MCMC MTSFB TC G038:2022

# TECHNICAL CODE

## END-TO-END (E2E) QUALITY OF SERVICE (QoS) AND QUALITY OF EXPERIENCE (QoE) USING CROWDSOURCE APPLICATION APPROACH

**Developed by**

Malaysian Technical Standards Forum Bhd

**Registered by**

MCMC

**Registered date: 17 August 2022**

© Copyright 2022

## MCMC MTSFB TC G038:2022

## Development of technical codes

The Communications and Multimedia Act 1998 ('the Act') provides for Technical Standards Forum designated under section 184 of the Act or the Malaysian Communications and Multimedia Commission ('the Commission') to prepare a technical code. The technical code prepared pursuant to section 185 of the Act shall consist of at least, the requirement for network interoperability and the promotion of safety of network facilities.

Section 96 of the Act also provides for the Commission to determine a technical code in accordance with section 55 of the Act if the technical code is not developed under an applicable provision of the Act and it is unlikely to be developed by the Technical Standards Forum within a reasonable time.

In exercise of the power conferred by section 184 of the Act, the Commission has designated the Malaysian Technical Standards Forum Bhd (MTSFB) as a Technical Standards Forum which is obligated, amongst others, to prepare the technical code under section 185 of the Act.

A technical code prepared in accordance with section 185 shall not be effective until it is registered by the Commission pursuant to section 95 of the Act.

For further information on the technical code, please contact:

**Malaysian Communications and Multimedia Commission (MCMC)**
MCMC Tower 1
Jalan Impact
Cyber 6
63000 Cyberjaya
Selangor Darul Ehsan
MALAYSIA

Tel: +60 3 8688 8000
Fax: +60 3 8688 1000
http://www.mcmc.gov.my

OR

**Malaysian Technical Standards Forum Bhd (MTSFB)**
MCMC Centre of Excellence (CoE)
Off Persiaran Multimedia
Jalan Impact
63000 Cyberjaya
Selangor Darul Ehsan
MALAYSIA

Tel: +60 3 8320 0300
Fax: +60 3 8322 0115
http://www.mtsfb.org.my

## Contents

## Committee representation

This technical code was developed by the Crowdsource Applications Sub Working Group under the International Mobile Telecommunications and Future Networks Working Group of the Malaysian Technical Standards Forum Bhd (MTSFB) which consists of representatives from the following organisations:

Celcom Axiata Berhad

Fraunhofer IIS

Maxis Broadband Sdn Bhd

Multimedia University

Orbitage Sdn Bhd

Rohde & Schwarz Malaysia Sdn Bhd

Tekmark Sdn Bhd

Telekom Malaysia Berhad

TIME dotCom Berhad

U Mobile Sdn Bhd

Universiti Putra Malaysia

Universiti Teknikal Malaysia Melaka

Universiti Teknologi Malaysia

Webe Digital Sdn Bhd

Xcelcius Consultancy Sdn Bhd

YTL Communications Sdn Bhd

## Foreword

This technical code for End-to-End (E2E) Quality of Service (QoS) and Quality of Experience (QoE) using Crowdsource Application Approach ('this Technical Code') was developed pursuant to section 95 and section 185 of the Act 588 by the Malaysian Technical Standards Forum Bhd ('MTSFB') via its International Mobile Telecommunications and Future Networks Working Group.

This Technical Code shall continue to be valid and effective from the date of its registration until it is replaced or revoked.

# END-TO-END (E2E) QUALITY OF SERVICE (QoS) AND QUALITY OF EXPERIENCE (QoE) USING CROWDSOURCE APPLICATION APPROACH

## 0. Introduction

The landscape of telecommunication services has changed drastically over the years with various advancements in technology that have enabled service providers to offer a variety of voice and data services effectively.

As a developing nation, Malaysia has done well in this field which has enabled telecommunication service providers to offer competitive data and voice packages. The effectiveness of such offerings can be clearly seen from Figure 1, where Malaysia end users were ranked amongst the top nations with highest average mobile data consumption in Quarter 1 2021. On average, Malaysians consumed 25.7 GB of data every month as stipulated in the OpenSignal report.

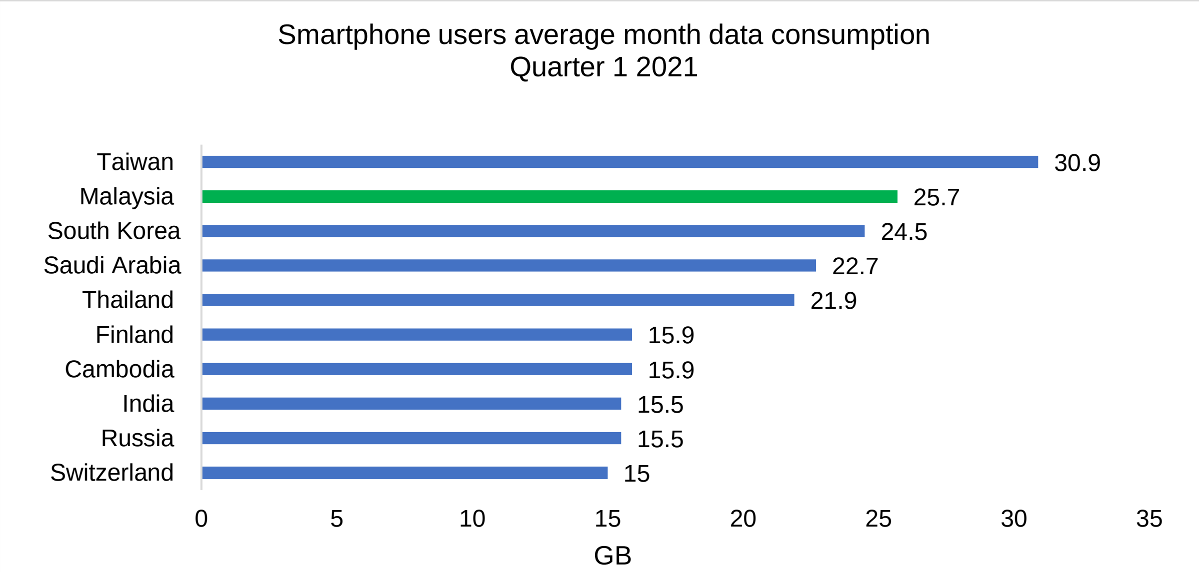


**Figure 1. Smartphone users' average monthly mobile data consumption in Quarter 1 2021**

With this continued high data consumption trend, the need to ensure Quality of Service (QoS) and Quality of Experience (QoE) is growing tremendously. In line with this, Jalinan Digital Negara (JENDELA) initiative was introduced to provide wider coverage of fixed and mobile services towards improving the overall quality of broadband service experienced by Malaysian users.

Conventional methods of measuring the QoS and QoE via Drive Test (DT) and static test are very costly, time consuming and labour intensive. Furthermore, on-the ground assessments could potentially expose engineers to potential health risks such as COVID-19.

The crowdsource approach is an alternative way of effectively measuring and reporting End to End (E2E) QoS and QoE of end users. Crowdsource applications are available for download for both Android and iOS platform or web-based applications catering fixed broadband users as well. Some of the available crowdsource applications measure only QoS, while others map the Key Performance Indicator (KPI) to QoE.

Crowdsource applications typically measure QoS and QoE from the end user's device all the way to the content on the Internet. Such a measurement methodology reflects the true user experience or network capability experienced at the point of the assessment. The main advantage of crowdsource data collection methods over conventional DTs or static tests is the ability to collect a large volume of data samples from end users throughout the country in a short time frame. The large volume of data strengthens the reliability and representativeness of the obtained results. Furthermore, it improves the usage of resources and allows countries with larger geographical masses to leverage on the public to collect data.

Crowdsource data collected on various service providers' networks using standardised methodology benefit from consistent data collection approaches and methodology across service providers. However, there are Crowdsource Vendors (CVs) who deploy a variety of data collection and post processing methodologies which presents both end users and regulators with challenges in deciding which is the best application that reflects their experience with accurate supporting data. The accuracy and the granularity of data collected is key to understanding the network conditions during the assessment so that corrective or optimised actions can be carried out effectively by the service providers.

The integrity of the crowdsource assessment data is very important particularly when the data is used for benchmarking. Any potential room for manipulation of the assessment or tampering with the data sets should be strictly avoided.

This Technical Code identifies the advantages and disadvantages of the crowdsource approach to QoS and QoE assessment as well as presenting both the precautions that should be taken and recommendations that should be considered in using such techniques in the Malaysian context.

## 1. Scope

This Technical Code provides requirements and recommendations for the E2E QoS or QoE assessment of both fixed and mobile internet access using crowdsource applications including:

a) overview of crowdsource applications for fixed and mobile internet access;

b) types of crowdsource data collection methods, characteristics and requirements;

c) methods to initiate crowdsource data collection;

d) crowdsource data post-processing requirements;

e) set up scenarios; and

f) policy and governance.

## 2. Normative references

The following normative references are indispensable for the application of this Technical Code. For dated references, only the edition cited applies. For undated references, the latest edition of the normative references (including any amendments) applies.

See Annex A.

## 3. Abbreviations

For the purposes of this Technical Code, the following abbreviations apply.

See Annex B.

## 4. Terms and definitions

For the purposes of this Technical Code, the following terms and definitions are applied.

### 4.1 Crowdsource data collection

A method to gather active and/or passive QoS measurements from a large number of subscriber devices.

### 4.2 Download

Transfer of data or programs from a server or host computer to one's own computer or device.

### 4.3 End-to-End (E2E) quality

Quality related to the performance of a communications system, including all terminal equipment.

### 4.4 Internet Protocol Packet Loss Ratio (IPLR)

Internet Protocol Packet Loss Ratio (IPLR) is the ratio of total lost Internet Protocol (IP) packet outcomes to total transmitted IP packets in a population of interest.

### 4.5 Jitter

A measure of the latency variation above and below the mean latency value. The maximum jitter is defined as the maximum latency variation above and below the mean latency value.

### 4.6 Latency

A measure of the delay from the instant when the last bit of a frame has been transmitted through the assigned reference point of the transmitter protocol stack to the instant when a whole frame reaches the assigned reference point of receiver protocol stack. Mean and maximum latency estimations are assumed to be calculated on the $99^{th}$ percentile of all latency measurements. If retransmission is enabled for a specific flow, latency also includes retransmission time.

### 4.7 Quality of Experience (QoE)

QoE reflects the totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service. It is the degree of delight or annoyance of the user of an application or service.

### 4.8 Quality of Experience (QoE) assessment

The process of measuring or estimating the QoE for a set of users of an application or a service with a dedicated procedure and considering the influencing factors (possibly controlled, measured, simply collected and reported). The output of the process may be a scalar value, multi-dimensional representation of the results and/or verbal descriptors. All assessments of QoE should be accompanied by the description of the influencing factors that are included. The assessment of QoE can be described as comprehensive when it includes many of the specific factors, for example most of the known factors. Therefore, a limited QoE assessment would include only one or a small number of factors.

### 4.9 QoE influencing factors

Includes the type and characteristics of the application or service, context of use, the user's expectations with respect to the application or service and their fulfilment, the user's cultural background, socio-economic issues, psychological profiles, emotional state of the user and other factors whose number will likely expand with further research.

### 4.10 QoS Class Identifier (QCI)

QoS Class Identifier (QCI) is a mechanism used in Long Term Evolution (LTE) networks to ensure carrier traffic is allocated with appropriate QoS. Different carrier traffic requires different QoS and therefore different QCI values. QCI value 9 is typically used for the default carrier of a User Equipment (UE) or Packet Data Network (PDN) for non-privileged subscribers. Examples of the QoS parameters include Guaranteed Bit Rate (GBR) or non-GBR, priority handling, packet delay budget and packet error loss rate.

### 4.11 QoS Flow Identifier (QFI)

QoS Flow Identifier (QFI) is unique identifier assigned to identify the QoS Flows in the 5G system.
There are 2 types of flows which are GBR and non-GBR QoS flows. Examples of the QoS parameters include GBR or non-GBR, priority handling, packet delay budget, packet error loss rate, data burst volume and averaging window.

### 4.12 Zero-rating

Zero-rating is when an Internet Service Provider (ISP) applies a price of zero to the data traffic associated with a particular application or class of applications (and the data does not count towards any data cap in place on the Internet access service).

### 4.13 Whitelisting

One of the methods to bypass the commercial speed-cap provisioned on packages to reflect the network speed capability rather than the product speed restrictions and such whitelisting is not the same as speed-test prioritisation as described in this technical code.

## 5. Types of crowdsource data collection

Crowdsource applications measure E2E QoS and QoE effectively as the measurements are triggered from the fixed or mobile end user's device. The measurement performed from the end user's device involves 3 main types of data collection which ITU-T E.806 categorises as active, passive and hybrid measurements. The data collection process can be either user initiated, triggered via background programs or a combination of both, often referred as a hybrid method.

### 5.1 Active

Data tests that are subscriber initiated or scripted. The approach creates artificial traffic (download, upload, ping, etc) to determine the network capability.

Figure 2 illustrates the setup environment for an active test on a mobile and fixed network.

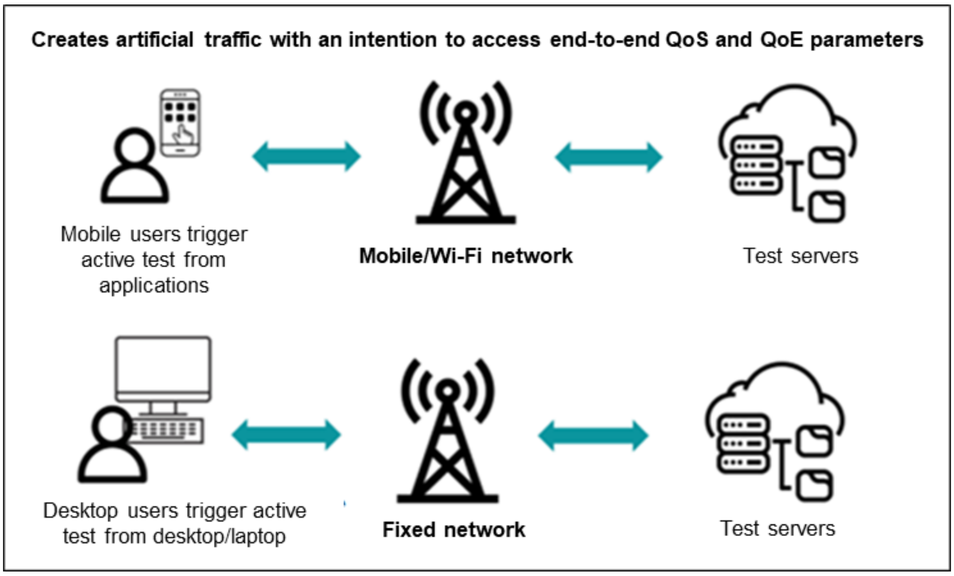


**Figure 2. Active data collection from a mobile and fixed network**

## 5.2 Passive

Data collection that does not require any form of user intervention. It does not inject or create any artificial traffic (e.g. network quality and coverage information, device battery level, etc).

Figure 3 illustrates the passive data collection type.

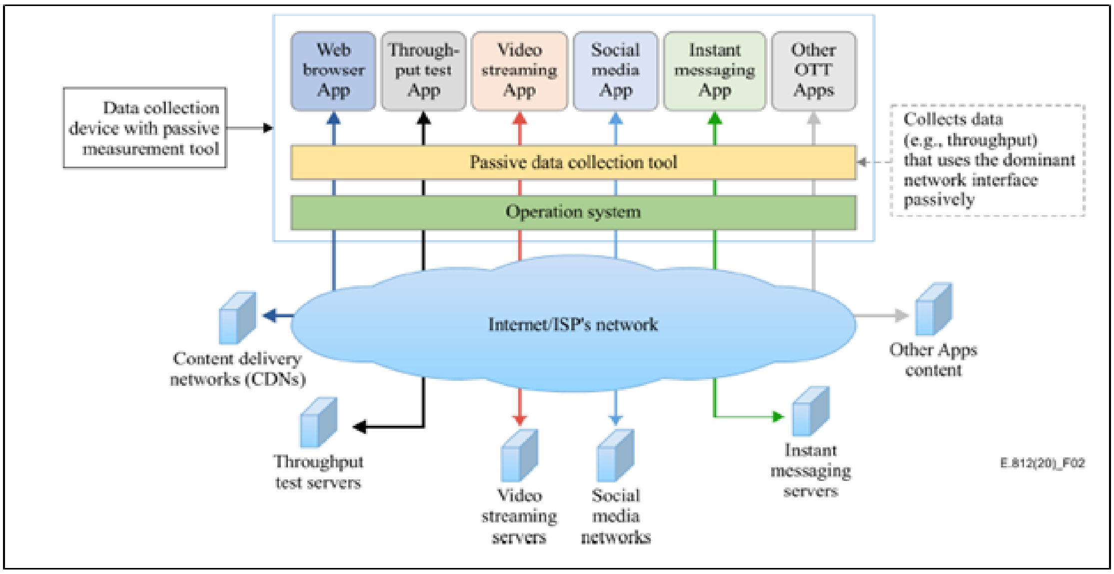


**Figure 3. Passive data collection from a mobile network**

The key differences between active and passive crowdsource data collection methods are shown in Table 1.

**Table 1. Differences between active and passive crowdsource data collection methods**

| Active | Passive |
|---|---|
| Parameters can be controlled. Examples of parameters include test duration, number of streams, size of packets, etc. | Test parameters vary depending on multiple factors including time of day, load of device, etc. |
| Injects artificial traffic into the network. Examples of traffic include data packets for packet loss, upload/download traffic, etc. | Does not create artificial traffic and uses whatever data is available. However, there are certain applications which conduct passive testing using artificial traffic as well. |
| Tests are initiated via an application, web-based using a browser, etc. or via background scripts. | Does not require user intervention. |

### 5.3 Benefits and challenges of active tests

#### 5.3.1 Benefits

Active tests method which introduces artificial traffic when measuring the E2E performance has its own advantages as below:

a) potential standardisation of active tests is possible since the measurements parameters such as test duration, number of streams, size of packets can be controlled;

b) testing is performed at application level (closer to the subscriber for a more complete E2E QoS); and

c) can be formulated to emulate behaviour of specific services (for example, lower latency tests for gaming, high bandwidth tests for High Definition (HD) video, etc).

#### 5.3.2 Challenges

Introducing artificial traffic during the measurement does have its drawbacks as captured below:

a) active tests introduce artificial traffic into the network thus increasing load to the network;

b) there is a potential impact to subscriber data quotas as additional data generated by the tests consumes the user quota. This is particularly problematic for customers who have not subscribed for unlimited data plan;

c) measurements designed to reflect peak throughput (such as HD video capabilities) may be impacted by other parameters or processes on the device as it competes for resources such as Central Processing Unit (CPU), network bandwidth and Random Access Memory (RAM). This is particularly true for background data collection where the users are not aware of when the application is performing an active test; and

d) some crowdsource solutions conduct active assessments of traffic to Content Delivery Network (CDN) in order to measure application experience (e.g. video, games, etc.) which may not accurately represent the actual user experience where the applications or data could be locally cached in the service provider’s network.

### 5.4 Benefits and challenges of passive tests

#### 5.4.1 Benefits

Passive method which does not introduce artificial traffic has many advantages and amongst those are as below:

a) collection of tests does not consume additional data;

b) a specific test server to initiate packet loss or ping tests is not required as data is not artificially introduced; and

c) does not saturate or contribute to congestion on the network.

#### 5.4.2 Challenges

Challenges of passive crowdsource data collection are captured as below:

a) platforms with different Operating System (OS) environments collects and presents data differently. For example, Android OS may provide more parameters compared to iOS while variety of device specification may result in the inconsistency of signal strength reporting;

b) passive measurements are not able to monitor certain QoS indicators such as latency and packet loss as these require artificial traffic to be ingested into the network; and

c) passive measurement can be intrusive if application specific data is collected together with consumer Identification (ID) information.

### 5.5 Typical use cases of crowdsourcing for mobile and fixed broadband

#### 5.5.1 Network coverage

Crowdsource applications collect signal strength measurements to develop coverage maps. This is done using passive background sampling to scan the radio information. Information such as operator information, user ID, radio signal information, radio access network and device information are gathered during each scan. Scanning happens in the background and this method replaces the need for conventional DT to collect such information.

Based on the radio signal of the device in each location, the coverage maps are created by plotting the signal strength of distributed points in a certain area. Mobile device parameters collected from the crowdsource application are used to visualise the network map and cell boundaries are identified.

The following use cases are aimed at identifying available mobile network coverage in both outdoor and indoor environments:

a) Outdoor

   i) With sufficient data points (determined by crowd participation), it can provide coverage maps of fine resolutions per mobile operator. This can provide a detailed map of network coverage per operator and avoid costly DTs in a timely and efficient manner.

   ii) If representative data is available, it can be used for complaint validation and to identify problematic zones with respect to E2E QoS.

iii) Can provide an indicator of user distribution for geographical zones of interest. Since the crowdsource data for a specific zone will have a sample distribution with more data points for operators with more users, it can be used as an indicator of how the users are distributed amongst the network operators.

b) Indoor

i) Indoor complaint validation.

ii) Possibility to locate and identify poor indoor coverage through signal level indicators, although signal level issues will likely affect location accuracy or may prevent coverage completely (e.g. lower floors of underground garages).

iii) Access to vital restricted buildings such as hospitals or public institutions.

iv) Can provide an indicator of the user distribution for critical public zones and commercial districts. Since the crowdsource data for a specific zone will have a sample distribution with more data points for operators with more users, it can be used as an indicator of how the users are distributed amongst the network operators.

Figure 4 shows a sample of coverage information collected from a crowdsource application.

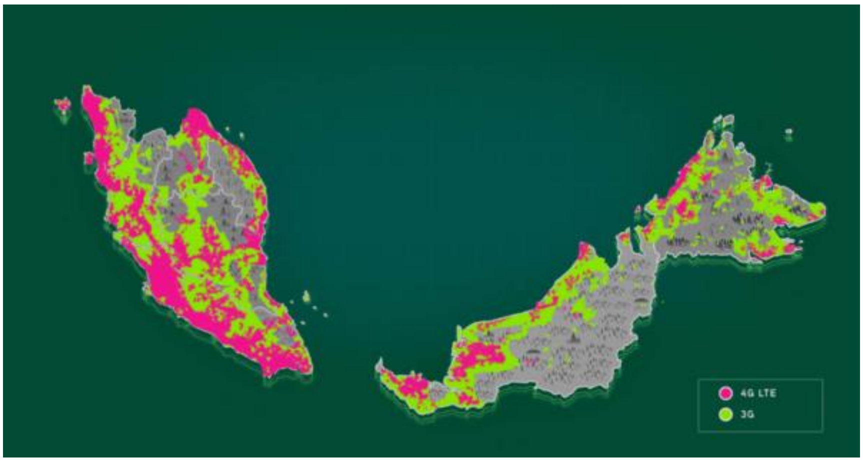


**Figure 4. Coverage information**

### 5.5.2 Performance monitoring and benchmarking

Performance monitoring and benchmarking data collection is done using both passive and active methods. In the active data collection method, the user is required to initiate a test from their device. Each test will establish a connection and gather information such as provider information, test ID, various performance and quality metrics or KPIs, device information and radio signal information.

Data collected from the performance and quality metrics include user speed, video experience, latency, jitter, etc. This can be used for benchmarking by providing, for example, download and upload speed scores, consistency scores, time periods, locations, radio networks and providers.

Below are some of performance monitoring and benchmarking used cases:

a) Through KPI monitoring (either active or passive) or user interaction (e.g. user feedback after a service session), the crowdsource data can be used to evaluate performance trends for different geographical levels (municipalities, cities, regions, etc).

b) Detailed crowdsource data (both in time and space) concerning access to the service and causes for service release can provide a good identification of the possible root cause for performance issues experienced by subscribers of a given version of a service at a given time and place and help with finding a quick fix.

c) When combined with user interaction such as surveys and other measurement result sources such as DTs, it can provide a more reliable comparison between network operators or service providers in terms of QoS compared to only using crowdsourcing data.

When selecting a crowdsource QoS and QoE application, it is important to distinguish if the application is capable of measuring the network, product capability or user experience as described below:

a) Applications that measure network capability are able to reveal the best possible speeds offered by the wired or wireless technology at the location of the measurement provided there is no restriction on the device capability supporting such technology. This type of application is suitable for benchmarking purpose as it reflects maximum capability and often used when gauging a service provider or a country ranking in terms of speed.

b) Applications that measure product capability or average user experience only conducts the measurement for download and upload using the common file sizes used by most applications which commonly falls between 3 MB to 5 MB file. When such small files were used during the measurement, the outcome of the results only showcase the bandwidth required to download or upload the file size. This kind of applications are suitable for gauging typical user experience.

c) The above measurement can also be impacted by product subscriptions which are restricted by bandwidth capping and Fair Usage Policy (FUP). Furthermore, CVs are unaware of end user’s product subscription and characteristics of the products.

### 5.5.3 Complaint verification

Complaint verification empowers end users to provide supporting data on issues regarding slow internet performance, poor or no mobile coverage (especially in low population areas), difficulty or impossibility to make calls, dropped calls, no mobile Internet (despite having coverage). All the scenarios mentioned above can be investigated and validated using the results from crowdsourcing data.

After confirmation of the issues related to a complaint, crowdsource data can also be useful for qualifying it and proposing suitable solutions. Through the performance monitoring using crowdsource network measurements, the network service providers can actively identify low performing areas, low service quality and network faults, regardless of whether the network service providers received any related complaints from their customers.

By using performance monitoring via crowdsource network measurement, the customers’ complaints can be resolved and verified much more effectively. By using the data to verify customers’ complaints, network service providers can also easily identify the critical areas that require attention and therefore prioritise improving or upgrading services in those critical areas.

### 5.5.4 Checking commitment to license

Mobile coverage obligations for an operator may include rollout commitments such as a percentage of the population or territory covered in each timeframe. Such obligations can be derived from the operator’s license conditions or through terms specified in a spectrum allocation. With sufficient data points, crowdsource data can be used to monitor and validate their required commitment to network rollout both in terms of infrastructure and spectrum.

Another example could be when a fixed operator has a commitment to guarantee a set of minimum QoS parameters to the end users. Crowdsource data can be used to monitor the performance of such parameters, verify it has been achieved or support implementation of improvements to achieve them.

### 5.5.5 Network planning

This clause details on the usage of crowdsource data for the purpose of network planning which describes as follows:

a) Expansion of rolling out new technologies. In this case, crowdsource data can be used to map the human activity (in terms of mobility) by looking at how the user distribution changes over time. ID of areas with high data usage and/or user density can be used within the scope of selecting the optimal location and density of deployment sites in the network.

b) Creation and tuning of propagation models in conjunction with topographical and geolocated data. In this case, the crowdsource data requires measurements of Radio Frequency (RF) characteristics such as, but not limited to, signal level, signal quality and usage of frequencies or frequency bands. In addition, crowdsource data used for this scope should be accurate, unbiased, free of artefacts possibly introduced during data collection and it needs to show high granularity. Guidelines for data collection requirements such as sampling, scheduling, filtering, categorisation and aggregation can be found in Clause 7.3.

c) Optimisation of traffic models used in planning.

d) Increased profitability based on the optimisation of quality (coverage, latency and throughput) versus Return on Investment (RoI).

### 5.5.6 Network optimisation

Using crowdsource data for network optimisation requires high data accuracy and granularity. If these requirements are met, then the following use cases can be supported by crowdsource data:

a) Regular (typically daily) monitoring of the data to identify trends in usage and QoS delivered by the network. The results of such monitoring can help to identify patterns which can be used to plan future improvements such as increase in network capacity, targeted at the correct location and time.

b) Establishing root causes for network issues. Crowdsource data can be used for geographical network problem detection related to service release, coverage, throughput and/or capacity.

c) Performing a dedicated collection of crowdsource data on a specific target (e.g. a geographical zone, or a group of users with the same model of mobile device) in order to detect and fix specific issues more quickly.

d) Optimising and/or replacing blind (anywhere) and blanket (all over) static testing with more focused and on-demand solutions, when and where a problem occurs.

e) Visualise capacity usage of mobile services using indoor subscriber density.

f) Monitor the efficiency of network optimisation solutions after deployment.

Table 2 summarises the types of crowdsource application use cases and types of data collection along with the environment of usage.

**Table 2. Summary of use cases and types of data collection**

| Use cases | Type of data collection | Type of broadband |
|---|---|---|
| Network coverage | Passive | Mobile broadband |
| Performance monitoring and benchmarking | Active and passive | Mobile and fixed broadband |

**Table 2. Summary of use cases and types of data collection** *(continued)*

| Use cases | Type of data collection | Type of broadband |
|---|---|---|
| Complaint verification | Active | Mobile and fixed broadband |
| Checking commitment to license | Active | Mobile and fixed broadband |
| Network planning | Active and passive | Mobile and fixed broadband |
| Network optimisation | | |

Table 3 below shows the typical QoS and QoE indicators for mobile and fixed broadband.

**Table 3. Typical QoS and QoE key performance indicators**

| Indicators | QoS or QoE | Type of broadband |
|---|---|---|
| Download speed | QoS | Mobile and fixed broadband |
| Upload speed | | |
| Latency | | |
| Jitter | | |
| Packet loss | | |
| Video experience | QoE | Mobile and fixed broadband |
| Gaming experience | | Mobile and fixed broadband |
| Voice experience | | Mobile broadband |

### 5.6 Recommendations on types of data collection

To successfully collect a large volume of data samples with high accuracy for both active and passive data collection types, the following recommendations should be considered:

a) Crowdsource solutions which employ a hybrid data collection type (i.e. active and passive) are preferred due to their ability to provide a holistic E2E QoS and QoE assessment. Hence, crowdsource applications with hybrid data collection should be the preferred choice of service providers or regulators to collect effective crowdsource measurements.

b) Selection of the right crowdsource application for performance benchmarking is very critical to ensure the objective of benchmarking exercise is met. Service providers, regulators and end users should verify if a particular crowdsource application is measuring network capability (for download and upload test) or typical user experience which could be affected by end user’s product package speed restrictions. Comparison of performance between these 2 types of application which employs different measurement methodology is not recommended.

# 6. Methods to initiate crowdsource data collection

This clause describes the methods used to collect crowdsource data, the type of data collected, the source of the data and how it is being collected.

Data collection is defined as the process of collecting, measuring, and analysing accurate insights for research purposes using standard validated techniques. In most cases, data collection is the primary and most important step for research, irrespective of the field of research.

## 6.1 Methods of data collection

There are 2 methods of initiating crowdsource data collection as defined by ITU-T E.812 as follows:

a) end-user initiated, where the subscriber is required to deliberately start data collection; and

b) automated, where the data collection occurs programmatically by pre-established start rules.

These solutions of measurement are measured either at a server placed at the core network or a server placed at the CDN for mobile networks as illustrated in Figure 5. Figure 6 illustrates the typical solution for fixed networks.

Some Mobile Network Operators (MNOs) deploy solutions such as peer and caching solutions to localise content so as to gain improved speeds and loading time to provide a better customer experience. In such cases, the measurement method implemented by some CVs may not take this into consideration, hence leading to an inaccurate representation of the user experience.

Figure 5 illustrates the user-initiated scenario where the user initiating the test or background collection using either Android or iOS platforms. The measurement then goes through the mobile network system and is captured at the test server located at the core network. For solutions that measure up to the CDN, the server is instead located at this point.

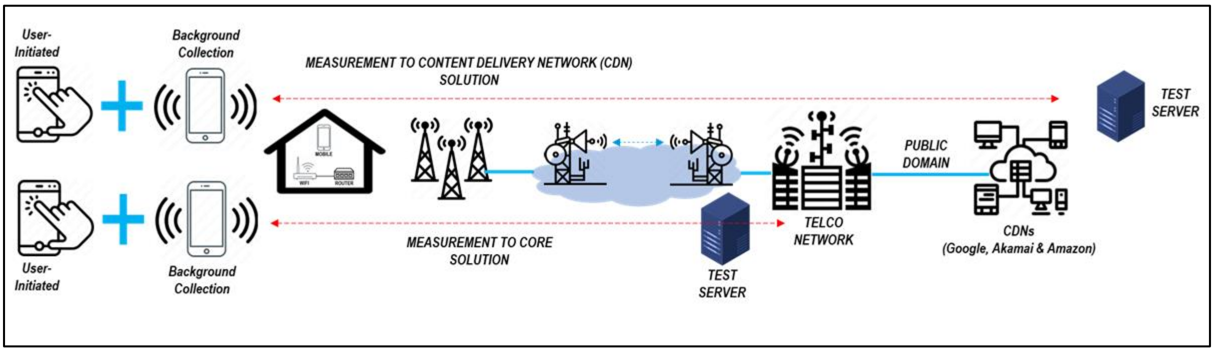


**Figure 5. Mobile network measurement methods**

Figure 6 illustrates the user initiating the testing through a website using either a laptop or mobile device. The measurement then goes through the fixed network system through its optical or copper transport network and is captured at the test server located at the core network. For solutions that measure up to the CDN, the server is instead located at this location.

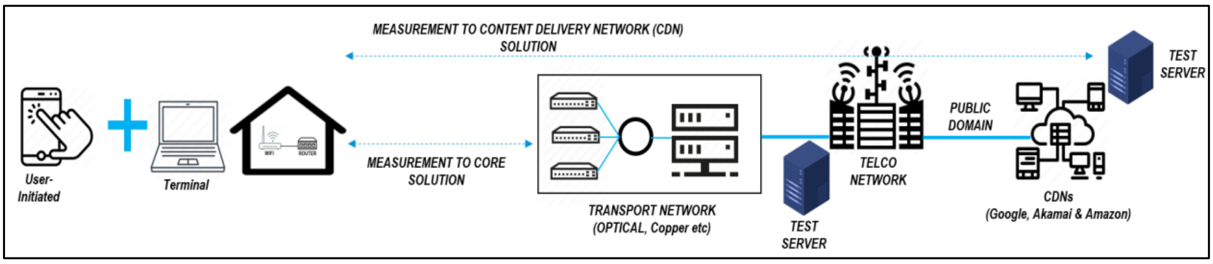


**Figure 6. Fixed network measurement overview**

## 6.2 Subscriber initiated measurement

This approach requires the subscriber to initiate the test and the initiated test results are typically provided to the end-users either by a mobile application or a website as illustrated in Figure 7.

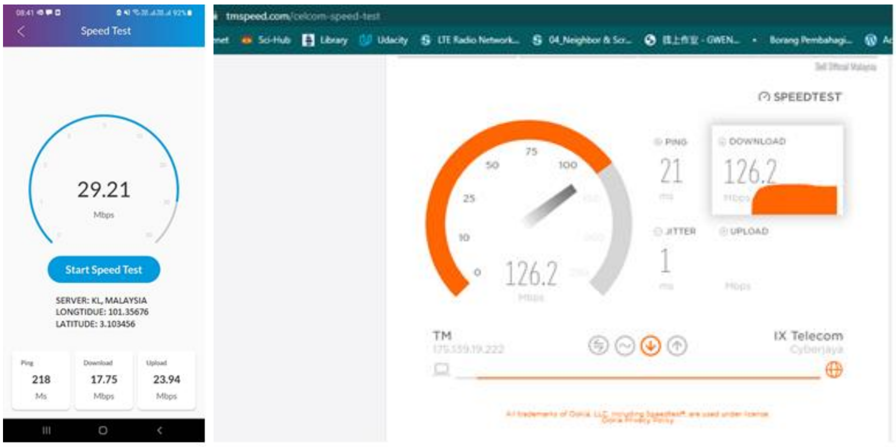


**Figure 7. Examples of user interface for mobile (left) and website (right) to initiate data collection**

## 6.3 Background or automated measurement

Automated data collection can be performed without the need for subscriber intervention either as an independent application or by embedded solutions within other applications or hardware. The tests can be scheduled to run regularly or triggered based on certain algorithms or specific rules.

This approach requires an embedded Application Program Interface (API) written into a mobile application or software installed on the device (laptop or mobile device) as shown in Table 4, e.g. a geolocation API to obtain the longitude and latitude of the mobile client-based Wireless Fidelity (Wi-Fi) and cellular tower information. The application will run background processes to collect pre-determined measurements from the user. Although started at random times, measurements are performed in the background at regular intervals if the user is inactive, and information such as the status of the device, network activity and operating system details are collected. In most cases, CV tend to sign partnerships with other application providers to share their background data to obtain a larger sample count.

**Table 4. Mobile API Reference**

| Field | JSON type | Description | Notes |
|---|---|---|---|
| cellid | number (uint32) | Unique identifier of the cell | Requirement for radioType gsm(default), cdma, wcdma and lte; rejected for nr |
| newRadioCellid | number (uint64) | Unique identifier of the New Radio (NR) or also known as 5G cell | Requirement for radioType nr, rejected for other types |
| locationAreaCode | number (uint32) | The Location Area Code (LAC) for Global System for Mobile Communication (GSM).<br>The Tracking Area Code (TAC) for LTE and NR networks | Requirement for radioType gsm(default), cdma, optional for other values.<br>Valid range with gsm, cdma, wcdma and lte, 0-65535<br>Valid range with nr: 0-16777215 |
| mobileCountryCode | number (uint32) | The cell tower's Mobile country Code (MCC) | Requirement for radioType gsm(default), wcdma, lte and nr; not used for cdma<br>Valid range: 0-999 |
| mobileNetworkCode | number (uint32) | The cell tower's Mobile country Code.<br>This is the Mobile Network Codes (MNC) for GSM, LTE and NR. | Required<br>Valid range for MNC: 0-999<br>Valid Range for SID: 0-32767 |
| NOTE: JSON is JavaScript Object Notation. | | | |

Tests initiated autonomously provide greater control to the entity that designs the tests, making it possible to determine the frequency of tests and the geographic area where they take place, which is not available for solutions that depend entirely on subscriber-initiated tests.

### 6.4 Typical data attributes of crowdsource measurement

There are several types of data attribute to be collected in the category of, but not limited to:

a) test related;

b) position related;

c) device related;

d) network related; and

e) performance related.

To illustrate further, Table 5 shows an example of these data fields. These data are required to be captured and run via crowdsourcing approach to allow further processing and create actionable insights.

**Table 5. Data attributes**

| Type of field | Name of field |
|---|---|
| Test related | a) open_test_uuid<br>b) open_uuid<br>c) time_utc<br>d) implausible |
| Position related | a) lat<br>b) long<br>c) loc_src<br>d) loc_accuracy |
| Device related | a) client_version<br>b) model<br>c) platform<br>d) product |
| Network related | a) cat_technology<br>b) network_type<br>c) network_mcc_mnc<br>d) sim_mcc_mnc |
| Performance related | a) download_kbit<br>b) upload_kbit<br>c) signal_strength<br>d) lte_rsrp<br>e) lte_rsrq<br>f) speed_curve<br>g) ping_ms<br>h) speed_curve_threadwise |

For user experience, these are divided into radio environment and base station information. For network capability, attributes related to the experience of the user are collected. These attributes are further described in the following clauses below.

### 6.4.1 Comparisons between active and passive measurement

There are 2 general types of crowdsource measurement in as described in Clause 7. The first type supports both active and passive measurements, while the other supports passive measurements only. These methods have both similarities and differences when it comes to how data is processed. Table 6 below summarises some of these.

**Table 6. Comparison of crowdsource measurement**

| Metric | Active/passive (measured at core) | Active/passive app (measured at CDN) |
|---|---|---|
| Test server | Required, on premise close to core | Not required, cloud server, CDN |
| Data storage | Cloud | Cloud |
| Measurement | Active and passive | Active and passive |
| Data granularity | Geopositioning | Geopositioning |
| Data representation | User behaviour | Aggregated, not visible |
| Data quantity | Low – high | Low – high |
| Radio environment | Default | Default |
| Network capability | Speed, latency, jitter etc | Speed, latency, jitter etc |
| Mobility | No, static test only | No, static test only |
| Application specific tests | Data, video | Data, video |
| Ability for follow up actions | Yes | No, limited |
| Shared data | Geopositioning | Aggregated, no Geopositioning |

The following Table 7 provide a complete summary of types of crowdsource data collection and the methods to initiate data collection, highlighting the benefits and the challenges.

**Table 7. Summary of active and passive data collection**

| Types of crowdsource data collection | Parameter | Methods to initiate crowdsource data collection | |
|---|---|---|---|
| | | End-user initiated | Automated |
| Active | Benefits | a) Perceived to be more transparent<br>b) Raise end-user awareness<br>c) Potential standardisation of active tests<br>d) Multi-platforms<br>e) Configurable to emulate services' behaviour<br>f) May be designed to provide an estimate of the end-to-end performance during test period | a) May have larger number of samples<br>b) Potential standardisation of active tests<br>c) Multi-platforms<br>d) Configurable to emulate services' behaviour<br>e) May be designed to provide an estimate of the end-to-end performance during the test period |

**Table 7. Summary of active and passive data collection** *(continued)*

| Types of crowdsource data collection | Parameter | Methods to initiate crowdsource data collection | |
|---|---|---|---|
| | | **End-user initiated** | **Automated** |
| Active | Challenges | a) May have smaller number of samples<br>b) May introduce biasness<br>c) Utilise additional resources<br>d) Potential increase in data usage<br>e) Results may be affected by data collection devices' condition | a) Perceived to be less transparent<br>b) In some situations, it is not supported by all platforms<br>c) Utilise additional resources<br>d) Potential increase in data usage<br>e) Result may be affected by data collection devices' condition |
| Passive | Benefits | a) Perceived to be more transparent<br>b) Raise end-user awareness<br>c) May have larger number of samples<br>d) Does not require test server<br>e) Does not further congest the network<br>f) Provides an indication of the end-to-end performance based on end-users' actual usage | a) May have larger number of samples<br>b) Does not require test server<br>c) Does not further congest the network<br>d) Provides an indication of the end-to-end performance based on end-users' actual usage |
| | Challenges | a) May have smaller number of samples<br>b) May introduce biasness<br>c) In some situations, it is not supported by all platforms<br>d) Limited QoS indicators to be monitored<br>e) May be intrusive | a) Perceived to be less transparent<br>b) In some situations, it is not supported by all platforms<br>c) Limited QoS indicators to be monitored<br>d) May be intrusive |

On top of the challenges highlighted above, it is known that crowdsource speed test traffic can be prioritised by service providers at the expense of other users' data experience. Such prioritisation artificially enhances speed test results and therefore creates misleading network performance capability as well as operator and country level rankings.

## 6.5 Requirements on methods to initiate crowdsource data collection

The environment for measuring E2E QoS and QoE performance shall be free from any form of prioritisation of radio network and core resources to avoid false measurement reporting of customer experience. Configuring priority for popular applications may be a norm for service providers to provide better user experience. However, this shall not be applied for network performance indicator in relation to crowdsource application which are also being used as a source for performance benchmarking.

Refer to Annex C on application prioritisation techniques and methods of detection.

### 6.6 Recommendations on methods to initiate crowdsource data collection

The recommended data initiation methods are as follows:

a) Information required to be disclosed by CVs

CVs have their own proprietary methods embedded to collect, process and report their results, both active and passive measurements, using either subscriber initiated or automated data collection methods. However, these proprietary methods may lead to different interpretations of results and failure of relevant parties to take further corrective actions. Therefore, it is recommended that the CVs should provide sufficient information on the crowdsource application to allow for further analysis and corrective actions. Below is the crucial information that should be shared either on their application or website:

i) data collection method;

ii) architecture of system;

iii) methodology of data processing; and

iv) granularity of data collection using Clause 7.2 as a baseline.

b) Zero-rated traffic for crowdsource applications

Zero-rating of crowdsource application traffic may be applied to increase the sample size without the concern of increased data consumption (for non-embedded application). Other than zero-rating, some service providers configure whitelisting rules for crowdsource speed test applications which are acceptable when measuring the network capable speed rather than product speeds.

c) Background assessment to be carried during off-peak and peak hours

For assessment of services which consume high data volumes (e.g. video), the assessment should only be done when there is no other application actively running (for background testing) and should not be limited to non-peak hours. This sampling is recommended so that a balance of samples during both peak and non-peak hours can be gathered, thus reflecting the end users' true experience; and

d) Time limit set for each assessment

A time limit should be set for each assessment so that a consistent duration of measurement can be achieved.

e) Operator network setup awareness

CVs should consider service providers network and application hosting setup architecture when measuring and reporting performance mainly pertaining Over-The-Top (OTT) applications which are locally hosted and cached to reflect closest user experience.

## 7. Crowdsource data post-processing requirements

### 7.1 Sampling and scheduling

The KPI data can be collected from various types of data collection devices. However, this collection will still depend on the capability of the test servers, storage as well as scheduling. Since the validation will be based on statistical properties, there should be a minimum number of samples considered. This minimum number will then depend on the predefined maximum acceptable error rate related to the type of probability distribution function and population associated. ITU-T E.806 provides some references on how the sample sizes are collected and distributed over a specific geographical area.

Other than the minimum number of samples, biased results that can affect the outcome should also be avoided and this can be done by having an appropriate sampling plan. Therefore, the geographical origin of the samples will need to be verified by the entity that is responsible for the data collection, ensuring statistical consistency of the geographical origin of the samples with the spread of the targeted population as well as portraying the correct QoS provided to the end-users.

In addition, the statistical methodology can also consider the geographical and/or temporal sampling distribution if necessary. Some examples include:

a) limiting the sampling during periods of high traffic; and

b) collecting a reasonable size of samples in an area where the subscriber density is high.

The recommendations for sampling include:

a) Establishing a minimum number of end-users that should be monitored regularly and randomly. The higher the number of samples used, the more accurate the evaluation will become. However, this will come at the expense of more time required to collect the data.

b) The samples need to be free from any contamination and thus the crowdsource data collected should undergo a post-processed to discard any noisy test results. However, the remaining number of samples after the removal of noise shall still comply with the statistical validation requirements. Examples of noise that can affect the results include:

    i) effect of testing being conducted during busy hours;

    ii) change of subscription plan by end-users;

    iii) restrictions in business plan by commercial customers; and

    iv) changes in access technology.

The sampling approach of computing the sample size should consider the following challenges:

a) Low confidence level of accuracy

A statistical tool can be used to estimate the estimation error when planning/scheduling a test.

b) Time

Time-sensitive and shall be completed within a certain amount of time. As a result, sample selection is necessary.

c) Financial implications

Cost-effectiveness benefit when a high number of population samples are needed.

d) Human resources

May have a restricted number of subjects with the necessary expertise related to what those investigations include.

e) Location

Sample selection becomes critical when dealing with limited access to the population of interest due to geographical limits.

In conclusion, if the results are aggregated for a city or region, a statistical analysis is needed to evaluate the sample's reliability, including the related estimation error and reliability level. In order to reduce the risks of non-sampling error, the modalities that can effectively ensure valid studies need to be considered.

### 7.2 Data processing

Proper data handling is required to produce reliable analysis. Hence, good processing steps can ensure that the objectives of the analysis are met accordingly. To produce good datasets, the following processing steps shall be followed diligently:

a) filtering;

b) categorisation; and

c) aggregation.

The details of each are described in the following clauses.

#### 7.2.1 Filtering

Filtering of crowdsource data should be designed to identify redundant, untrustworthy, or unnecessary material that should be removed from analysis. Here are several examples:

a) data that is duplicated;

b) data that was not acquired within the sample period under consideration, or data that did not have a valid timestamp; and

c) data that does not fall within the scope of the investigation or does not have a geographic context.

For active tests, the system shall remove tests that are prevented or limited by the device operating system or user preference, such as:

a) mode of power conservation;

b) mode of flight; and

c) data has been disabled by the user.

The following data filtering rules should be applied to crowdsource data collection as shown in Table 8.

**Table 8. Type of data filtering rules**

| Identified situation | Description | Observation |
|---|---|---|
| Duplications | Records representing the same time and device. | Data sample should be a unique test |
| Measurement failure | Failure flag fields indicating there is a failure in test conduction | Applies to an incomplete test either initiated by user or network |
| Measurement conditions changed | For active tests that do not complete instantly, such as download tests, where the network type or interface changes significantly (switch between cellular and Wi-Fi, or between different cellular technologies). | Applies for analyses with the objective to measure the performance for a specific scenario such as mobile-only or Wi-Fi-only. However, for certain analyses, these tests will be relevant and could be included. |
| Download and upload parity | Tests that present results only for download or upload. | Applies only for solutions in which each download test presents an upload test pair. |
| Test server ID | Test server does not correspond to accepted servers. | For example, if international traffic is out of scope of the measurement strategy, tests against servers located outside the country shall be excluded. If the goal is also to measure the on-net performance of an ISP, it is necessary to exclude tests against a server outside of the ISP’s network (within Malaysia only). |
| Maximum measurements per time window exceeded | If the number of measurements exceed a maximum | For automatic tests, it is also possible to set a maximum number of tests to avoid collecting this kind of data.<br><br>Alternatively, this data could be allowed into the pipeline so long as the statistical aggregation process prevents such readings having undue influence on the results. For example, this could be achieved by pre-aggregating to time-device bins ahead of the final calculation. |
| Data out of location and period scope | Tests presenting ranges of locations and/or time periods out of desired scope. | Filter out all non-related data that is out of desired scope. |
| Invalid or incomplete field values | Tests containing incomplete or invalid values for fields that are necessary for the calculation of indicators (such as location, battery level, device ID, etc.) | Acceptable rules for data fields shall be predefined. |
| Conflicting field results | Results in different fields that bring conflicting information. | Field results shall be relevant to the field indicator. |
| Low battery | Results obtained from devices in conditions of low battery or battery level usage under accepted limits | Applies for solutions embedded in the end-user’s device. |
| Concurrent traffic | Results undermined by concurrent traffic in the device | Applies only for active tests. For automatic tests, it is also possible to set this as a condition for not starting the test. |

### 7.2.2 Filtering anomalous testing behaviour

Some parties may try to influence the results of an actual experienced by performing rigorous crowdsource testing with good samples. This type of data shall need to be excluded from the overall data by identifying any unusual patterns detected.

Although automated filtering can be done, the malicious parties may evolve and change their strategies if they notice that their data is being filtered out. Therefore, the countermeasure needs to be continually reviewed.

Normally the anomalous testing behaviour is not meant to influence the overall results but more towards achieving personal objectives. For example, some malicious parties may want to influence the result so that they can get out of a contract by having the measurement done at places where it is known to have bad services and later share them over social media accounts.

One of the solutions to combat this type of anomalous testing behaviour is by having surveys within the crowdsourcing agents to find out on the motives of such behaviour. By getting this information in advance, the filtering can be done more efficiently.

### 7.2.3 Categorisation

Categorisation is the point at which the information is upgraded or revised to set it up for additional handling. The categorisation steps can be summarised as below:

a) Network ID mapping

Mobile networks would be able to broadcast different network names or operate with multiple MNCs. In this case it may help to map them to a canonical identifier and name. Note that particular care should be paid to cases where the MCC of the SIM card represents a different country to the country represented by the MCC of the connected network; depending on the analysis being performed it may be appropriate to remove these international roaming results.

b) Measurement time synchronisation

Since the time can be manually changed in subscriber devices, the device reported time may not be reliable. Corrections may be applied where a device's account of the time data that was sent significantly differs from the collection server's authoritative value.

c) Geocoding

Location coordinates in the form of latitude and longitude may be assigned location IDs, by using a hierarchical spatial index, or a specific set of polygons representing, for example, cities and provinces.

### 7.2.4 Aggregation

The aggregation step is where raw data from individual test results are gathered and expressed in a form of a summary for statistical analysis. There are various factors which determine the aggregation method chosen for a set of data, such as:

a) 'One-user, one-vote' strategy whereby the results are aggregated at device-user level first before an average is taken across the data. This method will prevent results being overly influenced by user-devices that report more data samples.

b) Re-weighting of data based on other levels such as geographical location, time, etc. Since there is no control of the geographical origin of the samples, one can estimate the statistical spatial representativeness by means of geographic stratification sampling.

Note that all entities involved in the data collection and data processing, i.e. vendors, operators and regulators shall comply with the corresponding data protection legislation. This is relevant to data processing because often aggregation will require unique user device identifiers and in some legal frameworks the presence of such information alongside location data constitutes personal data.

### 7.3 Difference between a mobile user sample and fixed broadband user sample

One way to differentiate a mobile user sample and a fixed broadband user sample is by looking at how the identity of the user is determined by the platform as depicted in Table 9.

**Table 9. Differences and similarity between mobile and fixed broadband user sample**

| Category | Mobile user sample | Fixed broadband user sample |
|---|---|---|
| Differences | Mobile platform declares their connection technology | Findings shall be deduced or queried |
| Similarity | Most of the other sample fields are almost similar. | |

The user identity in a mobile or desktop user test would be determined by the unique device identifier. For example, in a speedtest.net user test, IP address and the session identifier would be used. Users who log in to speedtest.net always have the same session ID.

### 7.4 Post processing of crowdsource data by application vendors

Millions of tests are performed by various users every day. Example of the approach for evaluating the fixed and mobile networks is shown in Figure 8.

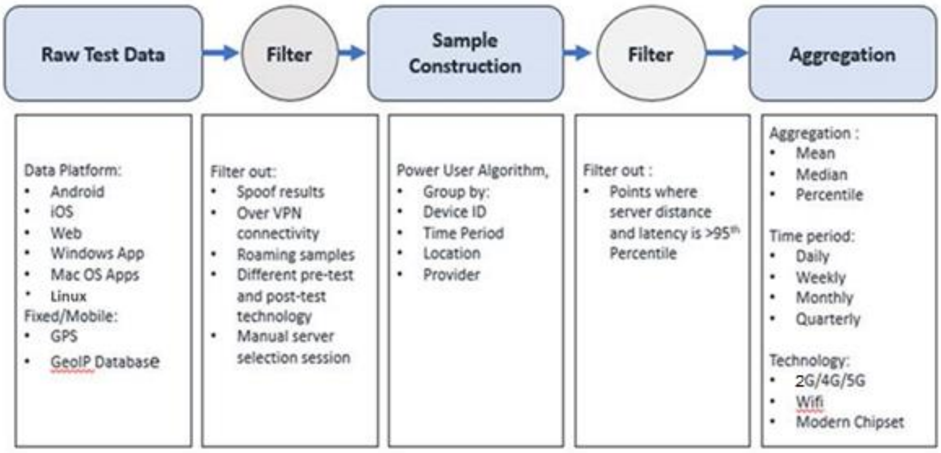


**Figure 8. Example of post processing procedure**

### 7.5 Crowdsource key metrics

Consumers' experience of connecting to the network services can be represented by a set of key metrics KPI as described in Table 10. On the other hand, detailed data for analytical purposes can be obtained by the network operators by subscribing to the CV's services. This data can later be used by the network operators to analyse and improve the performance of their services to the subscribers.

**Table 10. Key metrics**

| Key Metrics | Description |
|---|---|
| Download speed | Download speed experienced by users while using the operator's network either during one test or an average of multiple tests depending on the CV specification. Usually measured in kbps or Mbps. |
| Upload speed | Upload speed experienced by users while using the operator's network either during one test or an average of multiple tests depending on the CV specification. Usually measured in kbps or Mbps. |
| Latency | Time measured for reaction of a connection. Usually measured in ms. |
| Jitter | The difference between latency measured using the variation between back-to-back latency samples divided by the total samples minus one. |
| Packet loss | The number of packets that failed to reach the destination in a Transmission Control Protocol (TCP) connection. |
| RSRP | Single test Reference Signals Received Power (RSRP) normally given in dBm. |
| RSRQ | Single test Reference Signals Received Quality (RSRQ) normally given in dB. |
| Network availability | The average length of time when the users are connected to a network. |
| Network coverage experience | How the network user's experience is measured for the coverage. |
| Video experience | Measurement of video quality based on the International Telecommunication Union (ITU) approach for real-world video streams such as the picture quality, video loading time and stall rate. |
| Games experience | Measurement of mobile user experience while playing real-time multiplayer mobile gaming that can impact the gameplay such as latency, packet loss and jitter. |
| Voice experience | Measurement of voice services quality especially for OTT voice services such as Skype, WhatsApp, Facetime, Telegram, etc. |

### 7.6 Crowdsource application type

Crowdsource applications can be divided into public and enterprise applications as described below.

a) Public applications

Consumer applications that are created to solve consumer problems and can be downloaded free via Google Play Store, Apple App Store or from the vendors' website.

b) Enterprise or private applications

Designed for business or private purposes and are unavailable to be downloaded for free.

### 7.7 Crowdsource data post-processing recommendations

#### 7.7.1 Sampling size

Whenever crowdsource data from user-initiated testing or passive data collection is below a 95 % confidence level, statistical methods should be utilised to compute estimation error and assess sample reliability as per the references to general formula in Clause A.1.2 of ITU-T E.806:

a) The first formula is the selection of the number of geographical areas to be measured in the country.

b) The second formula involves using simple random sampling to determine the sample size for each of the previously selected geographical regions. The simple random sampling stratified with proportional allocation is more effective than the simple random sampling.

#### 7.7.2 Post data processing

A crowdsource post data processing system should comply with the following filtering, categorisation, and aggregation requirements to deliver reliable analysis. As a result, effective processing can ensure that the objectives of the analysis are satisfied. The data processing procedures shall be performed meticulously to obtain acceptable datasets as per ITU-T E.812.

#### 7.7.3 Key performance indicators and data protection legislation

All data gathered by public, enterprise or private applications should include at least the data of KPI such as download, upload, latency, jitter, and packet loss.

Data protection legislation shall be followed by CVs, operators, and authorities. This is relevant to data processing since aggregation frequently requires unique user device identifiers, and the availability of such information alongside location data may be considered as personal data under various legal frameworks.

#### 7.7.4 User Equipment (UE) specification

The tests performed on devices that do not comply with the network specifications should be removed from the final calculation of the results, especially when it involves publication of network capability performance. However, the raw datasets should contain all types of data regardless of the devices used for network operators to conduct further data analysis. All datasets should have the geolocation information for effective and accurate analysis of the crowdsourcing data.

## 8. Crowdsourcing E2E architecture scenarios

Crowdsource solution approaches for network performance measurements, namely QoS and QoE, can be classified as active or passive, and as subscriber initiated or automatic data collection of actual user traffic. In addition to the crowdsource solution approach, there are different 'set up scenarios' or E2E architectures' for implementing QoS and QoE data collection that shall be defined. This is mainly to ensure an effective troubleshooting process can be undertaken when network issues are encountered.

This crowdsource E2E architecture describes how the user traffic is routed from the crowdsource application to the test server for mobile and fixed networks. The various routing possibilities are based on the location of the test server. Clause 8 describes the crowdsource E2E architecture and key considerations that shall be factored in to ensure effective problem resolution.

Therefore, it is recommended that the E2E architecture be made accessible by the CV when offering crowdsource data for QoS and QoE due to the following considerations:

a) Measurements on QoE can be accounted for, based on the type of traffic and the respective network routing. Traffic dimensioning requirements between crowdsource solutions and the Test server, as well as the Test server dimensions, should be designed adequately.

b) The crowdsource E2E architecture includes data collection devices and applications routed over mobile or fixed network. The test server can be located based on either on-net or off-net set up scenarios. Accountability areas for MNO or service providers can be clearly defined with a transparent E2E architecture.

c) 5G cellular systems offer new solutions and features. The crowdsource E2E architecture should be designed to accommodate 5G new features for QoS and QoE considerations.

d) QoE traffic sample size recommendations should be based on standardised recommendations such as ITU-T E.812 and international best practices. This is discussed in Clause 7 ITU-T E.812. Insufficient traffic samples can potentially provide incorrect QoS and QoE conclusions.

e) The integrity of the data collected and stored can be analysed via the crowdsource E2E architecture.

f) Service provider network – the specified network route that is within MNO control and out of MNO control as described in the E2E architecture will ensure effective network fault diagnosis.

g) The ability of the test servers to support Artificial Intelligence (AI), Machine Learning (ML) and potential future related technologies will potentially ensure network fault diagnosis can be automated as the crowdsource data size increases in future (e.g. big data analysis) as described in Clause 8.1.2.

h) The type of QoE traffic (active and passive) to be measured includes voice, video data and multimedia as described in Clause 7 ITU-T E.812.

i) Data analysis could also be carried out by a neutral third party set up by the regulatory authority.

QoE is defined by ITU-T P.10/G.100 as the degree of delight or annoyance of the user of an application or service. QoE includes the complete E2E system encompassing client, terminal, network and services infrastructure. The QoE influencing factors include cultural background, social economic factors, psychological profiles and others.

ITU-T G.1011 provides a reference guide to existing standards for QoE assessment methodologies, in which the concept of QoE assessment can be either ‘subjective’ (for example using Mean Opinion Score (MOS)) or ‘objective’, (for example network planning QoS, operating network QoS and lab network QoS). Examples of QoS parameters in ITU-T E.812 in a particular location include:

a) average data throughput for download and upload;

b) latency;

c) jitter;

d) service availability; and

e) type of network and the respective coverage area and signal strength.

The 2 major considerations regarding the crowdsource E2E architecture according to ITU-T E.812 are:

a) the device in which the crowdsource solution (from CVs or solution owner) will be embedded; and

b) the network point in which the test server will be allocated.

It is important to highlight that passive crowdsource data collection solutions do not require a test server, since no artificial traffic or test payload is generated. Tests that are initiated by either the subscriber or autonomously have specific features that should be taken into account in the definition of the E2E architecture.

The characteristics of different E2E architectures for crowdsource data collection in fixed and mobile broadband networks are required. This is discussed in Clauses 8.1 and 8.2.

Data collection in a crowdsource approach may occur in different types of devices allocated in different elements of the service provision process. This is explained in the E2E QoS model introduced in ITU-T E.800, shown in Figures 9 and 10. In this Technical Code, the term ‘end-user’ is used, which is represented as the ‘user’ in these figures. Thus, when assessing E2E QoS, the data collection solution shall be in the end-user’s terminal equipment.

The test servers used for hosting active tests have a strong influence on the results and thus should be selected with care. The most used server hosting options are listed in Table 11.

**Table 11. Test server hosting option**

| Type of server hosting | Characteristics | Typical services |
|---|---|---|
| Network Point-of-Presence (PoP) | Test servers are located in the service provider’s network infrastructures or connected entities (e.g., universities, private enterprises, or government agencies), meant to be close to the end-user.<br><br>Test servers hosted here are designed to test the performance of the Access Network (AN). | Hosting of:<br><br>a) files; and<br><br>b) websites |
| CDN | Content resources are typically distributed across hundreds or thousands of nodes across the Internet and designed to serve content. CDN is a form of server-less computing and may have several tiers, with frequently accessed content being cached in many edge nodes.<br><br>Some CDNs allow the creation of certain applications, which can be used to perform tests. | Distribution of:<br><br>a) video and audio on demand.<br><br>b) mobile application binaries; and<br><br>c) website content (image, text, JavaScript files, etc.) |

**Table 11. Test server hosting option** *(continued)*

| Type of server hosting | Characteristics | Typical services |
|---|---|---|
| Cloud computing services | Computing resources are typically distributed across a few dozen locations across the Internet and designed to support a broad range of services that requires scalable computing resources.<br><br>This type of server hosting also includes edge computing models which introduces smaller servers at a much greater number of locations typically for applications that require lower latency. | Hosting of:<br><br>a) cloud-based applications;<br><br>b) databases;<br><br>c) game engines;<br><br>d) video OTT calls, group voice OTT calls;<br><br>e) Internet of Things (IoT) services (edge computing); and<br><br>f) cloud gaming (edge computing). |

The connectivity from the subscriber to the test servers also influences the characteristics measured. Test servers can be allocated in the operator's network (on-net) or externally to that network (off-net). A comparison of the types of server access is listed in Table 12.

**Table 12. Types of server access**

| Type of server access | Types of server hosting | Characteristics |
|---|---|---|
| On-net | a) Service provider of the end-user;<br><br>b) CDN caching servers; and<br><br>c) Edge compute caching servers of cloud computing services | Useful to qualify metrics of the access network, or of popular or frequently used services |
| Off-net | a) Connected entity (e.g. universities, private enterprises, or government agencies);<br><br>b) Service providers other than the provider of the end-user;<br><br>c) CDNs; and<br><br>d) Cloud computing services | Useful to qualify metrics of all types of network services and locations, whether popular or not. |

The profile of network and data services accessed by a subscriber on a given network will provide the proportion by which the measurements are made to on-net or off-net servers.

Data profiling is the process of reviewing source data, understanding its structure, content use and interrelationships. The profiles need to be conducted based on the service under test.

Regulators may select network data profiles consistent with their needs and to ensure Data Integrity (DI). In cases where there are multiple test servers, there could be options to select the test server automatically or manually.

To measure E2E QoS, it may not be sufficient to test against servers hosted in some neutral location (for example collocated with Internet Exchange Points (IXPs)) as most of the network traffic may not traverse that route. This approach of measuring the E2E QoS may introduce factors beyond the direct control of MNO.

When automatically selecting test servers, one of the options is to select servers close to the end-user, which will ensure that fewer network segments are included, thus more accurately measuring the access network. On the other hand, manual server selection allows the measurement of access to a given entity.

The server distribution for a representative measurement of QoS vary according to the service of interest. Active tests may be designed that are specific to different services. With respect to servers this might mean that a video on demand test would stream data from a CDN used by popular video services, whereas a multiplayer gaming test would communicate with a cloud server commonly used by game engines. Passive tests can include voluntary customer usage data using mobile apps, as well as mobile core systems data such as Call Detail Record (CDR), performance statistics from network elements, etc.

Given the large variety of services accessed by end-users and the corresponding diversity in the endpoints of these services, it is advisable to focus on a few core services, particularly ones which are high in demand and requires good E2E performance.

### 8.1 Mobile network E2E architecture scenario overview

For mobile networks, the crowdsource solution is located in mobile devices. The QoS and QoE evaluated by the test server includes the complete E2E system architecture, encompassing crowdsource mobile application, UE, network and services infrastructure as recommended by ITU-T E.800 and ITU-T E 812, as shown in Figure 9. Crowdsource solutions located in mobile devices can be, for example, applications dedicated to quality assessment, which are generally provided by:

a) specialised vendors; or

b) embedded in a specific application, such as the operator’s customer services application (when the operator builds its own solution); or

c) third-party applications, such as social media games and photo editors.

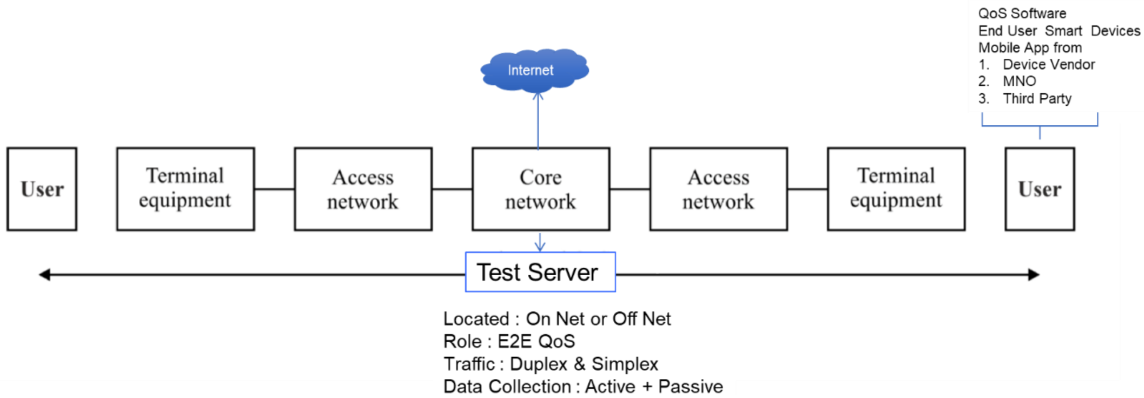


**Figure 9. Mobile network set up scenario**

This approach of measuring the E2E QoS (for QoE) is likely to introduce factors beyond the direct control of MNO or network providers such as 5G network providers. 5G access network deployment scenarios either through 5G Mobile Virtual Network Operator (MVNO) concept and potentially based on Multi-Operator Core Networks (MOCN) architecture as illustrated in Figure 10 or other 5G architecture options such as Multi-Operator Radio Access Network (MORAN) are also possible.

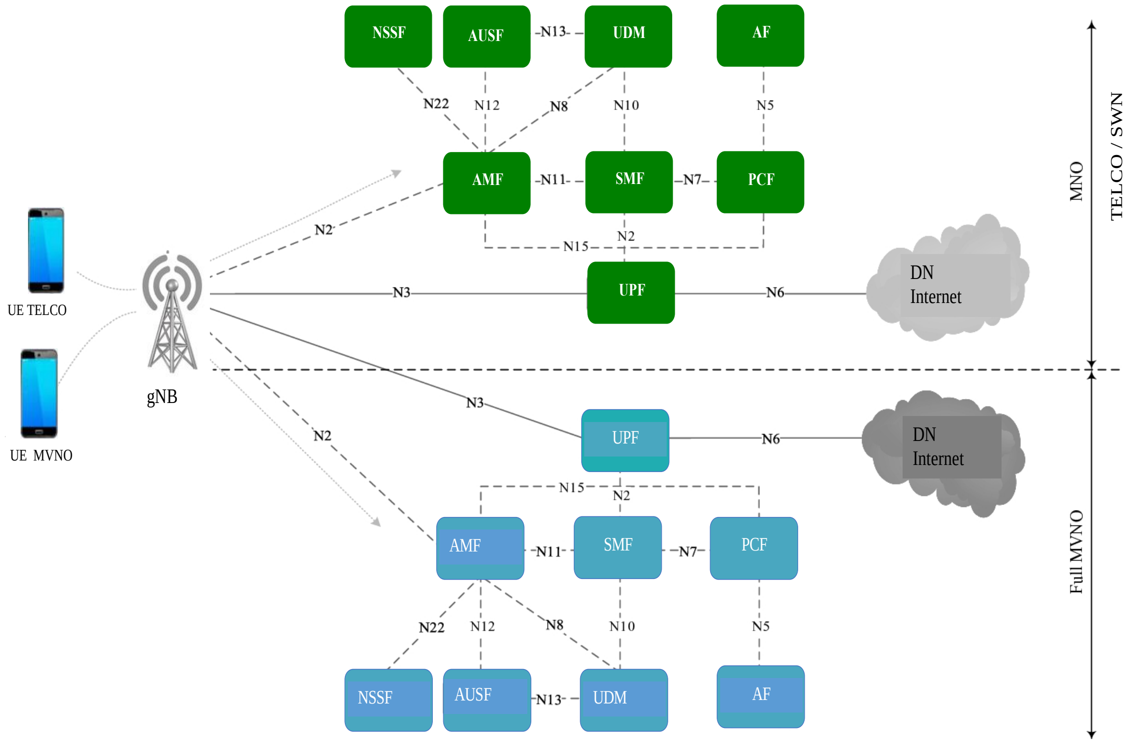


**Figure 10. 5G MVNO using MOCN based on 5G standalone E2E network architecture**

### 8.1.1 Malaysian 5G crowdsource E2E architecture impact on E2E QoS and QoE

An E2E architecture involving crowdsource applications and test server measurements for 5G systems is recommended to consider the following additional considerations to ensure the optimum QoE assessments can be undertaken:

a) the types of 5G services being analysed - Ultra-Reliable Low Latency Communications (URLLC), enhanced Mobile Broadband (eMBB) or massive Machine Type Communications (mMTC);

b) type of network slicing model implemented;

c) the priority of service rules applied at the Fifth Generation Core (5GC);

d) the QCI rules applied at the 5GC as stipulated in MCMC MTSFB TC G027:2021. QCI is now referred to as 5G QoS Identifier (5QI) for 5G QoS and it defines characteristics that influence scheduling weights, admission thresholds, queue management thresholds and link layer protocol configuration; and

e) test server location and hosting options.

The MVNO model used by the MNO (MOCN or MORAN) will determine the 5G network boundaries between the respective parties. The details of the MVNO model are described in Annex D. The 5G crowdsource E2E architecture impact on E2E QoS and QoE will depend on the Service Level

Agreement (SLA) between the MNO (which owns the 5G AN or 5G NR) with the MVNO. In a MOCN deployment, for optimum performance of the 5G AN, it is recommended that:

a) access to a 5G AN element management system for fault monitoring be offered to the MVNO; and

b) industry regulated 5G AN or 5G NR KPI levels be formalised.

#### 8.1.2 Upcoming 5G crowdsource applications for QoS and QoE

Worldwide 5G deployment has increased the demand for 5G DT parameters to address radio enhancements such as 4x4 Multiple Input Multiple Output (MIMO), massive MIMO, etc. and now 5G NR should have feature of a crowdsource RF DT tool.

The suggested features of an RF DT tool include support for:

a) capture of Global Positioning System (GPS) information along the drive route;

b) 2G, 4G LTE and 5G NR measurements;

c) data testing such as Hypertext Transfer Protocol (HTTP), latency and File Transfer Protocol (FTP) speed tests;

d) voice and Short Message Service (SMS) testing;

e) video streaming testing on mobile networks;

f) frequency scanning function for all Radio Access Network (RAN) technologies;

g) layer 3 and layer 2 message capture capabilities if RF deep diagnosis information is required;

h) script based call and data session for both manual and automatic methods;

i) portability of measurement software on smart phone devices;

j) real-time upload of test data to post-processing tool;

k) analysis of data on map-based view at the post-processing tool;

l) graphical and tabular reports for various features of GSM, LTE and 5G related network performance at the post-processing tool; and

m) 5G MIMO measurements.

Currently, sophisticated multi-channel tools from various CVs include application based QoE DT benchmarking tools which are used to measure several network technologies, including 5G, and service types simultaneously to a high degree of accuracy. This is to provide directly comparable information regarding competitive strengths and weaknesses. The respective crowdsource applications can be installed in UEs, including 5G devices, as well as in consumer devices or fleet owned devices such as delivery services, meter readers, utilities services vehicles, etc.

Therefore, it is recommended that 5G service providers or MVNOs consider the QoS and QoE measurements currently available in various crowdsource solutions as shown in Table 13. Additional features to be considered which are currently under development are shown in Table 14.

**Table 13. QoS and QoE measurements using 5G crowdsourced mobile applications**

| Key features - available | Individual | Corporate | Enterprise |
|---|---|---|---|
| Ping test | √ | √ | √ |
| Speed test (download and upload) | √ | √ | √ |
| Call test | √ | √ | √ |
| SMS test | √ | √ | √ |
| Video stream test | √ | √ | √ |
| Coverage survey maps (2G, 4G and 5G) | √ | √ | √ |
| QoE map visualisation reports for data, voice services | √ | √ | √ |
| Remote test on demand testing | √ | √ | √ |
| Test automation | √ | √ | √ |
| Voice KPIs (CSSR, dropped calls, setup time) | √ | √ | √ |
| CSFB and SRVCC KPIs | √ | √ | √ |
| Data KPIs reporting (data throughput) | √ | √ | √ |
| Device live tracking | √ | √ | √ |
| QoE maps showing data connectivity | √ | √ | √ |
| RAN technology type-based coverage | √ | √ | √ |
| Dynamic alarms panel | √ | √ | √ |
| Cell tower sector visualisation | √ | √ | √ |
| 2G,4G and 5G base station monitoring | √ | √ | √ |
| Cell availability KPI | √ | √ | √ |
| Cell radius, cell sector visualisation | √ | √ | √ |
| DET and FSA measurement for FTP tests | √ | √ | √ |
| CSV export | √ | √ | √ |
| Indoor testing/wall-testing feature | √ | √ | √ |

**Table 14. QoS and QoE measurements using 5G crowdsource mobile applications (future)**

| Key features - available | Individual | Corporate | Enterprise |
|---|---|---|---|
| Indoor testing or walk testing feature | X | √ | √ |
| Wi-Fi analyser | X | √ | √ |
| PDF report generator | X | √ | √ |
| Threshold crossing alert | X | √ | √ |
| Geolocation query | X | X | √ |
| Screen casting and controlling remote device | X | X | √ |
| Crowdsourcing licenses | X | X | √ |
| Customer query response time | X | X | √ |

*X*: being developed
√ : already developed

## 8.2 Fixed network E2E architecture scenario overview

For fixed broadband networks, crowdsourcing solutions are either embedded in Customer Premises Equipment (CPE) or in the end-user's device (such as, personal computers, smart televisions, etc). The QoS and QoE evaluated by the test server includes the complete E2E architecture effects, encompassing client, terminal, network and services infrastructure as recommended by ITU-T E.800 and ITU-T E.812 as shown in Figure 11.

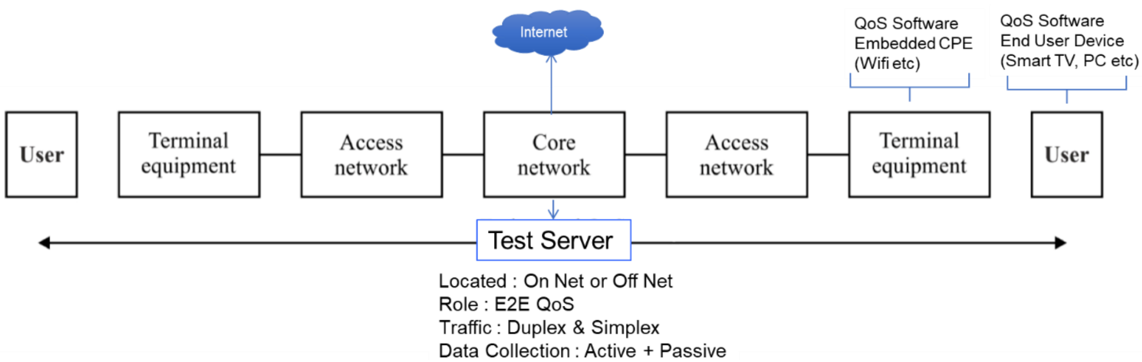


**Figure 11. Fixed network set up scenario**

## 8.3 E2E architecture requirements

The aim of defining the 'E2E architecture' is to ensure the data collected by the crowdsourcing solution accessing the test server are dimensioned and routed adequately to support the QoS and QoE measurements as specified in Clauses 5, 6 and 7.

Therefore, it is required that the E2E architecture be designed based on ITU-T standards guidelines and shall be made accessible by CVs when offering crowdsource data for QoS and QoE.

The requirements are summarised as follows:

a) For mobile networks, the QoS and QoE evaluated by the test server shall include E2E architecture effects, encompassing the crowdsource mobile application, UE, network and services infrastructure, as recommended by the ITU-T P.10/G.100 and ITU-T G.1011. This is shown in Figure 9. The test server location (on-net or off-net) and hosting option (PoP, CDN or cloud based), shall be made transparent to relevant QoS and QoE subscribers. Crowdsource solutions located in mobile devices should be applications dedicated to quality assessment, which are generally provided by:

i) Option 1: specialised CVs (such as vendor 1, 2, 3). The CV owns the QoS and QoE raw data from the mobile application;

ii) Option 2: embedded in a specific application, such as the operator's customer services application or DT applications. The MNO owns the QoS and QoE raw data from the mobile application; and

iii) Option 3: enhancement of third-party applications with mass usage, such as the Malaysian contact tracing application, MySejahtera. The government owns the QoS and QoE raw data from this mobile application.

b) For 5G systems, the E2E architecture involving crowdsource applications shall consider the following additional considerations to ensure that optimum QoE assessments can be undertaken:

i) the types of 5G services being analysed - URLCC, eMBB or mMTC;

ii) the type of network slicing model implemented;

iii) the priority of service rules applied at the 5GC;

iv) the QFI rules applied at the 5GC; and

v) the test server location (on-net or off-net) and hosting option (PoP, CDN or Cloud based).

c) For a 5G MVNO, the model used (MOCN or MORAN), will determine the 5G network boundaries between the respective parties. The 5G crowdsource E2E architecture impact on E2E QoS and QoE will depend on the SLA between the MNO (which owns the 5G AN or 5G NR) and the MVNO. In a MOCN deployment, for optimum QoS monitoring of the 5G AN, the 5G spectrum owner and operator shall:

i) provide access to the 5G AN element management system for fault monitoring to the MVNO; and

ii) ensure industry regulated 5G AN or 5G NR KPI levels are formalised and implemented.

d) For emerging crowdsource applications for QoS and QoE, 5G service providers or 5G MVNOs shall consider the QoS and QoE measurements currently available in various crowdsource solutions as shown in Tables 13 and 14.

e) For fixed broadband networks, crowdsourcing solutions are either embedded in CPE or in the end-user's device (such as personal computers, smart televisions, etc.). The QoS and QoE evaluated by the Test Server shall include the complete E2E system architecture, encompassing client, terminal, network and services infrastructure as recommended by by ITU-T E.800 and ITU-T E.812, and shown in Figure 11. The Test Server location (on-net or off-net) and hosting option (PoP, CDN or Cloud based), shall be made transparent to relevant QoS and QoE subscribers.

# 9. Policy and governance

## 9.1 Introduction

The objective of this clause is to describe the policy and governance requirements under the Malaysian laws. In addition to the existing laws, this Technical Code addresses a number of important issues pertaining to data protection, interference, manipulation and/or prioritisation of crowdsource applications, transparency and workability (ability to access granular information to troubleshoot the network).

## 9.2 Challenges

This clause covers the challenges faced by subscribers, service providers and regulators when using crowdsource application data:

a) with the availability of multiple CVs providing the same service of measuring performance, each of these CVs will have different methodology on measuring QoS and QoE;

b) some of the CVs may not disclose their exact methodology on aggregating results and therefore this Technical Code identifies the need for certain crucial granular data that should be disclosed by the CVs so that it can be used by service providers towards optimising, improving, and troubleshooting existing network or service;

c) accountability of the CVs in producing reports;

d) concerns of interference, manipulation and/or prioritisation by service providers to distort the crowdsource data collection results; and

e) the transmission of personal data (inside or outside of the country) which must comply with Act 709, *Personal Data Protection Act 2010*.

## 9.3 Concerns and limitation

The following are the discerning areas that requires attention by the stakeholders:

a) Uniformity

Multiple reports by the CVs will cause confusion as one party will want to appear to be the best at providing advice towards improving a network.

b) Neutrality

CVs should be fair and impartial with their reporting. Reports produce shall be able to assist one troubleshooting or improving the network.

c) CVs to provide supporting data

Supporting granular data is necessary for service providers to troubleshoot and make improvement to the network. The granular data should be captured for both fixed and wireless service by CVs to help service providers analyse performance and identify issues are:

i) Cell information

    1) MNC.

    2) MCC.

3) Cell ID.

ii) Connection info

1) Carrier name.

2) Pre and post connection type.

3) Data connection type.

4) Service connection type and state.

5) Wi-Fi frequency.

iii) Radio environment

1) RSRP.

2) RSRQ.

iv) Radio performance

1) Download.

2) Upload.

3) Latency.

4) Jitters.

5) Packet loss.

v) Geopositioning

1) Latitude.

2) Longitude.

vi) Server name

1) Server origin.

2) Distance.

vii) Device

1) OS.

2) Brand and model.

3) Chipset.

viii) Optional

1) Region name.

### 9.4 Responsibilities of service providers

Service providers shall ensure crowdsource data collection is performed on their network remain valid and reliable by not intervening in any manner that will change the results. Prioritisation techniques described in Annex C of this Technical Code amongst others shall not be implemented.

### 9.5 Responsibilities of Crowdsource Vendor (CVs)

The CVs should provide granular information to the relevant stakeholders (e.g. regulator and service provider) to allow continuous troubleshooting and improvements of the network.

### 9.6 Responsibilities of regulator

Regulator should be guided by the ITU-T E.812 recommendations.

If there is information that cannot be obtained from the regulator’s own data collection or information that could expire, the regulator may require the service providers to supply it.

To ensure comparability of results when using the crowdsourcing solutions implemented by service providers, the regulator may decide to adopt an approval or auditing process, which may include solution validation of the chosen set-up scenarios.

To ensure reliable comparisons of results between service providers, validation procedures may be used to evaluate the data collection solution and its ability to generate samples with a degree of accuracy and precision with respect to the established requirements such as sampling, data processing and testing methodology for data collection.

The regulator may request that the service provider or CVs provide an operational manual containing the testing methodology used, test set-up scenarios, technical specifications of the collected data or measured metrics, and the data processing methods used.

# Annex A
(normative)

## Normative references

Act 709, *Personal Data Protection Act 2010*

MCMC MTSFB TC G027:2021, *IMT-2020 (Fifth Generation) - System Architecture and Specifications*

Recommendation ITU-T E.800 (09/2008), *Definitions of terms related to quality of service*

Recommendation ITU-T E.806 (06/2019), *Measurement campaigns, monitoring systems and sampling methodologies to monitor the quality of service in mobile networks*

Recommendation ITU-T E.812 Amendment 1 (09/2020), *Crowdsourcing approach for the assessment of end-to-end quality of service in fixed and mobile broadband networks Amendment 1*

Recommendation ITU-T P.10/G.100 Amendment 1 (06/2019), *Vocabulary for performance, quality of service and quality of experience Amendment 1*

Recommendation ITU-T G.1011 (07/2017), *Reference guide to quality of experience assessment methodologies*

# Annex B
(informative)

## Abbreviations

| | |
|---|---|
| 2G | Second Generation |
| 4G | Fourth Generation |
| 5G | Fifth Generation |
| 5GC | Fifth Generation Core |
| 5G-GUTI | Globally Unique Temporary Identity |
| 5QI | 5G QoS Identifier |
| AI | Artificial Intelligence |
| AN | Access Network |
| API | Application Program Interface |
| AUSF | Authentication Server Function |
| CDMA | Code-division multiple access |
| CDN | Content Delivery Network |
| CDR | Call Detail Record |
| CPE | Customer Premises Equipment |
| CPU | Central Processing Unit |
| CV | Crowdsource Vendor |
| DI | Data Integrity |
| DT | Drive Test |
| E2E | End-to-End |
| eMBB | enhanced Mobile Broadband |
| EPC | Enhanced Packet Core |
| EPS | Evolved Packet switched System |
| FTP | File Transfer Protocol |
| FUP | Fair Usage Policy |
| GBR | Guaranteed Bit Rate |
| GPS | Global Positioning System |
| GSM | Global System for Mobile Communication |
| GUAMI | Globally Unique AMF ID |
| HD | High Definition |
| HTTP | Hypertext Transfer Protocol |
| ID | Identification |
| IMSI | International Mobile Subscriber Identity |
| IoT | Internet of Things |
| IP | Internet Protocol |
| IPLR | Internet Protocol Packet Loss Ratio |
| ISP | Internet Service Provider |
| ITU | International Telecommunication Union |
| IXP | Internet Exchange Point |
| JENDELA | Jalinan Digital Negara |
| JSON | JavaScript Object Notation |
| KPI | Key Performance Indicator |

| | |
|---|---|
| LAC | Location Area Code |
| LTE | Long Term Evolution |
| MCC | Mobile Country Code |
| MIMO | Multiple Input Multiple Output |
| ML | Machine Learning |
| mMTC | massive Machine-Type Communications |
| MNC | Mobile Network Code |
| MNO | Mobile Network Operator |
| MOCN | Multi-Operator Core Networks |
| MORAN | Multi-Operator Radio Access Network |
| MOS | Mean Opinion Score |
| MVNE | Mobile Virtual Network Enabler |
| MVNO | Mobile Virtual Network Operator |
| NF | Network Functions |
| NID | Networks ID |
| NR | New Radio |
| NSSAI | Network Slice Selection Assistance Information |
| OS | Operating System |
| OTT | Over The Top |
| PCF | Policy Control Function |
| PCI | Physical Cell Identifier |
| PDN | Packet Data Network |
| PDPA | Personal Data Protection Act |
| PoP | Point-of-Presence |
| QCI | QoS Class Identifier |
| QFI | QoS Flow Identifier |
| QoE | Quality of Experience |
| QoS | Quality of Service |
| RAM | Random Access Memory |
| RAN | Radio Access Network |
| RF | Radio Frequency |
| RoI | Return on Investment |
| RSRP | Reference Signals Received Power |
| RSRQ | Reference Signals Received Quality |
| SID | System ID |
| SLA | Service Level Agreement |
| SMS | Short Message Service |
| SUPI | 5G Subscriber Permanent Identifier / International Mobile Subscriber Identity |
| SWN | Single Wholesale Network |
| TAC | Tracking Area Code |
| TCP | Transmission Control Protocol |
| UDF | Unified Database Function |
| UE | User Equipment |
| UMTS | Universal Mobile Telecommunications System |
| URLLC | Ultra-Reliable Low Latency Communications |

| | |
|---|---|
| VAS | Value Added Services |
| Wi-Fi | Wireless Fidelity |
| WCDMA | Wideband Code Division Multiple Access |

# Annex C
(normative)

# Types of prioritisation techniques, field test requirements, test procedures, examples of prioritised and non-prioritised scenarios and verification method

## C.1. Types of prioritisation technique

There are various techniques of prioritising which can be configured at service provider's network. Below are the examples of prioritisation techniques available which shall not be practiced by service providers for crowdsourcing applications:

a) Application layer prioritisation at the Enhanced Packet Core (EPC) switch.

b) Radio Access Network (RAN) feature enabling prioritisation of certain application.

c) E2E EPS Dedicated Bearer QoS/QCI setting with or without Guaranteed Bit Rate (GBR).

d) Application layer prioritising via traffic management platforms.

NOTE: The above features of (a) and (b) are subject to EPC and RAN features available in the service provider's network.

## C.2. Crowdsource application prioritisation detection methodology: field test requirements

Below are the requirements for conducting a field verification test to detect if any prioritisation has been applied to a crowdsource QoS and QoE application.

a) Equipment and application

   i) 2 UE (same model and capability) with engineering capability (DT tools installed).

   ii) 2 commercial SIM cards. One SIM for each UE.

   iii) FTP server with a minimum of 1 GB file size or HTTP downloads.

   iv) Crowdsource speed test application.

b) Test location

In cells with coverage minimum of -98 dBm 90% of the time.

## C3. Crowdsource application prioritisation detection methodology (field test): test steps

### C.3.1. Test procedure

Prioritisation of a crowdsource application can be detected via a field test verification. The information below identifies the requirements for conducting such test:

2 UEs with SIM (1 SIM is for FTP/HTTP download test and another SIM for crowdsource speed test). Both UEs need to be connected to the same cell (i.e. same Physical Cell Identifier (PCI)). Figure C.1 illustrates this.

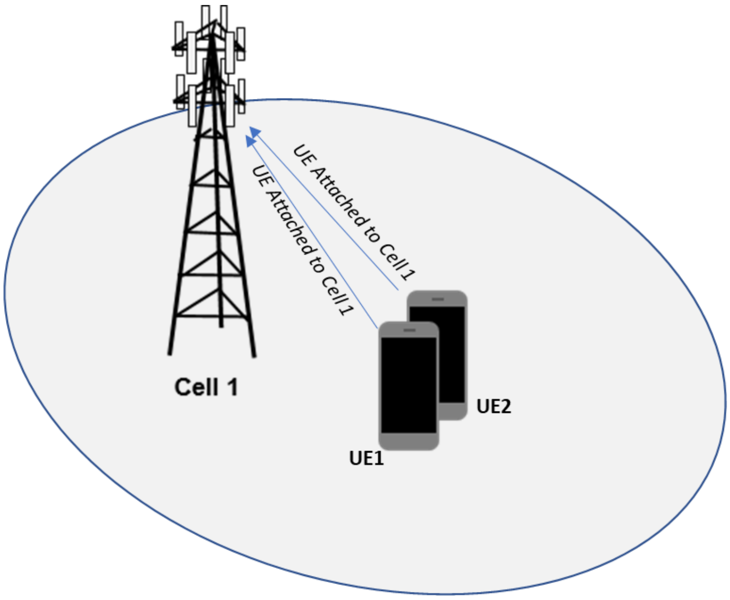


**Figure C.1. UEs connected to the same cell**

### C.3.2. Test sequence

The test sequence for the detection of crowdsource speed test prioritisation methodology is summarised in Figure C.2 below:

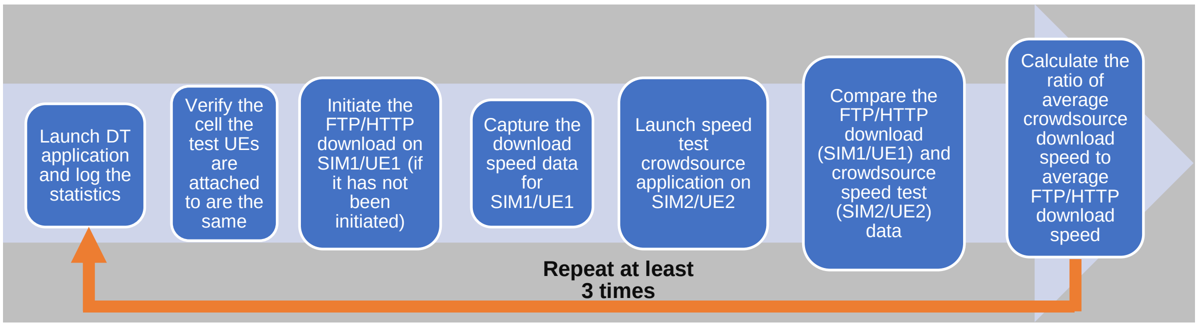


**Figure C.2. Test sequence for detection crowdsource speed test prioritisation methodology**

### C.4. Ratio of crowdsource speed test to FTP/HTTP speed to identify network prioritisation

In an unprioritised network, it will be seen that when the FTP/HTTP download session is initiated on SIM1/UE1 and then crowdsource speed test is initiated on SIM2/UE2, while both the UEs are attached to the same cell and in a location next to each other, it will be observed that the FTP/HTTP speed results will decrease to approximately match the crowdsource speed test download speed.

Theoretically the ratio of average download speeds of crowdsource speed test and FTP/HTTP will be close to 50:50. However in a prioritised network, where the crowdsource speed test application is prioritised for example through allocation of additional network resources while the FTP/HTTP application is allocated relatively lesser network resources, this ratio of download speed of crowdsource speed test and FTP/HTTP will be observed to be shifted away from 50:50 ratio, e.g. 90:10, 80:20, 70:30, 60:40 or some other ratio.

This Technical Code specifies that a minimum ratio of 65:35 for the download speed of crowdsource speed test to FTP/HTTP. If this ratio reaches or exceeds 65:35 consecutively 3 times as in Annex C.3.2, it is then determined under this Technical Code that the network on which the tests were conducted is prioritising the relevant crowdsource speed test application.

To determine the average speeds on a network with prioritised crowdsource speed test and FTP/HTTP test and subsequently its ratio, refer to example Figure C.3.

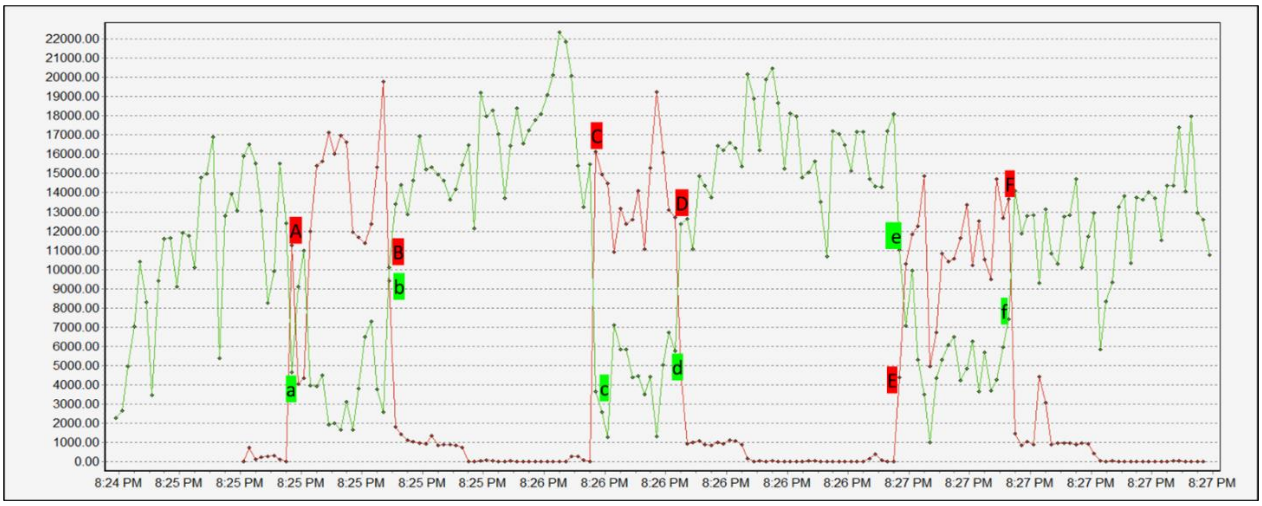


**Figure C.3. Example of prioritised crowdsource speed test comparing with FTP/HTTP download speed**

Referring to Figure C.3, 3 distinct crowdsource speed tests are initiated while FTP/HTTP session is progressing. It is observed that before data points A/a, the FTP/HTTP download has been initiated at 8.24 pm. The crowdsource speed test was initiated (red line) starting from data point A and ending in data point B. There were 17 data points between A and B (inclusive). In the same time frame, there were 17 data points between a and b (inclusive) for the FTP/HTTP speed test (green line). The average download speeds of all the data points between A and B (crowdsource speed test) and a and b (FTP/HTTP) and similarly for the remaining segments C/c to D/d (14 data points) and E/e to F/f (19 data points) are tabulated in Table C.1.

**Table C.1. Example of average download speeds of prioritised crowdsource speed test and FTP/HTTP**

| Test | Segment | Average speed (Mbps) | Ratio |
|---|---|---|---|
| Test 1 (17 data points) | A to B (crowdsource speed test) | 12.56 | 72:28 |
| | a to b (FTP/HTTP) | 4.82 | |
| Test 2 (14 data points) | C to D (crowdsource speed test) | 14.00 | 76:24 |
| | c to d (FTP/HTTP) | 4.45 | |
| Test 3 (19 data points) | E to F (crowdsource speed test) | 10.74 | 66:34 |
| | e to f (FTP/HTTP) | 5.60 | |

NOTES

1: Tests 1, 2 and 3 data points are generally dictated by the automatic duration determined by the crowdsource speed test. Therefore the FTP/HTTP data points used to determine average speed to be within this duration.

2: Referring to test 1, the first number in the ratio is calculated by [(12.56) / (12.56 + 4.82)] x 100 = 72 (rounded). The second number in the ratio is calculated by [(4.82) / (12.56 + 4.82)] x 100 = 28 (rounded). This calculation shall be used to derive all the ratios in this Technical Code.

Based on the ratios for all the 3 tests above, it is determined that these tests were conducted on a network with crowdsource speed test being prioritised since the measured ratios have reached or exceeded the 65:35 ratio.

Figure C.4 illustrates an alternate example of crowdsource speed test and FTP/HTTP on a non prioritised network. 3 distinct crowdsource speed tests are initiated while FTP/HTTP session is progressing.

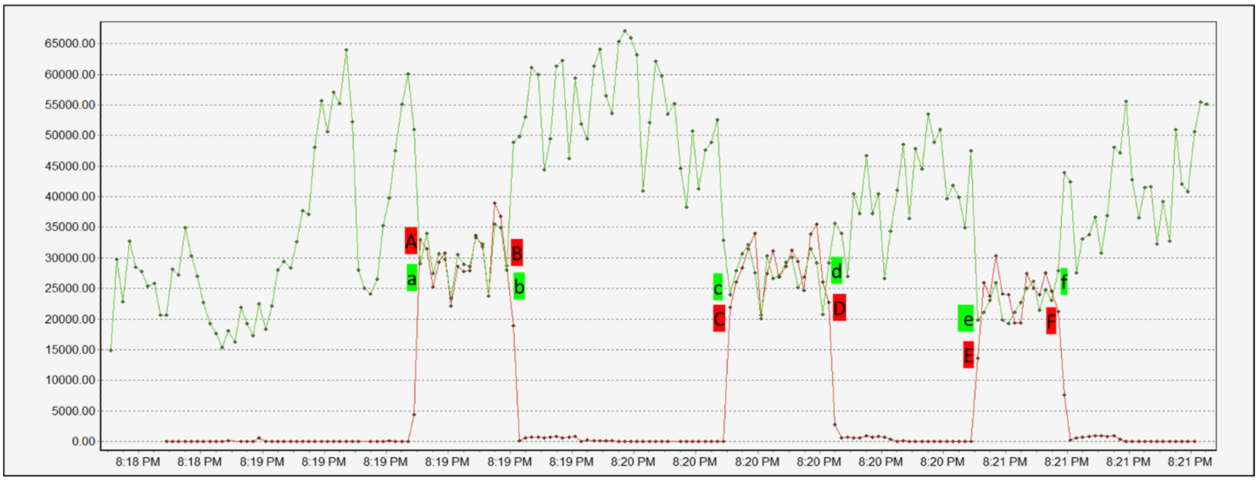


**Figure C.4. Example of non-prioritised crowdsource speed test comparing with FTP/HTTP download speed**

It is observed that before data points A/a, the FTP/HTTP speed test has been initiated at 8.18 pm. The crowdsource speed test was initiated (red line) starting from data point A and ending in data point B. There were 15 data points between A and B (inclusive). In the same time frame, there were 15 data points between a and b (inclusive) for the FTP/HTTP speed test (green line). The average speeds of all the data points between A and B (crowdsource speed test) and a and b (FTP/HTTP) and similarly for the remaining segments C/c to D/d (17 data points) and E/e to F/f (14 data points) are tabulated in Table C.2.

**Table C.2. Example of average download speeds of non-prioritiesed crowdsource speed test and FTP/HTTP**

| Test | Segment | Average speed (Mbps) | Ratio |
|---|---|---|---|
| Test 1 (15 data points) | A to B (crowdsource speed test) | 29.7 | 49.8:50.2 |
| | a to b (FTP/HTTP) | 29.9 | |
| Test 2 (17 data points) | C to D (crowdsource speed test) | 28.1 | 50.6:49.4 |
| | c to d (FTP/HTTP) | 27.4 | |
| Test 3 (14 data points) | E to F (crowdsource speed test) | 23.4 | 50.5:49.5 |
| | e to f (FTP/HTTP) | 22.9 | |
| NOTE: Tests 1, 2 and 3 data points are generally dictated by the automatic duration determined by the crowdsource speed test. Therefore the FTP/HTTP data points used to determine average speed to be within this duration. | | | |

Based on the ratios for all the 3 tests above, it is concluded that these tests were conducted on a network without crowdsource speed test being prioritised since the measured ratios are close to 50:50 and all the ratios are below the defined ratio.

The determination of the achieved ratio through actual measurement is independent of total cell throughput and number of active users in a particular cell. It is important to observe that any additional unknown active UEs in the same cell beyond the UEs conducting crowdsource speed test and FTP/HTTP tests will only serve to reduce the throughput of the cell available to be shared for the tests between the UEs.

Considering that this Technical Code is defining a minimum of 65:35 ratio of average crowdsource speed test to FTP/HTTP speed for the identification of network prioritisation, any false-positive is also avoided since in a non-prioritised network, this ratio will be close to 50:50 giving a 30% safety margin.

## C5. E2E EPS Dedicated Bearer QoS/QCI setting with or without Guaranteed Bit Rate (GBR)

**Verification of EPS dedicated bearer, QCI and GBR settings from the RAN DT logs (LTE)**

One of common method of configuring application prioritisation is by assigning a dedicated EPS bearer for a particular application rather than normal default bearer. A higher priority can be assigned via the QCI and GBR can be assigned as well. Below steps showcase how this configuration can be identified via a DT tool (if crowdsource application license is supported by the DT Tools).

a) Search for Message Type: Activate Dedicated EPS Bearer Context Request

b) Next, look for EPS QoS Setting under which the QoS QCI setting is defined. If the QCI setting is 4 and below, it means that the Dedicated Bearer with GBR has been configured for the service.

c) If any configuration of GBR was configured, the GBR of downlink and uplink will be defined in the configuration.

Table C.1 below shows the typical QoS/QCI mapping table as per 3GPP Release 14.

**Table C.3. QCI mapping**

| QCI | Resource Type | Priority | Packet Delay Budget | Packet Error Loss Rate | Example Services |
|---|---|---|---|---|---|
| 1 | GBR | 2 | 100 ms | $10^{-2}$ | Conversational Voice |
| 2 | | 4 | 150 ms | $10^{-3}$ | Conversational Video (Live Streaming) |
| 3 | | 3 | 50 ms | $10^{-3}$ | Real Time Gaming |
| 4 | | 5 | 300 ms | $10^{-6}$ | Non-Conversational Video (Buffered Streaming) |
| 5 | Non-GBR | 1 | 100 ms | $10^{-6}$ | IMS Signalling |
| 6 | | 6 | 300 ms | $10^{-6}$ | Video (Buffered Streaming)<br>TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.) |
| 7 | | 7 | 100 ms | $10^{-3}$ | Voice,<br>Video (Live Streaming)<br>Interactive Gaming |
| 8 | | 8 | 300 ms | $10^{-6}$ | Video (Buffered Streaming)<br>TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.) |
| 9 | | 9 | | | |

For 5G, same setting is defined as per the MCMC MTSFB G027:2021.

# Annex D
(informative)

## 5G Public Network MVNO Model using MOCN & MORAN

Mobile Virtual Network Operators (MVNO) network and business models are expected to play a dominant role in an environment where 5G cellular services are offered via a Single Wholesale Network (SWN), of which, the single 5G network provider has exclusive use of the 5G spectrum (sub 6 GHz frequency spectrum). The MVNO E2E network architecture will involve different system owners that are accountable to different companies or organisation. Ensuring E2E QoE and QoS can be more challenging for this model compared to the traditional regular MNO model. This is due to the multiple network owners in the MVNO model as opposed to a single network owner in the MNO model. Relevant Crowdsource Vendors and Crowdsource application users will need to be aware of these complexities when evaluating the crowdsource QoE or QoS data for network troubleshooting and restoration purposes.

This section discusses the details of the E2E MVNO network architecture. Modern virtual operators are characterized by several business models:

a) the high-level virtual operator (full MVNO); and

b) the low-level virtual operator (light MVNO), the reseller.

The main difference lies in the availability of its own core network, subsystems of operation and billing, platforms for the provision of Value Added Services (VAS) and Applications. This is shown in Figure D.1.

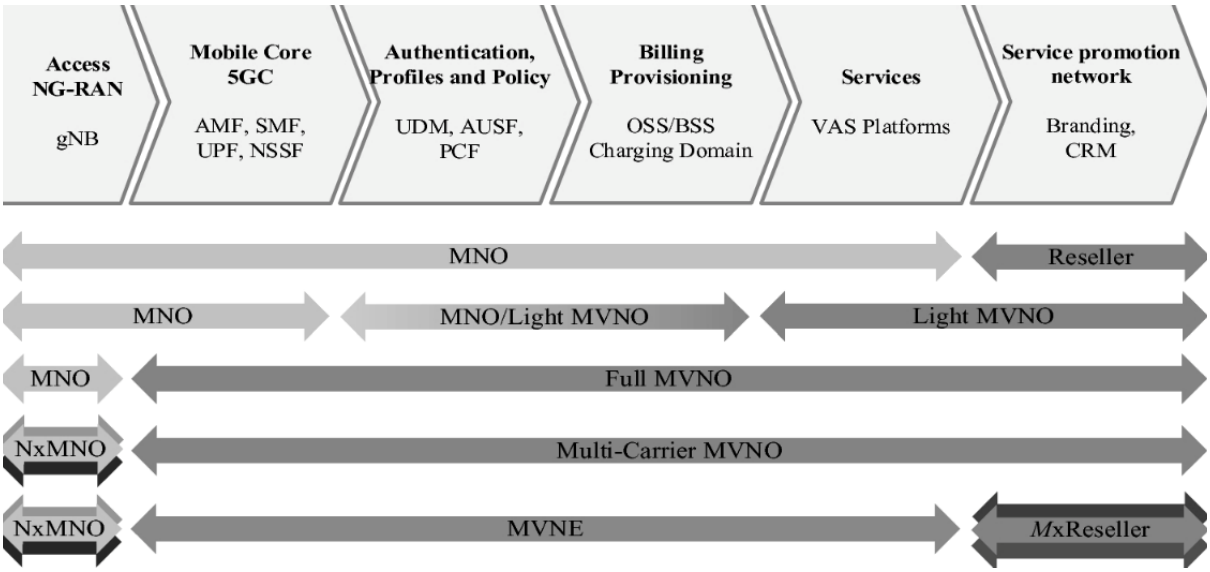


**Figure D.1. Full MVNO model**

The least complicated and costly business model is the model of a reseller, which does not have its own infrastructure and carries out only branding, subscriber services and promotion of its services on the market. The most complex and costly business model is the high-level virtual operator model or full MVNO, which has its own infrastructure except for the NG-RAN radio access network.

The high-level virtual operator namely, multi-carrier full MVNO can have simultaneous connection to several radio access networks of various MNO operators. The intermediate trade-off business model is the low-level virtual operator model, which, in contrast to the reseller, also has its own VAS platforms.

In addition, the low-level virtual operator can have its own 5G virtual Network Functions (NF), such as Unified Database Function (UDM), Authentication Server Function (AUSF) and Policy Control Function (PCF). The business models of Mobile Virtual Network Enabler (MVNE) network infrastructures are also known in the telecommunications market. They are specialized in creating and marketing the resellers. The infrastructure (platform) of the MVNE virtual operator is essentially a layer between the MNO and the resellers.

The MVNO architecture for RAN Sharing will be able to use the Multi-Operator Core Network or MOCN architecture as specified in 3GPP TS 23.251 allowing the sharing of the same architectural elements namely eNBs and gNBs. This MOCN architecture is shown in Figure 10.

The 5G network architecture implementation of a full MVNO that has its own core network can be an architecture based on network resource sharing technology. In accordance with the 3GPP technical specification, only one resource sharing technology is defined for the 5G network. This is the technology of sharing 5G radio access network (NG-RAN) simultaneously by several operators, which is referred as 5G MOCN.

The scheme of such a sharing network of an MNO and a high-level virtual operator (full MVNO) based on the 5G MOCN technology is shown in Figure 10.

The radio resources of the NG-RAN radio access network are distributed between the MNO and MVNO operators on the basis of the agreed internal policy and SLA.

If the full MVNO has its own mobile network code MNCMNO***,*** the gNBs of the Broadcast System Information of BCCH logical channel transmit this code along with the MNCMNO code of the 'full MVNO' of the MNO in each cell.

User Equipment (UE) of the virtual operator like MVNO can decide to register in the network or perform cell reselection or handover procedures.

The 5G base stations gNBs perform the procedure of selecting the module of the serving network Core Access and Mobility Management Function (AMF), having received the initial registration request from the UE subscriber terminal of the virtual operator. The base station gNB selects the operator of the AMF network function module (the 5GC) located in the full MVNO responsibility area.

The selection is based on the analysis of the information transmitted by the subscriber UE in the registration request 5G-GUTI (Globally Unique Temporary Identity) temporary identifier or SUPI/IMSI (5G Subscriber Permanent Identifier / International Mobile Subscriber Identity) constant identifier of the full MVNO subscriber, information on the required NSSAI (Network Slice Selection Assistance Information) network layers.

IMSI and GUTI identifiers used to identify the subscriber in the 5G network have a new designation 5G-GUTI and SUPI/IMSI which contain the network operator code MNCMVNO of the full MVNO. The 5G-GUTI identifier also contains the global GUAMI (Globally Unique AMF ID) identifier of the network access control function, namely the AMF of the full MVNO.

After gNB base station has selected the AMF network function in the full MVNO, the standard procedure described in 3GPP TS 23.251 is performed. Subsequently, all signalling (control plane) and traffic (data plane) of these subscribers UE are routed to the network of full MVNO.

In addition to MOCN, where radio access networks and spectrum are shared, 3GPP TR 38.801 also supports MORAN, where radio access networks are shared and dedicated spectrum is used by each sharing operator. This infrastructure sharing model is described in Figure D.2 below.

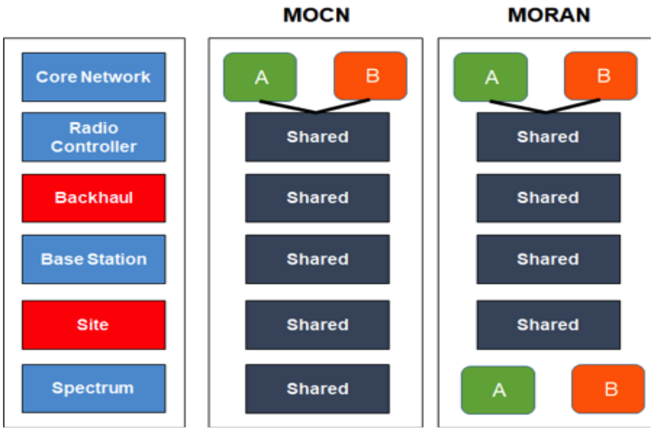


**Figure D.2. MOCN and MORAN Infrastructure sharing**

# Bibliography

[1] Recommendation ITU-T E.808 (06/2021), *Methods for objective and subjective assessment of speech and video quality*

[2] Tobias Hobfeld and Stefan Wunderer (2020/03), Würzburg, Germany, doi: 10.25972/OPUS-20232, *White Paper on Crowdsourced Network and QoE Measurements - Definitions, Use Cases and Challenges, eds.,*

[3] Open Signal Mobile Signal Experience Report (May 2020), The State of Mobile Network Experience 2020: One Year Into The 5G Era

## Acknowledgements

### Members of the Crowdsource Applications Sub Working Group

| | |
|---|---|
| Mr Shanmugam J.S.Inderan (Chairman/Draft Lead) | Maxis Broadband Sdn Bhd |
| Prof Mohamad Yusoff Alias (Vice Chairman) | Multimedia University |
| Mr Aaron Franklin Soon (Secretary) | Celcom Axiata Berhad |
| Ts Mohammad Hafiz Halal/ | Malaysian Technical Standards Forum Bhd |
| Mr Ahmad Syazilie Shamsuddin | |
| Mr Sharad Sadhu/ | Fraunhofer IIS |
| Ms Yeo Siew Ying | Maxis Broadband Sdn Bhd |
| Dr Ku Chui Choon Ivan | Multimedia University |
| Ir Ts Dr Jeffrey Alexander Roe Bannister | Orbitage Sdn Bhd |
| Mr Anwar Faizd Osman | Rohde & Schwarz Malaysia Sdn Bhd |
| Mr Chong Kok Onn | Tekmark Sdn Bhd |
| Mr Najib Fadil Mohd Bisri @ Bisri/ | Telekom Malaysia Berhad |
| Mr Yeoh Chun Yeow | |
| Mr Syed Fikril Hakim Syed Hud Al-Khaired/ | TIME dotCom Berhad |
| Mr Wong Yick Heng | |
| Mr Anthony Ng Fatt Yuen/ | U Mobile Sdn Bhd |
| Mr Khoo Poh Hean | |
| Prof Nor Kamariah Noordin | Universiti Putra Malaysia |
| Dr Imran Mohd Ibrahim | Universiti Teknikal Malaysia Melaka |
| Dr Hazilah Mad Kaidi/ | Universiti Teknologi Malaysia |
| Prof Sharul Kamal Abdul Rahim | |
| Ms Siti Najwa Muhammad/ | Webe Digital Sdn Bhd |
| Mr Tin Pon Nim | |
| Dr Norehan Yahya | Xcelcius Consultancy Sdn Bhd |
| Mr Chua Kim Siong | YTL Communications Sdn Bhd |

**By invitation:**

| | |
|---|---|
| Ts Dr Kesavan Ulaganathen | Politeknik Sandakan |