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SERIES J: CABLE NETWORKS AND TRANSMISSION OF TELEVISION, SOUND PROGRAMME AND OTHER MULTIMEDIA SIGNALS

Measurement of the quality of service

Quality of service ranking and measurement methods for digital video services delivered over broadband IP networks

ITU-T Recommendation J.241

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Summary

This Recommendation specifies performance requirements and objective measuring methods of QoS for the delivery of digital video services over broadband IP networks. The specified performance requirements are based on an IP QoS ranking at various levels, from "excellent" to "out-of-service". They rely on the objective end-to-end measurement of the values of a small number of parameters on the delivered IP streams, performed at the consumer premises equipment and relayed back to the head end. The recommended objective measurement methods and parameters are known to influence the Quality of Service delivered to the user.

Source

ITU-T Recommendation J.241 was approved on 6 April 2005 by ITU-T Study Group 9 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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Quality of service ranking and measurement methods for digital video services delivered over broadband IP networks

1 Scope

This Recommendation specifies performance requirements and objective measuring methods of QoS, for the delivery of digital video services over broadband IP networks. The performance requirements are based on an objective measurement of the values of a small number of parameters performed on the delivered IP streams at the consumer premises equipment. These parameters are known to influence the Quality of Service delivered to the user and they allow defining the measurements needed to evaluate the service quality degradation introduced by an IP network.

The definition of a complete system model of a digital television system over an IP network, including the definition of the appropriate FEC technique to be employed, is outside the scope of this Recommendation. It is well recognized that perceived video quality is highly affected by the performance of FEC. Therefore, this Recommendation does not guarantee that the classification that it provides is sufficient for assessing the perceived quality on a TV broadcasting over IP system, since IP end-to-end network performance it is measured before FEC is applied.

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 Recommendation G.1020 (2003), *Performance parameter definitions for quality of speech and other voiceband applications utilizing IP networks*.
- ITU-T Recommendation Y.1540 (2002), *Internet protocol data communication service – IP packet transfer and availability parameters*.
- ITU-T Recommendation Y.1541 (2002), *Network performance objectives for IP-based services*.

3 Definitions

This Recommendation defines the following term:

3.1 broadband IP network: Access IP telecommunications network offered by ADSL, ADSL2+, VDSL, Optical Access Network, etc.

4 Abbreviations

This Recommendation uses the following abbreviations:

BER Bit Error Ratio

CPE Customer Premises Equipment

FEC Forward Error Correction

IP Internet Protocol

IPER	IP packet Error Ratio
IPLR	IP packet Loss Ratio
MPEG	Moving Picture Experts Group
PLR	Packet Loss Ratio
QoS	Quality of Service
RTCP	Real Time Control Protocol
RTP	Real Time Protocol
SLA	Service Level Agreement
STB	Set Top Box
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VoD	Video on Demand

5 Quality of Service ranking and measurement methods for digital video services delivered over broadband IP Networks

5.1 Background

Digital transport streams based on MPEG2 encoding have become the prevailing technology for augmenting the experience of digital television services, since it allows combining the distribution of high quality digital television services with the opportunity for end users to enjoy real-time interaction with multimedia service platforms.

As broadband fixed communication networks start to be extensively deployed in several countries, clear opportunities emerge for extending this offer through transport based on IP protocols.

The native shared-access and bidirectional capabilities of an IP network, in fact, offer an ideal environment for providing customers with full end-user interactivity and support for advanced services; this offers advantages over traditional video streaming services. IP-based broadband communication networks thus provide another high-performance, bidirectional transport environment to transparently convey MPEG2-compliant video content.

5.2 Recommendation

Methods for Quality of Service measurements for digital television services streamed in a broadband IP network should be tailored to the specific features of the transport services provided by an IP communication network.

Annex A shows a conceptual block module of a system measurement model of a chain for IP transmission of television services.

In this measurement model, the Quality of Service should be measured end-to-end, namely, from the program injection point in the network, all the way to the Customer Premises Equipment (CPE). This provides readings that closely approximate the quality of service as it is delivered to the end user, and take into account the influence of the IP network on the video stream.

There are two kinds of Quality of Service measurement to be taken at the video receiver. These are described in Annexes B and C.

Annex B describes the recommended end-to-end measurements to be performed on the video stream after its IP packetized structure is removed.

Annex C describes the measurements to be performed on the video stream at its IP layer.

Annex A

System measurement model

In its simplest form, the television services distribution model, in an IP network, consists of three parts:

- The Head-end: This includes all the devices and applications needed to produce the video signals that are sent into the network.
- The Transport Network: This transports the video signal to the end user CPEs.
- The CPE: This is an IP end point (usually an STB) that decodes the video signal and displays it on a television set normally connected to it.

Explicit SLAs need to be established between the service provider and the telecommunications network operator for the transport of the video streams between the head-end and the transport network.

Audio, video, data and interactive services can be delivered in the IP transport network if the head-end and the STBs provide the necessary compliance. All the services and standards are compatible with the TCP/IP stack; the IP network should guarantee the required performance level and it should provide some test point where it can be measured.

This Recommendation assumes that the quality of the input video signal that is delivered to the IP network is under the responsibility and control of the head-end.

The head-end should inject the video streams in the network according to transport rules appropriate to the IP Network. These rules should define:

- Maximum packet rate per stream;
- Maximum number of sustainable streams;
- Maximum bandwidth per stream (or packet rate for a given packet size);
- Transport protocol to be used;
- Frame size (transport layer);
- Packet size;
- Allowed inter-packet gap profile;
- Maximum burst size.

On its side, the IP network should guarantee the agreed service level for the delivery of video streams to end-users.

In an IP network, Video on Demand (VoD) services are usually associated with unicast content distribution methods while television services are distributed by using IP multicast based protocols.

IP transport protocol used for unicast distribution maybe UDP or TCP while multicast distribution is transported on top of UDP.

The determination of the service level should be based on end-to-end measurements, which should provide information on:

- The quality offered to the user;
- The influence of the IP network on the video signal.

Figure A.1 shows the system measurement model that summarizes this approach.

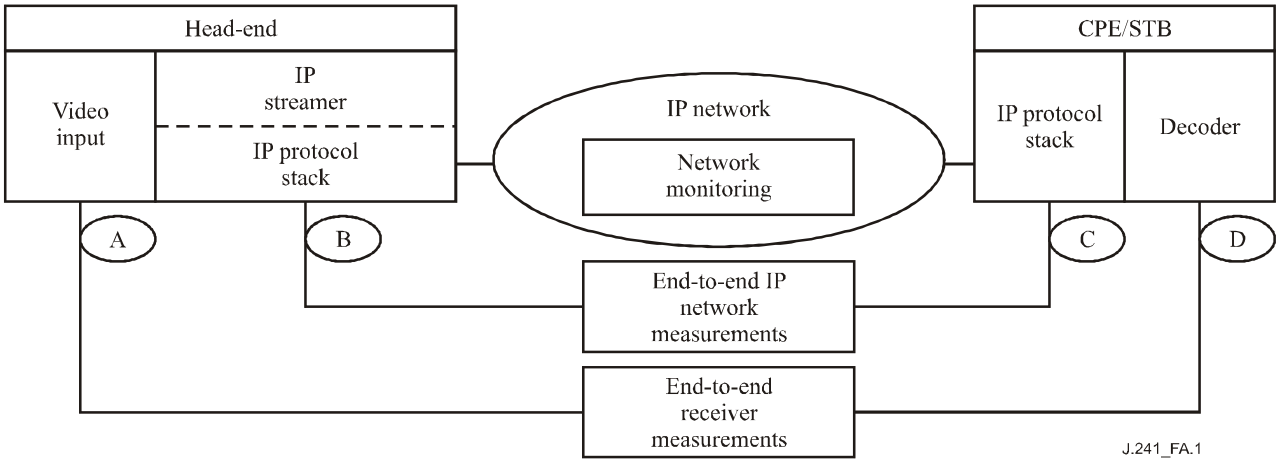

Figure A.1/J.241 – System measurement model

The following table describes the reference points A, B, C, and D shown in Figure A.1:

Reference point	Description
A	Video encoder
B	IP layer at head-end (Raw IP data).
C	IP layer at CPE (Raw IP data).
D	Video decoder

Annex B

End-to-end measurements

An IP network allows each CPE (STB) to also behave as a measurement end-point. This offers the valuable opportunity to have a measurement probe at each installed video CPE. Measurements and monitoring taken at the CPE are the ones closest to the user's real experience of the service.

Using a CPE as a measurement probe raises some point of attention since the CPE is not under the physical control of the network operator, and measurements may be affected by the user's equipment (cable not well plugged in vertical cabling issues, improper use of the home-network). The STB should have the capability to give additional information about the quality of the video signal that is being decoded. Receiver buffer fullness and frame rate are two important indicators of service availability and overall performance. CPEs measurements should be used to:

- Measure the end-to-end IP network performance;
- Measure the network performance at any hierarchical level or aggregation point through statistical analysis and data processing exploiting correlation among data;
- Estimate the video quality offered to the end-user of the service;
- Perform dedicated test sessions using test signals for qualification and troubleshooting.

As an example, some network operators currently perform end-to-end measurements at all the STBs available in their residential network, in order to evaluate end-to-end video service quality and network performance; STBs periodically send back frame rate and packet loss reports to provide a continuous quality feedback about the service in progress.

B.1 Video receiver measurements

The table below shows the parameters that should be measured at video receivers to estimate video quality, as described in the system measurement model. These measurements can be used for all the assessments outlined above.

Parameter	Value	Equipment	Purpose	Monitoring method	Measurement path (Note)
Video frame rate	As required by the video standards	STB	Image quality	In service through codec specific methods. Sampling	From A to D
Buffer underflows	N/A	STB	Image quality, smooth play-out	In service while playing video. Sampling Measure underflows events and percentage of service time spent by the STB in an "underflow" state	D
Buffer overflows	N/A	STB	Image quality, smooth play-out	In service while playing video. Sampling Measure underflows events and percentage of service time spent by the STB in an "overflow" state	D
Coding specific parameters	N/A	STB	Image/Service quality	In service while playing video. Sampling	N/A
NOTE – See Figure A.1 "System Measurement Model" in Annex A.					

Further studies should address video quality significant parameters which can be returned by the STB decoder, and that may help in better evaluating the video reproduction process that takes place at the decoder.

B.2 Frame rate analysis

Television standards use 30 or 25 frames per second.

The output of the decoder will produce exactly this frame rate, except in the presence of video information loss. Measure of the frame rate at the output of the decoder gives a rough estimate of the continuity of the service.

Figure B.1 shows, as an example, possible information that can be retrieved through frame rate analysis:

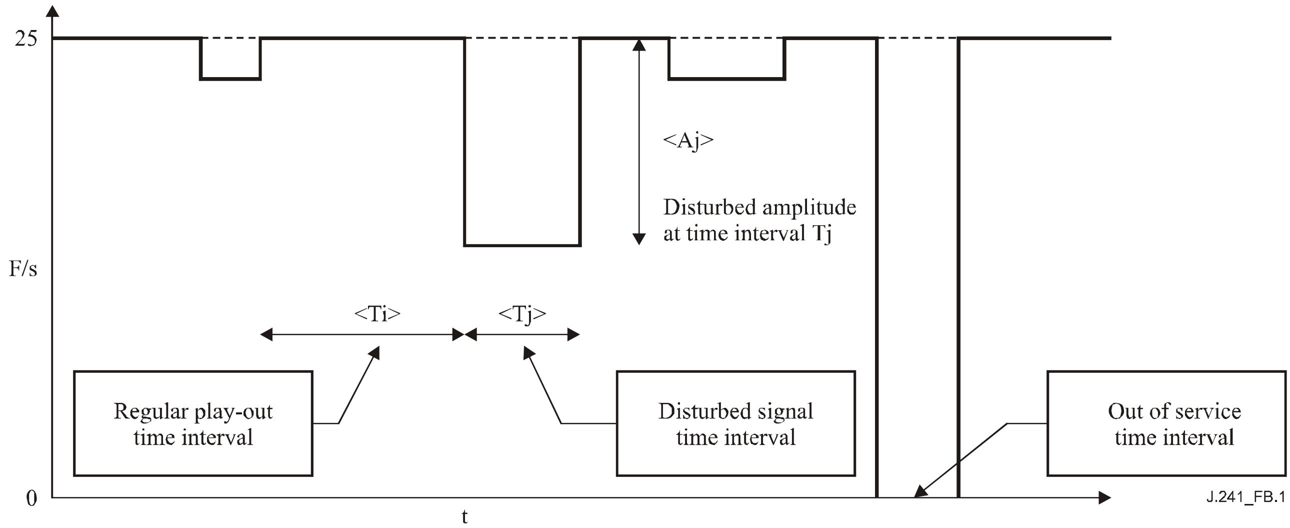

Figure B.1/J.241 – Possible information that can be retrieved through frame rate analysis

Annex C

IP layer

C.1 IP – transport requirements

IP networks are multi-hop, may be complex and different transmission technologies are usually employed along the network paths. The TCP/IP protocol stack sees all these as "below layer 3" layers.

Measurements and quality parameters at the IP layer make it possible to define reference values for network requirements that are agnostic of the underlying transmission technologies and are suitable for use in end-to-end quality assessment.

The noise introduced in an IP packet network is described by the following parameters:

– Packet loss ratio: The ratio between the number of the packets lost in the network and the total number of transmitted packets[1].
– Latency: The time interval between initial transmission and final reception of a packet.
– Jitter: The latency variation.

The quality of the video streams will impose a minimum value for the downstream throughput requirements; upstream end-to-end throughput requirements depend on application interactivity requirements.

[1] According to the measurement scheme and the methodology proposed in this Recommendation, the total number of lost packets in the Packet Loss Ratio parameter is the sum of IP lost packets (IPLR) and IP errored packets (IPER) as defined in ITU-T Rec. Y.1541. A more complete definition of this parameter is given in ITU-T Rec. G.1020, where clause 7.7 defines "Overall Loss Ratio" for frames or packets. Being the measurement header on top of the transport layer, if, for an IP packet, the IP or UDP checksum fails, this packet will not be presented to the measurement (or RTP) layer.

C.2 Video streaming IP service class

Video services, such as VoD or TV services, are classified also as streaming services. In a high-quality television environment, they have the following high-level requirements:

– good audio/video quality;

– high availability;

– medium interactivity.

These high-level requirements should be translated into values for transport requirements for an IP network.

As specified in Annex A, it is up to the head-end to introduce good quality video content into the network according to the maximum end-to-end bandwidth and packet rate available for video services. Any packet loss will reduce the quality of the video.

To preserve good quality of the image, a low value of packet loss is required.

C.3 IP transport measurements

The IP network layer should be unaware if the video signal, or any upper layer, is employing FEC or any error-correction techniques, and it should only guarantee the performance needed before any error-correction scheme is applied at any of the above layers.

C.3.1 Parameters

The table below lists IP network measurement parameters. All measurements should be taken from point B to point C in the system measurement model described in Annex A:

Parameter	Equipment	Motivation	Monitoring method
Packet loss ratio (PLR)	CPE (STB)	Image quality, video information loss estimation	In service or through test streams with RTP/RTCP or sequence numbers available on packet header. Periodic PLR summary. Reports with one-minute resolution. Measurement of PLR requires analysis of a number of packets at least 10 times greater than the number related to the target PLR value. This determines the rate at which the PLR is reported.
Network latency	Test probe at user side, within CPE (STB) or as closest as possible to user access link.	Smooth play-out	Test stream
Jitter	CPE (STB)	Smooth play-out	In service or through test streams with RTP/RTCP or timestamps available on packet header.
Downstream throughput	CPE (STB)	Service qualification, monitoring	Test signal representative of worst case encoding scenario, throughput test
Upstream throughput	CPE (STB)	Service qualification, monitoring	Throughput test

C.3.2 Values

Before giving reference values for transport requirements, it is important to note that in video services delivery architecture, a receiver buffer is employed at the CPE (STB) end to eliminate (to some extent) the jitter introduced by the network and to have a continuous video frame reproduction.

Values that should be achieved in the network are outlined and motivated in the following subclauses.

C.3.2.1 PLR value

It is preferable to specify PLR value that is "codec independent" and dimensioned on a worst-case scenario.

The PLR value needed to guarantee that an IP network seamlessly delivers video services is 10^{-5}.

The requirement for PLR < 10^{-5} is considerably more stringent than the IPLR objectives currently specified in ITU-T Rec. Y.1541. However, there are plans to support digital video transport with some new QoS Classes with the value of IPLR < 10^{-5}.

A PLR of 10^{-5} may appear a stringent requirement for the PLR. A rough estimation is done considering that potentially any video information loss will be noticed by the user.

The actual result of a packet loss is not predictable since it depends on the type of frame that is corrupted or on the part of the frame that is missing at the decoder (foreground, background, spatial, temporal, etc.). The degree of signal recovery in the presence of a certain loss depends on the power of the codec itself. Finally, the kind of scene that is being reproduced (steady, moving, etc.) greatly influences the chance that the user perceives video signal degradation.

To further reduce the BER offered to the video decoder, typical error-correction schemes can be applied on the video streams.

C.3.2.2 Latency and jitter

Latency and jitter values may vary according to specific multimedia service characteristics, such as interactivity, and according to the size of the de-jitter buffer and of the play-out delay employed at the CPE (STB) side.

For example, for high quality video streaming services, latency in the order of hundreds of milliseconds and jitter in the order of tenths of milliseconds may be tolerated.

It is recognized that the definition of objective values for jitter and latency needs further study, even taking into account the different application interactivity evolution, such as videoconferencing, which will impact the traditionally mainly unidirectional television service.

C.4 IP end-to-end service availability

The video service availability depends on the availability of all the elements that are controlled by the operator and that are significant for video service distribution, from the network device closest to the video source, to the access device closest to the user.

A classification of IP service availability is found in ITU-T Rec. Y.1540, a video streaming services availability function can be defined using the same approach: If PLR > PLR_out, then the service may be considered unavailable.

A value of 0.01 is proposed for PLR_out.

This value refers to a system where no FEC is employed; further study defining the FEC scheme, may, in the future, result in defining a different value for PLR_out. This evolution will be reflected in this Recommendation.

C.5 IP network service classification

In relation to video services, the performance of an IP network can be classified based on the value of PLR offered to the end user. The PLR must be measured between points B and C of the system measurement model described in Annex A.

In relation to the delivery of video services, the inclusion of the effect of latency and jitter for IP network classification purposes, as well as the evaluation of the impact of the definition of a FEC system needs further study.

Appendix I

Example of an IP network service classification

This appendix provides, for information, a description of the IP network service classification currently used by a major service provider for its own operation.

The classification used for digital television services is shown below:

$PLR \leq 10^{-5}$	excellent service quality (ESQ)
$PLR < 2 \times 10^{-4} - 10^{-5} >$	intermediate service quality (ISQ)
$PLR < PLR\_out - 2 \times 10^{-4} >$	poor service quality (PSQ)
$PLR < PLR\_out - 1 >$	IP end-to-end service not available.

The table below shows IP layer service classes that are related to the QoS service perceived by the end user. The picture quality also depends on encoding conditions (bit rate, picture size, intra refreshing method, etc.) and transmission parameters (packet size, FEC, etc.).

The evaluation interval for end-to-end service availability is from 1 to 5 minutes.

The network service classification is based on an evaluation interval of 30 minutes.

The end-to-end performance of an IP network can then be calculated adding up the time intervals in which the measured PLR was within the thresholds above during the reported time slot. This is shown in the following example:

Class	% time ESQ	% time ISQ	% time PSQ	Note
A	≥ 99.8	between 0 and 0.2	between 0 and 0.1	To be computed in service
B	≥ 99.8	between 0 and 0.1	between 0.1 and 0.2	To be computed in service
C	< 99.8	/	/	To be computed in service

The end-to-end unavailable service time is not included in the above example.

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