User Guide

EXpert IPTV Test Tools

IPTV Test Tools for FTB-200

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Telecom Test and Measurement

EXFO

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April 27, 2012

Version number: 2.0.0

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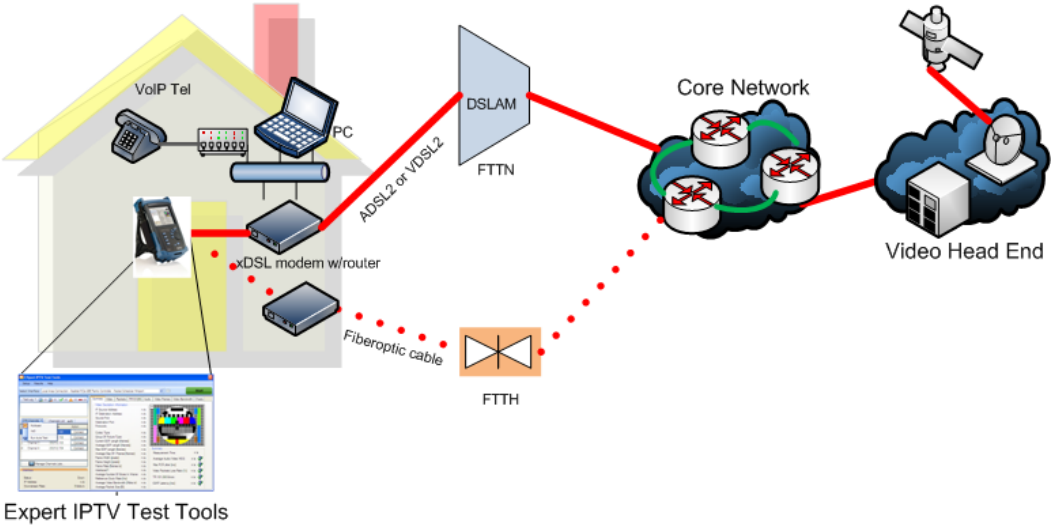
Table of Contents

Chapter 1 Introducing the EXpert IPTV Test Tools

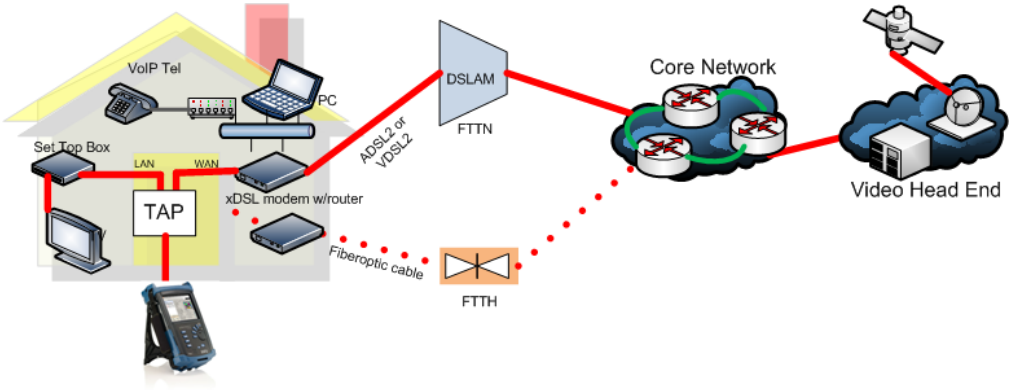
The EXpert IPTV Test Tools is a software FTB-200 based IPTV quality analyzer. It consists of several components:

- **Test Logger with multistream detection and synchronizer via the FTB-200 10/100/1000 Ethernet interface**
- **Set Top Box(STB) emulator for multicast and unicast streams**
- **Video Previewer**
- **Video Metrics**
- **Packet statistics**
- **TR 101290 Metrics**
- **Audio Metrics**
- **Video Frame Metrics**
- **Video Bandwidth Metrics**
- **Charts**

When used as a STB emulator The EXpert IPTV Test Tools is terminating the customer modem or GPON adapter.



When used as a passive monitoring device The EXpert IPTV Test Tools is connected via a manageable switch or aggregating tap to monitor bidirectionally the IGMP, RTSP and other protocols, and IPTV streams from the video server.

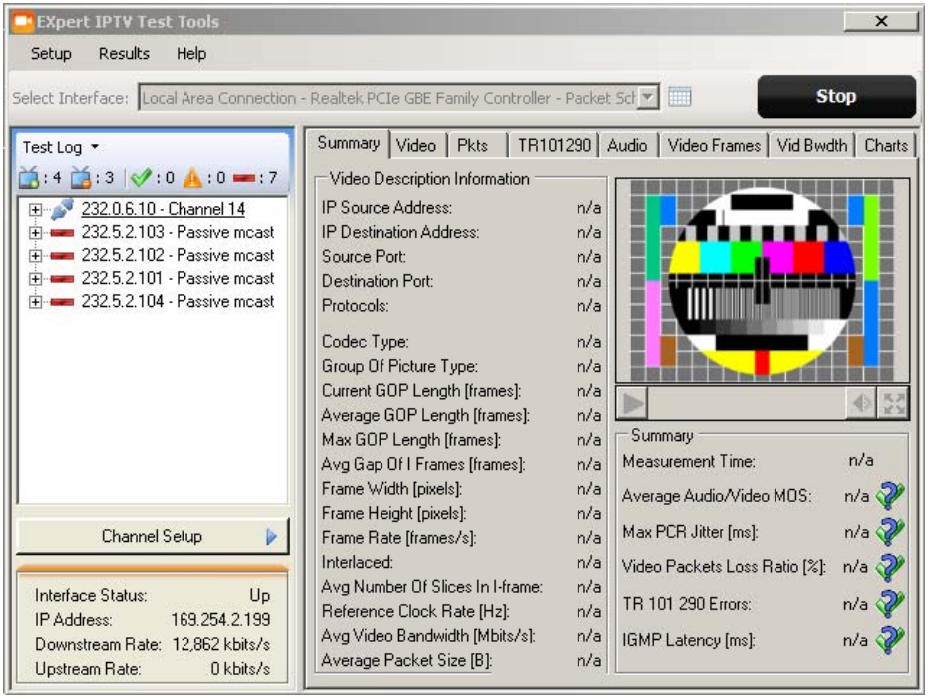


In both connection modes video and audio quality assessment is provided by VQMON algorithm.

Test results are continuously accumulated and saved on the FTB-200 hard drive. Live test results can be watched on the screen. Saved test results can be viewed in the report format, pdf format or be exported to a file.

Tested metrics can be sorted and viewed in text or graphical formats.

The example below shows The EXpert IPTV Test Tools during analysis of four IPTV streams with individual preview screens.



Conventions

Before using the product described in this guide, you should understand the following conventions:

WARNING

Indicates a potentially hazardous situation which, if not avoided, could result in *death or serious injury*. Do not proceed unless you understand and meet the required conditions.

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in *minor or moderate injury*. Do not proceed unless you understand and meet the required conditions.

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in *component damage*. Do not proceed unless you understand and meet the required conditions.

IMPORTANT

Refers to information about this product you should not overlook.

Chapter 2 Safety Information

Safety Information

Laser Safety Warnings

WARNING

Do not install or terminate fibers while a laser source is active. Never look directly into a live fiber, and ensure that your eyes are protected at all times.

Laser Safety Information

The EXpert IPTV Test Tools software is not provided with any hardware components. However, it may be used with your platform or modules which may contain laser components. Refer to the user guides of your platform or modules for further laser safety details and instructions.

Chapter 3 Getting Started

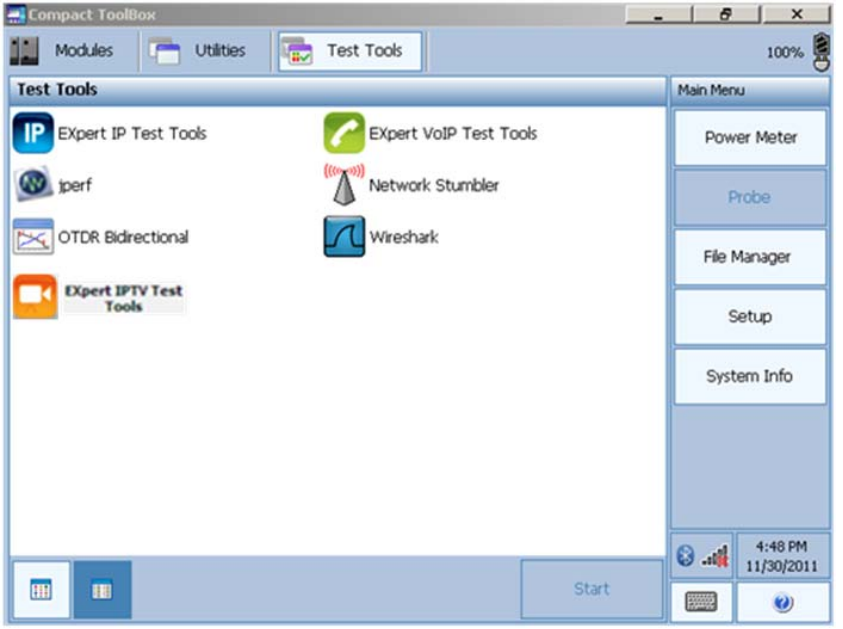
The EXpert IPTV Test Tools application is preinstalled on the FTB-200. If The EXpert IPTV Test Tools is not installed, refer to the FTB-200 User Guide for more information on how to install the application.

Starting Application

You can access many tools directly from your unit.

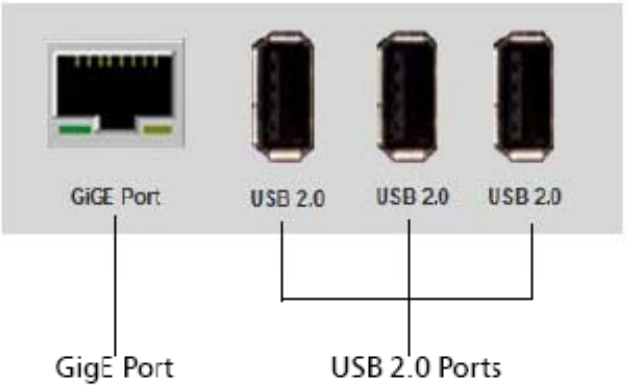
To start an application:

1. **From Compact Toolbox, select the Test Tools tab.**
2. **Click on the Expert IPTV Test Tools.**
   OR
   Select from the START menu EXFO, Tools and the Expert IPTV Test Tools.



Chapter 4 Physical Interface

The EXpert IPTV Test Tools uses the GigE port of the FTB-200.



Ethernet 10/100/1000 Mbits/s Ethernet Port

- **Connect the 10/100/1000 electrical signal with the IPTV to the port with the RJ-45 connector.**

Note: *Refer to the FTB-200 Compact Modular Platform User Guide for more information.*

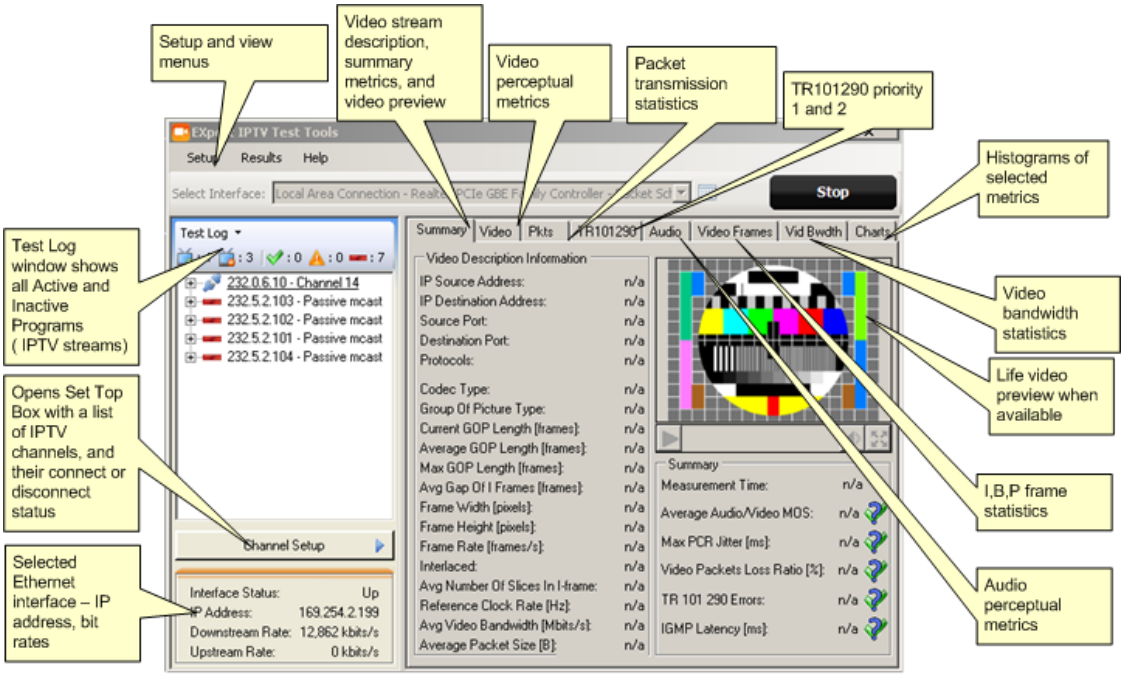
Chapter 5 Using the Graphical User Interface

This chapter describes the graphical user interface of your Expert IPTV Test Tools application.

The EXpert IPTV Test Tools allows you to start a test, connect and disconnect to IPTV streams, program and use Set Top Box, view information about the stream, view IPTV metrics and statistics, view or print test results, and more.

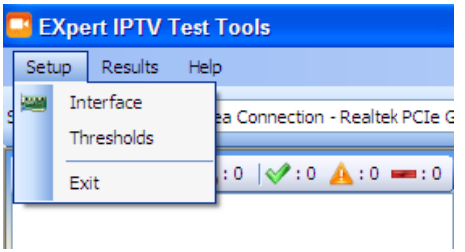
Main Window

Start the EXpert Test Tools IPTV application. The application allows to view the first level tabs and buttons for test setup and results:



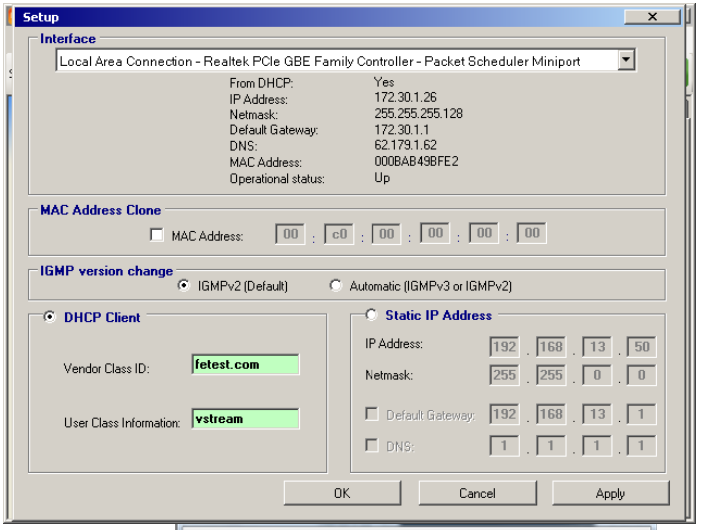
Chapter 6 Setting the IPTV Test

6.1 Setup Interface



The Expert IPTV Test Tools setup has factory defaults. Changing these defaults is necessary only if any of the following parameters is required for login process:

- **MAC address**
- **Static IP address**
- **or DHCP client-Vendor Class ID**
- **Changes in the Thresholds settings**

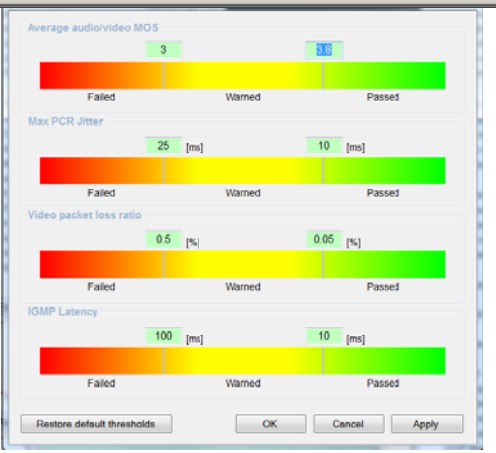


- **Local Area Connection Realtek PCIe GBE Family Controller-packet Scheduler Miniport**
- **No MAC address**
- **IGMPv2**
- **DHCP Client**

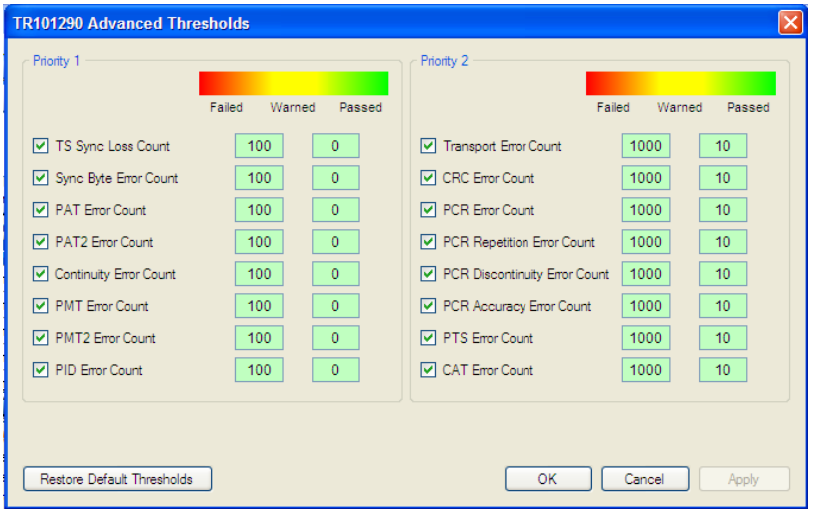
6.2 Setup Thresholds

Failed, Warned and Passed threshold parameters are preset for:

Average Audio/Video MOS, Max PCR Jitter, Video Packet Loss Ratio, IGMP Latency and TR101290. The TR101290 allows configuration or Priority 1 and 2 parameters from a separate menu as shown to the right.

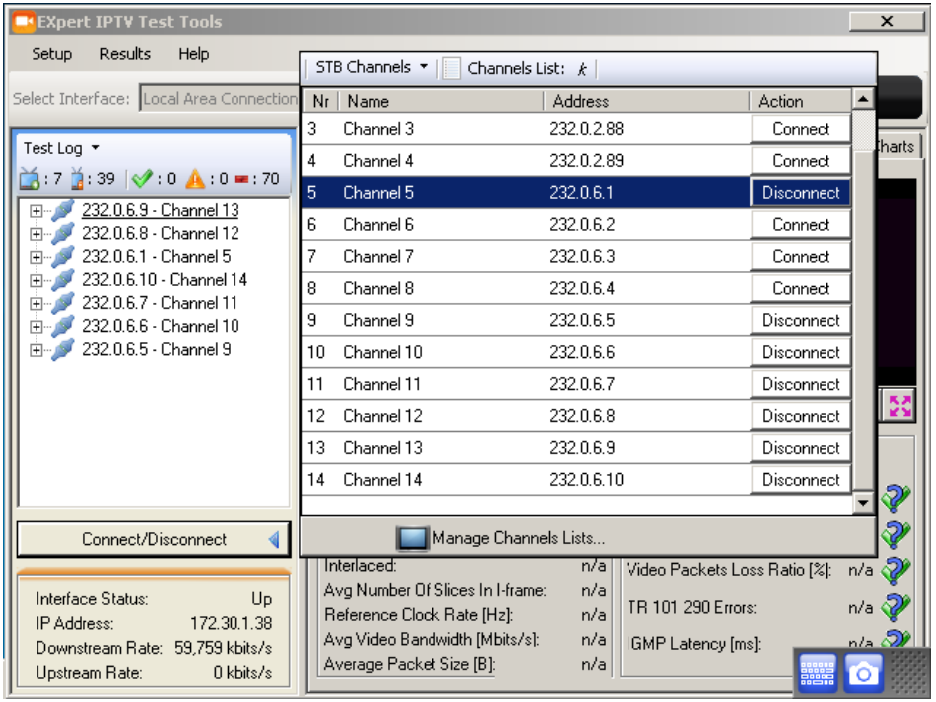


These color coded thresholds will then trigger the corresponding flags in the Summary pan. Unchecking any parameters removes it from the active metrics. Unchecking all parameters will result in  flag for the TR101290 Errors of Summary.



6.3 Manage Channel List

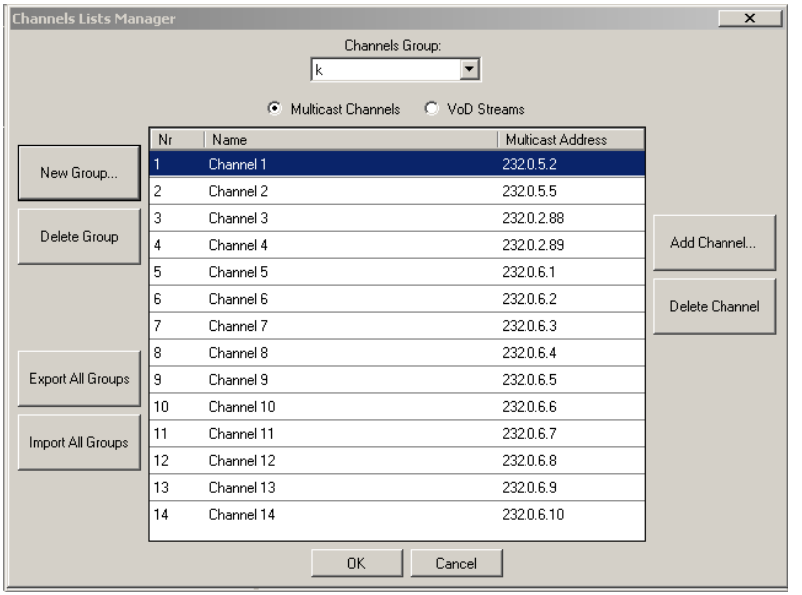
Click on Channel Setup and click again on Manage channel list.

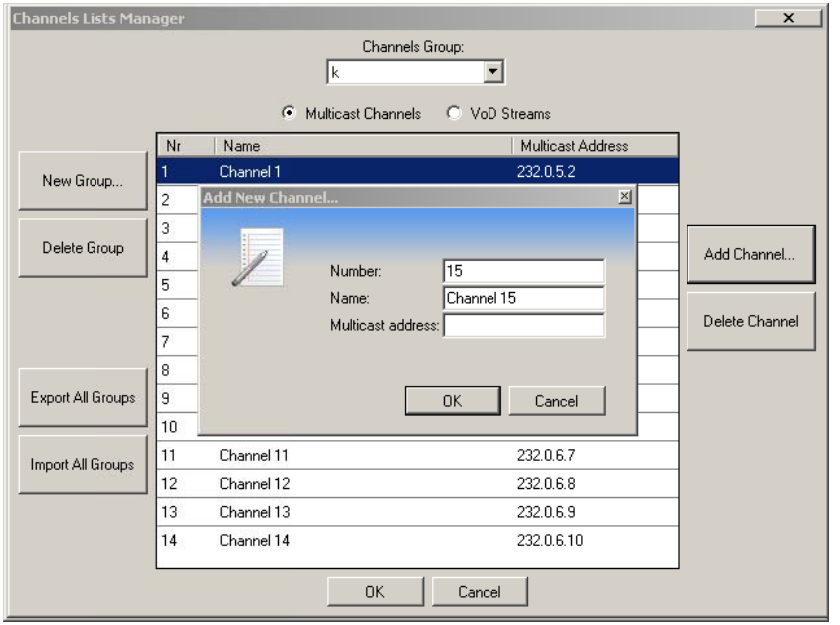


- **Enter New Group name as a channel list.**
- **Select either Multicast channels or VoD streams.**

For Multicast channels:

- **Enter New Channel Number, Name, Multicast address and Port.**
- **Press OK.**



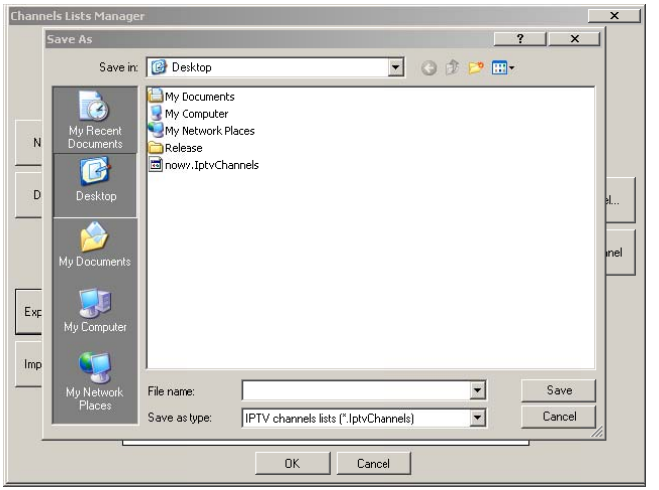


For VoD streams:

- **Enter New Channel Number, Name and rtsp uri and press OK.**
- **Repeat the above step for each additional channel (or rtsp uri) to be added to the multicast (or VoD) group.**

When Groups are exported a file with extension ".ExfoChannels" are created.

Groups can be imported only from files with this ".ExfoChannels" extension.

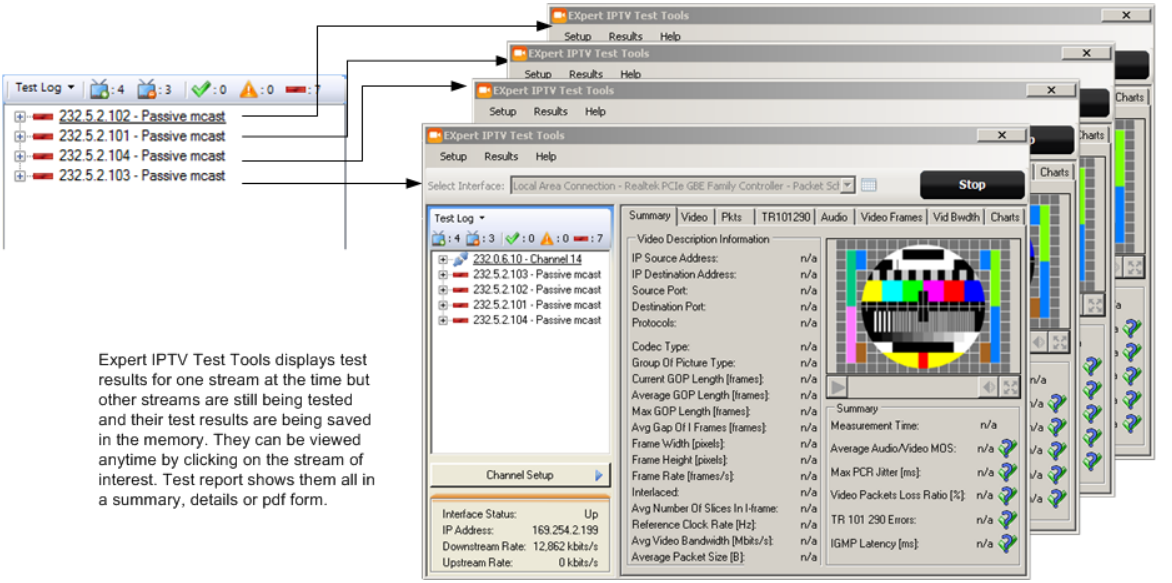


- **To import a Group click on "Import all Groups" then select the file form the desired folder and open it.**

- **To export a Group click on "Export all Groups" then type a file name and Save it.**

Chapter 7 Running IPTV Tests

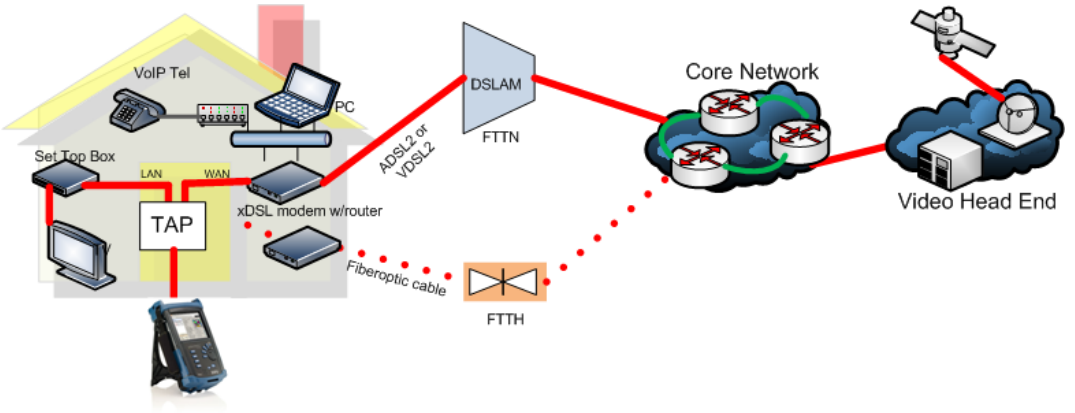
7.1 Simultaneous Testing of Multiple Channels

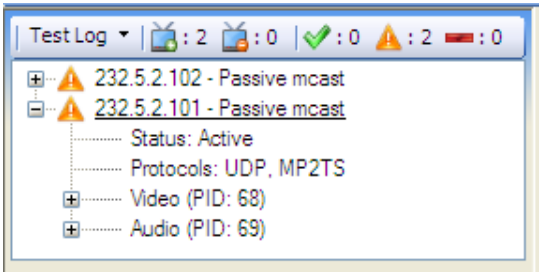


Expert IPTV Test Tools displays test results for one stream at the time but other streams are still being tested and their test results are being saved in the memory. They can be viewed anytime by clicking on the stream of interest. Test report shows them all in a summary, details or pdf form.

7.2 Passive Test

The Passive Test allows monitoring of any IPTV streams present at the interface, for quality of service and video preview. The Passive test can be performed via a 3- way Tap (or a manageable switch) as shown below:





The Passive Test starts automatically after depressing the Start and upon detection of a valid IPTV stream(s). All detected valid streams will be displayed in the Test Log box and marked as *Passive*.

- **Click on the channel to see its current metrics and preview**
- **Channel whose metrics and preview are currently displayed is <u>underlined</u>**
- **To view metrics and preview of another channel click on it in the Test Log box.**
- **Check the Summary metrics for a quick signal quality check.**
- **Click on the tab of a specific metrics of interest to view details.**
- **To stop the test on all channels press Stop button or disconnect the cable carrying the stream or wait until the stream(s) expires.**

7.3 Set Top Box Emulation Test

The Set Top Box Emulation Test allows IGMP or RTSP join& leave requests to one or multiple IPTV streams.

Once the stream(s) become detected and synchronized to the test metrics start and live video preview is available on non-encrypted streams.

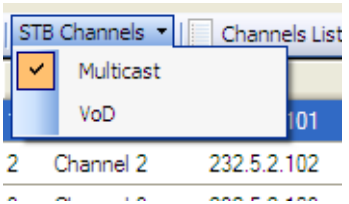
Number of channels that can be tested simultaneously is limited to 10. Exceeding this number will generate an ERROR message.

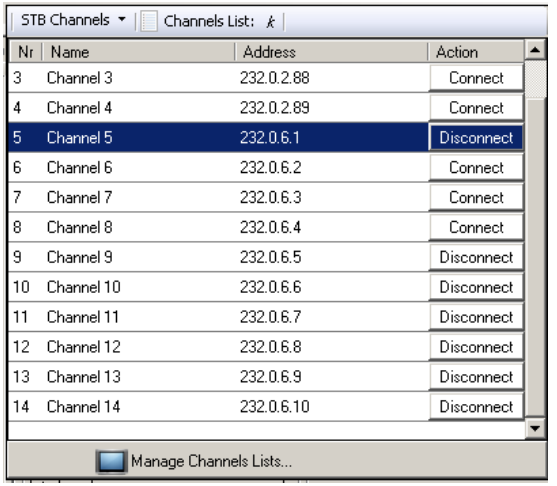
Live Preview is limited to one stream.

To start the Set Top Box Emulation Test:

- **Assuming that Setup has been already configured or default is uses start test press** Start.

- **From the STB channels pulldown menu select Multicast , VoD or Run auto test:**





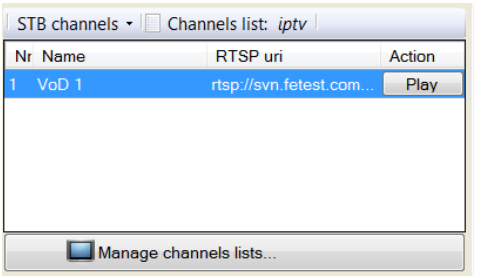
For Multicast streams:

- **Choose the channel to be tested from the Channel List in the STB**

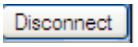
- **Click** Connect **button of the chosen channel in the Set Top Box. This will initiate IGMP request for this multicast channel. Once the stream is detected it will show up in the Test Log box as active.**
- **Repeat this process for all channels to be tested.**

For VoD streams (uri's):

- **Choose the RTSP uri to be tested from the Channel List in the STB**



- **Click on Play button of the chosen channel in the Set Top Box. This will initiate RTSP join request for this unicast channel. Once the stream in this is detected it will show up in the Test Log box as active. Repeat this process for all channels to be tested.**

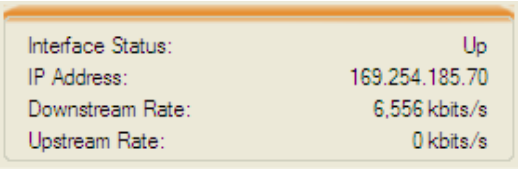
To stop the test of the specific stream press 

button, or press either 

or disconnect the Ethernet cable.

7.4 Ethernet Interface Status

The Interface panel shows the status of the selected Ethernet link.

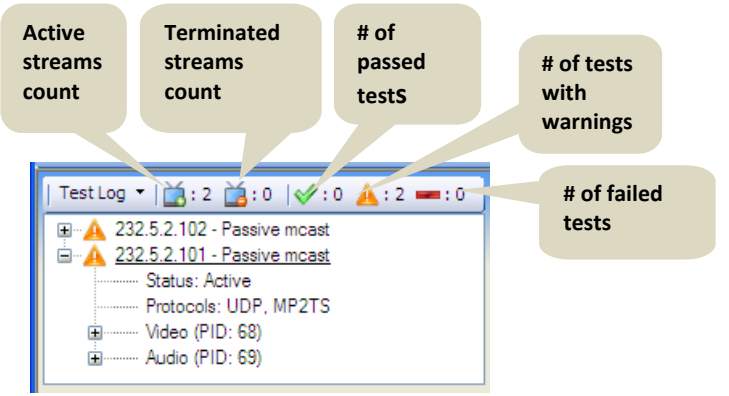


This information is useful to check if the link is up or down.

The Downstream Rate give the aggregate kbits/s for the all the streams present in the link.

Chapter 8 Getting IPTV Metrics

The channel whose metrics are currently displayed is <u>underlined</u> in the Test Log.

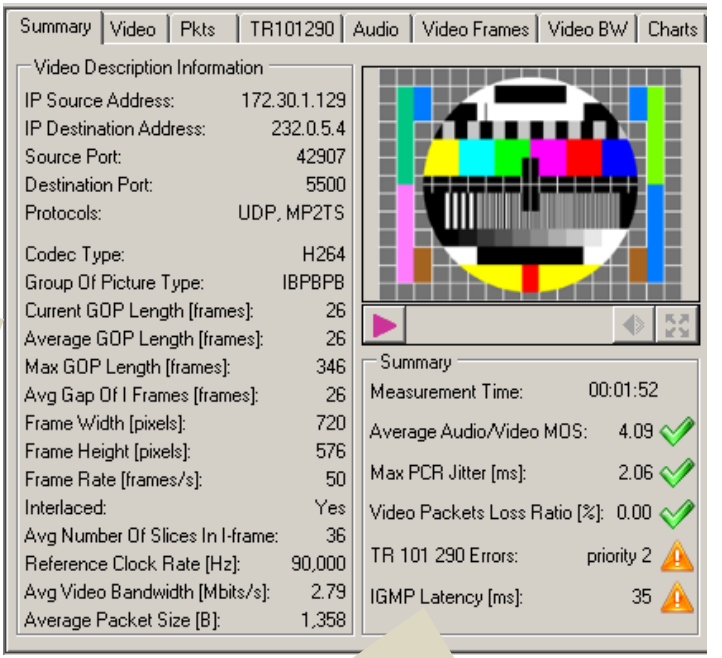


8.1 Basic IPTV Metrics Test

- **Check the Video Description Information for the stream characteristic and reference data.**

Video Description Information provides reference information extracted from the stream MPEG frames headers such as:

- **IP Address**
- **Encapsulation Protocols**
- **Code Type**
- **GOP Details**
- **Frame Details**
- **Frame Details**
- **Reference Clock**
- **Bandwidth and Packet Size**



Summary pan displays the most important metrics along with their Pass, Warning or Fail flags.

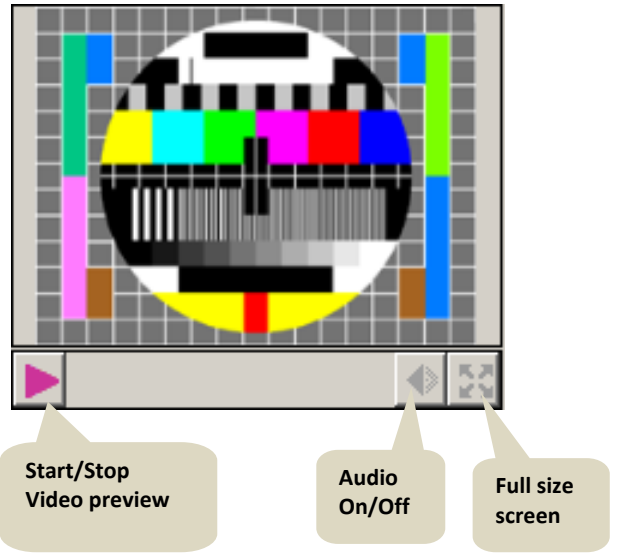
- **Check *Summary* metrics for a quick signal quality. Summary provides a list of industry most used parameters for quick evaluation of IPTV service quality such as MOS Score, PCR Jitter, Video Packet Loss, TR 101290 and IGMP Latency(zap time).**

Definitions:

Tab	Category	Metric Name	Range	Description
Summary	Summary	Measurement Time	0-12 hrs	Total duration of test in seconds from the time START was pressed to the time STOP was pressed
		Average Audio/Video MOS	1.0-5.0	The average MOS-AV across all completed audio/video streams monitored on the logical interface. (This does not include active streams.)
		Max PCR Jitter	ms	The PCR jitter in milliseconds
		Video Packet Loss Rate	%	Total proportion of stream transport packets lost or discarded (minus corrected)
		TR 101 290 Errors	NA	The occurrence of a TR101290 Priority 1 error, TR101290 Priority 2 error or both.
		IGMP Latency	0-3 sec	The time from IGMP Join request to the stream arrival time
	Video Description Information	IP Source Address	NA	The source IP address
		IP Destination Address	NA	The destination IP address
		Source Port	NA	The source transport port.
		Destination Port	NA	The destination transport port
		Protocols	NA	The encapsulation of the stream, for example UDP/RTP, UDP, UDP/TCP, etc.
		Codec Type	NA	The video codec used for the MPEG-TS frames in the stream
		Group of Picture Type	NA	The GOP structure expressed as a series of 'I', 'B', 'P' characters describing the frame type series in the structure.
		Current GOP Length	NA	The current GOP length, in frames.
		Average GOP Length	NA	The average GOP length, in frames.
		Frame Width	Pixels	The video frame image width, in pixels.
		Frame Height	Pixels	The video frame image height, in pixels.
		Frame Rate	Frames per sec	The video frame rate, in frames per one thousand seconds – e.g. 29,970 equals 29.97 frames per second.
		Interlaced	0 OR 1	A Boolean value indicating whether the stream is interlaced (TRUE), with alternating scanning of even and odd scan lines or progressive (FALSE), with scanning line by line in order.
		Average Number of Slices in I-frame		The average number of slice contained in each I-frame
		Reference Clock Rate	Khz	The 33-bit value of the MP2TS program clock reference (PCR) 90kHz portion.
		Average Video Bandwidth	Mbits/s	The average bandwidth of the video stream in Mbits/second.
		Average Packet Size		The average packet size of the video stream.

8.2 Live Stream Preview

- **Video and Audio preview of the channel whose metrics are currently displayed can be enabled at anytime in the main test window. The preview can be toggled to full screen size or stopped all together and audio can be turned on or muted.**



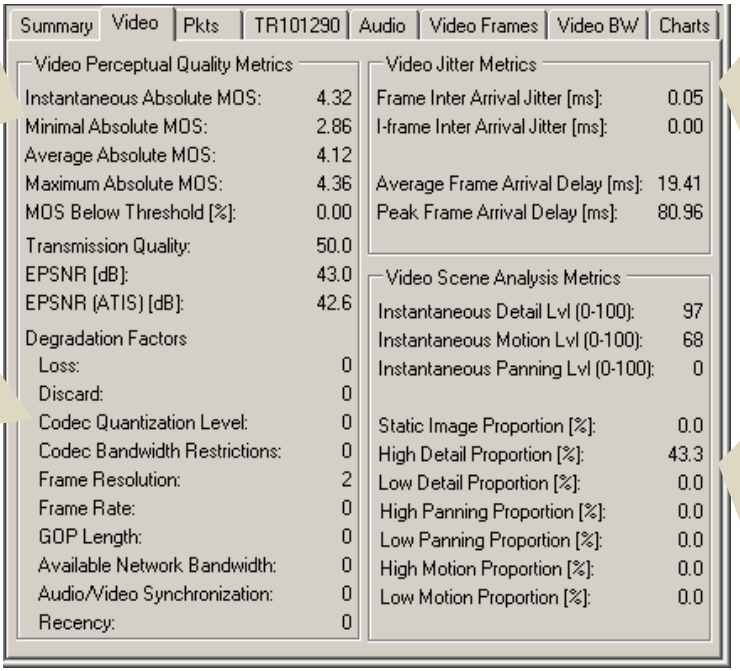
8.3 Advanced IPTV Metrics Test

8.3.1 Video Perceptual Quality Metrics

As described in the technical reference section Appendix A.1, the Perceptual Quality Metrics are calculated on the selected video stream to provide Mean Opinion Score (MOS) and related parameters.

Video Perceptual Quality provides the most essential QoE scoring metrics such a Video MOS scores that results from computation of a complex formula (see Technical Overview for details).

Degradation Factors provide insight into the nature of MOS score degradation by listing 10 contributing factors with their weight score.



Video Jitter Metrics provide amount of

Average Frame and I-frame Inter Arrival Jitter

Average and Peak Frame Arrival Delay in milliseconds

Video Scene Analysis Metrics provide proportions of the stream with Detail, Panning, Motion and Static Image.

These factors weight on the overall Video MOS score.

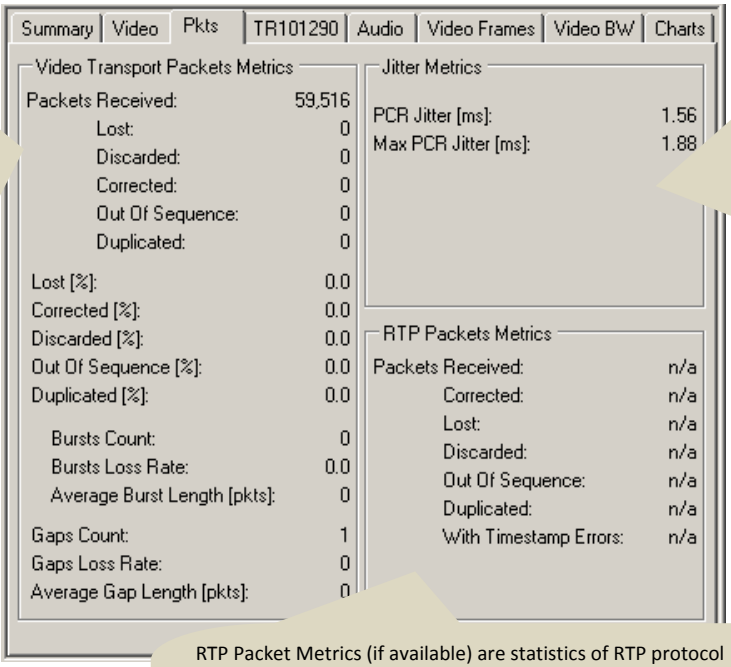
Definitions:

Tab	Category	Metric Name	Range	Description
Video	Video Perceptual Quality Metrics	Instantaneous Absolute MOS	1.0-5.0	The instantaneous absolute Video Mean Opinion Score, a 1-5 score that measures the impact of the video codec, image size, frame rate, packet loss distribution, GoP structure, content, and frame loss concealment on viewing quality
		Minimal Absolute MOS	1.0-5.0	The minimum absolute Video Mean Opinion Score, a 1-5 score that measures the impact of the video codec, image size, frame rate, packet loss distribution, GoP structure, content, and frame loss concealment on viewing quality
		Average Absolute MOS	1.0-5.0	The average absolute Video Mean Opinion Score, a 1-5 score that measures the impact of the video codec, image size, frame rate, packet loss distribution, GoP structure, content, and frame loss concealment on viewing quality
		Maximum Absolute MOS	1.0-5.0	The maximum absolute Video Mean Opinion Score, a 1-5 score that measures the impact of the video codec, image size, frame rate, packet loss distribution, GoP structure, content, and frame loss concealment on viewing quality
		MOS Below Threshold	0-100%	The proportion of the stream duration where the Absolute MOS-V fell below the configured analysis threshold.
		Transmission Quality	0-50.0	The codec-independent video service transmission quality rating
		EPSNR	dB	Estimated Peak Signal to Noise Ratio (PSNR) expressed in dB. This is an estimate of the distortion that has occurred between the source video stream and the output video stream.
		Degradation Factors :	0-10	Severity of perceptual quality degradation caused by (each of) the following factors: Loss, Discard, Codec Quantization Level, Frame Resolution, Frame Resolution, Frame Rate, GOP Length, Available Network Bandwidth, Audio/Video Synchronization, Recency
	Video Scene Analysis Metrics	Instantaneous detail level	0-100	Instantaneous detail level
		Instantaneous motion level	0-100	Instantaneous motion level
		Instantaneous panning level	0-100	Instantaneous panning level
		Static Image Proportions	%	The proportion of the video stream that contains static image[s]
		High Detail Proportions	%	The proportion of the video stream that contains high detail
		Low Detail Proportions	%	The proportion of the video stream that contains low detail
		High Panning Proportions	%	The proportion of the video stream that contains a high degree of panning
		Low Panning Proportions	%	The proportion of the video stream that contains a low degree of panning
		High Motion Proportions	%	The proportion of the video stream that contains high motion
		Low Motion Proportions	%	The proportion of the video stream that contains low motion
	Video Jitter Metrics	Frame Inter-arrival Jitter	ms	Average frame inter-arrival jitter in milliseconds. The inter-arrival jitter is computed relative to the expected arrival time based on the frame rate.
		I Frame Inter-arrival Jitter	ms	Average I frame inter-arrival jitter in milliseconds. The inter-arrival jitter is computed relative to the expected arrival time based on the frame rate.
		Average Frame Arrival Delay	ms	Average frame arrival delay, in milliseconds.
		Peak Frame Arrival Delay	ms	Peak frame arrival delay, in milliseconds. The peak maintains a hold time of approx. 10 seconds

8.3.2 Transport Packet Metrics

Transport Packets are MPEG-TS packets that carry Packet Elementary Stream (PES).

Statistics of these MPEG-TS Packets such as lost, discarded, corrected, out-of-sequence and duplicated packets allow detection of this major source of video picture degradation.



Jitter Metrics focus on the PCR Jitter which is defined as Time Stamp arrival time jitter.

PCR Jitter is a major contributor to loss of frames due to router or STB buffer overflow.

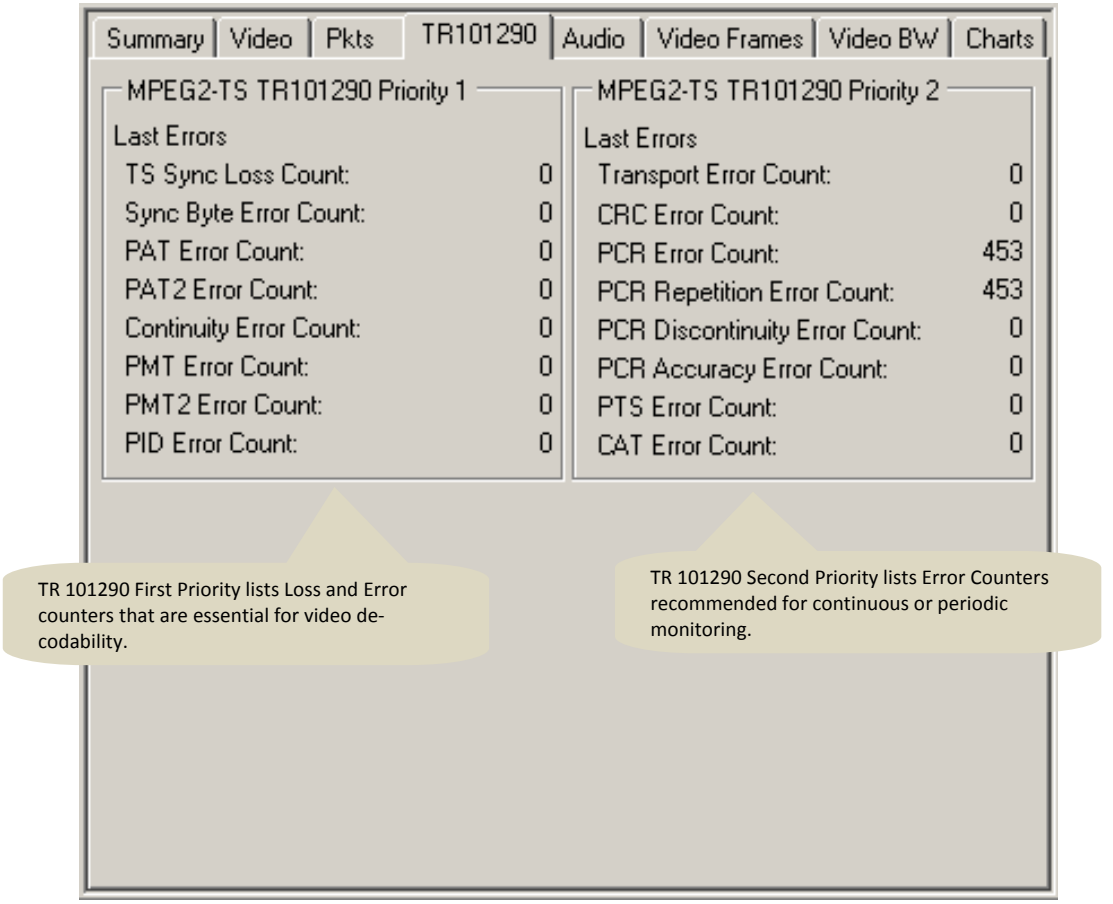
RTP Packet Metrics (if available) are statistics of RTP protocol encapsulation. RTP encapsulation is optional and is used to provide independent time stamping to video and audio. But it also adds overhead to the transmission.

Tracking RTP statistics allows problem isolation to the RTP encapsulating device.

Definitions:

Tab	Category	Metric Name	Range	Description
Packets	Video Transport Packet Metrics	Packets Received	NA	Number of video transport packets received properly for playout during the interval by the end system or observed at the monitoring point, excluding any duplicate packets.
		Packets Lost	NA	Number of video transport packets identified as lost at the endpoint or monitoring point during the interval
		Packets Discarded	NA	Number of video transport packets discarded by the receiving jitter buffer during the interval or an estimate of this value made at the monitoring point.
		Packets Out of Sequence	NA	Number of video transport packets arriving out of sequence during the interval.
		Packets Duplicated	NA	Number of duplicate video transport packets received during the interval.
		Lost%	0-100%	Total proportion of stream transport packets lost or discarded (minus corrected)
		Corrected and Lost %	0-100%	The proportion of stream transport packets lost in the transport network after error correction algorithms have been applied, e.g. FEC or Reliable UDP.
		Discarded %	0-100%	The proportion of stream transport packets discarded due to late arrival.
		Out Of Sequence %	0-100%	The proportion of stream transport packets arriving out-of-sequence.
		Duplicated %	0-100%	The proportion of stream transport packets arriving as duplicates of previously received packets.
		Burst Count	NA	The number of transport packet loss/discard burst occurrences over the duration of the stream.
		Burst Loss Rate	0-100%	The proportion of packets lost (before application of error correction algorithms) during burst periods.
		Average Burst Length	packets	The average length of a packet loss burst, in transport packets.
		Gaps Count	NA	The number of transport packet loss/discard gap occurrences over the duration of the stream.
		Gaps Loss Rate	0-100%	The proportion of packets lost (before application of error correction algorithms) during gap periods.
		Average Gap Length	packets	The average length of a gap, in transport packets.
	Jitter Metrics	PCR Jitter	ms	The PCR jitter in milliseconds
		Max PCR Jitter	ms	The maximum PCR Jitter in ms
	RTP Packet Metrics	Packets Received	NA	A count of a number of stream RTP transport packets received during the interval
		Packets Corrected	NA	A count of a number of stream RTP transport packets corrected by FEC during the interval
		Packets Lost	NA	A count of a number of stream RTP transport packets lost during the interval
		Packets Discarded	NA	A count of a number of stream RTP transport packets discarded lost during the interval
		Packets Out of Sequence	NA	A count of a number of stream RTP transport packets out-of-sequence lost during the interval
		Packets Duplicated	NA	A count of a number of stream RTP transport packets duplicated lost during the interval
		Packets w/Timestamp Errors	NA	A count of a number of stream RTP transport packets with a timestamp error during the interval

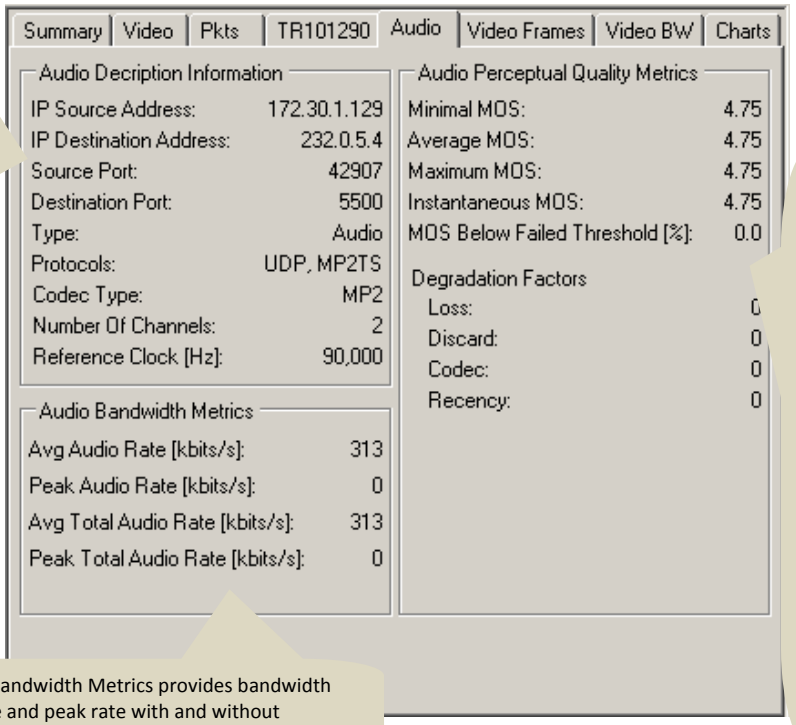
8.3.3. MPEG-TS TR 101290 Priority



Definitions: MPEG_2 Transport Stream TR 101290 Priority 1 Metrics

Tab	Category	Metric Name	Range	Description
TR101290	TR101290 Priority 1	Transport Stream Sync Loss Count	NA	Number of occurrences of transport stream sync loss, i.e., two or more consecutive sync bytes
		Sync Byte Error Count	NA	Number of occurrences of sync byte error.
		PAT Error Count	NA	Number of occurrences of Program Association Table (PAT) error.
		PAT 2 Error Count	NA	Number of occurrences of PAT 2 error.
		Continuity Error Count	NA	Number of occurrences of continuity counter error, i.e., incorrect packet order, duplicate packet, or lost packet.
		PMT Error Count	NA	Number of occurrences of Program Map Table (PMT) error.
		PMT 2 Error Count	NA	Number of occurrences of PMT 2 error.
		PID Error Count	NA	Number of occurrences of Process IDentifier (PID) error.
	TR101290 Priority 2	Transport Stream Error Indicators	NA	Indicators of the MP2TS errors that have occurred since this metrics block was last retrieved.
		Transport Error Count	NA	Number of occurrences of packet with transport error bit set.
		CRC Error Count	NA	Number of occurrences of PAT and/or PMT cyclic redundancy check (CRC) error.
		PCR Error Count	NA	Number of occurrences of Program Clock Reference (PCR) error
		PCR Repetition Error Count	NA	Number of times the interval between two consecutive PCR values is greater than 40 milliseconds.
		PCR Discontinuity Error Count	NA	Number of times the difference between two consecutive PCR values is outside the range of 0 to 100 milliseconds.
		PCR Accuracy Error Count	NA	Number of occurrences of PCR accuracy error.
		PTS Error Count	NA	Number of times the presentation timestamp (PTS) repetition period is greater than 700 milliseconds.
		CAT Error Count	NA	The number of occurrences of Conditional Access Table (CAT) error.

8.3.4 Audio Description and Perceptual Metrics Information



Audio Description Information is similar to Video Description Information providing essential reference information about the stream.

Audio Bandwidth Metrics provides bandwidth average and peak rate with and without headers.

Audio Perceptual Quality Metrics are MOS scores with subjective test content calculated with a specialized VQMON audio algorithm.

Degradation Factors provide severity of degradation due to Packet Loss, Packet Discard, Codec, a Recency of burst packet loss

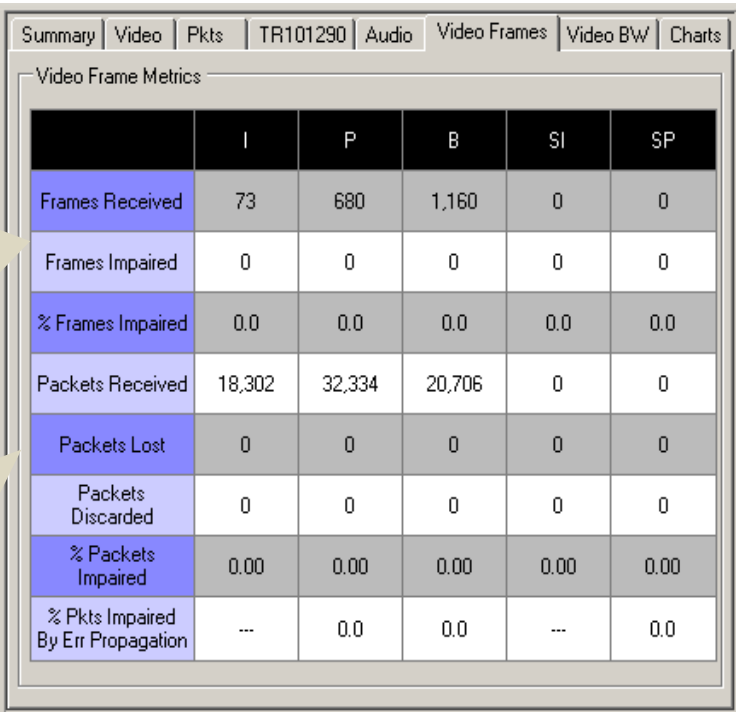
Definitions:

Tab	Category	Metric Name	Range	Description
Audio	Audio Description Information	IP Source Address	NA	The stream source IP address
		IP Destination Address	NA	The stream destination IP address
		Source Port	NA	The stream source TCP/UDP port number
		Destination Port	NA	The stream destination TCP/UDP port number
		Type	NA	The stream type- audio, video, voice
		Protocols	NA	The stream (s) transport protocols
		Codec Type	NA	The audio codec type for the audio stream
		Number of Channels	NA	The number of audio channels encoded in the audio stream
		Reference Clock	Hz	The reference clock (RTP timestamp or MPT2S PCR/PTS) rate, in Hz
	Audio Bandwidth Metrics	Average Audio Bandwidth	Kbit/s	Average audio bandwidth in bits/second, excluding transport packet overhead, FEC, and retransmissions
		Peak Audio Bandwidth	Kbit/s	Peak audio bandwidth in bits/second, excluding transport packet overhead, FEC, and retransmissions.
		Average Receive Bandwidth	Kbit/s	Average bandwidth of transport packets received, in bits/second.
		Peak Receive Bandwidth	Kbit/s	Peak bandwidth of transport packets received, in bits/second
	Audio Perceptual Quality Metrics	Minimal MOS	1.0-5.0	Minimal Audio Mean Opinion Score, a 1-5 score that measures the impact of the audio codec, bit rate, sample rate, and packet loss on audio quality.
		Average MOS	1.0-5.0	Average Audio Mean Opinion Score, a 1-5 score that measures the impact of the audio codec, bit rate, sample rate, and packet loss on audio quality.
		Maximum MOS	1.0-5.0	Maximum Audio Mean Opinion Score, a 1-5 score that measures the impact of the audio codec, bit rate, sample rate, and packet loss on audio quality.
		Instantaneous MOS	1.0-5.0	Instantaneous Audio Mean Opinion Score, a 1-5 score that measures the impact of the audio codec, bit rate, sample rate, and packet loss on audio quality.
		MOS Below Failed Threshold	0-100%	The proportion of the stream duration where the MOS-A value falls below the configured analysis threshold
		Degradation Factors: Loss, Discard, Codec, Recency	0-10	Severity of perceptual quality degradation caused by (each of) the following factors: packet loss, packet discard (jitter), codec distortion, and the recency of burst packet loss.

8.3.5 Video Frame Metrics

Video Frames (MPEG-TS) statistics provide the total number of Received and Impaired frames I, P, B and optional SI and SP. This breakdown allows better diagnostics of the distorted video.

Packet statistics such as Packet Lost, Packets Discarded and Packets Impaired correspond to the MPTEG-TS frame statistics and they allow more detail breakdown of the diagnostics.



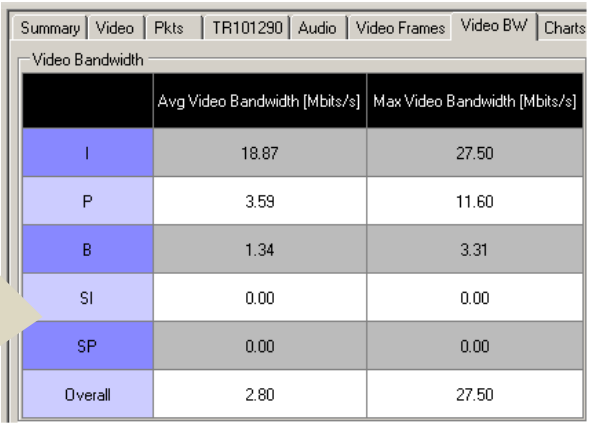
	I	P	B	SI	SP
Frames Received	73	680	1,160	0	0
Frames Impaired	0	0	0	0	0
% Frames Impaired	0.0	0.0	0.0	0.0	0.0
Packets Received	18,302	32,334	20,706	0	0
Packets Lost	0	0	0	0	0
Packets Discarded	0	0	0	0	0
% Packets Impaired	0.00	0.00	0.00	0.00	0.00
% Pkts Impaired By Err Propagation	---	0.0	0.0	---	0.0

Definitions:

Tab	Category	Metric Name	Range	Description
Video Frames	Video Frame Metrics	I Frames Received	NA	Number of I Frames received
		I Frames Impaired	NA	Number of I Frames impaired by packet loss/discard
		% of I Frames Impaired	0-100%	Proportion of I Frames impaired by packet loss/discard
		P Frames Received	NA	Number of P Frames received.
		P Frames Impaired	NA	Number of P Frames impaired by packet loss/discard
		% of P Frames Impaired	0-100%	Proportion of P Frames impaired by packet loss/discard.
		B Frames Received	NA	Number of B Frames received
		B Frames Impaired	NA	Number of B Frames impaired by packet loss/discard
		% of B Frames Impaired	0-100%	Proportion of B Frames impaired by packet loss/discard
		SI Frames Received	NA	Number of SI Frames received.
		SI Frames Impaired	NA	Number of SI Frames impaired by packet loss/discard.
		% of SI Frames Impaired	0-100%	Proportion of SI Frames impaired by packet loss/discard.
		SP Frames Received	NA	Number of SP Frames received.
		SP Frames Impaired	NA	Number of SP Frames impaired by packet loss/discard.
		% of SP Frames Impaired	0-100%	Proportion of SP Frames impaired by packet loss/discard.
		I Frame Packets Received	NA	Number of transport packets received containing video I frame information
		I Frame Packets Lost	NA	Number of transport packets lost containing video I frame information
		I Frame Packets Lost	NA	Number of transport packets discarded by the playout (jitter) buffer containing video I frame information.
		% of I Frame Packets Impaired	0-100%	Proportion of transport packets impaired by loss/discard containing video I frame information.
		P Frame Packets Received	NA	Number of transport packets received containing video P frame information
		P Frame Packets Lost	NA	Number of transport packets lost containing video P frame information.

8.3.6. Video Bandwidth

Video Bandwidth of I, P, B, SI and SP frames provides a useful information for traffic engineering. Looking and MOS and other metrics one can determine how much less or more bandwidth to add or reduce to maintain the quality goal and bandwidth utilizations at the same time.



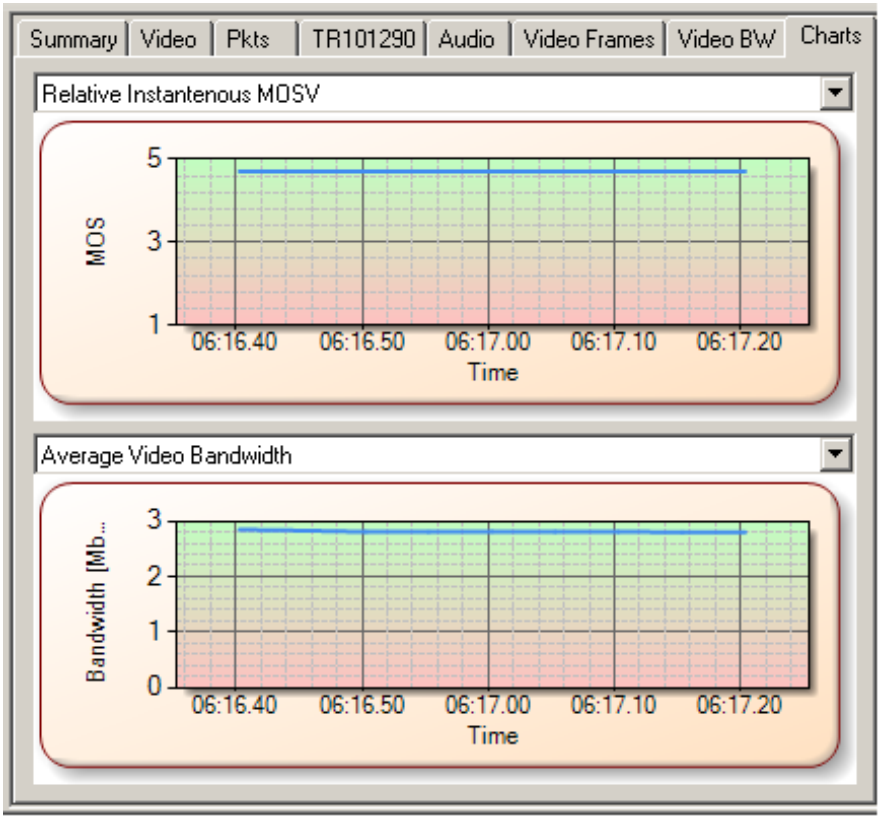
	Avg Video Bandwidth [Mbits/s]	Max Video Bandwidth [Mbits/s]
I	18.87	27.50
P	3.59	11.60
B	1.34	3.31
SI	0.00	0.00
SP	0.00	0.00
Overall	2.80	27.50

Definitions:

Tab	Category	Metric Name	Range	Description
Video Bandwidth	Video Bandwidth Metrics	I frame Average Video bandwidth	Mb/s	The average bandwidth of I-frame video content transmitted, in Mbits/second.
		I Frame Max Video Bandwidth	Mb/s	The maximum bandwidth of I-frame video content transmitted, in Mbits/second.
		P frame Average Video bandwidth	Mb/s	The average bandwidth of P-frame video content transmitted, in Mbits/second.
		P Frame Max Video Bandwidth	Mb/s	The maximum bandwidth of P-frame video content transmitted, in Mbits/second.
		B frame Average Video bandwidth	Mb/s	The average bandwidth of B-frame video content transmitted, in Mbits/second.
		B frame Max Video bandwidth	Mb/s	The maximum bandwidth of B-frame video content transmitted, in Mbits/second.

8.3.7 Metrics in Graphical Form- Histograms

Any two metrcis can be displayed as histograms allowing correlation of events for diagnostics.

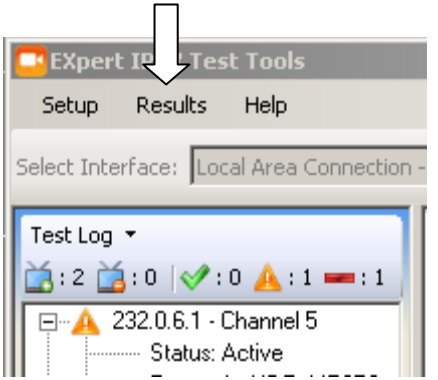


Chapter 9 Generating and Viewing Test Results

9.1 Test Results Log

9.1.1 Accessing Test Results

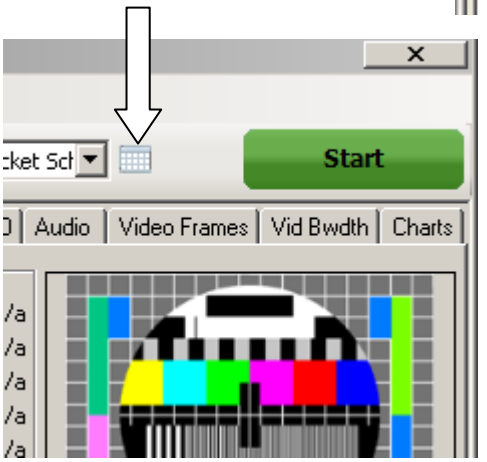
Access to the Test Results is available from 2 locations:



1. ***Results*** **button shown to the right**

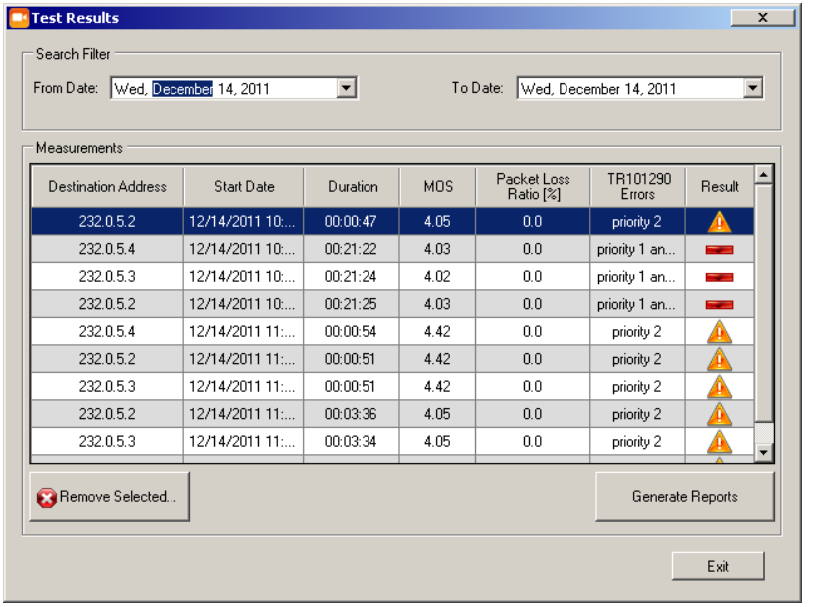
   OR

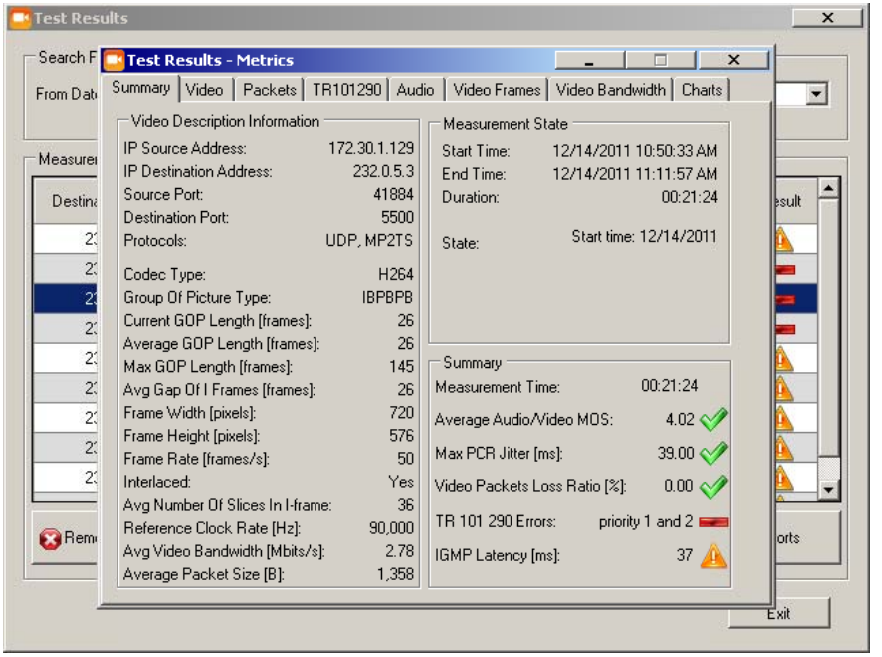
2. **Button**  **on the right top side of the screen**



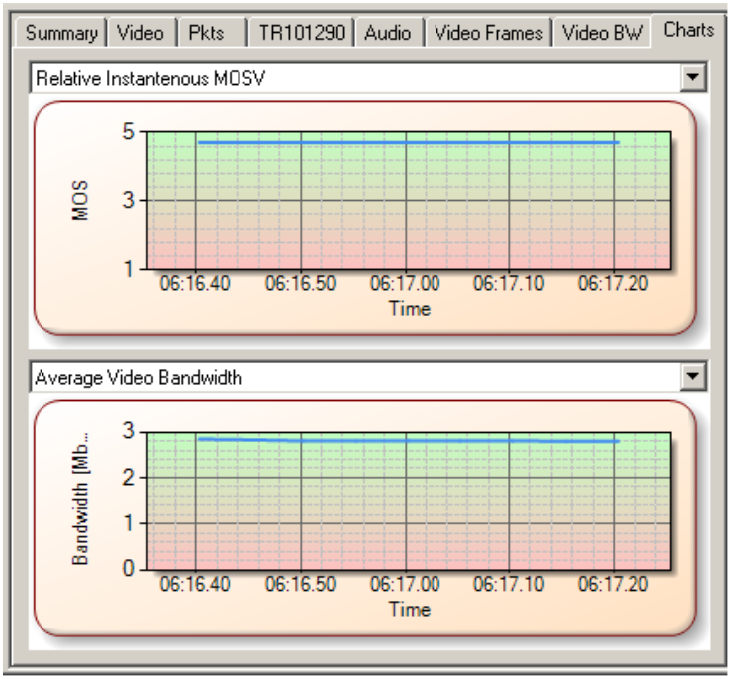
Test Results generated by *Results* button or

button produce the following log:



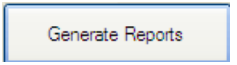


Double-clicking on the selected test record produces the metrics screen where all test metrics are accessible from the tabs:

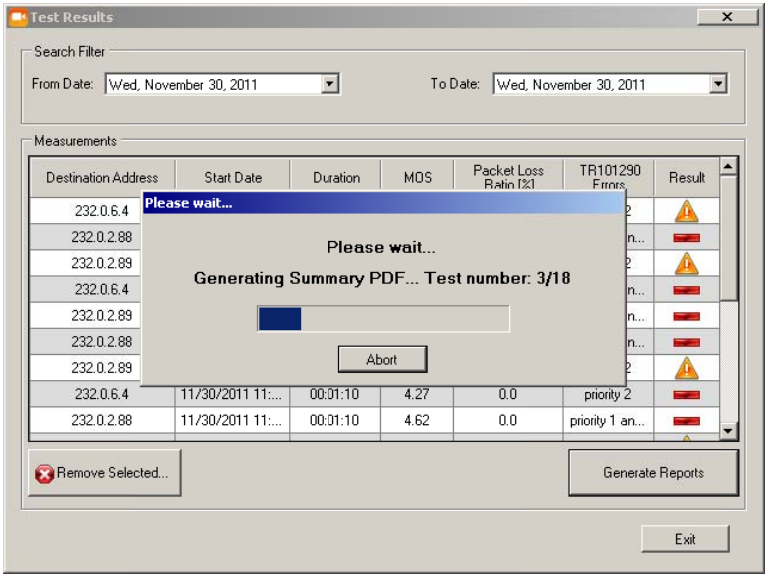


Here is an example of the Charts screen produced for the single test record.

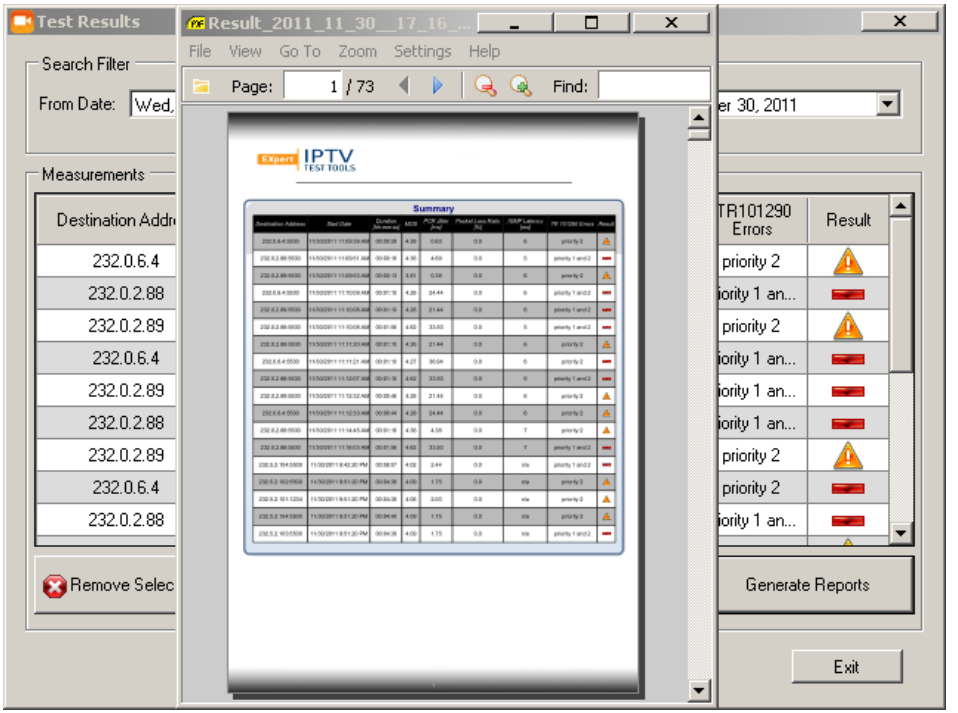
- **To generate a pdf report click on**



button and wait for the Summary PDF report to be generated.



The report start with the summary page followed with test metrics four pages long as shown below:



EXpert IPTV TEST TOOLS

General Results

Measurement Start Date: 9/17/2011
Measurement Start Time: 2:28 PM

Summary

Measurement Time:	00:13:39	
Average Audio/Video MOS:	4.02	✓
Max PCR Jitter [ms]:	2.56	✓
Video Packet Loss Ratio [%]:	0.00	✓
TR101290 Priority Errors:	priority 1 and 2	–
IGMP Latency [ms]:	n/a	

Summary Result

Failed

Details of test

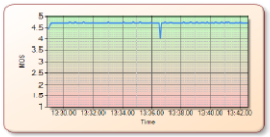
Video Description Information

IP Source Address:	169.254.116.62
IP Destination Address:	232.5.2.101
Source Port:	54586
Destination Port:	5500
Transport Protocols:	UDP/RTP/MPEG2-TS
Codec Type:	H264
Group Of Picture (GOP) Type:	IBBPBB
Current GOP Length [frames]:	26
Average GOP Length [frames]:	26
Max GOP Length [frames]:	346
Average Gap Of I Frames [frames]:	26
Frame Width [pixels]:	720
Frame Height [pixels]:	576
Frame Rate [frames/s]:	50.000
Is Interlaced:	Yes
Average Number Of Slices In I Frame:	36
Reference Clock Rate [Hz]:	90.000
Average Video Bandwidth [Mb/s]:	2.79
Average Packet Size [B]:	1,370

Audio Description Information

IP Source Address:	169.254.116.62
IP Destination Address:	232.5.2.101
Source Port:	54586
Destination Port:	5500
Transport Protocols:	UDP/RTP/MPEG2-TS
Codec Type:	MP2
Stream Type:	Audio
Number Of Channels:	2
Reference Clock Rate [Hz]:	90,000

Relative instantenous MOSV



EXpert IPTV TEST TOOLS

Video metrics

Video Perceptual Quality Metrics

Instantaneous Absolute MOSV:	4.32
Minimum Absolute MOSV:	2.13
Average Absolute MOSV:	4.12
Maximum Absolute MOSV:	4.36
Below Failed Threshold Absolute MOSV [%]:	0.1 %
Instantaneous Relative MOSV:	4.71
Minimum Relative MOSV:	2.53
Average Relative MOSV:	4.52
Maximum Relative MOSV:	4.76
Below Failed Threshold Relative MOSV [%]:	0.1 %
Instantaneous Audio/Video MOS:	4.22
Minimum Audio/Video MOS:	1.54
Average Audio/Video MOS:	4.02
Maximum Audio/Video MOS:	4.28
Below Failed Threshold Audio/Video MOS [%]:	0.1 %
Transmission Quality:	50.0
EPSNR [dB]:	44.8
EPSNR (ATIS) [dB]:	42.6

Video Degradation Factors

Loss:	0
Discard:	0
Codec Quantization Level:	0
Codec Bandwidth Restrictions:	0
Frame Resolution:	2
Frame Rate:	0
GOP Length:	0
Available Network Bandwidth:	0
Audio/Video Synchronization:	0
Recency:	0

Video Jitter Metrics

Frame Inter Arrival Jitter [ms]:	0.11
I Frame Inter Arrival Jitter [ms]:	0.09
Average Frame Arrival Delay [ms]:	4,788
Peak Frame Arrival Delay [ms]:	25,600

Video Frames Metrics

	Frames Received	Frames Impaired	Frames Impaired [%]
I Frame	1,534	0	0.0
P Frame	14,713	0	0.0
B Frame	24,564	0	0.0
SI Frame	0	0	0.0
SP Frame	0	0	0.0

EXpert IPTV TEST TOOLS

Audio-Video metrics

Video Scene Analysis Metrics

Instantaneous Detail Level:	97.0
Instantaneous Motion Level:	0.0
Instantaneous Panning Level:	0.0
State Image Proportion:	0.0
High Detail Proportion:	62.0
Low Detail Proportion:	0.5
High Panning Proportion:	6.8
Low Panning Proportion:	11.2
High Motion Proportion:	0.0
Low Motion Proportion:	0.0

Audio Perceptual Quality Metrics

Minimal MOS:	1.59
Average MOS:	4.52
Maximum MOS:	4.64
Instantaneous MOS:	4.64
MOS Below Failed Threshold [%]:	0.1 %
Audio Degradation Factors:	
Loss:	0
Discard:	0
Codec:	1
Recency:	0

Jitter Metrics

PCR Jitter [ms]:	0.50
Max PCR Jitter [ms]:	2.56

Audio Bandwidth Metrics

Average Audio Bandwidth [kbits/s]:	313
Peak Audio Bandwidth [kbits/s]:	313
Average Audio Bandwidth (incl. headers) [kbits/s]:	0
Peak Audio Bandwidth (incl. headers) [kbits/s]:	0

Video Bandwidth Metrics Per Frames

	Average Video Bandwidth	Max Video Bandwidth	Average (with headers)	Max (with headers)
I Frame	16.46	36.29	0.00	0.00
P Frame	3.70	16.13	0.00	0.00
B Frame	1.40	16.39	0.00	0.00
SI Frame	0.00	0.00	0.00	0.00
SP Frame	0.00	0.00	0.00	0.00
Overall	2.79	38.29	0.00	0.00

EXpert IPTV TEST TOOLS

Transport Metrics

Transport Packets Metrics

Packets Received:	1,521,781
Lost:	0
Discarded:	0
Corrected:	0
Out Of Sequence:	0
Duplicated:	0
Lost [%]:	0.0 %
Corrected [%]:	0.0 %
Discarded [%]:	0.0 %
Out Of Sequence [%]:	0.0 %
Duplicated [%]:	0.0 %
Bursts Count:	0
Bursts Loss Rate:	0.0
Average Bursts Length:	0
Gaps Count:	1
Gaps Loss Rate:	0.0
Average Gaps Length:	0

RTP Packets Metrics

Packets Received:	242,862
Corrected:	0
Lost:	73
Discarded:	0
Out Of Sequence:	0
Duplicated:	0
With Timestamp Errors:	0

MPEG2TS TR101290 Priority 1

TS Sync Loss Count:	0
Sync Byte Error Count:	0
PAT Error Count:	0
PAT2 Error Count:	0
Continuity Error Count:	1
PMT Error Count:	0
PMT2 Error Count:	0
PID Error Count:	0

MPEG2TS TR101290 Priority 2

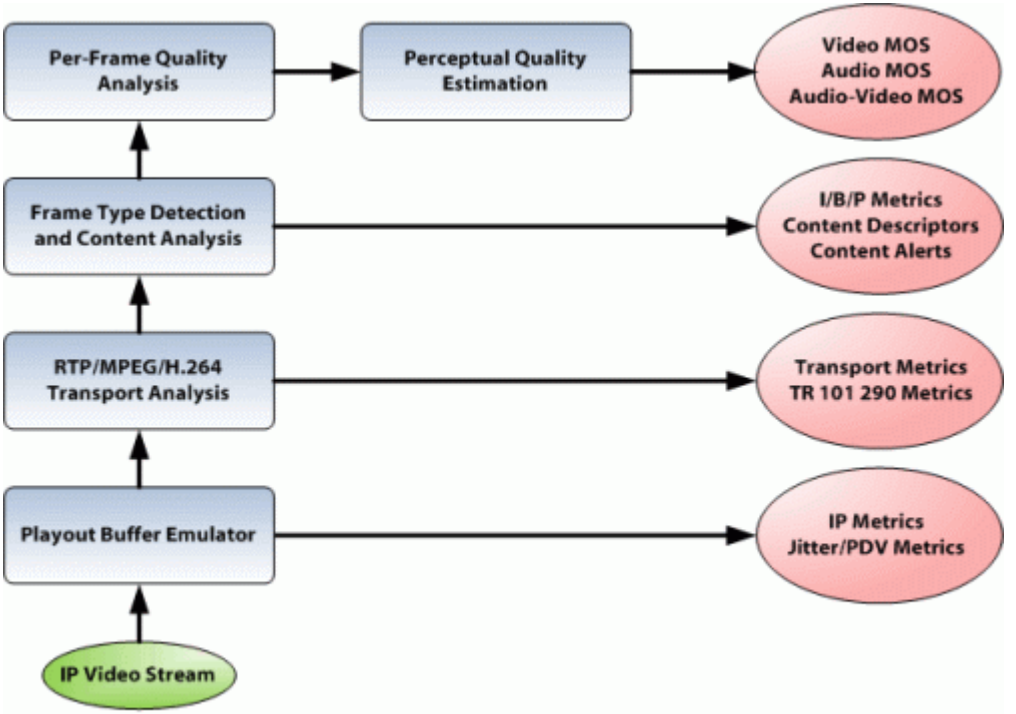
Transport Error Count:	0
CRC Error Count:	0
PCR Error Count:	11,666
PCR Repetition Error Count:	11,665
PCR Discontinuity Error Count:	0
PCR Accuracy Count:	0
PTS Error Count:	0
CAT Error Count:	0

Packets Metrics Per Frames

	Packets Received	Packets Lost	Packets Discarded	Packets Impaired [%]	Impaired By Error Ext [%]
I Frame	335,006	0	0	0.0	---
P Frame	722,454	0	0	0.0	0.0
B Frame	457,845	0	0	0.0	0.0
SI Frame	0	0	0	0.0	---
SP Frame	0	0	0	0.0	0.0

Appendix A

The IPTV Video Stream is subjected to multilevel analysis as shown here:



VQmon/HD Components and Reported Metrics

A.1 Understanding IPTV Video Perceptual Quality *

The perceptual quality of video transmitted across IPTV networks is susceptible to degradation from a number of transmission network sources including, frame errors caused by packet loss, discard of packets due to excessive delay/jitter, and discard of packets due to arrival sequencing errors. Simply relying on packet loss statistics, however, is not an accurate way to measure video quality as perceived by viewers. The same degree of packet loss may

cause obvious distortion or may not even be noticed by the end user, depending on which video frame types are impaired.

In addition, impairments can be introduced during the encoding/decoding process, by the codec itself or an inappropriately low bitrates. The video content (e.g., level of detail and motion onscreen) can also have a significant impact on the visibility of problems. Furthermore, perceptual quality is affected by subjective factors including human reaction time and the 'recency effect'. Coupled with the type of content, e.g., fast motion, high detail, or frequent scene changes, the quality of experience for the viewer will vary even under the same impairment conditions.

Each of these objective and subjective factors must be taken into consideration in order to accurately estimate IPTV video perceptual quality.

A.1.1 Transmission-Related Impairments

Packet-based video can be very sensitive to network impairments. Packet loss can cause sections of frames or complete frames to be corrupted or deleted. For example, the MPEG compression algorithm uses block-based motion compensation for the reduction of temporal redundancy and Discrete Cosine Transform (DCT)-based compression for the reduction of spatial redundancy. An MPEG encoder may generate three types of frame: Intra-coded (I), Predictive (P), and Bi-directional (B) frames.

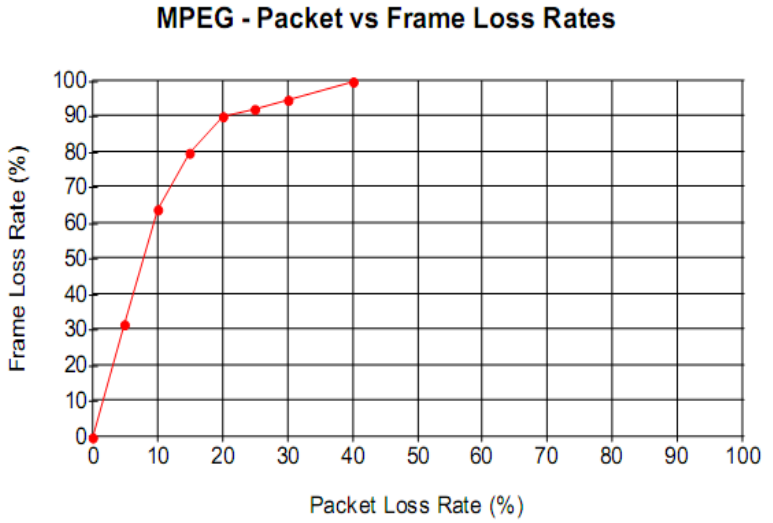


Figure2-1. Packet vs. Frame Loss Rates for MPEG

As a frame often spans multiple packets, and a typical video stream includes interpolated frames (P-frames and B-frames), a given packet loss rate can result in a frame loss rate six times higher [9]. See Figure 2-1 above.

In order to accommodate IPTV transmission network delay and low levels of delay variation, a playout buffer is used to temporarily store incoming frames. For streaming video, such as DVB or IPTV, it is permissible to apply arbitrary delays, and hence the playout buffer can be quite large. Interactive videoconferencing requires a relatively low delay, since a participant needs to respond immediately to questions or opinions of the other participants. Packets arriving too late may be discarded and will appear as lost packets.

Traditionally, video quality is measured by comparing the video sequence that has been processed by a video system to the original reference video sequence. It is not feasible to implement a mid-stream real-time monitoring system using this approach. This is because it needs to directly access the video source and decode video content, and has high computational complexity.

To overcome these disadvantages, it is therefore desirable to monitor transmission impairments in order to ensure good video quality. VQmon/HD is a *non-intrusive* monitoring technology that can passively measure the characteristics of live packet-based video streams and report quality scores in real-time. VQmon/HD models the way that time-varying impairments, most notably burst packet loss and possible playout buffer discards, affect perceived video quality.

A.1.1.1 Impact of Packet Loss and Jitter on Video Quality

Common video codecs, such as MPEG and H.263 implementations, use a combination of intra- and inter-frame coding methods. For intra-frame encoding (I frame) the image frame is divided into blocks, a Discrete Cosine Transform is used to convert each block to a set of coefficients and then variable length coding is applied. A group of blocks are combined into a single entity (slice), which can be carried within a single packet. If a transmission error occurs then the whole group may be lost, creating a "stripe" within the decoded image. For example, because the DC coefficients within each block are predicatively encoded from the first block in the slice, an error makes this information unusable for the remainder of the slice. Some errors may damage the frame structure and render the whole frame unusable.

For inter-frame or motion-based coding (P and B frames), motion vectors are determined for each block and encoded. As for intra-frame coding, errors can render a whole slice or frame unusable. In simple inter-frame coding systems, the loss of one I or P frame can make all subsequent frames unusable until the next I frame is received—resulting in a significant period of degraded, frozen, or blank video.

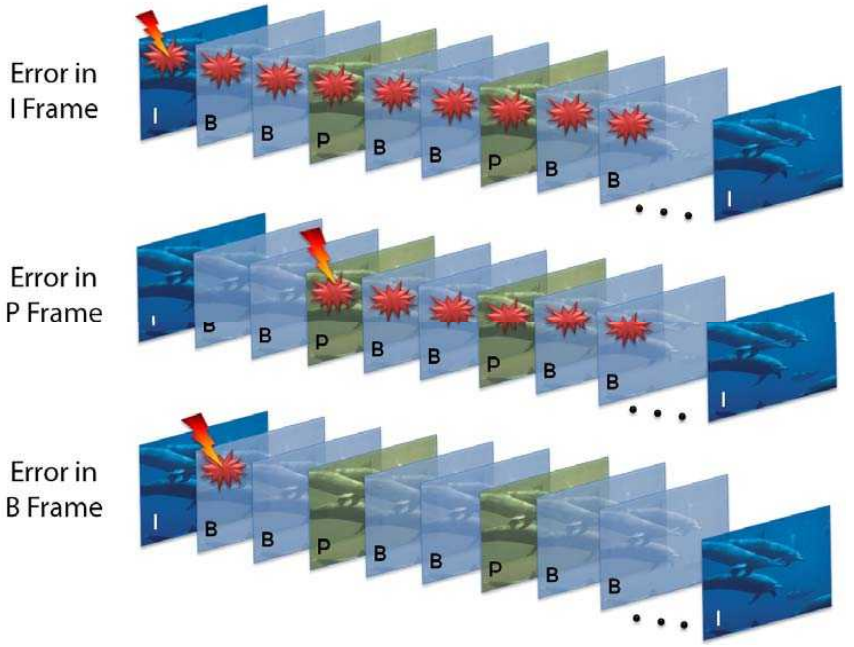


Figure 2-2. Error propagation through frames in a typical GOP

Note: **the H.264 (MPEG-4 AVC) codec standard introduces two new frame types, "Switching I" (SI) and "Switching P" (SP), which are designed to enable the decoder to more easily switch between video streams with different bitrates. VQmon/HD reports SI and SP frame metrics when H.264 is used.**

Figure 2-2 shows the impact of encoding errors on various frame types (I, B, and P) in a typical Group of Pictures (GOP).

In most cases, the standards for video coding provide considerable flexibility to both the encoder and decoder, allowing a range of cost/performance tradeoffs to be made. This can make it difficult to precisely assess the impact of network impairments without knowledge of the exact implementation.

A.1.1.2 Impact of Packet Loss on Specific Video Codecs

As shown in Figure 2-3, a simple non-robust video stream can be severely degraded with even low levels of packet loss due to the error propagation effects described above. Peak Signal-to-Noise Ratio (PSNR) is an objective measurement of video service quality comparing the maximum power of the video signal to the power of corrupting noise affecting the signal. Generally, a PSNR of under 20dB is regarded as unwatchable, and this level is reached for MPEG video with a loss rate under 1 percent.

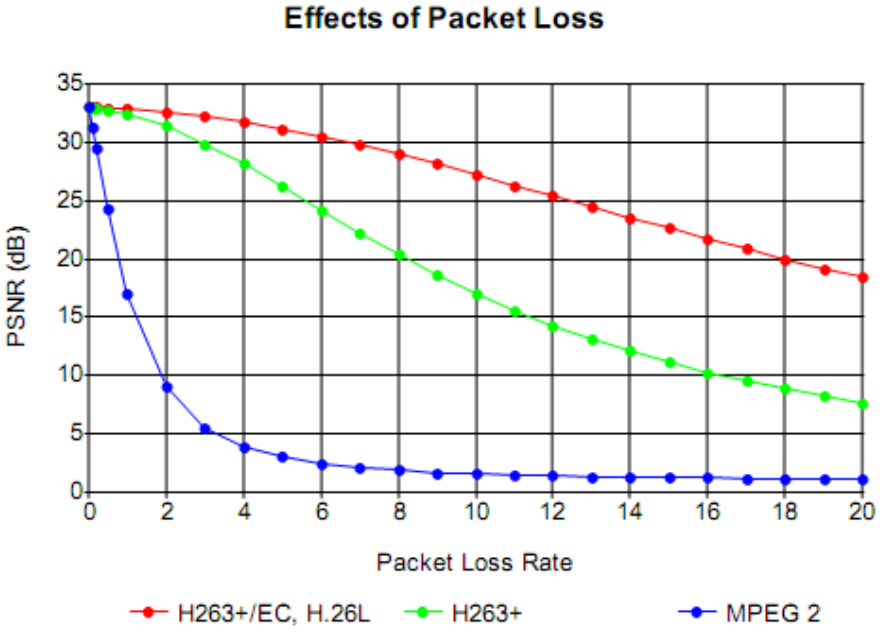


Figure 2-3. Estimated PSNR for Three Common Codecs

Error mitigation algorithms are being increasingly applied to help to compensate for packet loss [11][12]. Methods include:

***Forward Error Correction (FEC)* - redundancy is applied to the data stream to allow some proportion of lost or errored packets to be replaced**

Interleaving **- in which the video stream is split into alternate frames and each encoded separately**

Macro-block error concealment **- spatially corresponding macro-blocks are copied from the previous frame**

These approaches can help considerably with tolerance to packet loss.

A.1.1.3 Playout Buffer Configuration

It is assumed that both videoconferencing and streaming video systems provide a playout buffer; however, the configuration of these is quite different. It is highly desirable to determine whether an application is streaming or interactive, since the playout buffer configuration is typically very different for these two applications.

Following are examples for the playout buffer settings:

Videoconferencing - nominal 100ms (0.1 seconds), adaptive

Streaming Video - nominal 3,000ms (3 seconds), fixed

A.1.2 Encoding/Decoding Impairments

While transmission impairments such as packet loss are a common source of video quality degradation, quality can also be affected by the encoding/decoding process itself; i.e., some distortion can be introduced by the bitrate and codec used.

A.1.2.1 Impact of Coding Bitrate on Video Quality

For a typical MPEG-2 encoded video stream with standard resolution 720x486, GOP sequence IBBPBBPBBPBBPBB, at 30 frames per second, the mean square error (MSE) due to bitrate can be approximated by:

$$MSE_{br} = 0.00001 + 1.5 / (B + B^2 / 30000).$$

Where *B* is the bitrate in kilobits per second. The corresponding peak signal-to-noise ratio

(PSNR) value for the frame can be computed by

$PSNR_{br} = -10\ log_{10} MSE_{br}$.

Figure 2-4 shows the estimated PSNR value on coding bitrate for MPEG-2 encoded video.

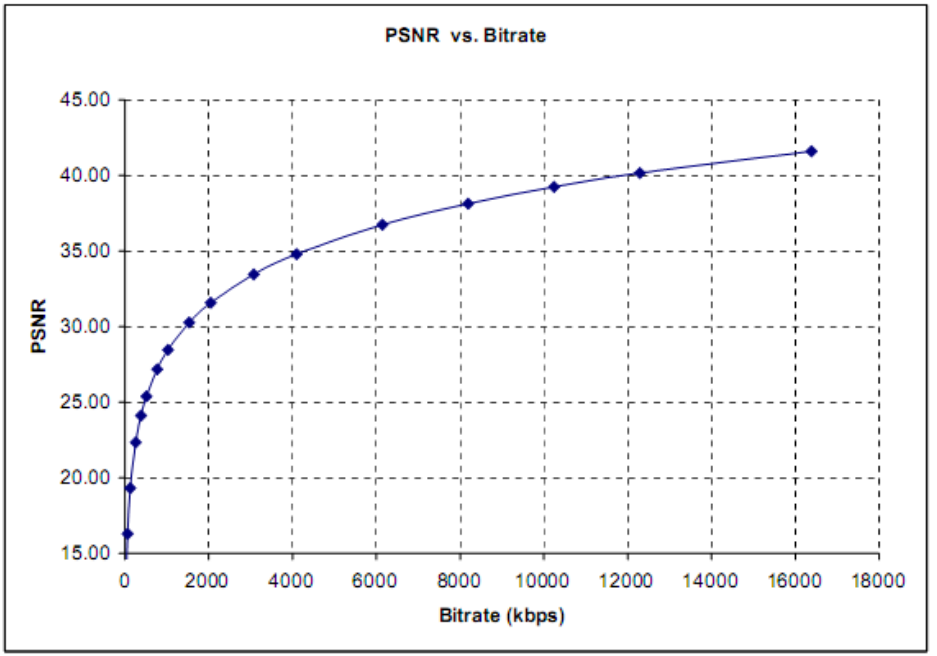


Figure 2-4

Estimated PSNR on Coding Bitrate for Standard Definition MPEG-2 Video at 30 Frames per Second

The following examples illustrate the impact of the coding bitrate on video quality. Both images show the same frame from a video sequence encoded with MPEG-2 at a resolution of 720x480, at 30 frames per second. In Figure 2-5 the sequence was encoded at a bitrate of 5000 Kbps (610KB/s).

Figure 2 -5

Still frame from MPEG-2 video sequence encoded at 5000Kbps

Figure 2-6.

Still frame from MPEG-2 video sequence encoded at 1127Kbps

In Figure 2-6, the sequence was encoded at a bitrate of 1127Kbps (138KB/s). The use of coarser quantization conserves bandwidth, but creates distortion that impairs overall image quality throughout the entire video sequence.

A.1.2.2 Performance of Video Coders

There are many standardized video coding algorithms, such as ITU-T H.261, H.263, H.264, ISO/IEC MPEG-1, MPEG-2 and MPEG-4, AVS, VC-1, etc. These standards do not explicitly define codecs; they only define the syntax of an encoded video bitstream together with the methods of decoding the bitstream. The consequence is that there might be significant quality differences between codecs conforming to the same standard [16]. The Windows Media 9 (VC-1) of Microsoft and RealVideo of RealNetworks are widely used proprietary video coding algorithms for video streaming applications.

As a rule of thumb, ITU-T H.263 reduces the coding bitrate by about 50% against H.261 for comparable video quality. ITU-T H.264/AVC significantly outperforms all other listed standards. Average bit-savings of more than 60% relative to MPEG-2 are reported. H.264/AVC Main Profile provides more than 1/3 bitrate saving relative to its competitors, MPEG-4 Advanced Simple Profile (ASP) and H.263 Conversational High Compression (CHC) Profiles [25].

Reports show that WMV 9 (VC-1) achieved similar quality to MPEG-2 and MPEG-4 with only 1/3

and 1/2 of the bitrate, respectively [21]. A paper by Bennet and Bock [13] concludes that comparing H.264/AVC and VC-1, there is very little performance difference between them.

A.1.2.3 Effective Coding Bitrate

The bitrate used in estimating the mean squared error as referenced in the beginning of section 2.2.1 can be adjusted to an *effective* bitrate based on performance of a video codec described above. The effective bitrate also needs to be adjusted based on the frame resolution and frame rate of the video signal. Videoconferencing applications generally support low to medium bitrates and frame resolution. The most commonly used resolutions are QCIF (176x144) and CIF (352x288) at 10 to 30 frames per second. Entertainment-quality IPTV applications generally support video encoded with SD resolutions of 720x486 (30 Hz) or 720x576 (25 Hz), or HD resolutions of 1280x720 (720p) or 1920x1080 (1080i) at an average bitrate of 3 Mbits/sec or higher.

Typically, the number of bits spent on coding a P-frame is about 20% of the number required for an I-frame, whereas a B-frame takes about 5% of the bitrate consumption of the I-frame. This implies that group of pictures (GOP) structure has a big impact on quality of encoded

video at a given bitrate under no loss condition, as well as under loss conditions as described below. VQmon/HD automatically adjusts the video stream effective bitrate based on the GOP structure of the encoded video stream.

A.1.3 Impact of Subjective Factors on Perceptual Quality

The degree to which viewers find video impairments annoying—or notice them at all— depends in part on the severity and duration of the impairment events, but also on certain inherent characteristics of human perception. The same type of impairment may be extremely irritating or barely noticed, depending on factors such as the scene content when the error takes place, and whether it occurs alone or simultaneously with other impairments.

A.1.3.1 Video Content

The visibility of video problems depends partially on the scene content; for example, frame freezes tend to be much more noticeable in sequences containing high levels of motion than in relatively static scenes, such as footage of a television news anchor. VQmon/HD performs content and scene analysis, detecting levels of detail, motion, and panning, and can detect and provide alerts for content problems such as noise/snow and frame freezes. Scene analysis data is leveraged to increase the accuracy of VQmon/HD's estimated perceptual quality scores.

A.1.3.2 Temporal Phenomena: Reaction Time, Masking and Recency Effects

Perceptual quality is affected somewhat by a natural delay in human reaction time when impairments occur, or when quality improves after a period of degradation; i.e., the viewer's reaction to either event is not immediate. As with audio, when two or more impairments occur simultaneously (or in rapid succession), there can be a "masking" effect that affects the way viewers perceive the severity of quality degradation. In addition, a "recency" phenomenon exists, wherein viewers tend to perceive impairments as more severe when they occurred recently, but are willing to "forgive" them to some extent as time passes.

VQmon/HD's quality analysis algorithm considers these temporal phenomena in order to calculate perceptual quality scores that correlate as accurately as possible to scores obtained from subjective tests of live viewers.

A.2 VQmon/HD Quality Analysis Algorithm *

This section describes VQmon/HD's video and audio quality analysis algorithms and lists some of the key metrics reported by VQmon/HD as part of the Telchemy Video Quality Metrics (TVQM) data set.

A.2.1 Video Stream Analysis

VQmon/HD's video quality analysis algorithm analyzes RTP or MPEG-2 Transport video streams and generates real-time perceptual quality scores and other diagnostic metrics.

Video codecs supported by VQmon/HD include:

- **Motion JPEG**
- **MPEG-1**
- **MPEG-2**
- **H.261**
- **H.263/263+**
- **H.264**
- **MPEG-4**
- **VC-1**

Figure 2-7 depicts the various components of the VQmon/HD video quality analysis algorithm and the metrics produced by each component.

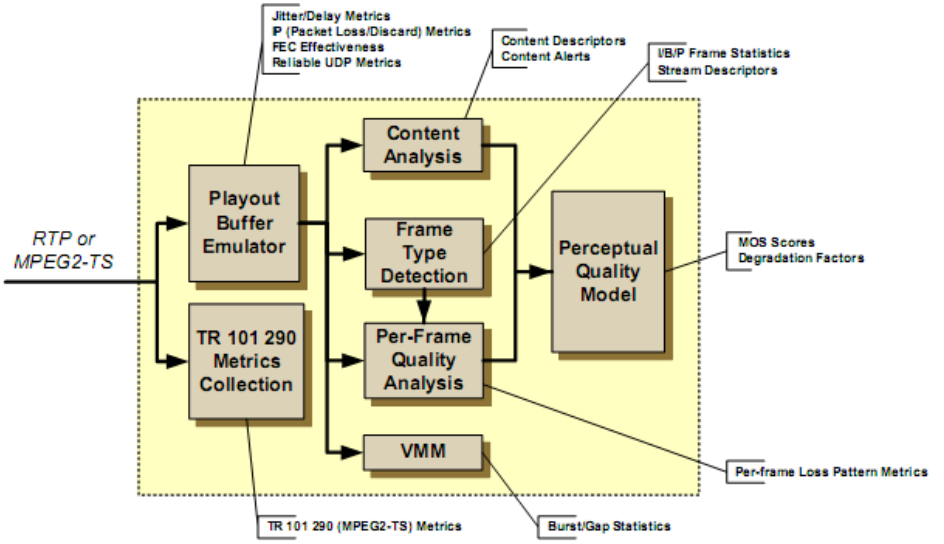


Figure 2-7. VQmon/HD video stream quality analysis algorithm

A.2.1.1 TR 101 290 Metrics Collection

VQmon/HD collects and reports the full set of Priority 1 and 2 metrics described in TR 101 290 for the measurement and analysis of MPEG-2 Transport streams.

A.2.1.2 Playout Buffer Emulator

VQmon/HD's playout buffer emulator component detects lost, duplicate, and out-of-sequence packets and measures packet-to-packet delay (jitter) levels, reporting PPDV (RFC3550) and MAPDV (ITU-T G.1020). Detailed IPTV packet loss/discard statistics are provided, along with metrics evaluating the effectiveness of Forward Error Correction (FEC), if used. If Reliable UDP is in use, VQmon/HD reports the proportion of retransmitted packets and the impact on bandwidth due to retransmission.

A.2.1.3 Content Analysis

VQmon/HD performs high-level content analysis to detect levels of detail, motion, and panning, and can also detect some scene changes. VQmon/HD also recognizes abnormal content conditions (including no content, noise/snow, and frozen image) and can generate alerts if they are detected.

A.2.1.4 Frame Type Detection

VQmon/HD identifies individual I, P, and B frames in the GoP and measures the packet loss rate and loss distribution occurring in each frame type. For unencrypted video streams, VQmon/HD performs picture header decoding to identify individual frames, GoP size, and frame rate. For encrypted/scrambled streams, heuristic algorithms are applied in order to detect frame boundaries and measure frame size.

As mentioned in Section 2.1.1.1, the GoP structure has impact on both the efficiency of video encoding and the robustness of encoded video. VQmon/HD takes the different I, P, and B frame packet loss/discard rates into account when calculating perceptual video quality metrics.

A.2.1.5 Per-frame Quality Analysis

VQmon/HD performs per-frame quality calculation using the frame type, frame size, codec type, video bandwidth, and packet loss data. The proportion of each frame type impaired by loss/discard is reported, along with the proportion of B and P frames impaired due to the propagation of errors from earlier reference (I or P) frames in the GoP.

A.2.1.6 Perceptual Quality Model

VQmon/HD's perceptual quality model calculates estimated perceptual quality (MOS) scores using the per-frame quality metrics and content analysis as inputs. The calculation model considers the sensitivity of the content to quality degradation (e.g., that frame freezes occurring during a high-motion scene will be more visible and annoying than those occurring during a static scene) and other subjective factors such as viewer reaction time, recency, and temporal masking (see Section 2.1.3.2).

A.2.1.7 VQmon Markov Model (VMM)

VQmon/HD uses a four-state Markov Model to gather and report packet loss statistics for "burst" periods (where quality is significantly degraded) and "gap" periods (periods between each burst interval when quality is relatively unimpaired).

VQmon/HD calculates quality metrics in these *burst* and *gap* states, and then combines them to generate the overall quality score on user experience. These calculations are based on the results of numerous subjective voice/video quality analysis tests that indicate there is not an instantaneous change in perceived quality when a transition between the gap and burst states occurs, but rather that the perceived quality exponentially "decays" from one level to another. For example, a 100-millisecond burst of "noise" is much less annoying than a 10 second burst of "noise".

Figure 2-8 illustrates the VQmon 4-state Markov model. The VQmon 4-state Markov model is defined as having the following states and associated transitions:

State Name	Description	Transitions
State 1 – Gap/no loss	Occurs when packets are being received properly under normal operating conditions	p_{11} – packet received p_{13} – packet lost (start of burst) p_{14} – isolated packet lost
State 2 – Burst/no loss	Occurs when a packet is successfully received while in a burst loss state	p_{22} – packet received within burst p_{23} – packet lost within burst
State 3 – Burst/packet lost	Occurs when a packet is lost during a burst loss condition	P_{31} – packet received (end of burst) p_{32} – packet received within burst p_{33} – packet lost
State 4 – Gap/packet lost	Occurs when a packet is lost during a gap state	p_{41} – packet received

Table 2-1. VQmon 4-state Markov model state transition descriptions

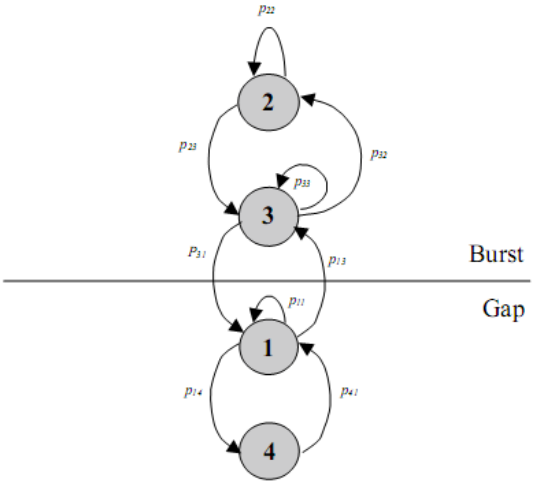


Figure 2-8.

VQmon Four-state Markov Model diagram

A.2.2 Audio Stream Analysis

VQmon/HD's audio quality analysis algorithm performs real-time analysis of audio stream packets and generates perceptual quality scores (MOS-A) and other metrics corresponding to those produced by the video quality analysis algorithm. Like the video stream analysis algorithm, the audio quality analysis algorithm calculates the impact of time-varying impairments (i.e., burst packet loss and jitter) and recency on perceptual quality.

VQmon/HD calculates overall multimedia quality (MOS-AV) by measuring both audio and video perceptual quality and the accuracy of the audio-video synchronization.

High-fidelity audio codecs supported by VQmon/HD include:

- **MPEG-1 Layer 1, 2, and 3**
- **MPEG-2 Advanced Audio Coding (AAC)**
- **AC-3**
- **MPEG-4 AAC, Low Delay AAC, and High Efficiency AAC**

A.2.3 Telchemy Video Quality Metrics

VQmon/HD provides real-time perceptual quality scores, performance statistics, and extensive diagnostic data for monitored video streams in the form of the TVQM™ (Telchemy Video Quality Metrics) data set.
TVQM metrics reported by VQmon/HD fall into three main categories:

a) *Perceptual Quality Metrics* – including Mean Opinion Scores (MOS) for picture quality (MOS-V), audio quality (MOS-A), and combined audio-video quality (MOSAV), expressed in a range of 1 to 5, with 5 being best. For picture quality, both "Relative" MOS (which does not consider the resolution of the display, frame rate, or progressive vs. interlaced scanning) and "Absolute" MOS (which includes consideration of these factors) are reported.

TVQM perceptual quality metrics also include an Estimated Peak Signal-to-Noise Ratio (ESPR) in dB, and a set of metrics indicating the severity level (on scale of 010) of several degradation factors including packet loss, jitter, codec type, etc.

b) *Video Stream Metrics* – including video stream description (image size, codec type, frame rate, etc.); content and scene analysis (detail and motion level) metrics; frame statistics indicating the number and proportion of each frame type (I, B, P, SI, and SP) received/impaired/lost/discarded; average and maximum bandwidth for each frame type and for the stream overall; video stream jitter and delay metrics; and interval metrics.

c) *Transport Metrics* –including VSTQ (Video Service Transmission Quality), a 0-50 codec-independent score that measures the ability of the IPTV network to carry reliable video; packet transport metrics (packets received/discarded/duplicate/out-of-sequence, along with burst and gap statistics); packet jitter metrics including PPDV (Packet-to-Packet Delay Variation); FEC (Forward Error Correction) and Reliable UDP metrics; and MPEG-2 Transport Stream (ETSI TR 101 290) metrics.

Table below lists some of the perceptual quality metrics reported by VQmon/HD, including acceptable ranges for each. (A complete list and description of the TVQM Video Quality Metrics reported by VQmon/HD is provided in Appendix C.)

Abbr. Name	Permitted Range	VQmon Scaled Range	Meaning
MOS-AV	1 .. 5	1 .. 5	VQmon Multimedia Quality. A VQmon Mean Opinion Score representing video service multimedia quality. It takes video picture quality, audio quality and audio/video synchronization into account to generate the overall multimedia quality.
VSTQ	0 .. 50.0	0 .. 100	VQmon Video Service Transmission Quality as defined in [14]. This is a codec-independent measure related to the ability of the bearer channel to support reliable video.
EPSNR	0 .. 60 dB	0 .. 60 dB	VQmon/HD Estimated Peak Signal to Noise Ratio. A measurement of the quality of a video signal. This corresponding to the maximum possible signal energy versus the energy of the noise.

A.2.3.1 Mean Opinion Scores (MOS)

VQmon/HD reports estimated Mean Opinion Scores (MOS) for picture quality (MOS-V), audio quality (MOS-A), and multimedia quality (MOS-AV) for each monitored video stream. MOS scores range from 1 to 5, with 1 considered "Unacceptable" and 5 "Excellent." MOS scores are reported as instantaneous (per-frame), minimum, maximum, and average values. Interval MOS scores are also reported as instantaneous and average values.
For picture quality, VQmon/HD reports both *Relative MOS-V* and *Absolute MOS-V* scores:

- Relative MOS-V **is an estimated perceptual quality score that considers the effects of codec/quantization level, the impact of IPTV impairments (e.g., packet loss) on the GoP structure and video content, and the effectiveness of loss concealment methods—but does *not* consider the image size/resolution, frame rate, or scanning method (interlaced vs. progressive).**

- Absolute MOS-V **is an estimated perceptual quality score that considers all the above mentioned factors as well as image resolution, frame rate, and the use of progressive vs. interlaced scanning.**

Some video formats offer inherently higher perceptual quality than others—for example, in unimpaired conditions, the quality of an HD broadcast will be higher than that of SD; 1080p better than 1080i or 720p; 60 frames per second better than 30 fps, etc. VQmon/HD's Absolute MOS-V score takes these factors into consideration, and thus provides an accurate estimate of "overall" perceptual quality.

Because it is independent of image resolution/frame rate, the Relative MOS-V score helps provide an indication of video quality relative to the ideal for a given video format.

Example: **An IPTV service provider offers 480i SD, 720p HD, and 1080p HD broadcasts. Assuming unimpaired conditions, the services might receive the following scores (values provided for example only):**
Absolute MOS-V: **480i = 4.0 720p = 4.3 1080p = 4.7**
Relative MOS-V**: 480i = 4.5 720p = 4.5 1080p = 4.5**

Relative MOS-V can be used to simplify alert thresholding in cases where multiple video formats are in use.

A.2.3.2 VQmon/HD Video Service Transmission Quality Metric - VSTQ

VQmon/HD produces a video services quality metric, *VSTQ* (*Video Service Transmission Quality)*, which is a codec-independent measure of the ability of the

bearer channel to support reliable video. This video service quality metric is expressed in the range of 0.0 to 50.0, as defined in [14].
VSTQ can be calculated by a mapping function from Peak Signal-to-Noise Ratio PSNR values as follows:

***VSTQ* = *max*(0, *min*(*50*, (*PSNR* - *12*) * *1.8*))**

Of course, VQmon/HD uses a more sophisticated algorithm to calculate the resulting VSTQ
score, which takes time-varying distributions of network impairments and recency into account.

Note: **The VSTQ score that VQmon/HD's API function produces actually ranges from 0 to 100. This value is scaled by 2 to get half-point accuracy for the score.**

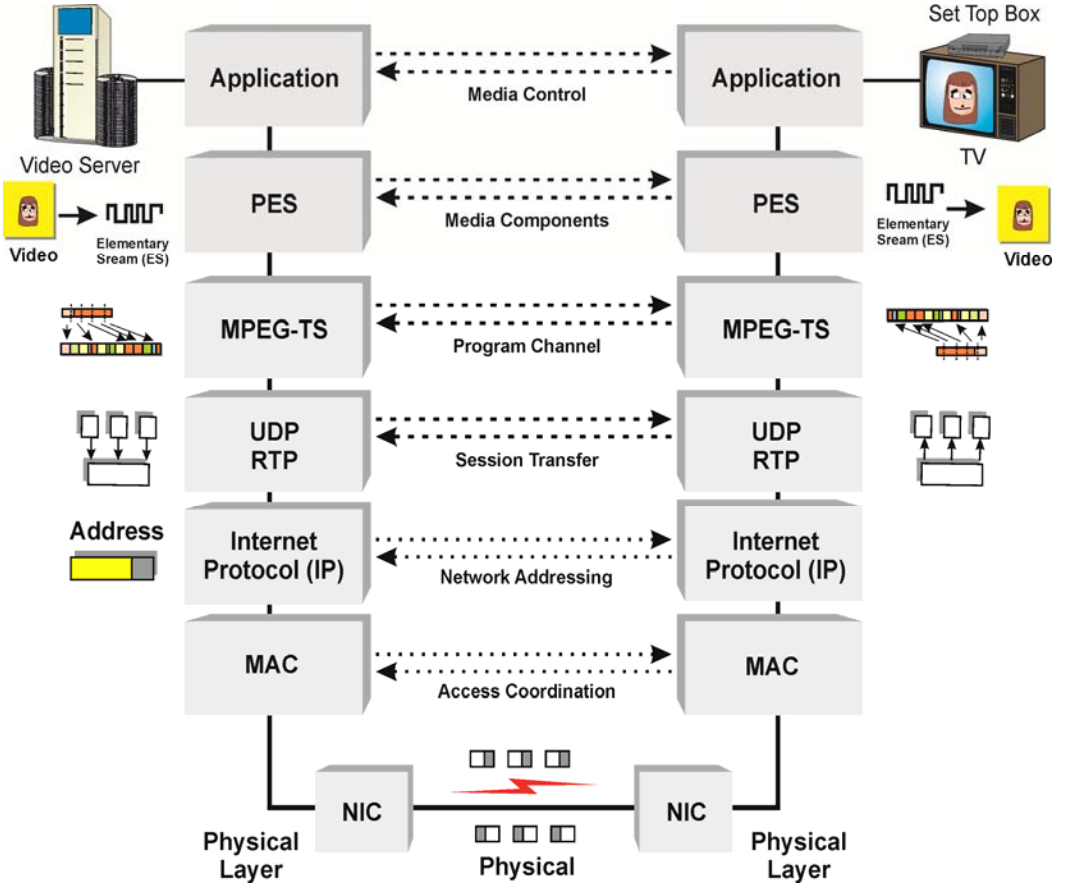
A.2.3.3 Degradation Factors

To facilitate troubleshooting, VQmon/HD has the ability to obtain a breakdown of factors contributing to quality degradation. VQmon/HD reports the severity of quality degradation (on a scale of 0-10, with 0 indicating no degradation and 10 indicating the most severe level of degradation) attributable to each of the following factors:

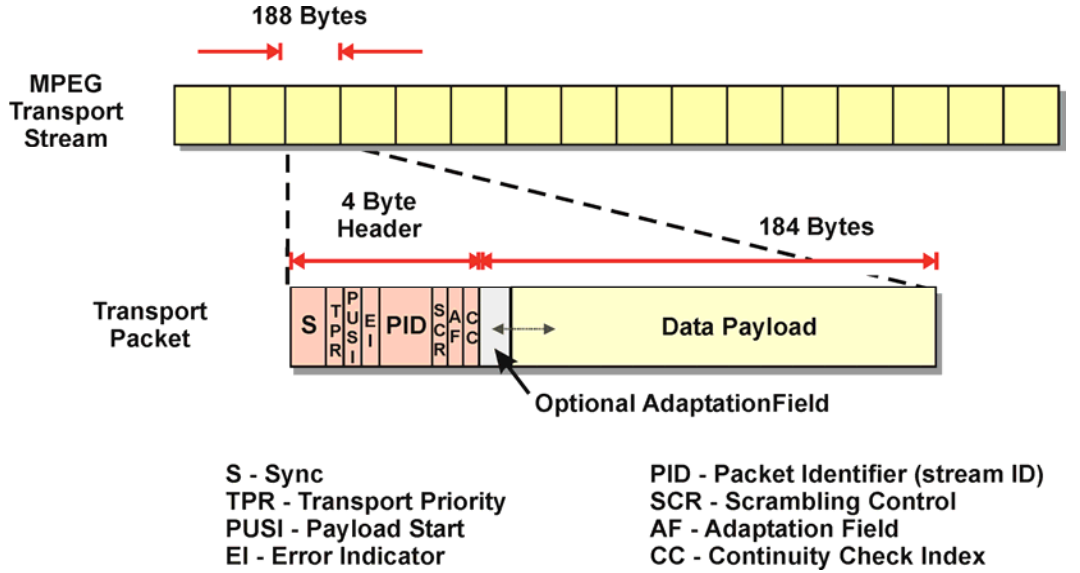
- **Packet loss**
- **Audio-video sync**
- **Codec quantization**
- **GOP length**
- **Codec bandwidth restriction**
- **Frame resolution**
- **Packet discards due to jitter**
- **Frame rate**
- **(One-way) delay**
- **Recency**

A.3 IPTV Protocols

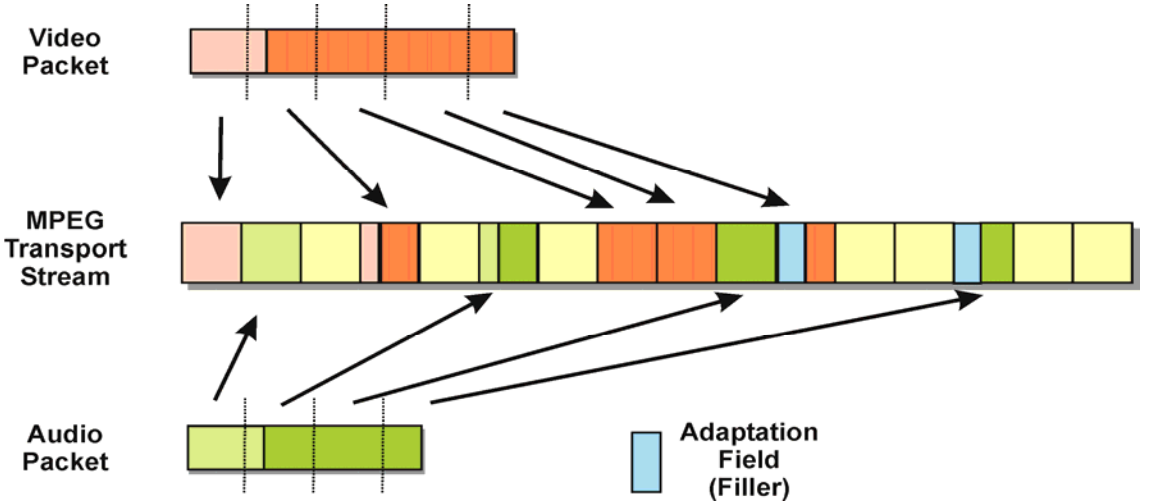
- **IPTV uses a multilayer protocol stack to deliver the media contents.**
- **The first 3 layers are typical for IPTV transmission.**
- **The UDP/RTP session layer is responsible for transferring packets between the sender and the receiver.**
- **The MPEG-TS transport stream layer combines multiple media streams (video, audio, data) into a single program transport stream.**
- **The PES layer assigns video and audio to specific packet streams.**
- **The application layer performs encoding and decoding of the video and audio using MPEG-2, MPEG-4, VC-1 or other formats.**



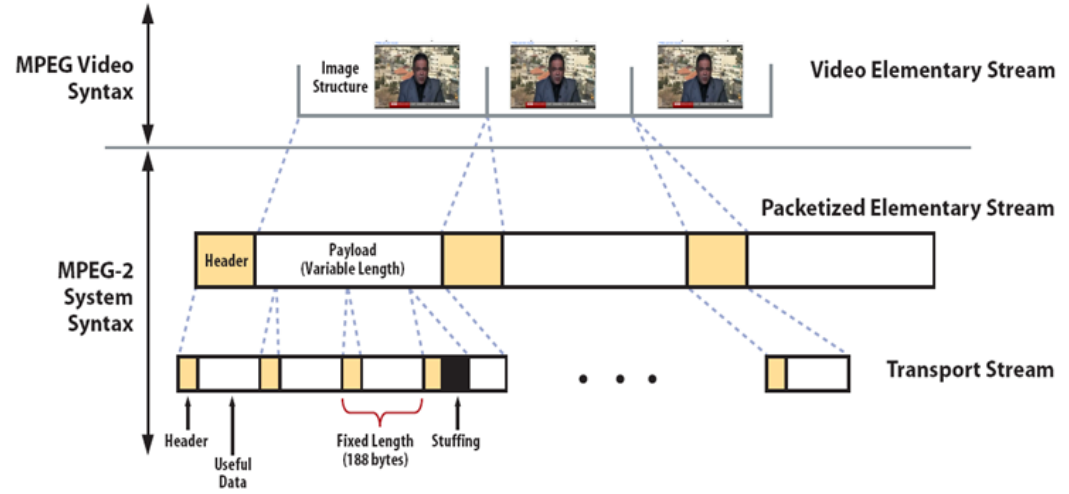
MPEG frame is fixed at 188 byte, with 184 Data Payload and 4 Byte Header. The 13-bit PID indentifies Packet Elementary Stream (PES).

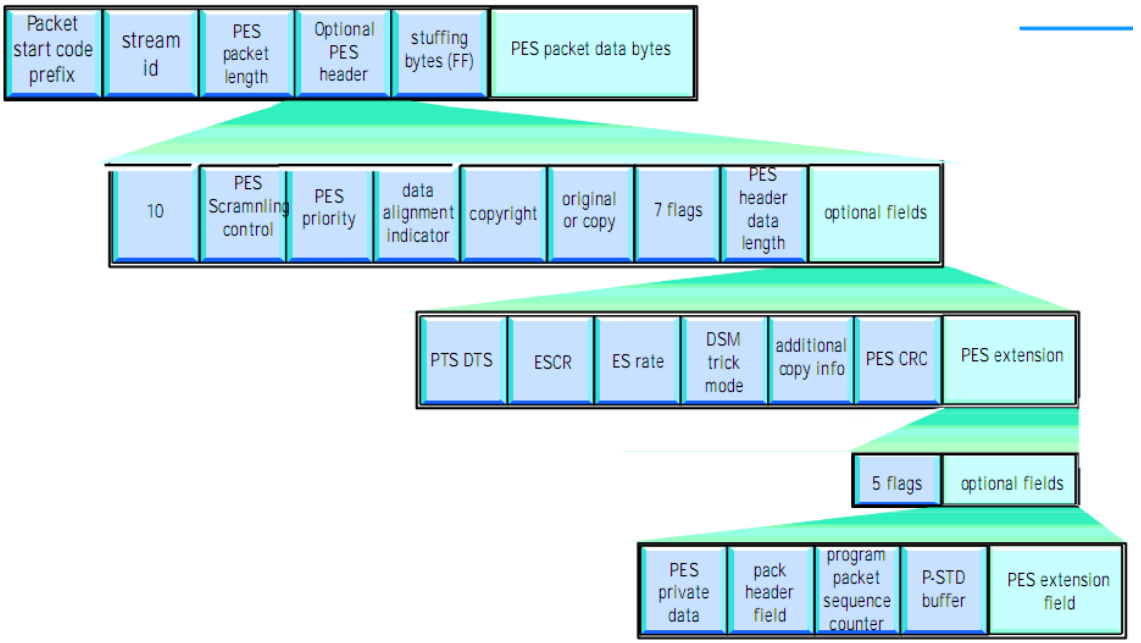


The PES is much longer than the MPEG frame so it is divided into segments over multiple MPEG frames.

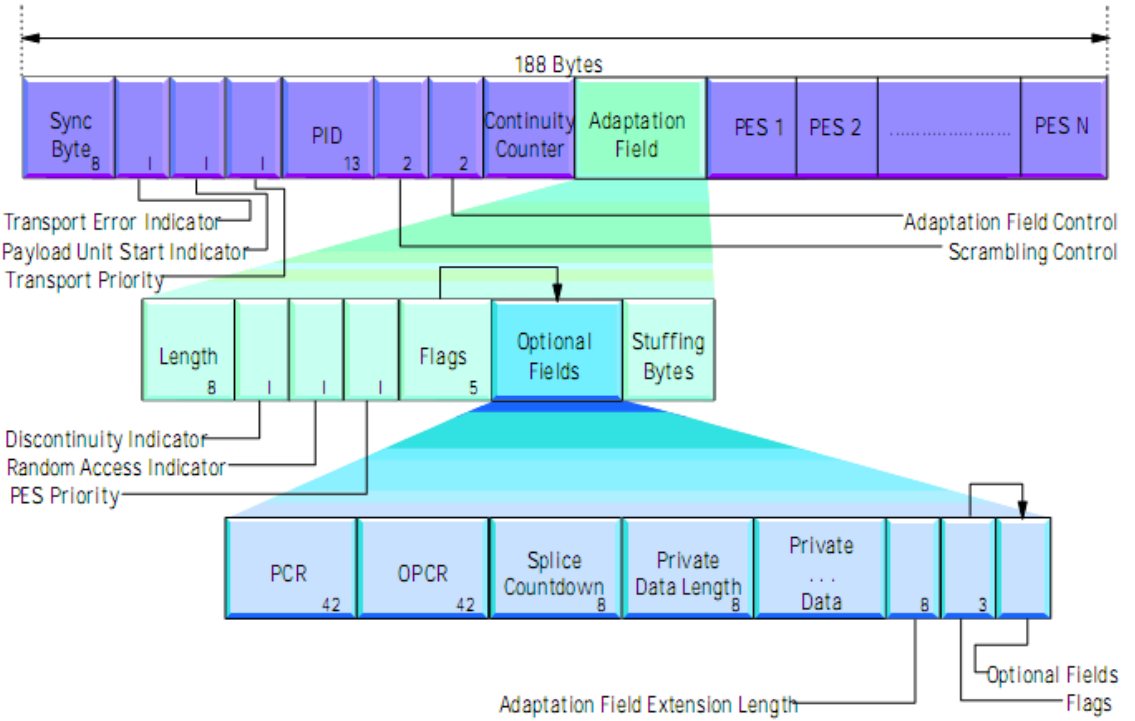


The Packetized Elementary Stream is converted into the Video Elementary Stream (MPEG-2 transport stream)



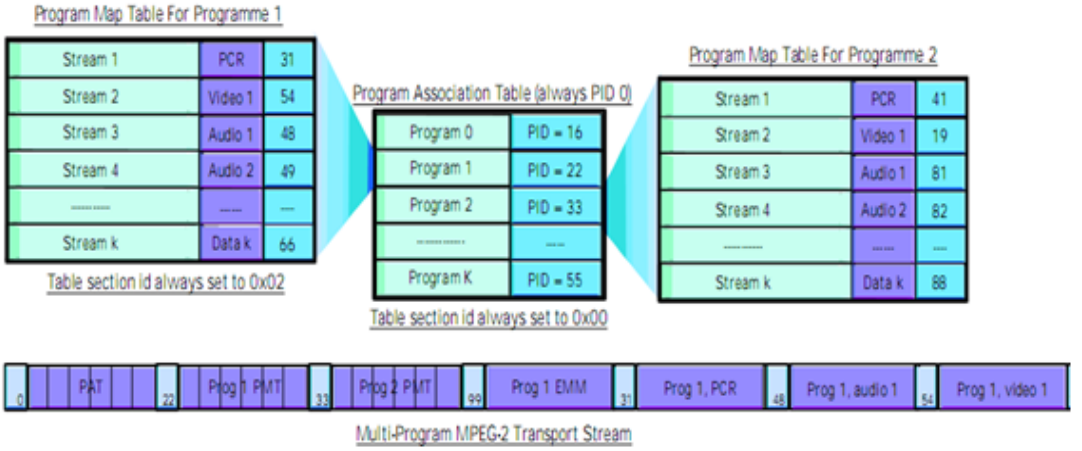


- **PES header contain information about the contents of the PES packet.**
- **Variable length packets typically up to 64 Kbyte but may be longer**
- **PTS and DTS allow a decoder to reconstruct the video from I, Band P frames sent by encoder.**
- **If header information is corrupted, entire PES packet will be lost.**
- **Fixed Length packets, multiplexes many PES packets.**
- **Program Identifier (PID) contains information to find, identify and reconstruct program contents**
- **Continuity Counter (CC) – 4 bit counter to detect loss or out of sequence packets**
- **Program Clock Reference (PCR) – clock reference to time sync the video and audio**
- **Sync byte set the start of a TS packet and allows synchronization**
- **Transport Error Indicator indicates a TS packet error**



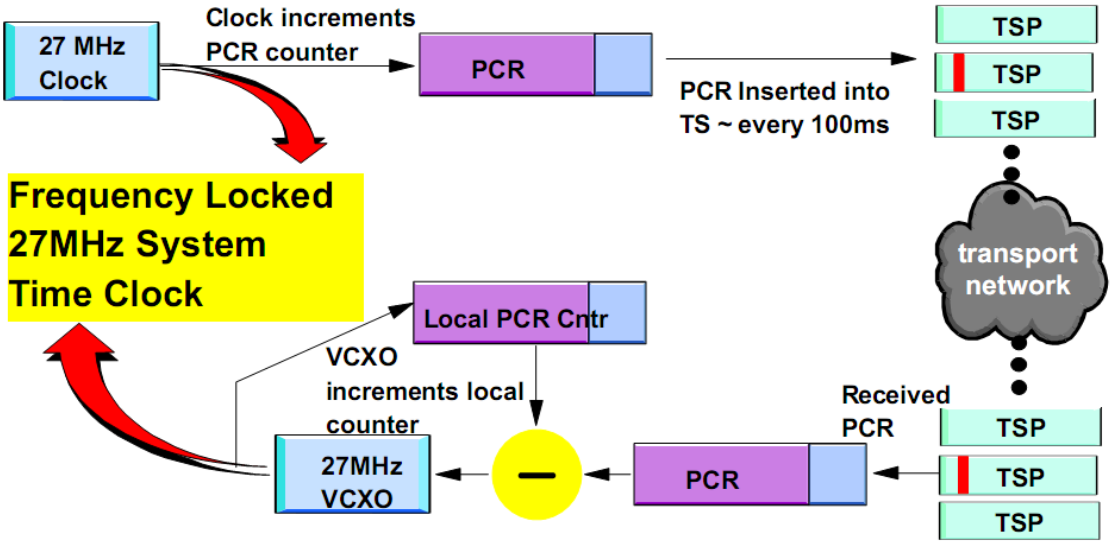
- **PAT lists all programs available in the transport stream with their program ID (PID).**
- **Each program has a PMT that lists the elementary streams for that program.**

- **Errors in PMT, PAT, PID/PSI(Packet Identifier/ Program Specific Information) Errors will cause the set top box lose contact with the stream. These errors may originate at any of the MPEG transport multiplexers when new streams are inserted.**



A.4 PCR Jitter

PCR (program counter reference) timestamps is generated by the MPEG-2 encoder and received throughout the subsequent links in the network at least 100 milliseconds apart. The decoder uses the PCR to lock its own 27 MHz clock to the encoder system time clock (STC). This 27Mhz clock is very sensitive to variations caused primarily by packet transmissions delays. Therefore, measurement of the PCR timestamp arrival time variation called commonly "PCR jitter" is essential. The 27 Mhz oscillator itself may not exceed 500nsec of internal jitter per TR 101290.



A.5 IGMP Latency vs. Zap time

The zap time is the total duration from the time viewer presses the channel change button, to the point the picture of the new channel is displayed, along with corresponding audio. These kind of delays exist in all television systems, but they are greater in digital television and systems that use the Internet like IPTV. Human interaction with the system is completely ignored in these measurements, so zap time is not the same as channel surfing.

Key Factors affecting Zap Time

- **Encoding**
- **Network**
- **Set top Box (leave and joins)**

Examples:

In this section some typical values of zap time are shown. Actually, in IPTV television these delays are greater than in other technologies:

- **Analog (Cable) ~ 1s**
- **Analog (off-air) ~ 1 – 3s**
- **MPEG2 over QAM ~ 1.2 – 3s**
- **MPEG2 over QPSK ~ 2 – 4s**
- **MPEG2 over IPTV Multicast ~ 1.5 – 3.5s**
- **H.264 over IPTV Multicast ~ 1.7 – 4s**

	Channel Change Latency Factor	Device/Location	Typical Latency	Cumulative Latency
1	Send IGMP Leave for channel X	STB	< 10 ms	
2	Send IGMP Join for channel Y	STB	< 10 ms	
3	DSLAM gets Leave for channel X	DSLAM/Network	< 10 ms	
4	DSLAM gets Join for channel Y	DSLAM/Network	< 10 ms	~ 20 - 40 ms
5	DSLAM stops channel X, and sends Channel Y	DSLAM/Network	~ 30 – 50 ms	~ 50 – 90 ms
6	DSL Latency (FEC/Interleave)	DSLAM/Network	~ 10 ms	~ 60 - 100 ms
7	Core/Agg Network Latency	Router/Network	~ 20 – 60ms	~ 80 – 160ms
8	De-jitter buffer	STB	~ 300 ms	~ 380 - 460 ms
9	Wait for PAT/PMT	STB MPEG buffer	~ 125 ms	~ 500 - 580 ms
10	Wait for ECM/CA	STB MPEG buffer	~ 125 ms	~ 620 - 700 ms
11	Wait for I-frame	STB MPEG buffer	~ 250 ms to 2s	~ 870 ms – 2.7s
12	MPEG buffer	STB MPEG buffer	~ 1s to 2s	~ 1.8s – 4.7s
13	Decode	STB	~ 50ms	~ 1.9s – 4.8s

IGMP is the signaling protocol used to access broadcast video services that use a multicast network design to efficiently manage network bandwidth. In this implementation, a join message is sent from the STB to the network.

The join message asks the network to send the requested program or channel to the STB by joining a multicast group carrying the desired broadcast channel.

IGMP latency, then, is the time between when the join message is sent and the first video packet is received by the STB.

This parameter measures network performance, but not the end user's experience with regard to channel changing time.

The IGMP latency plus the time it takes to fill the decode buffer and to decode and display the content is the total user experience time. However, the buffer fill time and the decode time are functions of the network architecture and are not variables. This total time is called Zap Time.

Appendix B Technical Specification

Physical Layers Supported -

10/100/1000 Ethernet, Wi-Fi 802.11 b/g/n.

Recognized Video Compression Standards Codecs -

unknown video
motion JPEG video
MPEG-1 video
MPEG-2 video
ITU-T H.261 video
ITU-T 1996 version of H.263 video
ITU-T 1998 version of H.263+ video
ITU-T H.264 video
MPEG-4 video
Microsoft VC1 video
MPEG2, MPEG4 part 2&10 (H.264).

Recognized Audio Compression Standards Codecs –

unknown audio
MPEG-1 Layer 1 audio
MPEG-1 Layer 2 audio
MPEG-1 Layer 3 audio
MPEG-2 Advanced Audio Coding
AC-3 audio
MPEG-4 Advanced Audio Coding
MPEG-4 Low Delay Advanced Audio Coding
MPEG-4 High Efficiency Advanced Audio Coding

Signaling Protocols -

IGMP versions 2 & 3, RTSP

STB Emulatiom -

IGMP Join and Leave request
IGMP latency
VoD RTSP Play and Stop
Connects up to 10 channels(streams)
Monitors up to 10 channels
Video preview (live full frame SD and HD)

Summary –

Video Description Information

IP source address
IP destination address
Source port
Destination port
Protocols
Codec type
Group of picture type
Current GOP length
Average GOP length
Max GOP length
Average gap of I frame
Frame width
Frame height
Frame rate
interlaced
Average number of slices in I frame
Reference clock rate
Average video bandwidth
Average packet size

Summary Metrics

Measurement time
Average audio/video MOS
Max PCR Jitter
Video packet loss rate
TR 101290 errors priority 1 and 2
IGMP Latency

Video -

Video Perceptual Quality Metrics

Instantaneous absolute MOS
Minimal absolute MOS
Average absolute MOS
Maximum absolute MOS
Instantaneous relative MOS
Minimal relative MOS
Average relative MOS
Maximum relative MOS
Instantaneous audio/video MOS
Minimal audio/video MOS
Average audio/video MOS
Maximum audio/video MOS
Transmission quality:
EPSNR
EPSNR(ATIS)
Degradation Factors:
Lost
Discarded
Codec quantization level
Codec bandwidth restrictions
Frame resolution
Frame rate
GOP length
Available network bandwidth
Audio/video synchronization
Recency

Video Jitter

Frame inter arrival jitter
I frame inter arrival jitter
Average frame arrival delay
Peak frame arrival delay

Video Scene Analysis Metrics

Instantaneous detail level
Instantaneous motion level
Instantaneous panning level
Static image proportion
High detail proportion
Low detail proportion
High panning proportion
Low panning proportion
High motion proportion
Low motion proportion

Packets –

Transport Packets Metrics -

Packets received
Lost
Discarded
Corrected
Out of sequence
Duplicated
Lost %
Corrected %
Discarded %
Out of sequence %
Duplicated %
Burst count
Burst loss rate
Average burst length [pkts}
Gap count
Gaps loss rate
Average gap length [pkts]

Jitter Metrics (RFC3550) -

Packet to packet delay variation
Max packet to packet delay variation

RTP Packets Metrics (Carrying MPEG2-TS)-

Packets Received
Corrected
Lost
Discarded
Out of sequence
Duplicated
With timestamp errors

MPEG2-TS TR101290 -

Priority 1 last errors

TS sync loss count
Sync byte error count
PAT error count
PAT2 error count
Continuity error count
PMT error count
PMT2 error count
PID error count

MPEG2-TS TR101290 –

Priority 2 last errors

Transport error count
CRC error count
PCR error count
PCR repetition error count
PCR discontinuity error count
PCR accuracy error count

Audio –

Audio Description Information

IP source address
IP destination address
Source port
Destination port
Type
Transport protocol
Codec Type
Number of channels
Reference clock

Audio Perceptual Quality Metrics

Minimal MOS
Average MOS
Maximum MOS
Instantaneous MOS
Degradation factors
Lost
Discarded
Codec
Recency

Audio bandwidth metrics

Avg audio bandwidth
Peak audio bandwidth
Avg audio bandwidth(incl headers)
Peak audio bandwidth(incl headers)

Video Frames I,P,B,SI,SP –

- **Frames received**
- **Frames impaired**
- **% frames impaired**
- **Packets received**
- **Packet lost**
- **Packet discarded**
- **% packets impaired**
- **%packets impaired by error propagation**
  - **Except for I and SI**

Video bandwidth of I,P,B, SI and SP frames –

- **Average video bandwidth**
- **Max video bandwidth**

Histograms (charts)

- **Up to two charts from any metrics**

LAN Port -

- **IP address**
- **Downstream rate**
- **Upstream rate**

Troubleshooting

Contacting the Technical Support GroupTo obtain after-sales service or technical support for this product, contact EXFO at one of the following numbers. The Technical Support Group is available to take your calls from Monday to Friday, 8:00 a.m. to 7:00 p.m. (Eastern Time in North America).

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Technical Support Group
400 Godin Avenue
Quebec (Quebec) G1M 2K2
CANADA

1 866 683-0155 (USA and Canada)
Tel.: 1 418 683-5498
Fax: 1 418 683-9224
support@exfo.com

Glossary

Perceptual Quality Metrics	
Metric	*Description*
MOS-V	**Video MOS, a 1-5 score that considers the effect of the video codec, frame rate, packet loss distribution and GoP structure on viewing quality**
MOS-A1 and MOS-A2 for 2 codecs that are present in some streams	**Audio MOS, a 1-5 score that considers the effect of the audio codec, bit rate, sample rate and packet loss on viewing quality**
MOS-A1V	**Audio-Video MOS – a 1-5 score that considers the effect of picture & audio quality and audio-video synchronization on overall user experience**
Video Service Transmission Quality (VSTQ)	**Transmission quality, a 0-50 codec independent score measuring the ability of the IPTV network to carry reliable video**
Video Service Picture Quality (VSPQ)	**Picture quality, a 0-50 score that considers the effect of the video codec, frame rate, packet loss distribution and GoP structure**
Gap VSPQ	**Picture quality during "good" periods when little or no degradation is occurring**
Burst VSPQ	**Picture quality during "bad" periods when significant degradation is occurring**
Video Service Audio Quality for 2 codecs (VSA1Q and VSA2Q)	**Audio quality, a 0-50 score that considers the effect of the audio codec, bit rate, sample rate and packet loss on viewing quality**
Video Service Multimedia Quality (VSMQ)	**Multimedia (Audio-Video) quality, a 0-50 score that considers the effect of picture & audio quality and audio-video synchronization on overall user experience**
Estimated PSNR (EPSNR)	**Estimated Peak Signal to Noise Ratio (PSNR) expressed in dB. This is an estimate of the distortion that has occurred between the source video stream and the output video stream.**
Degradation Factors	**Percentage degradation in quality due to (each of) Loss, Discard, Codec type, Audio-Video Sync, Delay and Recency.**

The Video Stream Description provides information on the type of codec being used, Group of Pictures structure and length, image size and other key factors.

Video Stream Description	
Metric	*Description*
Codec type	**Type of codec (e.g. MPEG4)**
GoP type	**Group of Pictures type (e.g. IBBP…)**
GoP length	**Number of frames in Group of Pictures**
Image size	**Image size in pixels (X x Y) (autodetected *) and number of frames per second**

Video Stream Metrics provide insight into the proportion of different type of video frame that are impacted by packet loss and discard, and to the overall video bandwidth.

Video Stream Metrics	
Metric	*Description*
I, P, B frame packets received	**Counts of the numbers of I, P and B frame packets received**
I, P, B frame packets lost	**Counts of the numbers of I, P and B frame packets**
I, P, B frame packets discarded	**Counts of the numbers of I, P and B frame packets**

Packet Loss Metrics provide essential data on IPTV packet loss before and after the effects of error correction (such as FEC or Reliable UDP). Burst and gap statistics provide valuable insight into the time distribution of lost and discarded packets.

MPEG-TS Packet Loss Metrics	
Metric	*Description*
Packet Loss Rate	**Percentage of MPEG-TS packets lost in the network**
Packet Discard Rate	**Percentage of packets discarded due to late arrival**
Out of Sequence Packet Rate	**Percentage of packets arriving out of sequence**
Duplicate Packet Rate	**Percentage of duplicate packets**
Burst Loss Rate	**Percentage of packets lost within burst periods**
Burst Length	**Average length of burst periods**
Gap Loss Rate	**Percentage of packets lost within gap periods**
Gap Length	**Average length of gaps between bursts**
PCR (Program Clock Reference) Jitter Metrics	
Metric	*Description*
PCR Jitter	**Program Clock Reference Jitter**
MDI (Media Delivery Index) Metrics	
Metric	*Description*
MDI Delay Factor	**Media Delivery Index Delay Factor is the maximum difference, observed at the end of each media stream packet, between the arrival of media data and the drain of media data**
MDI Media Loss Rate	**Media Delivery Index Loss Rate is the count of lost or out-of-order packets carrying streaming application information over a selected time interval,**

TR101 290 metrics provide green LED ON/OFF information on certain key error types that occur with MPEG Transport protocols, and are useful in identifying and resulting these error conditions.

TR 101 290 MPEG Metrics	
Metric	*Description*
TS_sync_loss	**Loss of synchronization at MPEG transport layer**
Sync_byte_error	**Invalid MPEG transport sync byte**
Continuity_count_error	**Incorrect packet order, duplicate packet or lost packet**
Transport_error	**Transport error indicator in MPEG transport header set**
PCR_repetition_error	**Time interval between two successive PCR values more than 40ms**
PCR_discontinuity_indicator_error	**Difference between two consecutive PCR values is over 100ms without discontinuity bit set**
PTS_error	**Interval between presentation time stamps more than 700ms**

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www.EXFO.com · info@exfo.com

CORPORATE HEADQUARTERS	400 Godin Avenue	Quebec (Quebec) G1M 2K2 CANADA Tel.: 1 418 683-0211 · Fax: 1 418 683-2170
EXFO AMERICA	3400 Waterview Parkway Suite 100	Richardson, TX 75080 USA Tel.: 1 972-761-927 · Fax: 1 972-761-9067
EXFO EUROPE	Omega Enterprise Park, Electron Way	Chandlers Ford, Hampshire S053 4SE ENGLAND Tel.: +44 2380 246810 · Fax: +44 2380 246801
EXFO ASIA-PACIFIC	100 Beach Road, #22-01/03 Shaw Tower	SINGAPORE 189702 Tel.: +65 6333 8241 · Fax: +65 6333 8242
EXFO CHINA	Beijing Global Trade Center, Tower C, Room 1207, 36 North Third Ring Road East, Dongcheng District	Beijing 100013 P. R. CHINA Tel.: +86 (10) 5825 7755 · Fax: +86 (10) 5825 7722
EXFO SERVICE ASSURANCE	270 Billerica Road	Chelmsford MA, 01824 USA Tel.: 1 978 367-5600 · Fax: 1 978 367-5700
EXFO NETHAWK	Elektroniikkatie 2	FI-90590 Oulu, FINLAND Tel.: +358 (0) 403 010 300 · Fax: +358 (0) 8 564 5203
TOLL-FREE	(USA and Canada)	1 800 663-3936

Printed in Canada (2012-04)

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