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Application Note

Title **Managing IPTV Performance**

Series IP Video Performance Management

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Contents

IPTV, Internet TV, and Video on Demand provide exciting new revenue opportunities for service providers. This Application Note describes some of the typical issues and problems affecting IPTV service quality, and introduces a cost-effective approach to service quality monitoring.

IPTV Services

IPTV offers exciting new opportunities for service providers to introduce integrated voice, video, and data services over broadband. A number of video service types can be delivered over IP:

- "IPTV" is generally used to refer to a closed Video over IP service with a broad range of content delivered by a service provider. Some definitions of IPTV would suggest that the broadband connection to the home would also be part of this service; however, within the context of this Application Note we regard the two as independent.

- "Internet TV" is generally a more open, Web-like service in which "stations" can broadcast on the Internet. This potentially allows anyone to generate video content and make it publicly available.

- Video on Demand (VOD) is a service that provides access to movies or other video content on demand. This could be part of an IPTV service or could be a service offered independently over the Internet.

In some cases, IPTV services are not seen as directly competing with existing cable or satellite service but may provide some specialization; for example, a VOD service or a service with content in some particular language.

Many different models can be used for delivery of content over IP. Real-time streaming services play video content over IP using either the UDP or TCP protocol and the video stream is decoded and played in near-real time. Other approaches include the download of entire movies or large "chunks" of video to a disk drive or memory.

This Application Note discusses some of the factors affecting the performance of IPTV and Internet TV services that use a streaming model, and explains how performance monitoring can provide real-time feedback to service providers.

Factors that Affect the Performance of IPTV

Codec, Bit Rate, and Video Content

Video content is typically encoded and compressed using MPEG-2, MPEG-4 Part 10 /H.264, Microsoft WMV9/VC1, or other codecs. Video codecs typically support a wide range of compression rates, allowing a trade-off between quality and bandwidth.

Much of this compression comes from the use of inter-frame difference encoding—rather than sending every video frame, only the difference between one frame and the previous frame is sent. This works well if there is relatively little change in the image; however, if there is considerable movement across much of the image, then either the bandwidth will increase or quality will reduce. Many video codecs allow either a constant bit rate (in which case quality may vary) or variable bit rate (in which case quality will vary less).

Common video codecs use a combination of intra- and inter-frame coding. For intra-frame encoding, the image frame (I 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 applied. A group of blocks is combined into a single entity (slice), sometimes carried within a single packet. If a transmission error occurs, then the whole group may be lost, creating a “stripe" within the decoded image. This may occur because, for example, the DC coefficients within each block are predictively 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, 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 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.

In most cases, the standards for video coding provide considerable flexibility to both 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.

Limited Bandwidth

Bandwidth limitations often occur in the access link—typically a DSL or cable connection. If there is insufficient bandwidth for the video stream, then some packets may be discarded in router buffers, leading to quality degradation.

A more subtle problem can occur due to the highly variable rate of packet transmission due to dissimilar sized I, B, and P frames. The peaks in packet transmission rate that occur during I frames can lead to packet loss and hence quality degration.

Packet Loss and Loss Concealment

Packet loss may occur for a variety of reasons, including network congestion, link failure, insufficient link bandwidth, and transmission errors. Packet loss is often bursty, with periods of high loss occurring when network congestion levels are high.

The type of quality degradation that occurs due to packet loss will depend on the protocol being used to carry video:

- If UDP is being used, packet loss will directly impact image quality, as some parts of the video stream will be missing.

- If Reliable UDP is used, then lost packets can be retransmitted; however, if retransmitted packets are lost, they will not be "re-retransmitted" and hence image quality will suffer.

- FEC may be used with UDP to replace lost packets; however, if the packet loss rate is too high (e.g., during bursts of loss), then FEC will not be as effective.

- If TCP is being used, then packet loss will lead to retransmission, which can in turn lead to the playout buffer in the set-top box being starved and to pauses in video playback.

For UDP-based video streams, packet loss can cause sections of frames, or complete frames, to be corrupted. As a frame often spans multiple packets, and typical video streams include interpolated frames, a given packet loss rate can result in a frame loss rate six times higher (Figure 1 below).

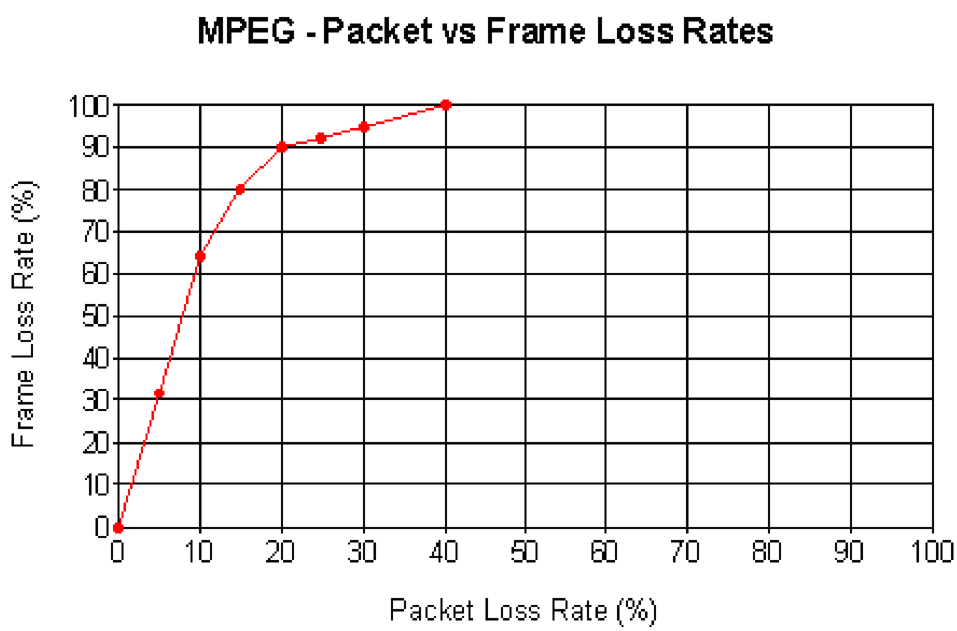
Server Congestion

Not all problems are due to IP impairments—if servers are not provisioned to support the maximum number of expected users, then server congestion can occur. This would generally lead to pauses in video playback as the playout buffer level is too low.

The use of protocols such as UDP Multicast can help with reducing server loading; however, these rely on a large proportion of the subscribers watching the same content at approximately the same time.

Jitter and Timing Drift

Network jitter is short term variation in packet arrival time, typically due to network congestion. IPTV set-top boxes or playback software typically buffer received video for 5-20 seconds before



■ *Figure 1. Impact of Packet Loss Rate on MPEG Frame Loss/ Error Rate* playout, which in essence means that typical network jitter levels have little effect. Larger delay variations, for example due to server congestion, can cause problems due to playout buffer starvation.

Timing drift occurs when the sending and receiving end clocks are running at slightly different rates. This may require the receiving end to adjust its clock rate in order to avoid occasional problems due to buffer underflow or overflow.

Core Network, Access Network, and Home Network

The IP transmission path typically starts at a video server and ends at a set-top box. This means that packets traverse multiple networks, often owned by different service providers. Core IP networks are often high capacity optical networks that operate well below congestion levels, and hence when problems occur, they are often located within the access network or home network.

Video Impairments

Encoding-related Impairments

Video encoding can introduce a number of different impairments, often related to the bit rate used for encoding and to the characteristics of the video sequence. Common problems include:

- *Blockiness* - typical video codecs process images in small blocks, and quantization of parameter or coefficient values can lead to discontinuities between blocks. This can be exacerbated by the Mach Band effect, in which the human eye tends to sharpen edges.

- *Blur* is a loss in detail that occurs around edges, typically due to the quantization of transform coefficients representing higher frequencies.

Modern video codecs are very effective, but can still suffer from degraded quality when operating at low bit rate where there is considerable movement in large areas of the video sequence.

Transmission-related Impairments

For IP video transmitted over the UDP protocol, packet loss can lead to significant quality degradation. 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.

Video quality is often represented in terms of PSNR (Peak Signal to Noise Ratio), which is a measure of the root mean square (RMS) error between the original and reconstructed video sequences. Generally a PSNR of under 20dB is regarded as unwatchable, and this level is reached for MPEG-2 with a loss rate of under 1 percent.

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

- *Forward Error Correction* - 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 frame encoded separately.

- *Macroblock error concealment* - spatially corresponding macroblocks are copied from the previous frame.

These approaches are used in some modern video codecs and can help considerably with tolerance to packet loss.

Video Performance Metrics

Video performance can be assessed in many ways. Full Reference (FR) methods such as PSNR compare the output video sequence with the input and measure the level of distortion that has occurred. This comparison is fairly computationally intensive and requires access to the video streams at both ends of the connection. Zero Reference methods, such as the algorithms used in Telchemy's VQmon®, look at the received IP video stream and estimate quality based on the type of video codec, loss rate, loss distribution, and other parameters.

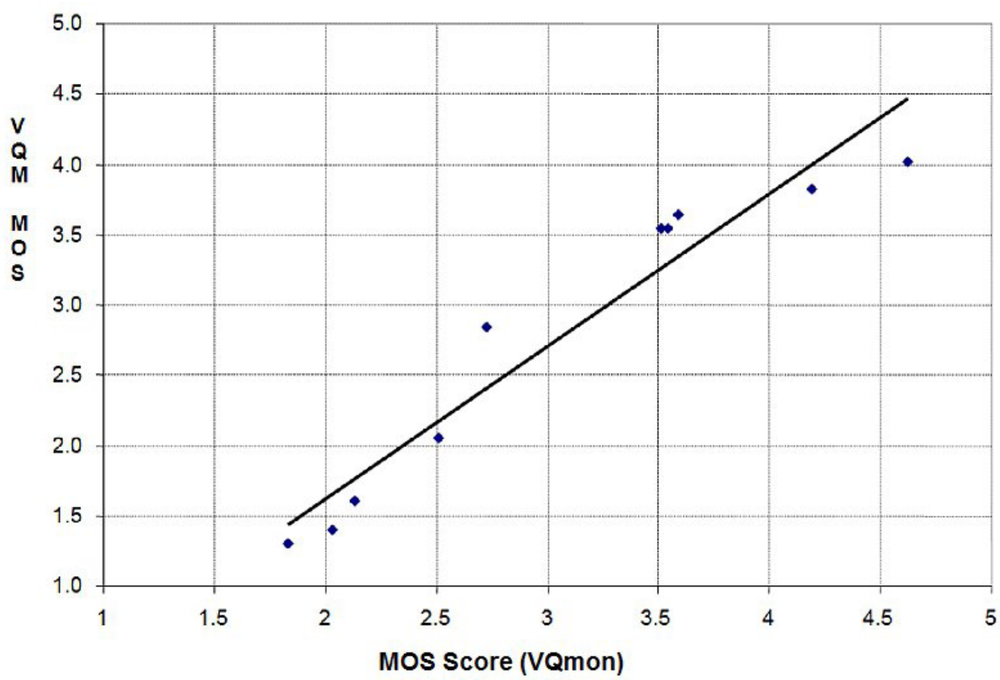
VQmon produces estimated perceptual quality scores (MOS) And a video transmission quality rating (VSTQ). The former provide estimates of the user-perceived quality of the video, and the latter provides a rating of the ability of the IP packet transport to support video.

Estimated Perceptual Quality Scores (MOS)

VQmon's estimated Mean Opinion Scores (MOS) provide a 1-5 rating (5 being best) of user-perceived quality, and incorporate some subjective factors such as content dependency factors. MOS values provided by VQmon include:

- Video MOS (MOS-V) - a score that considers the effect of the video codec, frame rate, packet loss distribution, and GoP structure on viewing quality. VQmon reports both *Absolute* MOS-V, which factors in the effects of frame resolution, and *Relative* MOS-V, which does not depend on frame resolution and is designed to measure video quality relative to the ideal for the current video format.

- Audio MOS (MOS-A) - a score that considers the effect of the audio bit rate, sample rate, and packet loss on viewing quality.



■ *Figure 2 - Comparison of VQmon MOS Score with Full Reference VQM Score*

- Audiovisual MOS (MOS-AV) - a score that considers the effect of picture and audio quality and audio/video synchronization on the overall user experience.
- Burst MOS (Burst MOS-V, Burst MOS-A) - scores indicating picture/audio quality during "bad" periods when significant degradation is occurring.
- Gap MOS (Gap MOS-V, Gap MOS-A) - scores indicating picture/audio quality when little or no degradation is occurring.

Video Transmission Quality Rating (VSTQ)

VQmon's Video Service Transmission Quality (VSTQ) score is a 0-50 rating that indicates the ability of the IP network to reliably transmit video. VSTQ considers packet loss rate, the distribution of lost packets (i.e., burstiness), and the type and bit rate of codec.

PLC Effectiveness Calculation

In addition to modeling the behavior of a wide variety of video codecs, VQmon also models four classes of packet/frame loss concealment, which covers the range of typical implementations. Class A loss concealment algorithms are very robust and able to tolerate high levels of loss, whereas Class D algorithms are very sensitive to even low rates of loss.

Figure 2 on page 5 shows how VQmon's MOS-V score compared to MOS scores estimated by the full reference NTIA VQM tool for a range of video files and test conditions.

Content Detection

VQmon's content dependency factors allow more accurate MOS values to be determined for different types of video content. If low levels of impairments occur in a video sequence with considerable activity—for example, a sporting even—subjective quality would not be impacted as severely as it would if the video sequence were slow-moving and contained many fine details. High levels of impairment, however, would cause the video stream to break up or freeze, and hence would be annoying in any video sequence.

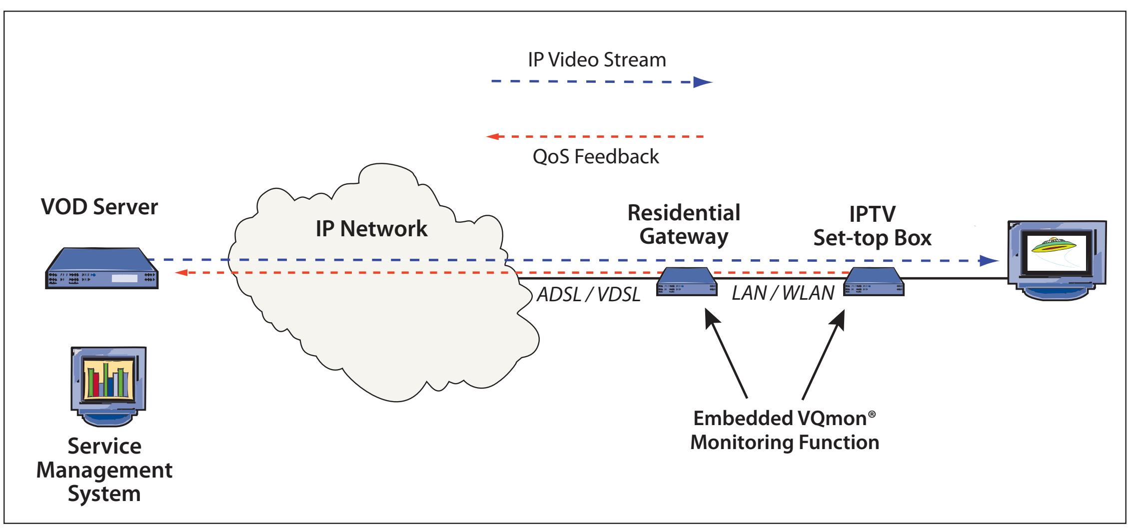


Figure 3 - Example of Embedded IPTV Service Quality Monitoring Function

IPTV Performance Management

Performance Monitoring

IPTV services can benefit from real time non-intrusive performance monitoring. Lightweight agents, such as VQmon, can be directly integrated into set-top boxes and residential gateways to provide service providers with real-time feedback on service quality, and can potentially provide feedback to servers to enable optimization of the video streaming algorithm. Extensions to RTCP XR (RFC3611) are being developed to support the transport of metrics during video sessions.

Typical feedback metrics would include:

- MOS-V, MOS-A, and MOS-AV scores, providing estimates of user-perceived picture, audio, and audiovisual quality
- Packet loss rate, burst density, burst length, gap density, and gap length, providing some insight into the impact of IP impairments
- I, B, and P frame statistics, including the packet loss rate within each type of frame

Impact of Content Scrambling/Encryption

Scrambling or encryption is often used to protect video content (often called Digital Rights Management or DRM). This means that IPTV performance measurement systems cannot decode the picture stream. Telchemy's VQmon has been specifically designed to work with encrypted content, and is able to extract information related to both video content and I/B/P frame loss.

Packet Loss vs. Perceptual Quality Scores

Some service providers attempt to measure video quality based solely on packet loss metrics. If packet loss affects I frames, the resulting errors will extend through the entire Group of Pictures and be very obvious to the viewer. If the same packet loss rate affects B or P frames, the resulting error typically lasts for just one frame (e.g., 1/60th second) and the viewer may not even notice the event. Video performance monitoring algorithms such as VQmon are able to measure the impact of each packet loss event on specific frame types, and hence more accurately measure performance.

Acronyms

ADSL	Asymmetric Digital Subscriber Line
DC	Discrete Cosine
DCT	Discrete Cosine Transform
DRM	Digital Rights Management
DSL	Digital Subscriber Line
FR	Full Reference
GoP	Group of Pictures
IETF	Internet Engineering Task Force
IP	Internet Protocol
LAN	Local Area Network
MDI	Media Delivery Index
MOS	Mean Opinion Score
NTIA	National Telecommunications Information Administration
PLC	Packet Loss Concealment
PSNR	Peak Signal-to-Noise Ratio
QoS	Quality of Service
RFC	Request for Comments
RMS	Root Mean Square
RTCP XR	RTP Control Protocol Extended Reports
RTP	Real Time Protocol
SLA	Service Level Agreement
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VDSL	Very high speed/bit rate DSL
VOD	Video On Demand
VoIP	Voice Over Internet Protocol
VQM	Video Quality Metric
VSTQ	Video Service Transmission Quality
WLAN	Wireless Local Area Network

Summary

IPTV is an exciting new service, or range of services, that has the potential to open up substantial new markets for video content provisioning. IPTV does need to gain the confidence of the consumer, and this requires that quality levels are acceptable.

This Application Note outlined some of the issues and problems affecting the performance of IPTV and Internet TV services, and explained how lightweight non-intrusive service quality monitoring software can provide real-time feedback to service providers and support automatic adaptation of the video server to mitigate problems.

References

[1] IETF RFC3611 RTP Control Protocol Reporting Extensions (RTCP XR), November 2003

About Telchemy, Incorporated

Telchemy, Incorporated is the global leader in Voice and Video over IP Performance Management with its **VQmon®** and **SQmon™** families of call quality monitoring and analysis software. Telchemy is the world's first company to provide voice and video quality management technology that considers the effects of time-varying network impairments and the perceptual effects of time-varying call quality. Founded in 1999, the company has products deployed and in use worldwide and markets its technology through leading networking, test and management product companies. For more information, please visit **www.telchemy.com**.

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