9 Audio or video streaming measurement

For audio or video streaming services, the success rate of access to a set of audio or video files hosted on the streaming servers can be measured using average fixed duration tests launched from a mobile probe simulating a mobile subscriber in a fixed location to a predetermined series of streaming servers. Furthermore, the initial video loading duration, the frequency and duration of stalling events, and the overall throughput can be used as indicators for streaming performance. Access attempts are randomly allocated between the different servers tested.

4.3.10 General recommendations for post processing

The first step in the post processing of results is to determine the radio coverage limit for which the electronic service of a mobile communications network is considered to be provided. This limit should be set for each technology (e.g., 2G, 3G, 4G) separately. These limits will determine which tests will be taken into consideration when exporting the final results. Also, rules should be laid down as to when a measurement should be taken into account in the results. Such rules are, for example, if during a measurement there is a period of time that does not meet the radio coverage limit, how long should that period be for the test to be taken into account in the results.

The following general recommendations should be practiced by all users of monitoring systems during the post-processing action for all measurement methodologies.

- In order to examine events that occur during the measurements, signaling information should be taken into account. The post-processing of the measurement results should consider and manage all log files obtained during the measurement campaign. It is recommended to consider all software errors. The final number of measurements gathered in the measurement campaign will have an impact on the estimation error of the results. The estimation error can be calculated based on the sample size. If it is larger than desired, it is recommended to repeat the measurement campaign for the target area. More information is provided in Annex A and [ITU-T E.802], [ITU-T E.840] and [ITU-T P.1401].
- Users of monitoring systems who conduct QoS measurements should check the integrity of the measurement data and cleanse the data accordingly. Outlier samples can be generated for many reasons, e.g. equipment alarms due to equipment or software failure or malfunction, network element upgrade, incidents or maintenance.
- All log files gathered from the testing equipment should be checked, if missing or corrupted.
- It is essential to set the accepted percentage threshold for fake or false samples collected in a measurement campaign. Except for crowdsourced data collection methodologies, it is important to determine the need to re-measure so as to maintain the accuracy and integrity of the results.

4.4 Training Plan for Effective Implementation of the New Framework

4.4.1 Basic Course

This training is a basic course to understand the 4G LTE/LTE-Advanced system, which is currently commercialized and widely used around the world, and the 5G system, a next-generation mobile communication technology that is scheduled to be commercialized as a fully completed standard near future. This is the process of explaining communication technology and QoS testing method in an easy-to-understand way.

Items	**Description**
Class name	Basic Engineer Course
Program Objective	By focusing on basic concepts rather than complex technologies, the contents are organized so that you can understand concepts without much difficulty even if you do not have technical expertise in wireless/mobile communication. This training will be conducted centering on the concept of technology, and is not intended to cover the overall overview of the standard and to explain detailed standard specifications.
Participants	✓ People who need a basic concept by newly in charge of 4G/5G related tasks ✓ People who want to understand the overall contents of 4G/5G technology and the difference between the two technologies
Contents	✓ Basic concept and understanding of RF and microwave ✓ LTE/LTE-Advanced/5G overview and comparison ✓ 4G/5G multiple access technology ✓ 4G/5G multi-antenna technology ✓ Carrier Aggregation (CA) Evolution ✓ Major wireless communication technologies used in 4G/5G ✓ Understanding network analyzer basic measurement parameters ✓ Explain the principles of network analysis ✓ Basic calibration theory and types ✓ Basic standards of quality factors (MOS, POLQA, PESQ, 3GPP) ✓ Voice quality measurement methods

4.4.2 Advanced Course

This course is a practical course. Therefore, it is for those who have taken the basic course and have the basic concept of communication technology. This includes understanding and handling various instruments. After taking the course, you will be able to take responsibility for measuring and managing QoS and QoE of 4G or 5G systems.

Items	**Description**
Class name	Advanced Operator practical course
Program Objective	By taking this course, you will learn the principles and operation of basic measuring equipment. This is to know the real-time analysis ability and post analysis ability method together. In addition, you will be able to know how to measure indoors and how to test driving. As a result, you can measure and analyze directly to improve the quality of QoE and QoS.
Participants	✓ People who do QoS management work related to 4G/5G technology ✓ People who have taken the basic course and have the basic concept of communication technology ✓ People who work on mobile communication-related operating, planning, and maintenance
Contents	✓ Spectrum analyzer measurement method ✓ Understanding RF concepts and network analyzer measurement parameters ✓ Network analyzer principle and understanding of calibration ✓ QoE Measurement (Voice, Video, Data throughput) ✓ Auto call testing ✓ Area and event , Log analysis ✓ Time based analysis ✓ Hands-on Outdoor & In-Building test ✓ Air interface message analysis ✓ Data gathering and analysis using Scanners

4.4.3 Overseas Training Program (NIA Global Academy)

4.4.3.1 Introduction of NIA Global Academy

The Global Academy of the National Information Society Agency (NIA) was established in 2013 by the Ministry of the Interior and Safety (MoIS) of the Republic of Korea to provide professional training courses with the aim to share Korea's experience in ICT and e-government policy with the world. The Global Academy plans and operates professional training courses to enhance the ICT/e-government policy capabilities of domestic and overseas high-ranking government officials and experts. From 2014 to 2019, more than 4,500 people from 104 countries completed the training courses in cooperation with ITU, WB, ADB, IDB, AfDB, WeGO, UNPOG, UNDP, KOICA, SNU ITPP, KAIST ITTP and OECD KPC. AITI may utilize NIA Global Academy's training program for effective implementation of revised CoP QoS regulatory framework.

Key Objectives

- To deliver professional knowledge on e-government/ICT
- To strengthen cooperation with partner countries and international organizations
- To improve the expertise of human resources

Achievement

<Table 26 > [Invitational/Outreach Program] Number of participants/participating countries by year

	'14	'15	'16		'17	'18	'19	Total
No. of Participants	1,415	854	851		683	457	661	4,921
No. of Countries	32	38	53		43	45	41	252

Source: https://eng.nia.or.kr/site/nia_eng/01/10102050100002016100702.jsp#active (NIA, Republic of Korea)

4.4.3.2 Invitational Program

Global Academy organizes the Korean ICT Capacity Building Program to share experiences of operating ICT with governmental authorities from countries around the world, who share a vision of innovative technology introduction. In this regard, we invite government officials in charge of the sector to Korea and share knowledge and know-hows.

- Participants: Government Officials from Telecommunication-related ministries and Telecommunication Operators in Brunei Darussalam
- Program Objective: To invite policy-makers and working-levels of Brunei Darussalam to Korea and provide the best practices and know-hows of Korea accumulated in the process of Telecommunication Service Quality Evaluation
- Contents: The Global Academy operates the fully government funded program that invites high-level government officials of partner countries to share the experiences of Telecommunication Service Quality Evaluation and 5G Introduction. The program consists of lectures, study visits and seminar on thematic strategies, major policies and services etc.

- Curriculum (Example)

Day	Category	Program
Day1	Event	Orientation, Welcoming Ceremony
	Lecture	Telecommunication Quality Evaluation Framework of Korea
	Study Visit	National Information society of Agency, Public Communication Service Team
Day2	Lecture	Telecommunication Service Testing Equipment
		Telecommunication Service Testing Method
	Seminar	Standard of QoS Performance Parameter inclusive of 5G
Day3	Study Visit	Telecommunication Operator (SKT, KT, LG U+), Ministry of Science and ICT of Korea
Day4	Lecture	Wired and Wireless Internet Usage inclusive of 5G
		Requirements for Implementation of QoS, QoE Evaluation
Day5	Seminar	Presentation of Korea and Foreign Cases
	Event	Closing Ceremony

4.6.4.3 Customized Program

- Participants: Government Officials from Telecommunication-related ministries and Telecommunication Operators in Brunei Darussalam
- Program Objective: To provide a country-customized program by analyzing the status and requirements of telecommunication service quality evaluation in Brunei Darussalam
- Contents: The customized program schedule and contents will be decided based on the agreement between the Global Academy and Brunei Darussalam