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GSTP-IPTV-QoS
Performance metrics for end-to-end IPTV video quality

Summary

This Technical Paper describes useful QoS performance metrics for video quality of IPTV service in all domains of IPTV architecture intended to enhance end-to-end video quality and, as a result, improving quality of experience of end-users. Detailed explanation of measurement methodologies of these metrics on each domain from headend to home network is presented.

Keywords

IPTV, monitoring points, video quality, performance parameters, QoS.

Change Log

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NOTE – This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this Publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

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Technical Paper ITU-T GSTP-IPTV-QoS

Performance metrics for end-to-end IPTV video quality

1 Scope

This Technical Paper describes useful QoS performance metrics for video quality of IPTV service in all domains of IPTV architecture intended to enhance end-to-end video quality and, as a result, improving quality of experience of end-users.

Delivering high quality IPTV service requires performance metrics to be monitored at a number of different points in the complete end-to-end architecture. For each performance metric in each domain from headend to home network, detailed explanation of calculation method is presented in this Technical Paper. Also, for each domain, all metrics are categorized into four level:

– The video quality metrics;

– The server performance metrics;

– The transport metrics;

– The client metrics.

2 References

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3 Definitions

3.1 Terms defined elsewhere

This Technical Paper uses the following term defined elsewhere:

3.1.1 video on demand (VOD) [ITU-T Y.1910]: A service in which the end user can, on demand, select and view video content and where the end user can control the temporal order in which the video content is viewed (e.g., the ability to start the viewing, pause, fast forward, rewind, etc.).

3.2 Terms defined in this Technical Paper

This Technical Paper defines the following terms:

3.2.1 timeshift TV: A feature that allows customers to stop/resume, rewind or restart the content during live media streaming with time shifting feature.

3.2.2 catch-up TV: A feature that allows customers to watch old programs listed on the electronic program guide for selected live TV channel. Majority of catch-up TV content is within the current and last day.

4 Abbreviations

This Technical Paper uses the following abbreviations and acronyms:

ACR Absolute Category Rating

ADSL Asymmetric Digital Subscriber Line

CDN Content Delivery Network

CM Content Manager

CPE Customer Premise Equipment

CRC Cyclic Redundancy Check

DF Delay Factor

DHCP Dynamic Host Configuration Protocol

DRM Digital Rights Management

DSL Digital Subscriber Line

DSLAM Digital Subscriber Line Access Multiplexer

EPG	Electronic Program Guide
FEC	Forward Error Correction
FFW	Fast ForWard
GOP	Group of Pictures
GUI	Graphical User Interface
HD	High Definition
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPTV	Internet Protocol Television
MDI	Media Delivery Index
MDN	Media Delivery Network
MLR	Media Loss Rate
MOS	Mean Opinion Score
MPLS	Multi-Protocol Label Switch
MPEG	Moving Pictures Experts Group
MTBE	Mean Time Between Error
MTBR	Mean Time Between Resynch
MW	Middle Ware
NTP	Network Time Protocol
PAT	Program Association Table
PID	Packet Identifier
PMT	Program Map Tables
PTS	Presentation Time Stamp
QoE	Quality of Experience
QoS	Quality of Service
RTP	Real Time Transport Protocol
RTCP	RTP Control Protocol
RTSP	Real Time Streaming Protocol
SD	Standard Definition
STB	Set-Top Box
TS	Transport Stream
VCR	Video Cassette Recorder
VDSL	Very High Speed Digital Subscriber Line
VOD	Video on Demand

5 Monitoring domains and monitoring points for IPTV architecture

Delivering high quality IPTV service requires performance metrics to be monitored at a number of different points in the complete end-to-end chain, including the customer premises, key aggregation points and at interconnect points between disparate and service provider network domains. [ITU-T G.1082] defines IPTV performance monitoring points covering all domains as shown in Figure 1.

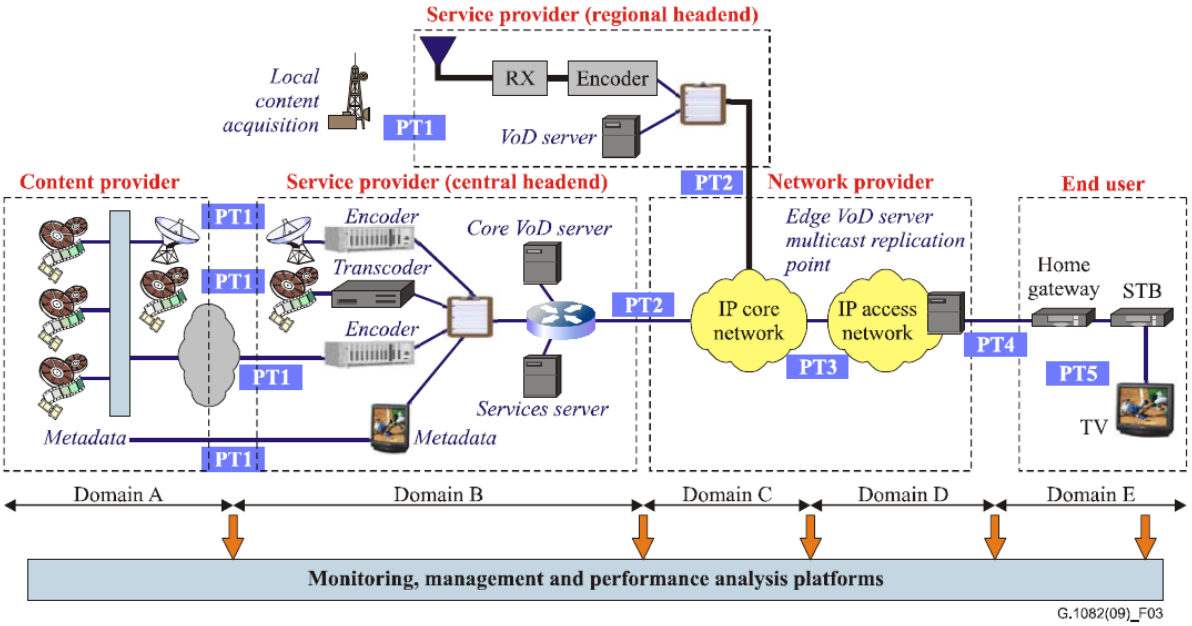

Figure 1 – IPTV performance monitoring points

5.1 Monitoring domains

As mentioned in [ITU-T G.1082], Domain A provides content-related information, which is outside of the scope of this Technical Paper.

Domain B, namely Headend, selects and processes video signals obtained from satellite and delivers them through an MPLS/Core network. A variety of equipment is used at the headend, including antennas and satellite dishes to receive signals, preamplifiers, frequency converters, demodulators, modulators and servers (such as middleware, DRM, etc.).

Domain C, namely IP Core Network, primarily provides interconnection and transfer between edge networks (Headend and Access Network). Core network transmits television signals (live channels) throughout a large geographic area. In addition, it provides individual connection to CDNs for stored media programs (such as video on demand programming).

Domain D, namely Access Network, connects individual subscribers and devices to IP Core Network. IPTV access networks can be xDSL (ADSL, VDSL) or optical lines. In this Technical Paper, the access network is considered as part of the fixed network. Performance metrics for other access types like 4G should also be considered.

Domain E, namely Home Network, directly relates to end-user QoE. Home network consists of Modem (CPE), STB and TV. In this Technical Paper, the access network is considered as part of the fixed network. For considerations of other access types, home network devices should be reconsidered, and related performance metrics should be discussed.

5.2 Monitoring points

As mentioned in [ITU-T G.1082], Domain A provides content-related information, which is outside of the scope of this Technical Paper and thus monitoring point 1 is also outside of the scope.

Monitoring point 2 is located between headend and IP core network. As mentioned in [ITU-T G.1081], it may help to measure performance parameters of service-related servers and VOD servers at the core node of service provider.

Monitoring point 3 is located between the IP core and IP access networks. As mentioned in [ITU-T G.1081], it may help to measure IP-related performance parameters and be placed on any type of interface between the IPTV core network and the access network.

Monitoring point 4 is located between the IP access and home networks. It may help to measure parameters related to error controlling techniques for data transmission through access line.

As mentioned in [ITU-T G.1081], Monitoring point 5 is at the final end-point and directly relates to end-user QoE since it enables to measure IPTV service attributes as perceived by the end-user.

In section 6, some performance metrics to monitor are recommended for each monitoring point.

6 Overall IPTV service event flow

In general, the messages during STB boot up process are similar for all manufacturer. Basically, STB retrievals IP address and system time zone info. At the end of authentication phase, a list of some required applications (such as user interface, channel list, electronic program guide, DRM keys etc.) are downloaded. When subscribers make request for a content, video streaming process begins. In this stage, the message types and streaming protocols may vary depending to broadcast options either multicast or unicast.

The end-to-end IPTV quality approach requires identifying and measuring all these processes with possible KPIs.

Figure 2 depicts the basis for a generic service concept for IPTV broadcast.

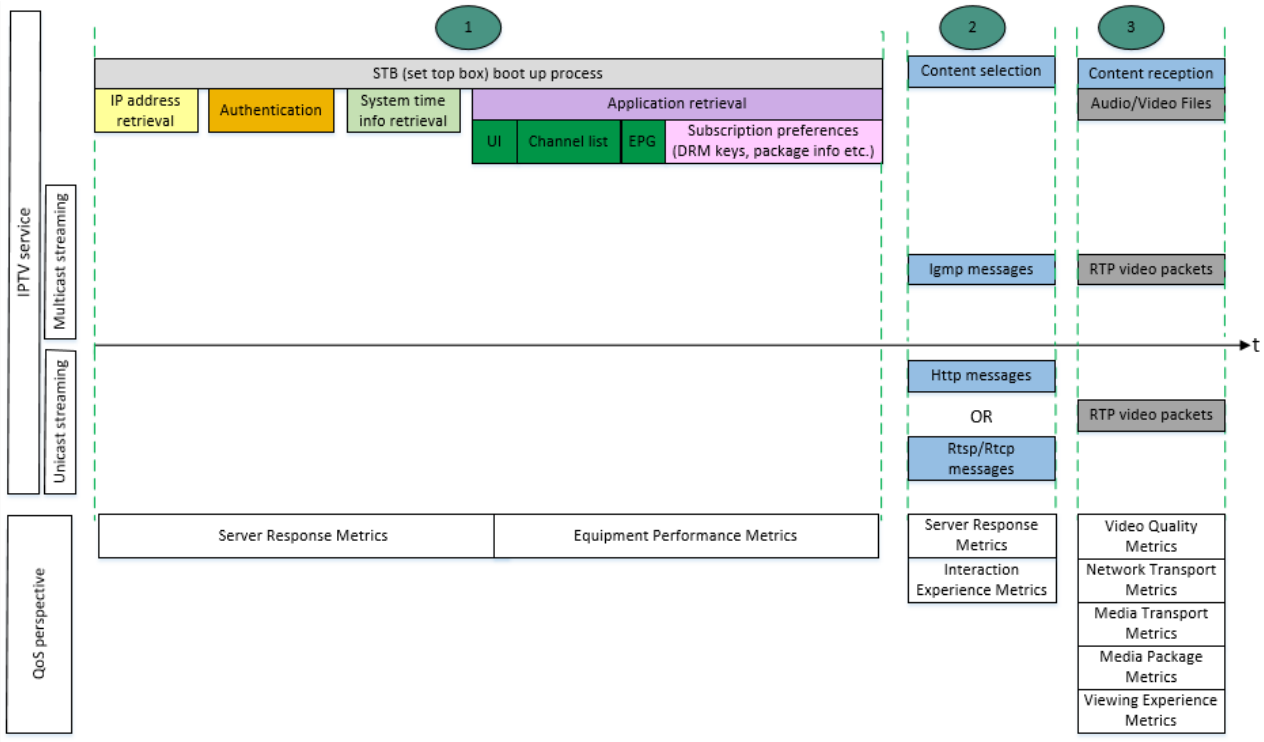

Figure 2 – Overall IPTV Service Event Flow

7 Performance parameters for video quality of IPTV

It is proposed that metrics recommended in this part shall be reviewed and assessed for creation of a new Recommendation to generate an integrated document to bring together the most critical performance metrics of video quality at each domain in IPTV architecture, to explain why that metric is important and how it can be measured. These metrics are selected after an extensive research of worldwide literature and references.

For each domain from headend to home network, the listed metrics may not be able to be correctly monitored due to the encrypted media stream. To solve the problem, measurement points should be authorized by the IPTV service providers to obtain enough information.

For access and home network, performance metrics are for fixed network. For other access technology types, other related metrics should be considered.

Some metrics may be monitored by multiple domains. For example, network problems in each domain can lead to packet loss.

All the metrics can be divided in to four categories: video quality metrics, server performance metrics, network metrics and client metrics.

7.1 Video quality metrics

Video quality the basic factor that determines the user's video experience. The metrics affecting video quality include video bit rate, resolution, frame rate and so on. These metrics will affect the clarity and fluency of the video. Video quality metrics can be monitored before and after transcoding in the headend. Also, we can monitor these metrics by the software probe planted in the STB in the home network.

7.1.1 Video quality metrics

Performance metrics for video quality are described in Table 1.

Table 1 − Performance metrics video quality

Metric(unit)	Domain	Description	Calculation/Derivation
Video MOS	HEAD/STB	Video MOS is the mean opinion scores (MOS) on a five-point ACR scale. Score 1 to score 5 respectively represent bad, poor, average, good, excellent view experience to users.	ITU has published a series of recommendations for MOS calculation. For IPTV, if the video MOS is monitored at the headend, models proposed in [ITU-T J.144], [ITU-T J.341] and [ITU-T P.1204.4] can be used for the SD, HD and 4K video respectively. If the video MOS is monitored at the STB, models proposed in [ITU-T P.1201] and [ITU-T P.1202] are suggested.
Video Bit Rate (Mb/s)	HEADEND	Video Bit Rate is the number of bits per second. It generally determines the size and quality of video files: the higher the bitrate, the better the quality and the larger the file size. In general, a higher bitrate will accommodate higher image quality in the video output.	Video resolution can be obtained from media stream information. The unit of the video rate is Mbps. The calculation formula of video rate is : Video Rate = Video File Size * 8 / Video Length The unit of the video file size is MB, and the unit of the video length is the time seconds

Table 1 − Performance metrics video quality

Metric(unit)	Domain	Description	Calculation/Derivation
Video Resolution	HEADEND	Video Resolution is a measure of the amount of detail in an video image.Video Resolution determines the clarity of the video.	Video resolution can be obtained from media stream information. Taking H.264 code stream as an example, the information on the H.264 stream is stored in SPS (Sequence Parameter Set). There are two members in the SPS, pic_width_in_mbs_minus1 and pic_night_in_map_units_minus_1, indicating the width and height of the image. The calculation formula of video resolution is : Video Resolution = (pic_width_in_mbs_minus1 + 1)*16 * (pic_height_in_map_units_minus_1+1)*16
Frame Rate (fps)	HEADEND	Frame rate is the frequency at which images in frames appear continuously on the display. Frame rate will affect the fluency of the video.	Frame rate can be obtained from media stream information. The calculation formula of frame rate is : Frame Rate = Video Frames number/ Video time Length. Frame rate can be set when the video is encoded or decoded.

7.2 Server performance metrics

Server performance metrics reflect the performance of the servers like transcoders, VoD servers, service servers, CDN servers, etc. These metrics can be monitored in the headend, IP core network and the homework. From the perspective of users, we can also divide these metrics into two categories: media package metrics and server response metrics.

7.2.1 Media package metrics

Performance metrics for media package are described in Table 2.

Table 2 – Performance metrics for media package

Metric(unit)	Domain	Description	Calculation/Derivation
TS_sync_loss	CORE NETWORK	When the transport stream is out of sync, it means that some data will be lost during the transmission process, which will directly affect the quality of the decoded picture. Details can be found in [ETSI TR 101 290].	In the transport stream, it is proposed that five consecutive correct sync bytes should be sufficient for sync acquisition, and two or more consecutive corrupted sync bytes should indicate sync loss.
Sync_byte_error	CORE NETWORK	This error indicates that some data has an error during transmission, which may cause mosaic, and more seriously, the decoder may not be able to solve the signal when it is serious. Details can be found in [ETSI TR 101 290].	In the transport stream, if the Sync_byte does not equal 0x47, it means that there is Sync_byte_error. The indicator is set as soon as the correct sync byte (0x47) does not appear after 188 or 204 bytes.

Table 2 – Performance metrics for media package

Metric(unit)	Domain	Description	Calculation/Derivation
PAT_error	CORE NETWORK	The Program Association Table (PAT), which only appears in PID 0x0000 packets, tells the decoder what programs are in the TS and points to the Program Map Tables (PMT) which in turn point to the component video, audio and data streams that make up the program. If the PAT is missing then the decoder can do nothing, no program is decodable. Details can be found in [ETSI TR 101 290].	If the PID identifying PAT does not appear at least once for 0.5s, or the packet with PID of 0x0000 has no content, or the encryption control segment in the packet with PID of 0x0000 is not zero, it means that there is PAT_error.
Continuity_count_error	CORE NETWORK	This error indicates that the current transport stream has packet loss, error packets, packet overlap, etc., which will result in the decoder decoding incorrectly, and the image appears mosaic. Details can be found in [ETSI TR 101 290].	The continuity counter is a 4-bit field incrementing with each Transport Stream packet with the same PID. The continuity counter wraps around to 0 after its maximum value. If the packets come in the incorrect order or a packet occurs more than twice, or there is packet lost it means that there is Continuity_count_error.
PMT_error	CORE NETWORK	The Program Association Table (PAT) tells the decoder how many programs there are in the stream and points to the PMTs which contain the information where the parts for any given event can be found. Parts in this context are the video stream (normally one) and the audio streams and the data stream (e.g., Teletext). Without a PMT the corresponding program is not decodable. When the PMT is encrypted, the decoder cannot search for the corresponding program. If the PMT times out, the decoder switching program time will be affected. Details can be found in [ETSI TR 101 290].	PMT error means that sections with PMT do not occur at least 0.5 second on the PID which is referred to in the PAT or the scrambling_control_field is not 0 for all PIDs containing sections with PMT.
PID_error	CORE NETWORK	It is checked whether there exists a data stream for each PID that occurs. This error might occur where TS are multiplexed, or demultiplexed and again remultiplexed. Details can be found in [ETSI TR 101 290].	A PID error means that the TS packet of one PID specified in a PMT does not exist in the TS stream; or the repetition interval of the TS packet of the PID is greater than the user-defined interval (usually 500ms).

Table 2 – Performance metrics for media package

Metric(unit)	Domain	Description	Calculation/Derivation
Transport_error	CORE NETWORK	Each TS packet contains a Transport_error_indicator that flags whether the receiver has detected an unrepairable TS packet error. If error protection could not fix all errors in the package, this indicator will be set, and the TS packet must be discarded. This metric shows the statistical evaluation of the errors. Details can be found in [ETSI TR 101 290].	If the Transport_error_indicator in the TS-Header is set to "1", it means that the Transport_error occurs.
PTS_error	CORE NETWORK	The Presentation Time Stamp (PTS) should occur at least every 700 ms. They are only accessible if the TS is not scrambled. Details can be found in [ETSI TR 101 290].	If the PTS repetition period is more than 700 ms, it means that the Transport_error occurs.

7.2.2 Server response metrics

Performance metrics for server response are described in Table 3.

Table 3 − Performance metrics for server response

Metric(unit)	Domain	Description	Calculation/Derivation
STB applications availability (about server respond) (%)	HEADEND	This metric describes successability of the Middleware server to respond incoming STB application requests. Whenever STB is rebooted, it starts communication with Headend for various applications over HTTP messages. Example of STB applications are summary of EPG, advertisement info, channel list, weather forecast, etc.	Calculation can be made by a probe system which is located between MW server and loadbalancer equipment so that whole HTTP based application traffic is replicated and analyzed. It is the ratio between total number of MW server http responds with success status codes and total number of incoming all STB application http get messages [Turk Telekom IPTV Service Technical Quality Report].
IPTV broadcast outage duration (s)	HEADEND	This metric describes the amount of total downtime minutes observed for IPTV broadcast. This kind of metric has to be handled one by one channel based. It should not be thought that all customers are affected by these interruptions. Only the customer group is affected who were watching the interrupted channels during issue.	Packet by packet measurement on traffic leaving encoder can be done with a probe connected to encoder. It is the ratio between quantity of outage suffered channels times amount of outage time and total channel quantity times total measurement duration [Turk Telekom IPTV Service Technical Quality Report].

Table 3 − Performance metrics for server response

Metric(unit)	Domain	Description	Calculation/Derivation
MW STB bootup requests success rate (%)	HEADEND	This metric describes whether STBs are successfully start after they open by customers. There are various message types are created between Middleware server and STB during bootup period. The Bootstrap message is common for each box and it basically used to authentication in initialization process.	Calculation can be made by a probe system which is located between MW server and loadbalancer equipment so that whole HTTP based application traffic is replicated and only URL logs for Bootstrap messages are sorted. It is the ratio between total number of MW server http responds with success status codes and total number of incoming Bootstrap http get messages [Turk Telekom IPTV Service Technical Quality Report].
MW server VOD requests success rate (%)	HEADEND	This metric describes successful responds for HTTP based client VOD content requests.	Calculation can be made by a probe system which is located between MW server and loadbalancer equipment so that whole HTTP based application traffic is replicated and only URL addresses for VOD application messages are sorted. It is the ratio between total number of MW server http responds with success status codes and total number of incoming VOD application http get messages [Turk Telekom IPTV Service Technical Quality Report].
MW server timeshift TV requests success rate (%)	HEADEND	This metric describes successful responds for HTTP based client timeshift TV interactions.	Calculation can be made by a probe system which is located between MW server and loadbalancer equipment so that whole HTTP based application traffic is replicated and only URL addresses for timeshift TV application messages are sorted. It is the ratio between total number of MW server http responds with success status codes and total number of incoming timeshift TV application http get messages [Turk Telekom IPTV Service Technical Quality Report].
MW server catch-up TV requests success rate (%)	HEADEND	This metric describes successful responds for HTTP based client catch-up TV interactions.	Calculation can be made by a probe system which is located between MW server and load balancer equipment so that whole HTTP based application traffic is replicated and only URL addresses for catch-up TV application messages are sorted. It is the ratio between total number of MW server http responds with success status codes and total number of incoming catch-up TV application http get messages [Turk Telekom IPTV Service Technical Quality Report].

Table 3 − Performance metrics for server response

Metric(unit)	Domain	Description	Calculation/Derivation
DHCP/NTP server response time (s)	CORE NETWORK	This metric describes total time elapsed for DHCP/NTP server responds for receiving IP from DHCP server and time zone info from NTP server. Each modem receives an IP address (10.x.y.z subnet) by DHCP server as distinct from default internet address. Thus, IPTV traffic and internet traffic are isolated from each other. The newly started STB device (during boot-up period) firstly requests time zone info from NTP server. Than it keeps to making further steps (like key Exchange request from DRM server, multicast channel list request, sending first join message to default channel etc.).	Calculation can be made by obtaining DHCP/NTP server's response time by simulating the following steps using probe system: DHCP Discover->DHCP Offer->DHCP Request->DHCP Ack & Clock Synchronization Request Packet->Response Packet->Synchronize It is total time elapsed through all these steps [Turk Telekom IPTV Service Technical Quality Report].

7.3 Transport metrics

Transport metrics can be monitored from the headend to the homework.

From the perspective of the transport content, we can also divide these metrics into two categories: media transport metrics and network transport metrics.

7.3.1 Media transport metrics

Performance metrics for media transport are described in Table 4.

Table 4 − Performance metrics for media transport

Metric(unit)	Domain	Description	Calculation/Derivation
Delay factor (s)	CORE NETWORK	This metric describes how long a data stream must be buffered at its nominal flow bit rate to avoid packet loss. It gives a hint for minimum size of buffer required at the next downstream node.	Calculation can be made at every packet arrival. It is the maximum observed value of the flow rate imbalance over a calculation period. The difference between media payload size received and drained over a 1 second period is computed. Then observed maximum difference is divided by the nominal media flow rate. Details can be found in [RFC 4445].
MLR	CORE NETWORK	The unit of MLR is the number of media packet losses per second. This value indicates the transmission packet loss rate of the video stream under test. Because the packet loss of video information will directly affect the video playback quality, the ideal IP video stream transmission requires the MLR value to be zero. Because specific video playback equipment can compensate for packet loss through video	Calculation can be made at every packet arrival. The Media Loss Rate is the count of lost or out-of-order flow packets over a selected time interval, where the flow packets are packets carrying streaming application information. There may be zero or more streaming packets in a single IP packet. Details can be found in [RFC 4445].

Table 4 − Performance metrics for media transport

Metric(unit)	Domain	Description	Calculation/Derivation
		decoding or packet retransmission, the MLR threshold can be adjusted accordingly in actual tests.	
Loss distance	CORE NETWORK	This metric describes the spacing between loss periods. It helps characterize the importance of loss events in a flow. It can be used with other parameters to determine the level of FEC overhead required for reconstructing packets in the presence of loss for a given FEC algorithm [VSF Test and Measurement AG Report].	It is the difference in sequence numbers of two successively lost packets. Example: In a packet stream, the packets with sequence numbers 10-20 is considered lost, followed by the packets with sequence numbers 50-55. The loss distance is 30 Details can be found in [RFC 3357].
Index File Request Successful Ratio (%)	HOME NETWORK	If the STB start an index file HTTP request and receive the HTTP response within 4 seconds, it means that a successful request was finished.	It is calculated by the ratio between the M3U8 request successful times and the total times. This metric can be obtained by the player in the STB.
Index File Request Delay (s)	HOME NETWORK	The index file request delay is defined as the length of time for the terminal to receive the video index information returned by the video server from initiating the video index request to the video scheduling server.	It is calculated by the delay between the STB starting an index file HTTP request and receiving the HTTP response. This metric is obtained by capturing the network packets.
TS File Request Successful Ratio (%)	HOME NETWORK	If the STB start a HTTP request and receive the HTTP response within 4 seconds, it means that a successful request was finished.	It is calculated by the ratio between the TS file request successful times and the total times. This metric is obtained by capturing the network packets.
TS File Request Delay(s)	HOME NETWORK	The average delay of the media file request during the current sampling interval (the time from HTTPGET to receipt of an HTTP reply).	It is calculated by the delay between the STB starting an index file HTTP request and receiving the HTTP response. This metric is obtained by capturing the network packets.
TS File Downloading Quality(s)	HOME NETWORK	If the downloading time is longer than the playing time, the user side will display a frozen picture. If the downloading time is shorter than the playing time, the user will have a good viewing experience.	It is calculated by the playing time of a TS file' minus its downloading time This metric is obtained by capturing the network packets.
TS File Request Interval(s)	HOME NETWORK	If the interval is longer than a TS file playing time, the user side will display a frozen picture. If the interval is shorter than a TS file playing time, the user will have a good viewing experience.	It is the interval between the next TS file's initial requesting time and the previous TS file's requesting time. This metric is obtained by capturing the network packets.

7.3.2 Network transport metrics

Performance metrics for network transport are described in Table 5.

Table 5 − Performance metrics for network transport

Metric(unit)	Domain	Description	Calculation/Derivation
Channel availability (%)	CORE NETWORK	This metric describes how much time the multicast channel is accessible in core network.	Calculation can be made by IPTV probes in the core network that send multicast join packets through network for the defined sample HD and SD channels. It is the ratio between total outage time and total measurement time [Turk Telekom IPTV Service Technical Quality Report].
VOD session quality	CORE NETWORK	This metric describes whether VOD sessions has been established and terminated successfully. Purpose is to observe quality parameters for VOD streaming sessions. This metric is significant if RTP transmission protocol is used for unicast streaming services.	Mostly RTP is used with RTCP protocol that provides some quality parameter about transmission. The primary function of RTCP is to provide feedback on the quality of service being provided by RTP. STB and CM (Content Manager in MDN) communicate periodically during VOD sessions. Transmission statistics and quality informations such as octet and packet counts, jitter, and round-trip time realizations are calculated over RTCP logs on CM equipment. [Turk Telekom IPTV Service Technical Quality Report].
Frequency of burst lost packets	CORE NETWORK	This metric describes number of events of loss period length that occur over a user settable measurement period. The loss period length defined in [RFC 3357] captures the number of consecutive packets lost in a loss period and represents the burstiness of each loss period. Knowing distribution of burst loss sizes may be useful for optimizing FEC settings. It can help to determine how heavy FEC scheme is needed to protect video traffic.	It is the total number of burst losses of size n packets over user defined measurement period. If burst loss packet threshold is defined as n packets, then each time the loss period length is greater than n packets, total number of burst losses of size n will increase by 1 [VSF Test and Measurement AG Report].
FEC blocks with loss	ACCESS NETWORK	This metric is useful to determine quality of FEC protected IP flow at a high level. Increase of value of this metric indicates video corruption.	It is the number of FEC blocks that have at least one unrecoverable packet by FEC decoder [VSF Test and Measurement AG Report].
Unrecoverable IP packets count	ACCESS NETWORK	This metric describes the number of packets that are lost following FEC processing and will result in video stream corruption. It is useful to calculate IP loss rate of the FEC protected network.	It is the count of data packets in a block that can not be recovered after FEC decoding completed [VSF Test and Measurement AG Report].
Mean time between error (MTBE) (%)	ACCESS NETWORK	This metric classifies each subscriber's copper network such as stable, unstable or risky according to MTBE (Mean Time Between Error) value.	It is the ratio between numbers of CRC errors and uptime period of DSL line.

Table 5 − Performance metrics for network transport

Metric(unit)	Domain	Description	Calculation/Derivation
Mean time between resynch (MTBR) (%)	ACCESS NETWORK	This metric classifies each subscriber's copper network such as stable, unstable or risky according to MTBR (Mean Time Between Resynch) value. DSLAMs and modern routers can differentiate source of resync whether it stems from network or subscriber (e.g., reconnection of modem, power down of modem by end user) and resyncs due to subscriber's action are not included into calculation.	It is the ratio between numbers of resynch and uptime period of DSL line.
STB Downlink Bandwidth (Mbps)	HOME NETWORK	The downlink bandwidth of the STB determines the data transmission rate of downloading video from the network. The larger the bandwidth is, the shorter the STB buffering delay is, the more smoothly the videos play.	This metric can be obtained from the system software of the STB.
STB Uplink Bandwidth (Mbps)	HOME NETWORK	The uplink bandwidth of the STB determines the data transmission rate at which the STB sends information to the network. This metric may affect all the metrics related to the interaction time between and the network.	This metric can be obtained from the system software of the STB.
STB decoding delay (s)	HOME NETWORK	After the STB starts to receive and buffer a multicast stream, STB decodes buffer data to render them to the TV screen.	It is the time needed for processing buffer data and rendering them to TV screen. It also include codec decoding delay and I-frame acquisition delay. Details can be found in [ITU-T G.1080].

7.4 Client metrics

Client metrics directly relates to end-user QoE.

From the perspective of users, we can also divide these metrics into three categories: equipment performance metrics, interaction experience metrics and viewing experience metrics.

7.4.1 Equipment performance metrics

Performance metrics for equipment performance are described in Table 6.

Table 6 − Performance metrics for equipment performance

Metric(unit)	Domain	Description	Calculation/Derivation
STB Buffer Size (MB)	HOME NETWORK	The buffersize of the STB. This metric affects the STB buffering delay.	This metric can be obtained from the system software of the STB
STB Memory Occupancy (%)	HOME NETWORK	This metric reflects the fluency of the STB system which may affect the fluency of user video viewing.	It is calculated by the ratio between the occupied memory and the total memory. This metric can be obtained from the system software of the STB.

Table 6 − Performance metrics for equipment performance

Metric(unit)	Domain	Description	Calculation/Derivation
STB CPU Load (%)	HOME NETWORK	This metric also reflects the fluency of the STB system which may affect the fluency of user video viewing.	It is calculated by the sum of CPU occupancy for all tasks. The contribution of a task to CPU occupancy is calculated by the ratio between its total running time in a cycle and the total time of the cycle. This metric can be obtained from the system software of the STB.
Screen Resolution	HOME NETWORK	The resolution of the screen directly affect the clarity of video presentation.	This metric can be obtained from the STB system.
Customer modem IP retrieval performance (%)	HOME NETWORK	This metric can be helpful to clarify especially subscriber lines which suffer often DHCP and/or network issue.	It is the percentage of successfully IP obtained CPEs [Turk Telekom IPTV Service Technical Quality Report].

7.4.2 Interaction experience metrics

Performance metrics for interaction experience are described in Table 7.

Table 7 − Performance metrics for interaction experience

Metric(unit)	Domain	Description	Calculation/Derivation
Channel change time (s)	HOME NETWORK	This metric describes the time elapsed from user request of new channel by pushing button on the remote control to the display of new channel on the screen including both video and audio. It is affected by IGMP delay (IGMP leave-join messages for channel changes), STB buffering delay and STB decoding delay.	It is the total delay time that is the sum of IGMP leave/join delay, STB buffering delay and STB decoding delay. Details can be found in [ITU-T G.1080].
VOD trick latency (s)	HOME NETWORK	This metric describes the delay of each control function (video selection, play, stop, rewind, pause and FFW). This delay includes STB buffering and decoding delay.	It is the total delay time that is the sum of STB command processing delay, VOD server delay in processing commands and generating required media stream, STB buffering delay and STB decoding delay. Details can be found in [DSLF TR-126].
EPG user interface navigation responsiveness (s)	HOME NETWORK	This metric describes the interval of time elapsed between the moment the EPG button of the remote control is pushed and the moment the EPG page is displayed [ITU-T G.1080].	It is the total delay time that is the sum of time interval between the remote control action and GUI update and middleware server processing time for some functions. Details can be found in [DSLF TR-126].

7.4.3 Viewing experience metrics

Performance metrics for viewing experience are described in Table 8.

Table 8 − Performance metrics for viewing experience

Metric(unit)	Domain	Description	Calculation/Derivation
STB buffering delay (s)	HOME NETWORK	As the STB receives IPTV multicast traffic, it stacks the packets in a buffer.	It is the time from arrival of first multicast traffic in STB buffer until sufficient data to play on the screen is filled in it [ITU-T G.1080].
Abnormal Interruption Frequency	HOME NETWORK	The STB player may exit unexpectedly when a video or a program is playing.	The number of times the video unexpectedly exits during viewing. This metric can be obtained by the player in the STB.
Stalling Frequency	HOME NETWORK	The video will stall when the buffer is empty. This metric is the total frequency of the stalling during an interval.	The number of times that the video stutters when the buffer is empty during the video viewing. This metric can be obtained by the player in the STB.
Stalling Length (s)	HOME NETWORK	The video will stall when the buffer is empty. This metric is the total length of all the stalling during an interval.	The sum of the lengths of the stalling when the buffer is empty during the video viewing. This metric can be obtained by the player in the STB.
Blurring Frequency	HOME NETWORK	If there are errors in the transport stream, the video image on the terminal screen may blur. This metric is the total frequency of blurring during an interval.	The number of times that the screen blurs during the video viewing. This metric can be obtained by the player in the STB.
Blurring Length (s)	HOME NETWORK	If there are errors in the transport stream, the video image on the terminal screen may blur. This metric is the total length of blurring during an interval.	The sum of lengths that the screen blurs during the video viewing This metric can be obtained by the player in the STB.
Average Blurred Screen Area Percentage (%)	HOME NETWORK	If there are errors in the transport stream, the video image on the terminal screen may blur. This metric is the average blurred screen area during an interval.	It is calculated by the ratio of the blurred screen area percentages sum to times. This metric can be obtained by the player in the STB.