International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.1545.1

Amendment 1

(06/2021)

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet protocol aspects – Quality of service and network performance

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Framework for monitoring the quality of service of IP network services

Amendment 1

Recommendation ITU-T Y.1545.1 (2017) – Amendment 1

ITU-T

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Recommendation ITU-T Y.1545.1

Framework for monitoring the quality of service of IP network services

Amendment 1

Summary

Recommendation ITU-T Y.1545.1 is a diagnostic reference for IP network quality of service (QoS) monitoring, and is primarily a guide used to assist regulators in monitoring the QoS of Internet provided by service providers (although subscribers and network service providers may also benefit).

The Internet, known as the information superhighway, has established a worldwide borderless cyber society. Nowadays, the Internet is acknowledged worldwide as an essential component for electronic communication services. The rapid increase in the use of the Internet has changed the way people live, and has become an important factor in daily life.

As reliance on Internet networks, in promoting socioeconomic development, increases the QoS of Internet networks also becomes very critical and important. However, occasionally the scenarios under which Internet is sold to customers is not fair and unfortunately Internet subscribers are not well informed on the Internet QoS provided to them by Internet service providers (ISPs).

Therefore, this Recommendation highlights the necessity of testing the QoS of network services offered by ISPs, from a diagnostic and regulatory point of view. This Recommendation also addresses QoS evaluation scenarios, sampling methodology and testing tools for regulators. This Recommendation gives guidance to regulators about minimum QoS parameters for evaluating the quality of Internet services.

Recommendation ITU-T Y.1545.1 gives guidance to regulators about QoS parameters for evaluating the quality of internet services, QoS evaluation scenarios and sampling methodologies. Amendment 1 introduces text for the radio coverage availability parameter, which was previously identified for further study.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.1545.1	2017-03-01	12	11.1002/1000/13199
1.2	ITU-T Y.1545.1 (2017) Amd. 1	2021-06-13	12	11.1002/1000/14699

Keywords

Data rate, IP network service, QoS.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Framework for monitoring the quality of service of IP network services

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T Y.1545.1 (2017).

1 Scope

This Recommendation highlights the need for testing the quality of service (QoS) of IP network service offered by Internet service providers (ISPs), from a regulatory and diagnostic point of view. This Recommendation describes QoS evaluation scenarios and sampling methodology for both measuring and monitoring QoS. This Recommendation also gives guidance to regulators about the minimum set of QoS parameters necessary for evaluating the quality of IP network services.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T E.802 Amd.1] Recommendation ITU-T E.802 (2007) Amd.1 (2017), *Framework and methodologies for the determination and application of QoS parameters*.

[ITU-T E.804] Recommendation ITU-T E.804 (2014), *Quality of service aspects for popular services in mobile networks*.

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

[ITU-T G.1000] Recommendation ITU-T G.1000 (2001), *Communications Quality of Service: A framework and definitions*.

[ITU-T Y.1540] Recommendation ITU-T Y.1540 (2016), *Internet protocol data communication service – IP packet transfer and availability performance parameters*.

[ITU-T Y.1546] Recommendation ITU-T Y.1546 (2014), *Hand-over performance among multiple access networks*.

[ITU-T Y.1731] Recommendation ITU-T Y.1731 (2011), *OAM functions and mechanisms for Ethernet based networks*.

[IETF RFC 2681] IETF RFC 2681 (1999), *A Round-trip Delay Metric for IPPM*.

[IETF RFC 7398] IETF RFC 7398 (2015), *A Reference Path and Measurement Points for Large-Scale Measurement of Broadband Performance*.

[IETF RFC 7799] IETF RFC 7799 (2016), *Active and Passive Metrics and Methods (with Hybrid Types In-Between)*.

[ETSI EG 202 057]	ETSI EG 202 057-04 V1.2.1 (2008), *Speech Processing, Transmission and Quality Aspects (STQ); User related QoS parameter definitions and measurements; Part 4: Internet access*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 active methods of measurement [IETF RFC 7799]: Active methods of measurement have the following attributes: Active methods generate packet streams. Commonly, the packet stream of interest is generated as the basis of measurement. Sometimes, the adjective "synthetic" is used to categorize active measurement streams [ITU-T Y.1731]. An accompanying packet stream or streams may be generated to increase overall traffic load, though the loading stream(s) may not be measured. The packets in the stream of interest have fields or field values (or are augmented or modified to include fields or field values) that are dedicated to measurement. Since measurement usually requires determining the corresponding packets at multiple measurement points, a sequence number is the most common information dedicated to measurement, and it is often combined with a timestamp. The source and destination of the packet stream of interest are usually known a priori. The characteristics of the packet stream of interest are known at the source (at least), and may be communicated to the destination as part of the method. Note that some packet characteristics will normally change during packet forwarding. Other changes along the path are possible, see [STDFORM]. When adding traffic to the network for measurement, active methods influence the quantities measured to some degree, and those performing tests should take steps to quantify the effect(s) and/or minimize such effects.

3.1.2 dedicated component (links or nodes) [IETF RFC 7398]: All resources of a dedicated component (typically a link or node on the reference path) are allocated to serving the traffic of an individual subscriber. Resources include transmission time-slots, queue space, processing for encapsulation and address/port translation, and others. A dedicated component can affect the performance of the reference path or the performance of any sub-path where the component is involved.

3.1.3 IP network service [b-ITU-T Y.1241]: An IP network service is defined as a data transmission service in which the data passed across the interface between the user and provider is transferred in the form of Internet protocol (IP) packets (sometimes called datagrams). IP network service includes the service provided by using the IP transfer capabilities.

3.1.4 IP-based service [b-ITU-T Y.1241]: An IP-based service is defined as a service provided by the service plane to an end user (e.g., a host (end system) or a network element) and which utilizes the IP transfer capabilities and associated control and management functions, for delivery of the user information specified by the service level agreements.

3.1.5 managed and unmanaged sub-paths [IETF RFC 7398]: Service providers are responsible for the portion of the path they manage. However, most paths involve a sub-path that is beyond the management of the subscriber's service provider. This means that private networks, wireless networks using unlicensed frequencies, and the networks of other service providers are designated as unmanaged sub-paths. The service demarcation point always divides managed and unmanaged sub-paths.

3.1.6 measurement point [ITU-T Y.1540]: The boundary between a host and an adjacent link at which performance reference events can be observed and measured. Consistent with [b-ITU-T I.353], the standard Internet protocols can be observed at IP measurement points (MPs). [b-ITU-T I.353] provides more information about MPs, for digital services.

3.1.7 parameter [b-ITU-T Y.1545]: A quantifiable characteristic of a service with specified scope and boundaries.

3.1.8 passive methods of measurement [IETF RFC 7799]: Passive methods of measurement are based solely on observations of an undisturbed and unmodified packet stream of interest (in other words, the method of measurement MUST NOT add, change, or remove packets or fields or change field values anywhere along the path). Dependent on the existence of one or more packet streams to supply the stream of interest. Dependent on the presence of the packet stream of interest at one or more designated observation points. Some passive methods simply observe and collect information on all packets that pass observation point(s), while others filter the packets as a first step and only collect information on packets that match the filter criteria, and thereby narrow the stream of interest. It is common that passive methods are conducted at one or more observation points. Passive methods to assess performance metrics often require multiple observation points, e.g., to assess the latency of packet transfer across a network path between two observation points. In this case, the observed packets must include enough information to determine the corresponding packets at different observation points. Communication of the observations (in some form) to a collector is an essential aspect of passive methods. In some configurations, the traffic load generated when communicating (or exporting) the passive method results to a collector may itself influence the measured network's performance. However, the collection of results is not unique to passive methods, and the load from management and operations of measurement systems must always be considered for potential effects on the measured values.

3.1.9 probing packet [b-ITU-T Y.1545]: An individual IP packet associated with active performance testing, i.e., a test packet [b-ITU-T Y.1543].

3.1.10 quality of service [b-ITU-T E.800]: Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service.

3.1.11 reference path [IETF RFC 7398]: A reference path is a serial combination of hosts, routers, switches, links, radios, and processing elements that comprise all the network elements traversed by each packet in a flow between the source and destination hosts. A reference path also indicates the various boundaries present, such as administrative boundaries. A reference path is intended to be equally applicable to all IP and link-layer networking technologies. Therefore, the components are generically defined, but their functions should have a clear counterpart or be obviously omitted in any network architecture.

3.1.12 resource transition point [IETF RFC 7398]: This is a point between dedicated and shared components on a reference path that may be a point of significance and is identified as a transition between two types of resources.

3.1.13 service demarcation point [IETF RFC 7398]: This is the point where a service managed by the service provider begins (or ends) and varies by technology. For example, this point is usually defined as the Ethernet interface on a residential gateway or modem where the scope of a packet transfer service begins and ends. In the case of a WiFi service, this would be an air interface within the intended service boundary (e.g., walls of the coffee shop). The demarcation point may be within an integrated endpoint using an air interface (e.g., long-term evolution user equipment (LTE UE)). Ownership does not necessarily affect the demarcation point; a subscriber may own all equipment on their premises, but it is likely that the service provider will certify such equipment for connection to their network or that a third-party will certify standards compliance.

3.1.14 shared component (links or nodes) [IETF RFC 7398]: A component on the reference path is designated a "shared component" when the traffic associated with multiple subscribers is served by common resources.

3.1.15 subscriber [IETF RFC 7398]: A subscriber is an entity (associated with one or more users) that is engaged in a subscription with a service provider. The subscriber is allowed to subscribe and unsubscribe to services and to register a user or a list of users authorized to enjoy these services. Both the subscriber and service provider are allowed to set the limits relative to the use that associated users make of subscribed services.

3.1.16 sub-path [b-IETF RFC 5835]: A sub-path is a portion of the complete path where at least the sub-path Source and Destination hosts are constituents of the complete path. We say that such a sub-path is "involved" in the complete path.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 commercial Internet connectivity provider (CICP): A company supplying a subscriber with Internet connectivity if it is contracted to do so, where Internet connectivity is comprised of enabling the transfer of IP packets between subscribers' terminal equipment or a residential gateway and the Internet.

3.2.2 hotspot: A selected stationary access site in a pre-defined city where there is mobile network coverage. E.g.: pre-selected hotspots must be discussed and agreed on before the start of hotspot drive assignment on data services key performance indicators (KPIs).

3.2.3 Internet application: An application operating above the IP layer, choosing one of the appropriate transport layers. Examples are VoIP, (additional) AAA, cloud service, e-mail, web-service, IPTV, and streaming. Some of these applications may comprise components of the CICP’s complete service offering, at the discretion of the CICP.

3.2.4 probe: Is an end-point test tool which uses probing packets to collect measurements.

3.2.5 supporting service: An essential service to assist configuration of the IPlayer, or operating above the IP layer. Examples are DHCP, DNS, and AAA.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3G	Third Generation
4G	Fourth Generation
AAA	Authentication, Authorization, and Accounting
API	Application Programing Interface
AS	Autonomous Systems
CICP	Commercial Internet Connectivity Provider
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
GRA GW	Globally Routable Address Gateway
ICT	Information and Communication Technology
IMS	Internet Multimedia Subsystem
IP	Internet Protocol
IPDV	Internet Protocol Packet Delay Variation
IPER	Internet Protocol Packet Error Ratio
IPLR	Internet Protocol Packet Loss Ratio
IPTD	Internet Protocol Packet Transfer Delay
IPTV	Internet Protocol Television
ISP	Internet Service Provider

IXP	Internet Exchange Point
KPI	Key Performance Indicator
LTE	Long-Term Evolution
MP	Measurement Point
OAM	Operations, Administration and Maintenance
PIA	Percent IP service availability
QoS	Quality of Service
RSRP	Reference Signal Received Power
RSSI	Received Signal Strength Indicator
RTT	Round-trip Time
VoD	Video on Demand
VoIP	Voice over Internet Protocol
VoLTE	Voice over LTE

5 Conventions

None.

6 Different aspects of quality of service

6.1 Four viewpoints of QoS

This Recommendation outlines the four viewpoints of QoS specified in [ITU-T G.1000], shown in Figure 1, and maps them with QoS requirements of IP-based network services. The vertical division between customer and service provider (commercial Internet connectivity provider (CICP)) corresponds to the service demarcation point.

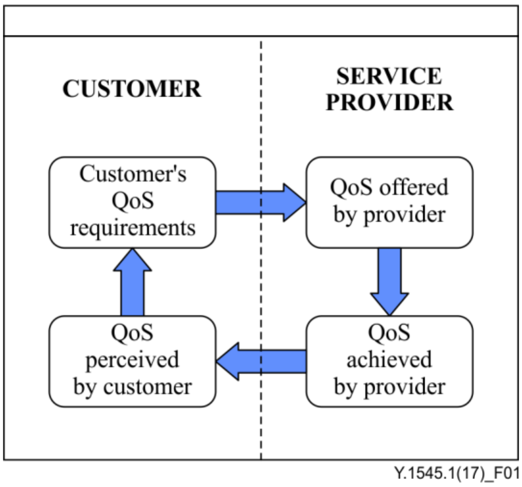

Figure 1 – Four viewpoints of QoS according to [ITU-T G.1000]

Customer QoS requirements: Each application/service available on the Internet requires a level of QoS for the Internet connection for it to operate satisfactorily. In turn, every subscriber has their preferred applications, and inherently a requirement of the level of QoS of their Internet service.

QoS offered or planned by service provider: The QoS that the ISP pledges to offer to its subscribers. This should serve as a reference for both subscribers and the ISP when benchmarking the level of service provided. In most cases, at the point of sale, the service is primarily characterised in terms of upload/download speeds of the Internet connection and there are no QoS commitments included.

QoS achieved or delivered by service provider: The actual level of the service delivered to the subscriber. A comparison between the QoS offered and the QoS delivered indicates the level of performance achieved by the ISP in terms of specific QoS parameters. By comparing the QoS delivered with the QoS advertised, the subscriber is better equipped to determine whether there is a significant mismatch between the promised and the delivered QoS for the subscribed services.

End-user perception: End-users are generally not interested in technical aspects of their connection, but they are interested in what they can do with the connection, and the quality of their experience when accessing different applications/services over their Internet connection.

6.2 QoS offered and QoS delivered

The QoS of the Internet offered (advertised) by ISPs is evaluated by:

- ISPs for optimization purposes or;
- Regulators, because occasionally the QoS promised by ISPs (in advertisements) is totally different from the QoS delivered.

In some countries, service characteristics used by ISPs may not be satisfactory to define the service for the following reasons:

- Services may be sold without providing a guaranteed minimum QoS to subscribers;
- Subscribers are not given any guidelines on how service characteristics can be interpreted;
- QoS figures provided by different ISPs are not comparable;
- Subscribers are not well informed on the QoS that the Internet connection is able to provide.

Therefore, to improve the situation, regulators are advised to:

- Determine the set of QoS parameters required for monitoring the quality of Internet services;
- Determine thresholds for each required monitored parameter;
- Monitor the QoS delivered to the end users effectively by establishing a mechanism through which the parameters can be measured;
- In cases where there is no competition in service provision, establish a mechanism by which the ISP’s conformance to the contractual obligations with their subscribers can be validated;
- Publish test results through detailed benchmarking reports;
- Provide end users with a trusted tool, used by themselves, to test the main key performance indicators (KPIs).

7 Minimum set of parameters for evaluating the quality of IP network service

7.1 IP network service activation time

Clause 7 of [ITU-T Y.1546] defines:

- Successful IP activate time, (multiple measurements may be summarized using statistics such as the minimum, maximum, median, mean, variance, percentiles);
- Incorrect IP activate ratio;
- Failed IP activate ratio.

These parameters apply to a set of individual attempts to access and utilize IP network services, and are supplied by the dynamic host configuration protocol (DHCP) server of the service provider. See Figure A.2/Annex A of [ITU-T Y.1546] for an illustration of DHCP IP activation. In another typical case, the parameters apply to the user equipment (UE) activation on 3rd Generation Partnership Project (3GPP) long term evolution (LTE), and Figure B.1 of [ITU-T Y.1546] illustrates an LTE IP activation (host connect (HC) -> host activation (HA)).

7.2 DNS response time

[IETF RFC 2681] defines a round-trip delay metric for IP networks, and the metric definition has been adapted using the details of the domain name system (DNS) query packet type, such that the measurement yields DNS response time. See section 6 in [b-IETF ippm].

Multiple per-subscriber measurements may be summarized using statistics such as the minimum, maximum, median, mean, variance, percentiles, etc.

7.3 Number of IP network interconnection points

This metric is a count of the number of interconnection points to other autonomous systems (AS), based on creating a diagram of the network being measured according to the procedures specified in [IETF RFC 7398] where all interconnection points (designated globally routable address gateway (GRA GW)) are included, and counting the number of unique interconnection points in the diagram.

Occasionally these interconnections occur at public Internet exchange points (IXPs). This diagram should be supplied by the IP network service provider, and is subject to verification using "traceroute" tests from representative subscriber locations.

7.4 Round-trip delay (RTT to IP network interconnection points)

This metric measures the round-trip delay between subscribers' service demarcation points and the interconnection points to other autonomous systems. Occasionally these interconnections occur at public IXPs. [IETF RFC 2681] defines a round-trip delay metric for packet transfer between a known (host) source and remote destination.

The target IXP IP addresses for measurement may be obtained using "traceroute" tests from representative subscriber locations, or the IP network service provider may provide the appropriate remote addresses.

Multiple per-subscriber measurements may be summarized using statistics such as the minimum, maximum, median, mean, variance, percentiles, etc.

The set of mean per-subscriber round-trip time (RTT) for each interconnection point (see clause 7.3) should be recorded as the range indicated by the minimum and maximum values.

7.5 IP delay variation (one-way delay variation to IP network interconnection points)

The one-way delay variation performance parameter is defined in clause 6.2.2 of [ITU-T Y.1540]. See clause 7.4 for summarization on per-subscriber to interconnection point measurements, and across multiple interconnection points.

7.6 IP packet loss (one-way packet loss to IP network interconnection points)

The one-way packet loss performance parameter is defined in clause 5.5.6 of [ITU-T Y.1540]. See clause 7.4 for summarization on per-subscriber to interconnection point measurements, and across multiple interconnection points.

The IP service availability function defined in clause 7.1 of [ITU-T Y.1540], is also based on IP packet loss. See clause 7.2 of [ITU-T Y.1540] for summarization on per-subscriber to interconnection point measurements, and clause 7.4 above for summarization across multiple interconnection points.

7.7 Data rate (download and upload)

7.7.1 mean data rate achieved: The average of the data transfer rate achieved for a given number of samples.

Formula:

$$\text{Mean Data Rate achieved } = \frac{\sum_{i=1}^{N} H_i}{N}$$

where:

H[1]: data transfer rate (in kbits/s or Mbits/s) achieved when downloading or uploading a specified IP packet payload stream between two measurement points (e.g., server and probe)

N: number of samples

NOTE – Specification of the IP packet payload stream: The payload stream should consist of incompressible data. This is normally achieved by generating a sequence of random numbers. Another practical solution is to use a stored stream that is already compressed, e.g., from a zip or jpg file, or to use the digits of the number Pi. The payload stream should have at least twice the length (in kbit) of the theoretically maximum data transmission rate per second (in kbit/s) of the Internet access under consideration. Refer to the requirements in clause 6.12 of [ITU-T Y.1540], and the supporting material in Appendix IX of [ITU-T Y.1540].

7.7.2 % of the mean data rate: Denotes the deviation between the data rate contracted/advertised and the data rate achieved.

Formula:

$$\text{\% of Mean Data Rate} = \frac{Mean\ Data\ Rate\ achieved}{Data\ Rate\ contracted} \times 100\%$$

NOTE – In this case, a given regulator can set a target of, for example 70%, 80%, of the maximum data rate contracted by the subscriber, depending on the country's information and communication technology (ICT) market.

7.8 Internet IP network service availability

Definition: Internet availability represents the fraction of time probability that an end user is able to access IP network packet transfer Internet services via access to their Internet connection. See clause 7 of [ITU-T Y.1540].

Formula:

Percent IP service availability (PIA)

The percent IP service availability (PIA) is the percentage of total scheduled IP service time (the percentage of T_{av} intervals) that is (are) categorized as available using the IP service availability function (refer to clause 7 of [ITU-T Y.1540]).

7.9 Radio coverage availability

Refer to [ITU-T E.806] for description and measurement methodologies of this parameter.

~~NOTE – This parameter seeks further study~~.

1 It should be noted that H, the data transmission rate metric and method of measurement are still under discussion.

8 Quality of service measurement methodologies

Methods of measuring the IP network services provided by ISPs are categorized as active and passive methods of measurement [IETF RFC 7799]. This Recommendation focuses on the active methods of measurement.

Active methods of measurement

- Advantage:
  - The data (probing packets) are originated from a controlled source with predefined settings and therefore types of services can be fully controlled;
  - Easy benchmarking/comparison between measurements obtained from different Internet connections provided by different ISPs.
- Disadvantage:
  - Requires that the line under test be fully available;
  - Test design must ensure that the line is idle before testing;
  - Requires both sending and receiving probes (monitoring tools).

Passive methods of measurement:

- Advantages:
  - The probe needs only one connection point to the network which means less hardware;
  - Does not 'take over' the line under test, so is never an inconvenience to end users.
- Disadvantages:
  - Unknown traffic type makes it difficult to test maximum line capability;
  - Difficult to average different tests as the data traffic is not consistent.

8.1 Testing tools

Testing tools adopted in the active testing method are hardware- and software-based tools (probes).

Hardware-based Tools: in this case there are at least three options of implementation:

1) First option: probes completely replace the end user's equipment and no other equipment can be connected to the Internet while the probe is performing measurements. This is applicable for both fixed and mobile Internet access.
2) Second option: probes share Internet access with ordinary traffic. E.g., probes can be connected to a customer's residential gateway. Appropriate probes can monitor the end user's traffic behaviour and perform tests only when there is no traffic being transferred.
3) Third option: a testing application programing interface (API) is embedded into the customer's residential gateway, through a firmware update, in order to act as a probe and test the fixed Internet connection.

Software-based tools: in this case, there are at least three types of software-based tools:

1) A web-based tool: download and execution of measurement software is initiated via the end user's web browser by accessing a specific webpage.
2) A dedicated software client: measurement software is permanently installed on the end user's terminal equipment. In this case, different versions of software are needed to support different operating systems and terminal equipment.
3) A testing API: an API can be included in the code of one popular website in order to perform test transparently every time the users access the website.

Regardless of what type of test tool is chosen, the test tool specifications shall be sufficiently detailed so that two independent implementations of the test tools should measure statistically equivalent performance (with high confidence) when measuring the same network path under the same conditions.

8.2 Quality of service evaluation scenarios

Scenarios usually applied to evaluate the QoS of IP network service are:

- Evaluation scenario at a national level (test server located at local Internet exchange point (IXP));
- Evaluation scenario at the international level (test server located at an international IXP).

Measurements are conducted on the selected QoS parameters that have impact on the user's experience when utilizing IP network services.

This clause focuses on the evaluation scenario at a national level and the evaluation scenario at an international level is described in Appendix I.

8.2.1 Evaluation scenario at a national level

In the evaluation scenario at a national level, the test server is located at the local IXP and probes are installed at the end user’s point of view. Measurements can be carried on with or without involvement of ISPs by regulators and the measurement path includes a complete Internet connection from the customer to the test server located at the local IXP. ISPs or regulators can use standardized hardware- or software-based probes.

The benchmarking/comparability of the ISPs can be best reached, in cases where all ISPs are connected in a similar way to the local IXP (or any central measuring point). This scenario allows regulators to conduct evaluation of the QoS experienced by subscribers provided by ISPs. In fact, tests initiated by probes are directed to the local IXP when testing local KPIs (such as download/upload mean data rate, latency).

The measurement set-up that can be used to conduct measurement tests for QoS of Internet is given in Figure 2.

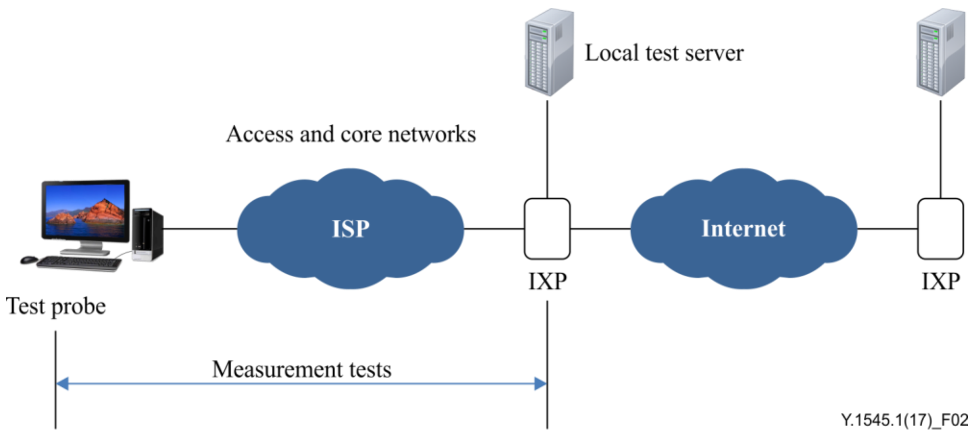

Figure 2 – Measurement set-up at a national level

[IETF RFC 7398] provides details of reference paths and measurement points. This path goes beyond the details of the reference path in clause 3.1/Figure 1 of [ITU-T Y.1540]. Figure 3 below, based partly on Figure 2 of [IETF RFC 7398], allows reference to measurement points by number.

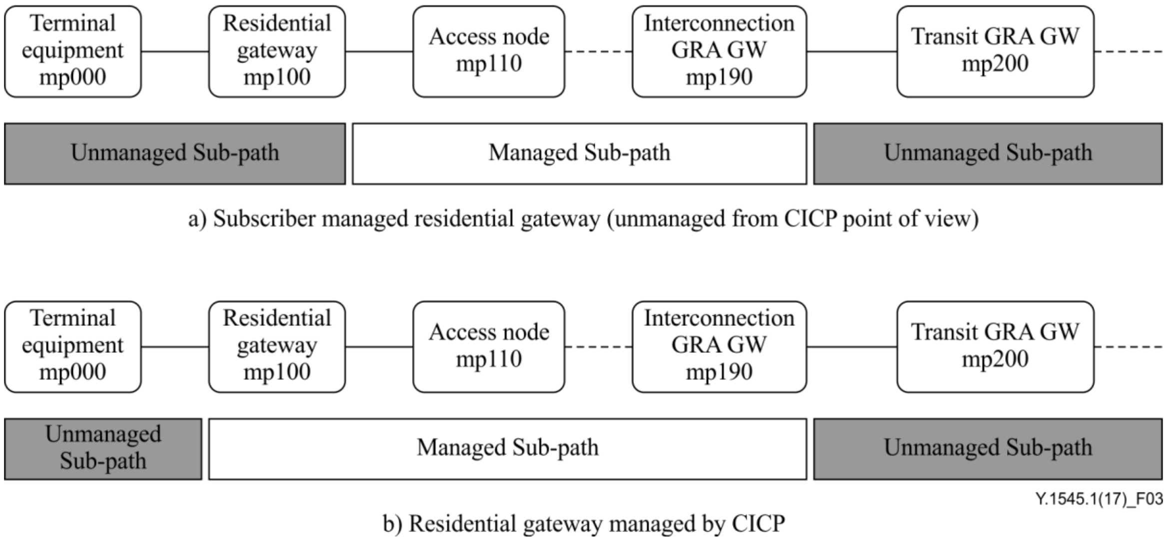

Figure 3 – Reference path of a CICP offering fixed Internet connectivity

Tests at the national level for a single IP network service provider should be conducted between mp100 and mp190 ideally. Tests which include the IXP would be conducted between mp100 and mp200, with the caveat that this testing scope includes components of two IP network service provider's domains, and possibly three domains if the IXP is operated by a third party. Both mp190 and mp200 are generally described as interconnection points in the metrics defined in clause 7.

NOTE – National IXP locations may be in another country or on another continent, such that it may not be possible to test purely at the national level between some service providers (and it may be necessary to add a clause on regional level tests).

Measurements from the subscriber's device (mp000) complicate the measurement of fixed IP network services. One or more private networks will influence the measurements, and more so if there are wireless networks involved. These private networks are referred to as the unmanaged sub-paths in [IETF RFC 7398].

Wireless access networks connecting subscribers usually don't consist of residential gateways managed by a subscriber. This is shown in Figure 4.

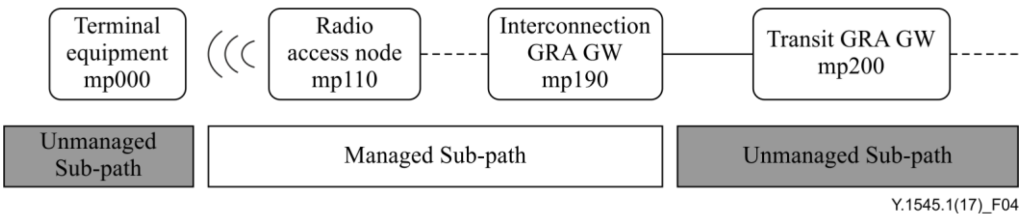

Figure 4 – Reference path of a CICP offering wireless network Internet connectivity

This figure may be generalized if "Radio" is omitted for the access node, such that it corresponds to Figure 4.

The reference paths of CICPs to application servers do not depend on the access offered to a subscriber. For the sake of simplicity, only fixed access subscribers are used to illustrate the following reference paths.

To be authorised for Internet connectivity operated by a CICP, a subscriber will have to authenticate. Thus, prior to communicating with the Internet, the subscriber requires access to an application service of the CICP. The generic reference path to a service offered by the CICP is shown in Figure 5 below:

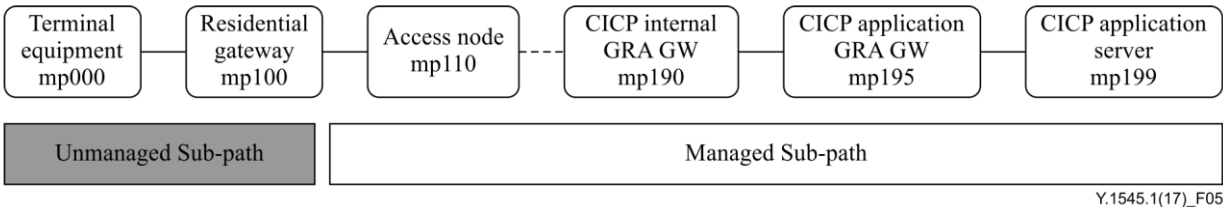

Figure 5 – Reference path to a CICP application service

Supporting services and applications (above the IP layer) offered by a CICP to a subscriber may include:

- Authentication, authorization, and accounting (AAA) and IP address assignment (this service is not optional);
- DNS;
- Operations, administration and maintenance (OAM) service;
- E-mail;
- Voice over Internet protocol (VoIP) (like Internet multimedia subsystem (IMS) or voice over LTE (VoLTE));
- Internet protocol television (IPTV) (multicast based, but also unicast based);
- Cloud services;
- An Internet portal (including web-based e-mail access);
- Streaming services like video on demand (VoD) (progressive download);
- Shopping (of e.g., equipment and services offered by the CICP);
- Ad-servers and subscriber monitoring.

Some applications may consist of several services which may be implemented on independent application servers. In general, signalling and application IP flows of a single application may be operated on separated hardware.

9 Sampling methodology

The number of probes to be used in testing the QoS of Internet measurements should be enough to guarantee that the data collected are representative for that region and sufficient from a statistical perspective. Further, the data collection plan should be designed to ensure that the results sufficiently reflect the QoS as perceived by the user.

It is recommended that the selection of panellists (end-user access points, where to install probes) should takes into consideration various factors such as technologies (e.g., xDSL, fibre optic, wireless networks), Internet data rate packages (depending on popularity), locations, and should be based on a voluntary process to avoid ISP traffic prioritization for those users being tested.

The choice of satisfactory measurement tests, i.e., geographical locations of origin and destination of tests as well as traffic variations, is a crucial point with respect to the comparability and validation of the statistics to be calculated for the measured parameters.

Test connections and data transfer attempts should be carried out in such a way that they match the traffic variations in the network. The measurements obtained in each test should be weighted by a factor according to the level of the traffic operator's network (% of bandwidth used) corresponding to the location and time when the test was conducted.

Guidance on how to calculate the number of samples needed to perform QoS measurements for Internet services is available in Annex C of [ETSI EG 202 057 04] and in Amendment I of

[ITU-T E.802]. Furthermore, post processing and statistical methods can be found in clause 11 of [ITU-T E.804].

9.1 Selecting access lines for each speed package

In national QoS evaluation studies for Internet, the percentage of access lines (for each data rate package) of ISPs to be selected in rural, suburban and urban regions should be statistically representative.

The sampling methodology should have a stable level for the confidence intervals obtained in various regions and for different ISPs. If the final results of the access lines per ISP correspond closely to the market share of the ISP, it is likely that the sampling criteria followed by the national measurement campaign are representative. In the case of under-representation of access lines offered by some ISPs, the best option will be to exclude those particular ISPs from the campaign.

However, there is a difference between fixed and mobile access to Internet in selecting the access point. For mobile Internet, it is possible to measure QoS everywhere where coverage is ensured. In this case, a number of hotspots should be selected for the measurements across the country. This can be calculated depending on the size of the country, geographic coverage percentage and classification of rural, urban and suburban areas.

On the side of fixed Internet, selection of access points for fixed ISPs is quite challenging, because in order to perform the measurements, in most cases, it is necessary to access the consumer premises. This problem is faced by both regulators and ISPs. However, this obstacle may be solved through development of cooperation between regulators, consumers and ISPs.

Experience in this regard shows that to develop cooperation and attract sufficient numbers of volunteers, each attempt should be led by appropriate advertising campaigns and publication of information using various media channels.

9.2 Selecting the measurement moments

The moments for the measurements should, in principle, cover high and low traffic, including peak hours. However, for simplicity, the measurements may cover only high-traffic hours, including peak hours. If the Internet access service (IAS) is working properly in peak hour (or at least in high traffic hours) the conclusion could be made that quality in low-traffic hours should be even more acceptable.

The frequency of the measurements should be based on the number of users participating in the campaign, the option(s) taken for the overall set of measurements and the level of statistical error and confidence intervals acceptable for the project. Decisions in this regard should be taken after consulting all relevant options in order to best adapt the frequency [b-ECC Report 195].

Appendix I

Evaluation scenario at international level

(This appendix does not form an integral part of this Recommendation.)

In this scenario, as shown in Figure I.1, test server is located at an international IXP (i.e., an IXP installed in another continent, or another country). Usually, the Internet connection that ISPs provide to customers is to the entire Internet. Therefore, the more bandwidth capacity in the ISPs' connections, the better the quality of the Internet connection provided by the ISPs will be.

This scenario allows regulators to test the international data transmission KPIs (e.g., download/upload data rate, delay). This allows the comparison between the connectivity of IP-based services inside the country and outside (different countries/continents).

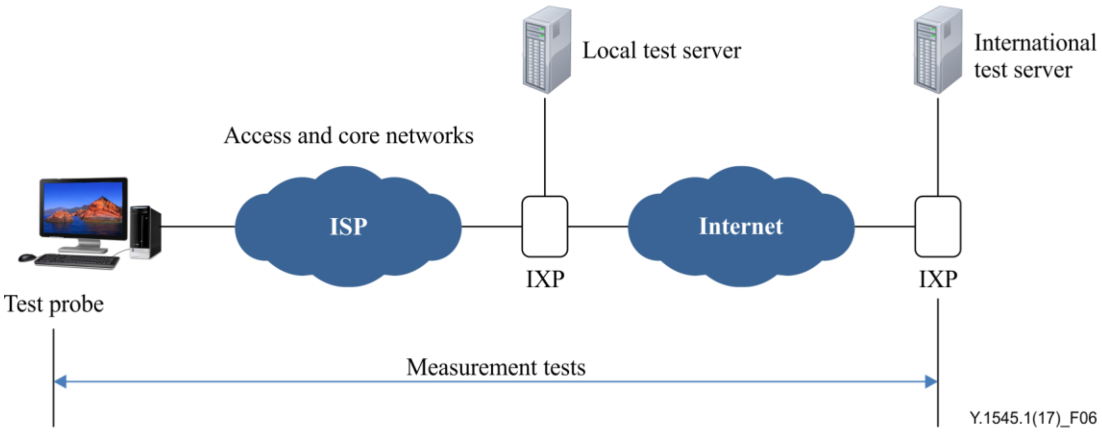

Figure I.1 – Evaluation scenario at international level

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Printed in Switzerland
Geneva, 2021