Testing MPEG based IP video QoE/QoS

Shenick Network Systems

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References

[1] RFC2250…………………….**RTP Payload Format for MPEG1/MPEG2 Video**
[2] RFC2236…………………….**Internet Group Management Protocol, Version 2**
[3] TR 101 290………………….**Digital Video Broadcasting (DVB); Measurement guidelines for DVB Systems**
[4] ISO/IEC-13818-4……………**Information technology -Generic coding of moving pictures and associated audio information -Part 4: Conformance testing**

Glossary

CLEC	Competitive Local Exchange Carrier
DTS	Decode Time Stamp
ECM	Entitlement Control Messages
EMM	Entitlement Management Messages
ES	Elementary Stream
IPTV	Television over Internet Protocol Networks
MOS	Mean Opinion Score
MPEG – TS	MPEG Transport Stream
NTSC	National TV Standards Committee (Television format)
OSI	Open Sytems Interconnection Model
PAL	Pase Alteration Line (Television format)
PES	Packetized Elementary Stream
PEVQ	Perceptual Evaluation of Video Quality
PID	Packet Identifier
PiP	Picture-in-Picture
PSI	Program Specific Information
PTS	Presentation Time Stam[
PVR	Personal Video Recorder
QoE	Quality of Experience
QoS	Quality of Service
RTP	Real Time Protocol
SECAM	Sequential Colour And Memory(Television format)
SI	Service Information
STB	Set-Top Box
UDP	User Datagram Protocol
VoD	Video on Demand

Abstract

This paper outlines procedures and tests for IP video including IPTV and Video on Demand (VoD) media streams in determining subscriber Quality of Experience(QoE). This paper can be used as part of an overall IP video test and monitoring procedure.

Overview

Testing IPTV/VoD media streams over converged IP or Triple Play networks is a daunting and somewhat unfamiliar area for many. IPTV has added a new level of complexity and challenge to the network, the addition of real-time or broadcast television. IPTV must offer a high quality of service and experience in which users will not tolerate any distortion and is error free. The aim of this paper is to outline key video concepts plus the technical issues that may arise. The paper will also outline methodologies and guidelines that should be used in testing and monitoring for IPTV QoE.

Fundamentals of MPEG based Video Streams

A brief overview of the video stream encapsulation layers are depicted in Figure 1. The IPTV MPEG-TS model is sampled against the OSI model. The most comprehensive test scenario will cover all 7+ layers of the relevant OSI model.

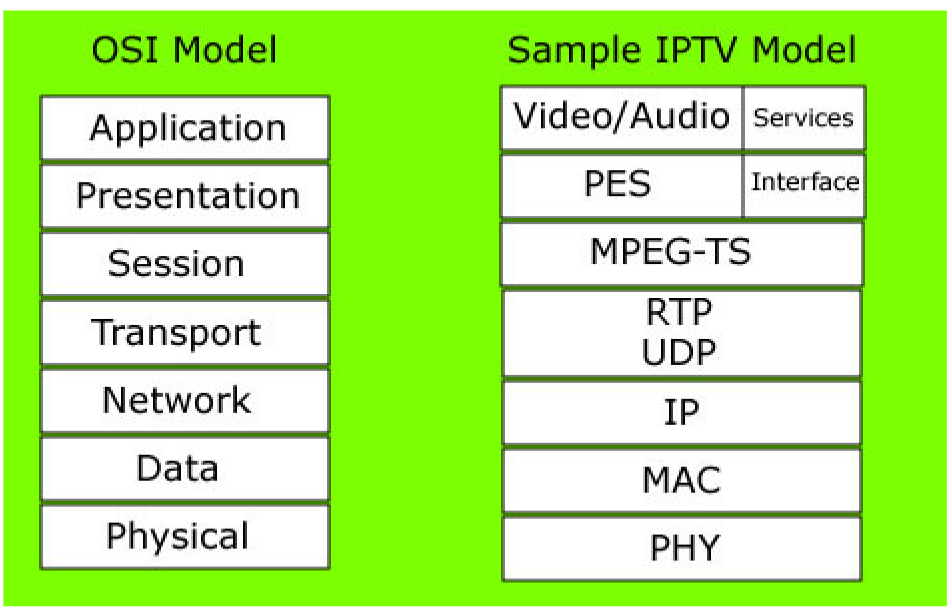

Figure 1 – IPTV OSI Model

The IPTV Model in Figure 1, uses MPEG-TS (Transport Streams), this representation applies equally to other CODECs such as AVC, VC-1, etc.

The sample IPTV model may be further sub divided into two very distinct sections; the service layers and the transmission layers. The service layers exist above the RTP UDP layer and the transmission layers extend from the RTP UDP layer to the Physical layer. QoE testing on IPTV must encompass both service and transmission layers for the most accurate result. Ideally testing the actual received decoded video stream against a known good source on an end to end basis provides the most accurate results.

In Figure 2, the relationship between each layer is outlined in the construction of an MPEG-2 media stream. Understanding the interaction of the layers is of fundamental importance.

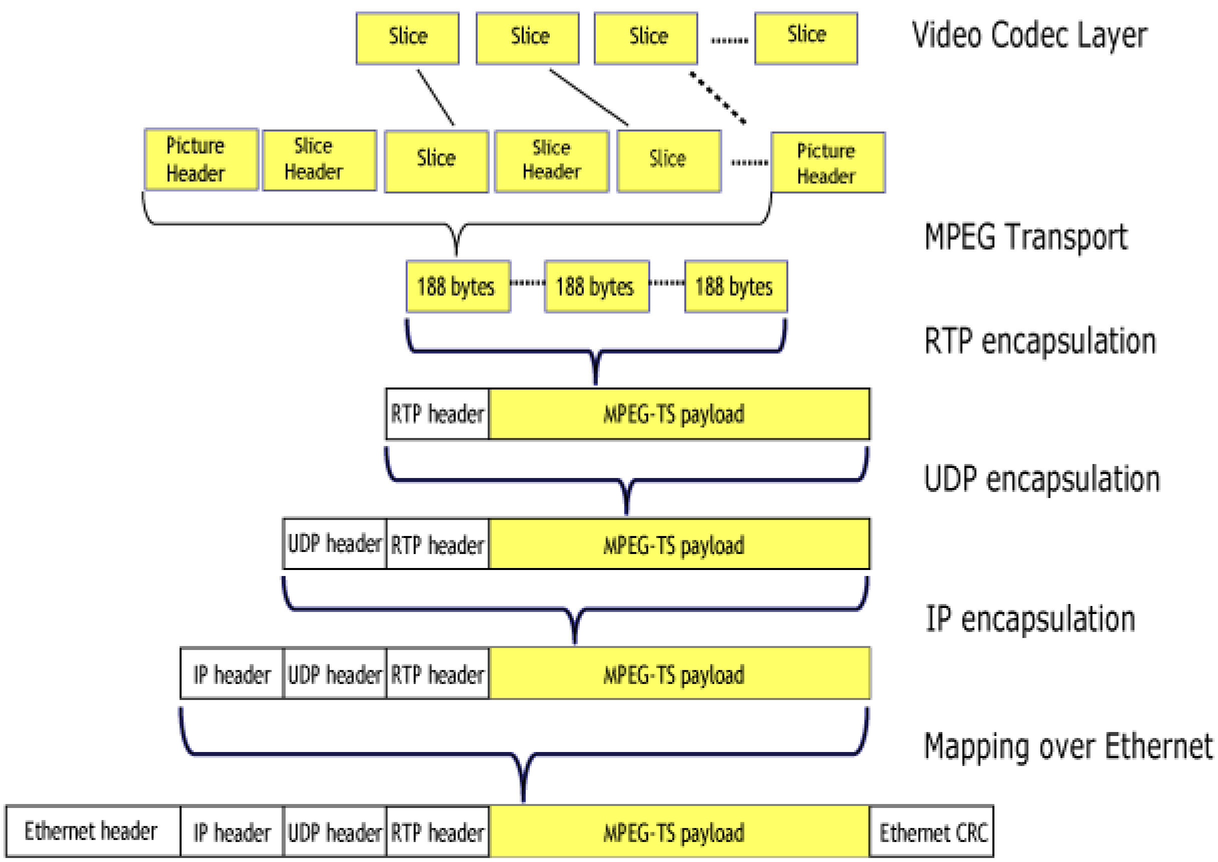

Figure 2 – Encapsulation Layers

The video signal can be in Analog format such as NTSC, SECAM or PAL which is inputted into an encoder. The encoder performs digitization and compression in this example, MPEG-2, to generate an Elementary Stream (ES) of video and audio content. The encoder will then process or slice the ES to generate a Packetized Elementary Stream (PES). MPEG-4 is assembled in a similar a manner.

Each individual PES will contain a picture and a slice header, the relevance and importance of each can be found in the section on Test Procedures. The process continues by multiplexing individual PES into a Transport Stream (TS). Using an Ethernet network as an example; the Maximum Transfer Unit is fixed at 1560bytes, the defined size for the PES is set at 188bytes, allowing up to 7 * 188bytes to be transported as an encapsulated MPEG-TS.

The initial steps, readying the video, are considered part of the Service layers. However not covered above is the addition of the Service Information (SI), Program Specific Information (PSI), Entitlement Control and Entitlement Management Messages (ECM and EMM respectively) used mainly on encrypted channels. Broadcasters rely on encryption to generate premium content channels. Encryption is generally applied to the MPEG payload and not the headers. In general terms the PES are then multiplexed into the MPEG-TS.

Following the service layers are the transmission layers for readying the MPEG-TS for delivery across the network.

As the focus of this paper is testing IPTV subscriber QoE, below is a list of the protocol standards which reference the various layers in Figure 2 – Encapsulation layers. These standards are recognized by the IETF in the delivery of IPTV.

- RFC 2250 – A Packetization method for transportation of MPEG-TS utilizing RTP protocols.
- RFC 1889 – An outline of RTP and RTCP, provisioning a method of transportation independent of transport and network layers.
- RFC 768 – UDP, a delivery of application program messages across a packet switched network.
- RFC 2236 – IGMPv2 (Internet Group Management Protocol), outlining the principles of multicasting and membership reports.
- RFC 791 – Internet Protocol.

Network Architecture

Before implementing a test plan and outlining the key test requirements, the network architecture must be considered. Service Providers are or should at least be aware of the bandwidth limitations or processing bottlenecks in their existing networks. Figure 3 below highlights a sample IPTV network architecture topology. As this is an open paper on subscriber IPTV QoE, the tests proposed herein will remain transport medium independent (optic or copper limitations are not covered).

In the initial stages of development and deployment network architects will have incorporated the ability of the network to scale with subscriber growth. As part of the network test plan, consideration must be given to scale tests from individual subscribers to whole access segments or neighborhoods.

As part of the IPTV network infrastructure, Service Providers will have chosen the network components which include head end broadcast servers, Codecs, error correction deployed in the transport stream, the multicast delivery protocol such as IGMP or MLD, IPTV Set Top box (STB) and Electronic Program Guides (EPG) deployment.

Service Providers will have considered key offerings defining their unique differentiating IPTV service such as movie/sports channels, gaming and even intelligent interactive advertising. Certain sports or movie channels maybe considered as premium channels and will be encrypted. IPTV advertising requires specialized equipment for stream splicing and ad insertions, which will not be covered in this paper.

Implementing all of the above is challenging and at the very least a test plan must include functionality, scalability, interoperability and performance and most important subscriber QoE assessment.

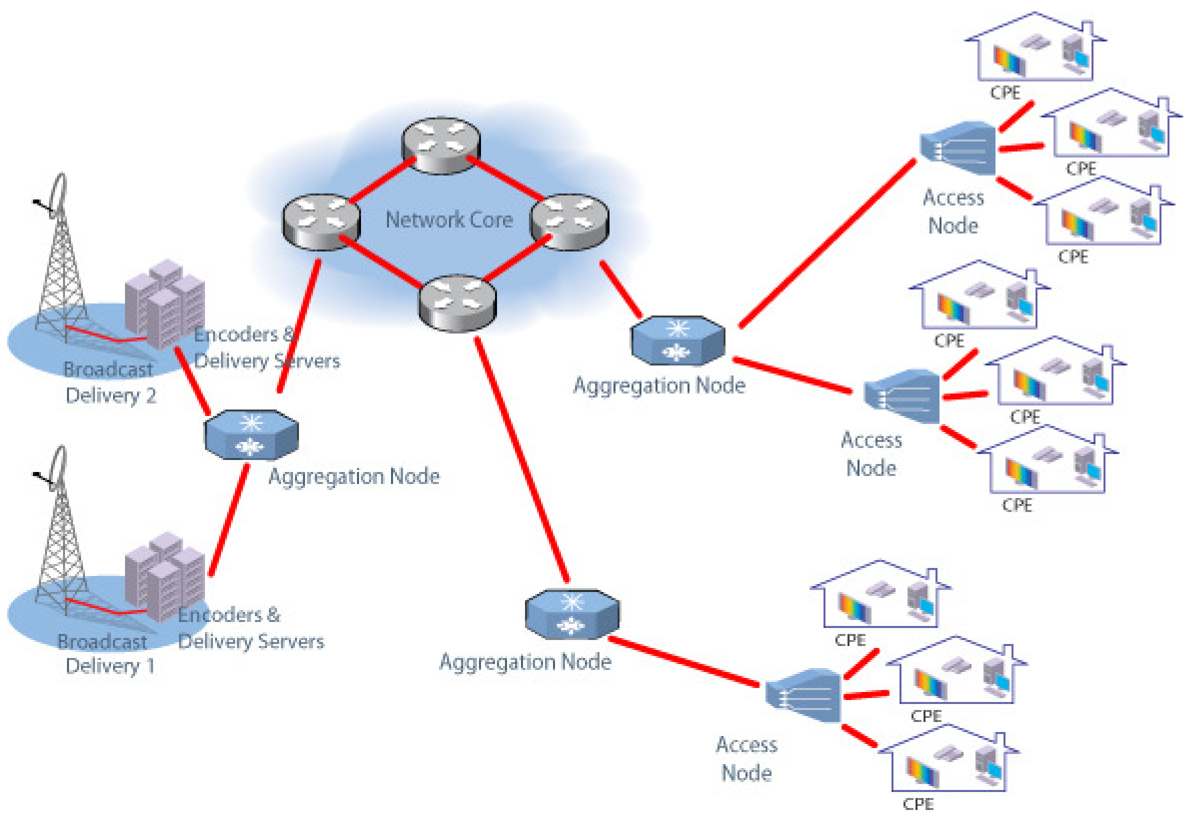

Figure 3 – IPTV Network Architecture Topology

Test Plan

The following proposed test plan will be split into three main sections Service Layers testing, Transmission Layers testing and finally video monitoring. The test plan draws on key concepts provisioned in the ISO/IEC 13818-4 "Information Technology – Generic coding of moving pictures and associated audio information – Part 4: Conformance Testing".

From the DSL Forum, document WT-126 is referenced as a guide to implementing the test plan and outlines the use of Video Quality Metrics subjective testing using MOS Scoring. The document also outlines guidelines video QoE metrics across several layers:

- Application Layer :
  - o Data Plane (Video/Audio bitrates)
  - o Control Plane (Channel Zap Rate)
- Service Layer : MoS Scoring
- Transport Layer :
  - o Data Plane (Packet Loss Ratio for SDTV and HDTV)
  - o Control Plane (IGMP Processing)

The tests covered in the following sections will include PES header analysis, MPEG-TS analysis and finally Video Analysis is introduced including the concept of MoS Scoring. Other tests includes Zap Rate measurements.

Service Layer Testing

PES Analysis:

Scenario: The familiar expression "I have picture and no sound" means that at the very least network service providers must have a means of being able to identify the IP video stream contents and ensure the there is also audio being delivered along with the video. More important is the correct audio stream being delivered for the viewed video stream.

In Figure 4 below the PES packet structure is shown.

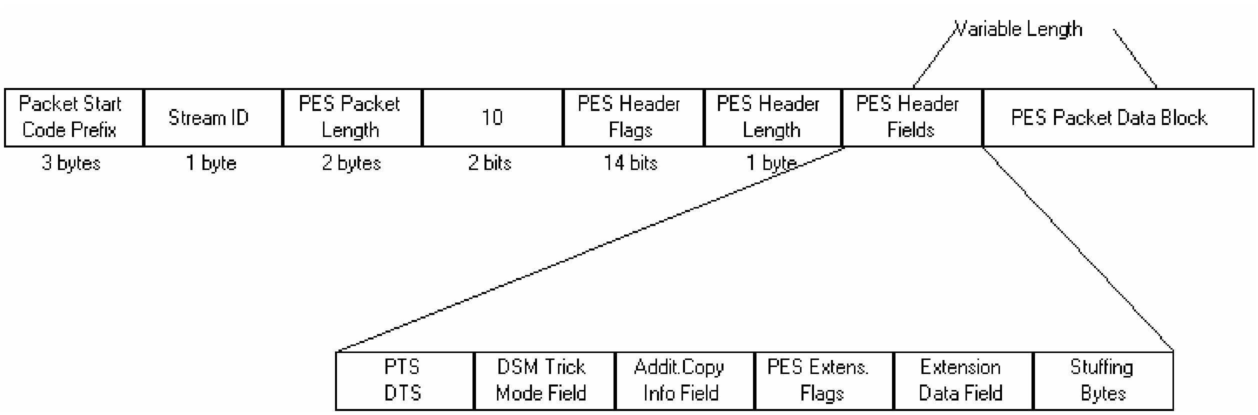

Figure 4 – PES Packet Structure and Header Fields

A QoE measurement requirement is the ability to identify the packet contents – determine the packet type from the stream ID:

Stream ID	Function
1111 0000	ECM
1111 0001	EMM
1110 xxxx	MPEG Video Stream number xxxx
111x xxxx	MPEG Audio Stream Number xxxxx
1011 1110	Padding Stream

Table 1 – PES Stream ID

PES Header Flags contain Timestamps indicators which indicate the presence of the Presentation Time Stamp (PTS) or PTS and the Decoding Time Stamp (DTS). The PTS refers to the start of the first complete audio frame in the packet and should be spaced less than 700ms apart.

In the PES Header fields the DTS and PTS can be found, these are important. DTS is used to indicate when the frame should be decoded and PTS indicates when the frame should be displayed. As covered in MPEG basics earlier, the transmission order of frames is different from display order. In summary DTS and PTS are used to reconstruct the video from the I, B and P frames.

MPEG-TS Analysis:

The ability to analyze the MPEG-TS provides quantifiable measurements for IPTV subscriber QoE that may not be captured in the transmission layers or from the RTP layer down. A typical monitoring scenario of the transmission layers can produce statistics suggesting that quality is not an issue, such as the fact that network jitter is not excessive. However, problems may occur in the service layers leading to poor subscriber QoE. This section looks at key problems and suggested reasons where issues may occur in the MPEG-TS. An introduction to subjective analysis and MOS scoring is provided.

In Figure 5 below the MPEG-TS header is shown.

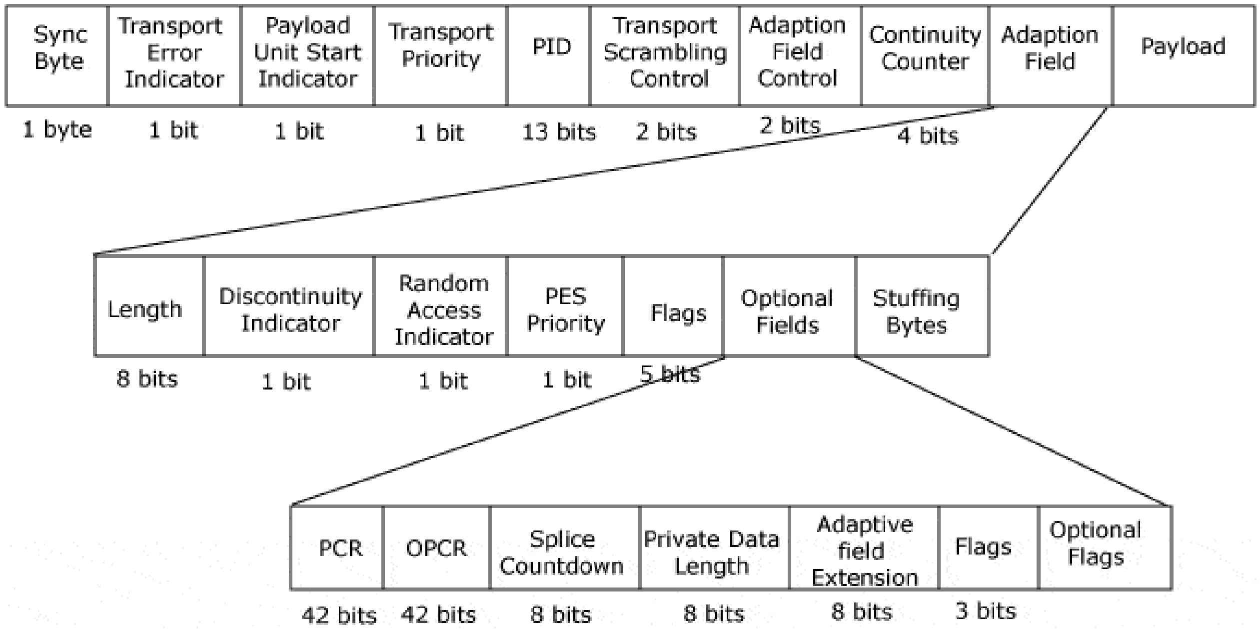

Figure 5 – MPEG-TS Headers

The key measurements required to ensure subscriber QoE include:

Packet Identifier (PID) – PID is a unique channel address identifier. PID enables identification and reconstruction of the programme. PID is used in conjunction with the Programme Service Identifier (PSI) packets, the decoder uses the PID and PSI to identify the Programmes Association tables (PAT), PAT contain Program Map tables (PMT) that point the decoder to the packets associated with the channel or programme such as video, audio and data content in the transport stream.

Continuity Counter – This counter increments zero through 15 for each PID, used to determine if packets are lost or repeated.

Lost Packets evidently affect the subscriber QoE, image quality may feature blockiness and blurriness.

Program Clock Reference (PCR) – PCR is used to synchronise the decoders clock to the same rate of the original encoder clock. PCR is also used by PTS and DTS.

Excessive PCR Jitter affects the stream in particular the image. Visible problems include pixelization, loss of color or even frame freezes delivering poor subscriber QoE in IPTV. There are several causes to PCR jitter. It may start at the encoding stages, it could be network related and a key factor for Service Providers jitter may be introduced when ad insertion takes place. Network related jitter measurements are covered further on in this paper.

Introducing Passive and Active Video Analysis

The ability to measure and monitor key parameters of an MPEG-TS including PES headers provides an indication of the video stream quality. The ability to measure RTP jitter in the transmission layers will indicate if the fixed buffers in the network, including the Set-top Box (STB) jitter buffers will over or under run, which evidently will lead to poor QoE. An important factor not is the actual video performance.

There are two methods for qualitative video analysis. The first method analyzes actual video payload, known as Active Analysis and involves a full and detailed video reference comparison. The second method is Passive Analysis which is a real time video quality assessment by analyzing header details. Passive analysis has the added benefit of being able to determine video quality on encrypted streams.

Active Video Analysis is the most accurate of all video analysis systems since the measurement is conducted on a frame by frame, ‘pixel by pixel’ basis. Users perform analysis which compares a received stream against a generated source stream. Comparing the received stream frame versus the source frame enables providers to determine high end issues such as brightness, chrominance, pixelization and luminance.

Passive Video Analysis will not consider the actual payload but runs analysis on the encapsulating video frame headers. Passive Analysis enables multiple parallel packet inspection. Parallel Packet Inspection provides greater detail and diagnostic capabilities.

Subjective analysis or Mean Opinion Scoring (MOS) is performed by both passive and active analysis method and is one the leading requirements for the DSL Forum. Requirements for such tests are referenced in test document WT-126. MOS Scoring simplifies the need for understanding all the required test results. MOS scores simplify the analysis output and in some cases are used as alarm threshold indicators, to highlight potential network problems in real time monitoring scenarios.

Forward Error Correction (FEC) is enabling higher rates of QoE to be achieved. However FEC functionality is outside the scope of this paper. It is important to note the various versions of transmission error corrections. Inclusion and determining the benefit of using FEC should be included in all test plans.

Active Analysis Details:

Active analysis with Perceptual Evaluation of Video Quality (PEVQ) is the nearest comparison to a human Video Expert analyzing the video quality output on a real TV. The received stream is compared with a reference stream as in Figure 6.

In terms of Figure 2, analysis is completed on the payload. Payload analysis is by far the most accurate solution available. The outcome of Active analysis is a PEVQ score, the score is then mapped to a MOS score of 1 to 5, excellent quality is represented by 5.

Table 2 indicates some of the key metrics used in determining IPTV video quality.

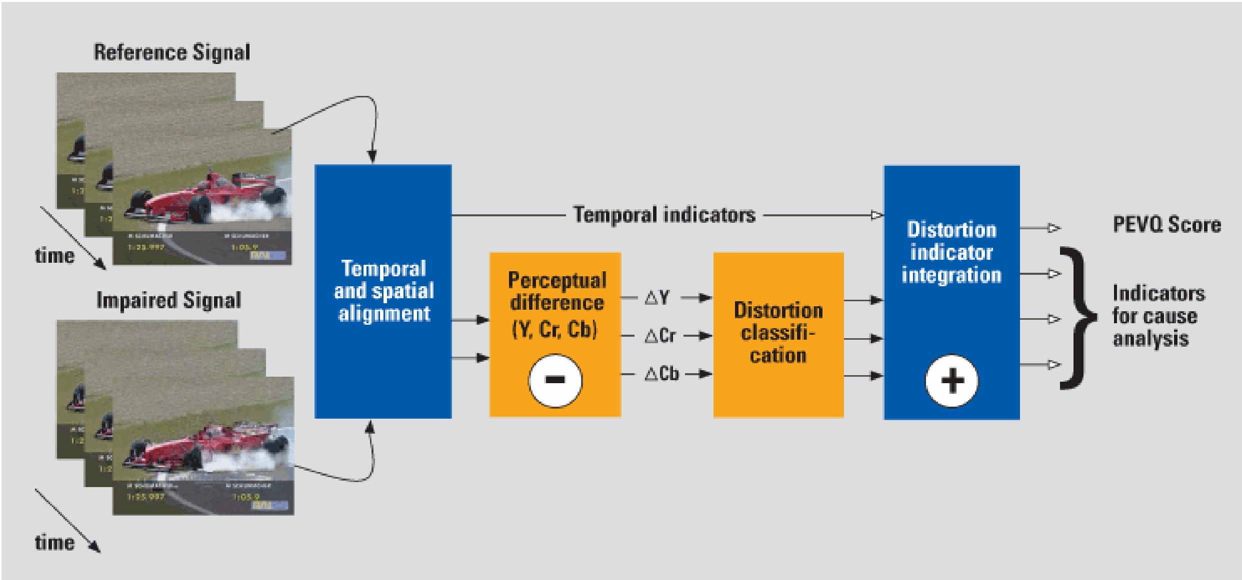

Figure 6 - Active Analysis Test Overview

PEVQ MOS
The PEVQ MOS value lies within a range from 1 (bad) to 5 (excellent). The PEVQ MOS is based on a multitude of perceptually motivated parameters.

Distortion indicators
For a more detailed analysis the perceptual level of distortion in the luminance, chrominance and temporal domain are provided.

Delay
The delay of each frame of the test signal related to the reference signal.

Brightness
The brightness of the reference and degraded signal.

Contrast
The contrast of the distorted and the reference sequence.

PSNR
To allow for a coarse analysis of the distortions in different domains the PSNR is provided for the Y, Cb and Cr components separately.

Jerkiness
describes the smoothness of a video playback which is often impaired by down-sampling, coding processes and perturbed transmissions.

Blur
is a distortion characterized by reduced sharpness of contour edges and spatial detail.

Blockiness
is often the result of a low bit rate coding that uses a block matching algorithm for the motion estimation and a coarse quantization for the image blocks.

Frame Skips and Freezes
are temporal artefacts occurring in video transmissions caused by e.g. overloaded networks.

Effective Frame Rate
Down-sampling of a video signal on a frame by frame basis often results in loss of information which often leads to the degradation of the video signal. The effective frame rate is an indicator quantifying the severeness of such a process.

Temporal and Spatial Activity
Temporal and spatial activity indicators quantify the amount of activity /movement in the video content. These indicators are derived from ITU-T recommendation P.910.

Table 2 – Active Analysis Key Metrics

Passive Analysis Details:

Passive analysis is a codec dependent real-time video quality metric. Passive analysis with Television Video Quality metrics (TVQM) performs video analysis on video frame headers. This is a highly accurate method of analysis which provides MOS scores.

This type of testing offers key insights into the video performance which includes the ability to tell if audio is being delivered with the video. Key metrics for Passive Analysis are indicated in Table 3 below.

VSTQ
A 0-50 rating which considers packet loss rate, the distribution of lost packets (i.e. burstiness), the type and bit rate of the CODEC. Data results on video transmission

Video Quality Score (MOS)
A 1-5 rating which also incorporates some other subjective factors such as content dependency factors. This is a user perceived estimate of quality.

Transport Metrics
IP, RTP, MPEG Transport Statistics
Packet Loss Rate Packet Discard Rate Gap Loss Rate and Gap Length Burst Loss Rate and Burst Length Number of Bursts FEC Effectiveness RTP Jitter (PDV) PCR Jitter
TR 101 290 Decodability Metrics
Transport Stream Synchronization loss Sync byte error Continuity count error

Transport error PCR error PCR repetition error PCR discontinuity indicator error PTS error
Video Stream Metrics
Codec type Group of Pictures Type (auto-detected) Group of Pictures Length (auto-detected) Image Size I frame packets received, lost, discarded P frame packets received, lost, discarded B frame packets received, lost, discarded Number of Good I frames Number of Impaired I frames Number of Good P frames Number of Impaired P frames Number of Good B frames Number of Impaired B frames
Perceptual Quality Metrics
MOS-V Video MOS MOS-A Audio MOS MOS-AV Audio-Video MOS EPSNR - Estimated PSNR VSTQ - Transmission quality VSPQ - Picture quality Gap VSPQ - Picture quality during gaps Burst VSPQ - Picture quality during bursts VSAQ - Audio quality VSMQ - Multimedia quality

Table 3 – Passive Analysis Key Metrics

Zap Rate Testing

A key challenge in provisioning IPTV is zap rate testing, again as outlined as part of the DSL forum documentation WT-126. Channel zap rates should be considered. Various metrics can be measured whilst doing zap rate tests, these will include channel join times, channel delay time, packets dropped.

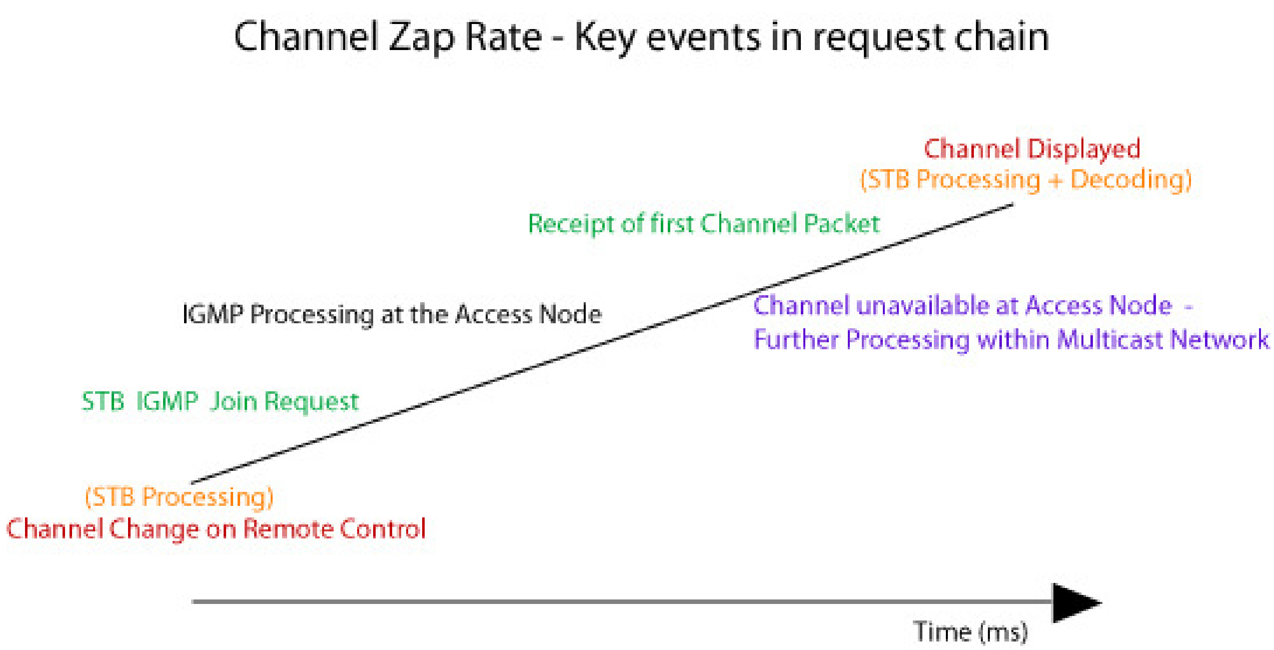

Figure 7 – Zap Rate Events

The expected time to display a channel after changing should be sub 700ms.

Another scenario to be considered - are multiple STBs in the home. This may impede zap rate performance. Other important tests identify how individual STBs interact with each other and the video quality being delivered on a per STB basis.

Analysts predict up to 4 STBs per home, therefore tests need to be run for worse case scenario, a sample test case is 4 STBs requesting 4 different channels at the same time. This equates to 4 IGMP membership reports being generated and sent through the network. Another issue not discussed here is configuring and scaling tests to enable PVR and PiP delivery.

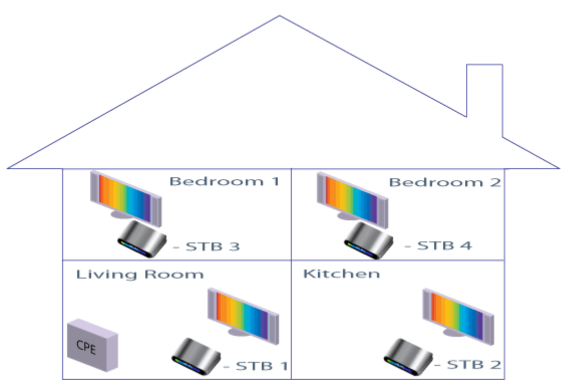

Figure 8 – STBs in the Home

Conclusions

Providers need to assure QoE in their networks, especially with the deployment of delay sensitive IP video media streams for IPTV and VoD applications. Simply put, customers of IP based video services will have zero tolerance to any disruption in quality.

It is clear from the documents introduced by various standards bodies that ensuring IPTV QoE necessitates the use of IP based test tools that are flexible and scalable offering both a macro and micro view of video quality. Service providers and infrastructure vendors supplying to them require the ability to measure lower layer network performance statistics. As important, if not more so, is the ability to emulate actual video head end and user behavior to determine quality of performance measurements at each layer in the stack.

Understanding the delivery mechanism or overall network performance is not sufficient to guarantee QoE in IPTV or streamed video networks. Standard bodies are recommending that service providers have the ability to conduct both payload and frame header analysis.

An example would involve a service provider adding a new IPTV channel. A real attribute to IPTV is the ability to add channels quickly and easily, at the highest quality levels. However, a channel video stream payload will pass through a logo keyer. These devices may introduce delay on the video stream whereas the audio stream may be unaffected. The service provider needs to test the quality of the delivered video and audio streams with Active Analysis and Passive Analysis to guarantee satisfactory QoE levels. Using the MoS scores, the service provider will have a benchmark upon which to test the complete network. Using Passive Analysis MoS Scores in the network, problems will be highlighted as they occur, in real time. Therefore, within hours service providers will release in confidence a new channel to their subscribers.

A key decision in choosing a system that provides both Passive and Active video analysis, is to obtain the highest level of subscriber QoE possible. Active Analysis enables providers to benchmark network performance at the highest levels of quality assessment. Passive Analysis is also a highly accurate test which also produces MOS scores in real time.

Shenick is an award winning provider of converged IP network test systems that offer a completely integrated video analysis solution for IPTV/VoD services and the triple play of video, voice and data applications. Key to the power of Shenick's diversifEye™, is the per flow architecture which provides QoS/QoE on a per subscriber, per application flow basis. Per subscriber testing ensures the highest level of QoE/QoS is delivered, plus the Provider has the ability to scale the IPTV/VoD service in confidence. Visit us at www.shenick.com or email your comments or questions to info@shenick.com

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