Delivering Digital Video Services: Ensuring Quality and Compliance

Technical Brief

Tektronix®

Introduction

Digital television has tranformed the television viewing experience and has offered video service providers the ability to deliver hundreds of channels of programming with better picture and sound quality. Since digital television was first launched, there have been a great deal of new technologies and capabilities emerge including HDTV, digital ad insertion, tru2way, MHP, VOD and most recently—multiscreen or OTT (Over The Top) video. As networks converged and service offerings increased, video service providers have dealt with the ongoing, arduous task of ensuring the quality of these services for their subscribers. Ensuring quality involves monitoring both the Quality of Service (QoS) and the Quality of Experience (QoE). Understanding the difference between QoS and QoE as well as how Perceptual Video Quality ties into the overall QoE equation is crucial for any monitoring deployment and knowing what, where and how to monitor results in reduced trouble calls, a faster ability to detect and repair issues, reduced churn and a reduction in operational expenditures.

This report will explain the difference between QoS and QoE and the monitoring requirements needed to achieve the best picture and sound quality for subscribers. In addition, the monitoring requirements for compliance issues such as closed captioning and audio loudness will be discussed, as well as ad insertion monitoring, RF monitoring and multiscreen (OTT) monitoring.

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Live Network Monitoring of Digital Video Services

Monitoring live digital video services in today's complex networks requires an entirely new type of equipment in order to be highly confident that the services can be correctly decoded and displayed on any compliant digital TV or set top box. In digital video services, the content is highly compressed and wrapped in many different layers from IP (internet protocol) down to the MPEG (Moving Pictures Expert Group) frame, slice, macroblock, and block. In contrast, previous NTSC/PAL analog video services had just one layer that was significantly easier to monitor and troubleshoot.

Background

Today, digital video services do not readily show transmission impairments or video artifacts until the signal is extremely corrupt (also known as the "cliff effect"). This is due to RF symbol redundancy and error protection in the digital modulation schemes (e.g., PSK, VSB, QAM, COFDM, etc.). Once the signal becomes extremely corrupt, the digital video service normally freezes or becomes quite useless. To make monitoring today more challenging, the previously used analog test signals in the line just above active video are now stripped out during the compression process. Only the active video lines get compressed and sent. Monitoring equipment must now rely on new parameters for assessing the quality of the digital video service.

To maintain high quality using minimal bit rates, digital video services are segmented into several layers and associated measurements. They include the following:

- RF/IP layer with frequency, power level, modulation formats, etc., or IP headers, checksums, payloads, packet timing (jitter), etc.
- Transport Stream (TS) layer with headers, payloads, continuity counters, Program Clock Reference (PCR) timing, and Program Specific Information (PSI) tables (basic electronic program guide)
- Packetized Elementary Streams (PES) including headers, payloads, audio/video decode and presentation timing (also known as Access Units)
- Elementary Stream Sequence headers including codec format, frame size and rate
- Picture frame slice headers, Macroblocks (16x16 set of pixels), and finally Blocks (8x8)
- Audio Frames or Access units in small blocks of time (e.g., 32 ms for Dolby AC-3 at 448 kbps using 5.1 surround)

Monitoring equipment must be able to validate each of these many layers in order to achieve high confidence that the digital video service can be received and decoded on any compliant digital TV or set top box. Anything less would question the mandated interoperability between the service provider and the TV.

Initially, MPEG test equipment vendors submitted a group of important transport stream monitoring requirements for broadcasters to ensure encoder/multiplexer completeness (ETSI TR 101 290). This is an excellent standard for testing digital services, but it only covers one of the many different layers. For example, to say that the TS headers have been measured and comply to the ETSI TR 101 290 requirements has nothing to say about the audio levels or the picture quality being delivered. One must be able to traverse from the highest layer of RF/IP all the way down to the pixel or audio level before one can be confident that the digital video service is acceptable. There are two different approaches to help maintain high quality. One approach is called quality of service (QoS) testing and monitoring which looks for errors at the physical layer and TS layer. The second approach is called quality of experience (QoE) testing and monitoring that focuses more on the video and audio aspects of the decoded program. Both methods are very important, but approach the issue of testing and monitoring in very different ways.

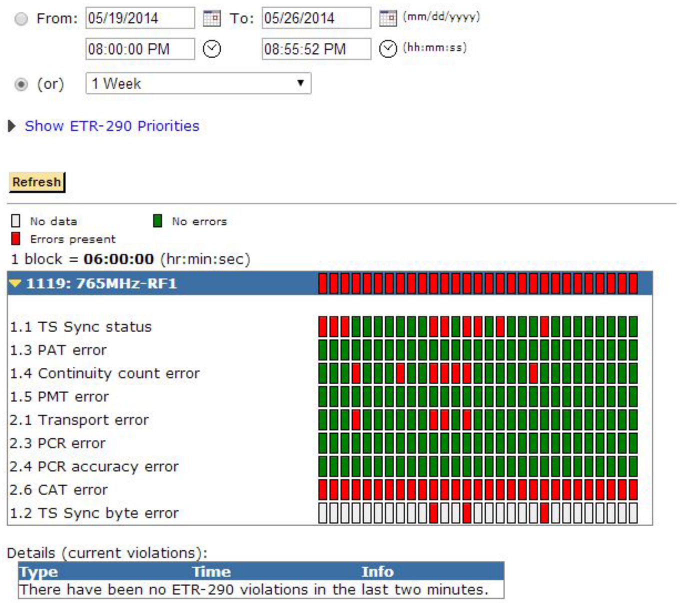


Figure 1. ETR290 history over seven days on channel 765 MHz (EIA-119).

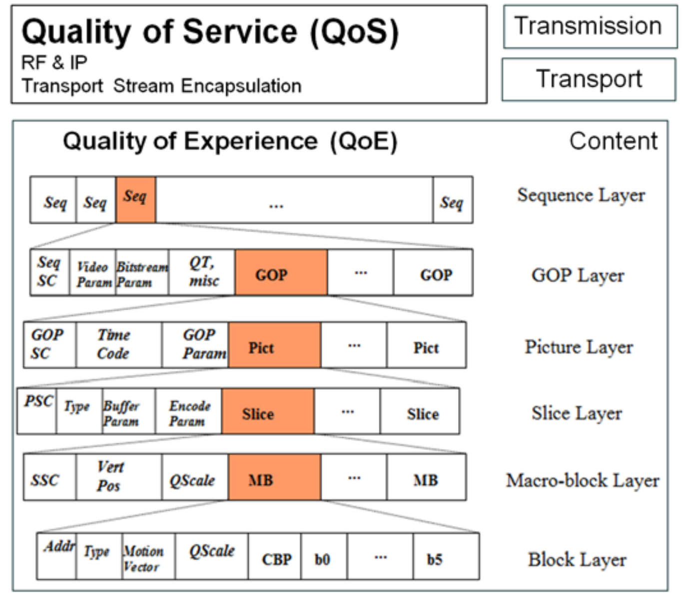


Figure 2. QoS and QoE layers.

Quality of Service vs. Quality of Experience

Using ETSI TR 101 290 (ETR290) to measure the TS is a good way to measure QoS. The ETR290 test includes three levels of testing:

1. **Priority 1** for highly important tests such as Sync error/loss and missing tables or packets
2. **Priority 2** for demodulation failures and PCR/DTS/PTS timing failures
3. **Priority 3** for Electronic Program Guide failures and buffer failures

Testing and monitoring with ETR290 is a good way to understand the health of the network and TS. But, it will be almost impossible to determine how badly the audio and video service will be affected by an ETR290 failure. Figure 1 summarizes one of many RF channels on a local cable TV network. This specific channel is being reviewed here because it was known to have significant RF impairments. As we can see, there have been several TS Sync and dropped packet issues over the last seven days.

Due to the problematic nature of this specific RF channel, it becomes imperative to also look at RF characteristics that might be leading to TS problems. RF testing will be discussed in more detail later in this Technical Brief.

A good graphical example of QoS and QoE layers is shown in Figure 2, which shows the different layers that will be evaluated during QoS and QoE testing and monitoring.

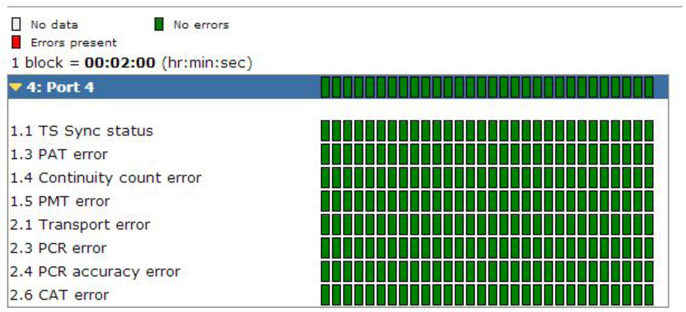


Figure 3. ETR 290 with no TS errors.

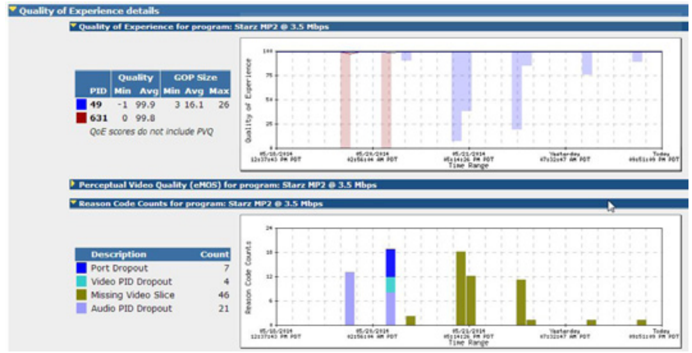


Figure 4. QoE plot with audio/video missing packets and slice errors.

To contrast QoS and QoE, think of QoS as a means of rating the quality of the signal which when error free, should create a good digital video service at the TV or set top box. Think of QoE as a means of watching the video and listening to the audio and rating the quality independent from the physical or TS layer quality. We can easily have a bad QoS with a bad QoE, but there are times when we can have a good QoS and still measure a bad QoE due to video or audio coding problems somewhere upstream. QoS will tell us when the TS is broken, and by default, the QoE should degrade also, but it may be more important to know when the QoE drops no matter if it is due to poor RF conditions, or upstream codec failures.

An example of a good QoS and bad QoE can be seen in Figures 3 and 4 where we show perfect ETR290 with bad audio and video QoE issues. These are good case examples where we know the transmission was perfect, and the error **must** be coming from the content provider.

The conclusion of Figures 3 and 4 tell us that the encoder or multiplexer from the content provider is failing, but the transmission is perfectly fine. The solution here would be to make a call to the content provide to correct equipment failures.

A good monitor should go deep into the QoE testing and monitoring of every layer of every video and audio service in every TS. Whenever the monitor detects an audio or video codec command that is in error, it denotes a drop in QoE. The monitor increases the relative weight of each video protocol impairment (i.e., syntax or semantic) depending upon the type of video frame (i.e., I, B, or P), as well as where the impairment landed in the frame (i.e., center vs. corner). See Figure 4 for the drop in QoE ratings related to audio and video errors.

This is an excellent example of QoE ratings where bad audio and video protocol drop the scores from a perfect 100 down to something significantly lower depending upon the error in the video or audio frame, and the repetition of the error.

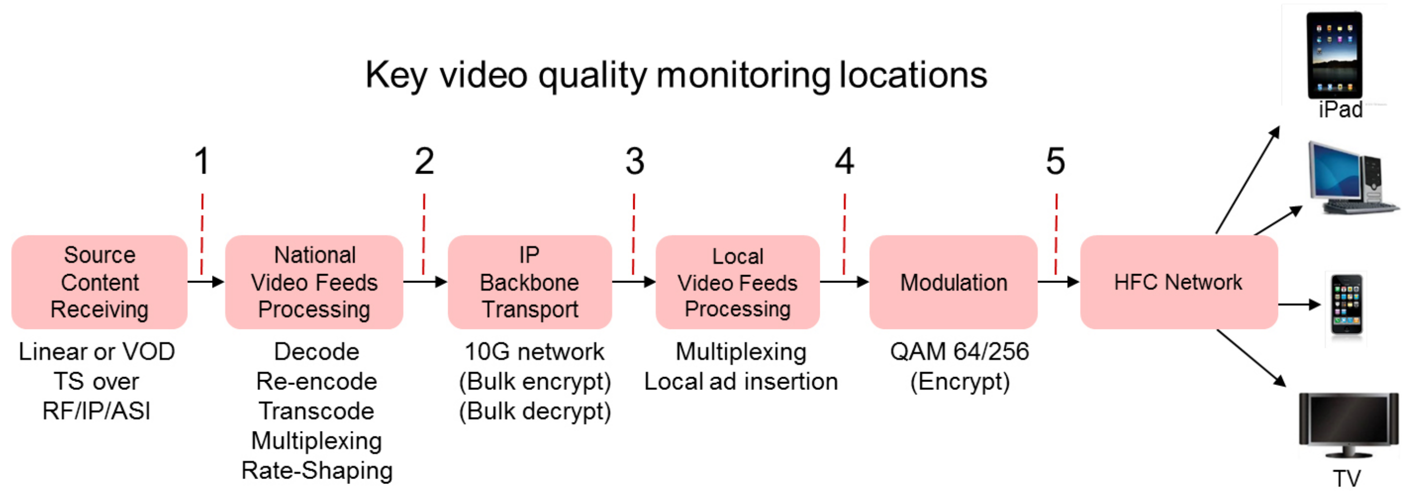


Figure 5. Five suggested monitoring points from ingest to egress in a typical digital video cable network.

QoS Monitoring Tradeoffs

Measuring QoS can help us to understand the relative health of the transmission path, but it can mislead an operator to thinking that a video service/program channel is error free when it might have a codec error several layers below the TS. Think of QoS and a good indicator of the transmission path and multiplexer completeness, but QoE is still needed to determine the health of each digital video service. Another minor point with ETR290 is that it is for the entire transport which often includes several digital video services. If you see a continuity counter error (i.e., dropped TS packet), you will not readily know which video service/program channel was affected, or if it was an audio packet or video packet.

Key Video Quality Monitoring Locations

Choosing the right monitoring locations is just as important as which parameters to measure. See Figure 5 for an example of typical monitoring locations in a cable TV architecture.

We need to monitor at the ingest (test-point #1) for two reasons:

1. To make sure that we have a clean error-free link from the content provider to the ingest receiver. If we have dropped or erred TS packets, then we already know that the digital video service will suffer.
2. We need to monitor the encoded service to make sure that there are no audio or video syntax or semantic errors. This is because TV's and set top boxes are not designed to handle services with errors. Receiving a clean ETR290 transport with embedded audio/video errors means that the QoE is going to be less than perfect. Therefore, is critical to always measure the source.

In order to localize the service, it might be transcoded into a different format, or simply modified slightly by inserting a commercial at various locations in the stream (test point #4). With today's highly compressed services, problems can occur in the video layer as well as the audio layer. Therefore, it is also critical to monitor the output of any equipment that modifies the stream.

Now, what if an error was detected after the QAM modulator? It would now be possible to know which piece of equipment introduced the error based upon the results of the monitoring equipment just upstream from the modulator.

Figure 6. Program Dashboard Reporting.

Using QoE Scoring Methods to Develop a Service Benchmark

With video services often originating from a wide variety of sources, there tends to be a wide difference in QoE impairments when all are compared against each other. In a large collection of ingest sources, a QoE report can be helpful to focus work on the worst or bottom 10% rather than treat all sources equally. Another idea is to congratulate the top 10% as high achievers. QoE ratings and reports can also be generated on a daily, weekly, or monthly basis depending upon your needs and urgency of reports.

One example of scoring programs is to create a dashboard of a set of measurement categories. Within each category, a summary of all of the programs is shown. Figure 6 below shows eight categories of measurements with a rating summary for each of the many programs. In most cases, green is a good sign, and red is a bad sign. The dashboard makes it easy to quickly see the health of the entire network.

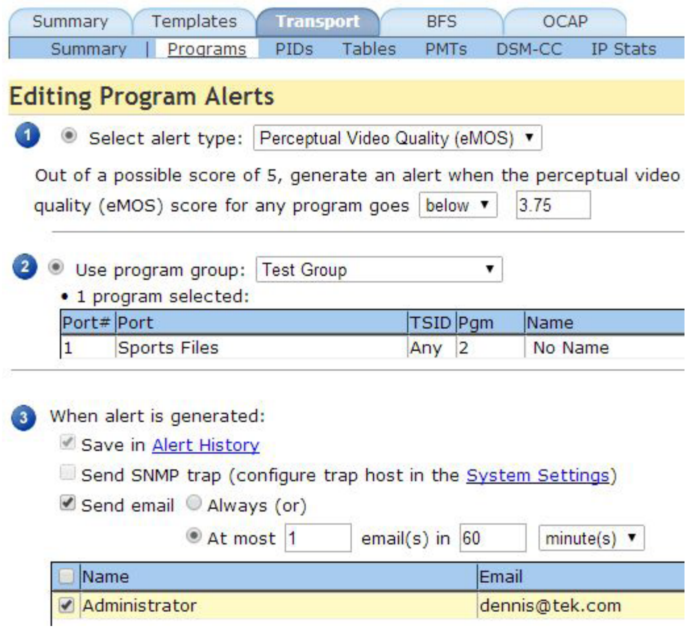


Figure 7. Configuring an Alert condition.

Detecting Artifacts and Impairments before Subscribers

The last thing that a network operator wants is to get a call from a frustrated subscriber explaining audio or video problems in a service. The more frustrated that the customer becomes, the more likely they are to cancel their subscription. Therefore, it is imperative to catch audio and video impairments before customers call in with complaints.

In order to track such impairments, the monitoring system should allow for triggered alerts to send out an SNMP trap, or an email message to one or more operators or administrators. Alert definitions should be available in a wide array of choices from no audio or video over a defined window of time, to audio DialNorm/Loudness deviations or video over-compression. Once the alerts have been defined and then applied to each or all of the video services, the operators can rest assured that all defined alerts will raise immediate SNMP traps and or email messages when triggered. For example, Figure 7 shows how an alert message gets triggered via email whenever the video quality drops below 3.75 (i.e., 25% drop).

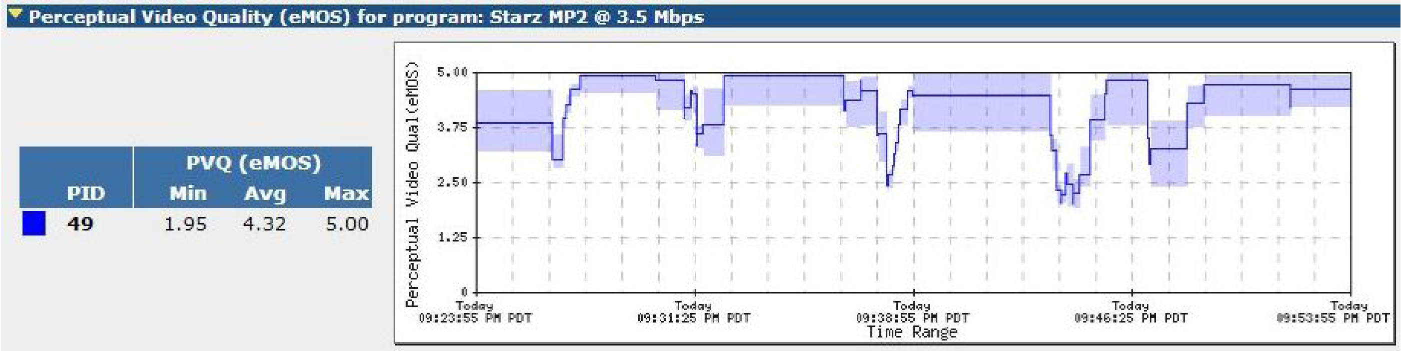


Figure 8. PVQ showing blockiness impairments due to running MPEG-2 HD and only 3.5 Mbps (over-compression related to motion).

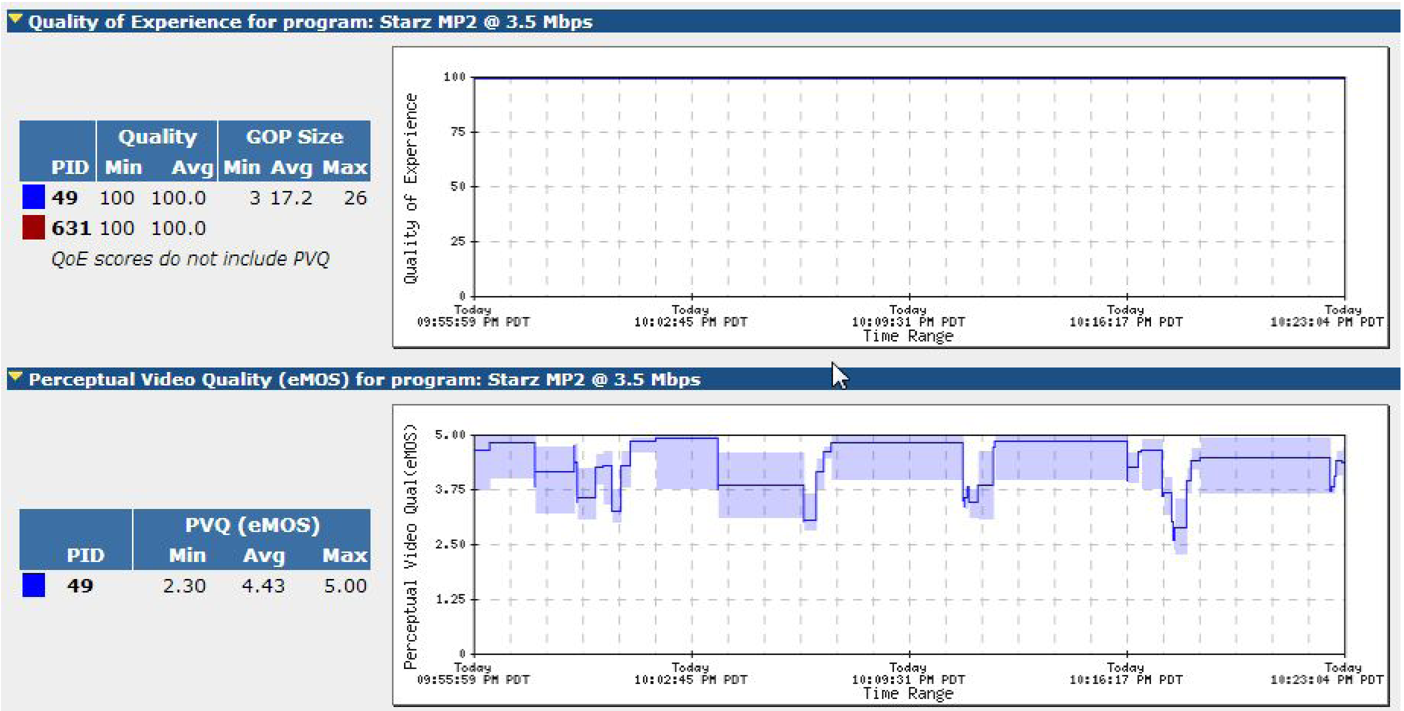
Figure 9. Mezzanine-level compression at 50 Mbps without blockiness or over-compression.

Figure 10. Transcoding from 50 down to 3.5 Mbps resulting in blockiness and over-compression.

Perceptual Video Quality: Compression and Encoding Artifacts

Within HD encoding systems, two choices are available related to bandwidth (bandwidth). We can choose variable bit rate (VBR) where the encoder uses less bits as the scene becomes stable or easy to compress, and then we have constant bit rate (CBR) which is excellent if the video is to be remultiplexed downstream with other programs. The problem with CBR is that we often get a variable quality depending on the complexity of the video scene. One moment there is enough bandwidth to preserve all of the original video attributes, and then when the scene becomes much more complex, and the encoder does not have enough bandwidth to keep up with the complexity, the encoder must over-compress parts of the video causing a reduction in the video quality (i.e., blockiness). The perceptual video quality (PVQ) test performs a quality rating based upon over-compression. If a video program always has enough bandwidth to maintain high quality, then the PVQ score will be at 5.0. Figure 8 started with an HD program in MPEG-2 at 50 Mbps with a PVQ rating of 5.0 for the entire 30-minute clip. After running the clip through a transcoder and recompressing the clip to 3.5 Mbps in 1080i HD, the scenes with low motion stayed at 5.0, but then drop significantly lower as motion increases.

Figures 9 and 10 show the results of transcoding from 50 Mbps to 3.5 Mbps over a 30 minute clip. To provide a visual understanding as to how these two video services compare, let's look at the same frame in the two clips where a fast action scene is being played out. The frame below correlates to about 20 minutes into the above graph where the PVQ plot drops from 5.0 to about 2.5. The example is where a pirate is being catapulted over the deck of a ship. Notice that in Figure 9 at 50 Mbps, the pirate is not blocky, although he may look a little blurry due to the film and camera shutter-speed. The same pirate in Figure 10 at 3.5 Mbps is heavily over-compressed due to high motion and limited bandwidth.



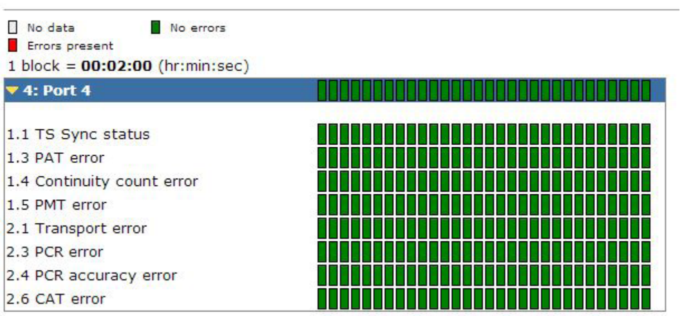


Figure 11. Good QoS and QoE but still blocky.

It is important to point out that most monitoring systems do not look at the actual video service even though they provide valid QoS and QoE metrics. In this case, if we just look at the QoS and QoE results, we see a perfect service. We find no ETR290 issues, and no syntax issues either. In fact, due to high motion in the video, there are times when the Perceptual Video Quality rating is perfect (i.e., 5.0) and other times at 2.3 (i.e., tiling, blocky, heavily over compressed, but still legal), as shown in Figure 11.

In light of this example, it should be important to always measure every layer from RF/IP down to blockiness and audio loudness in order to effectively measure QoS, QoE and PVQ.

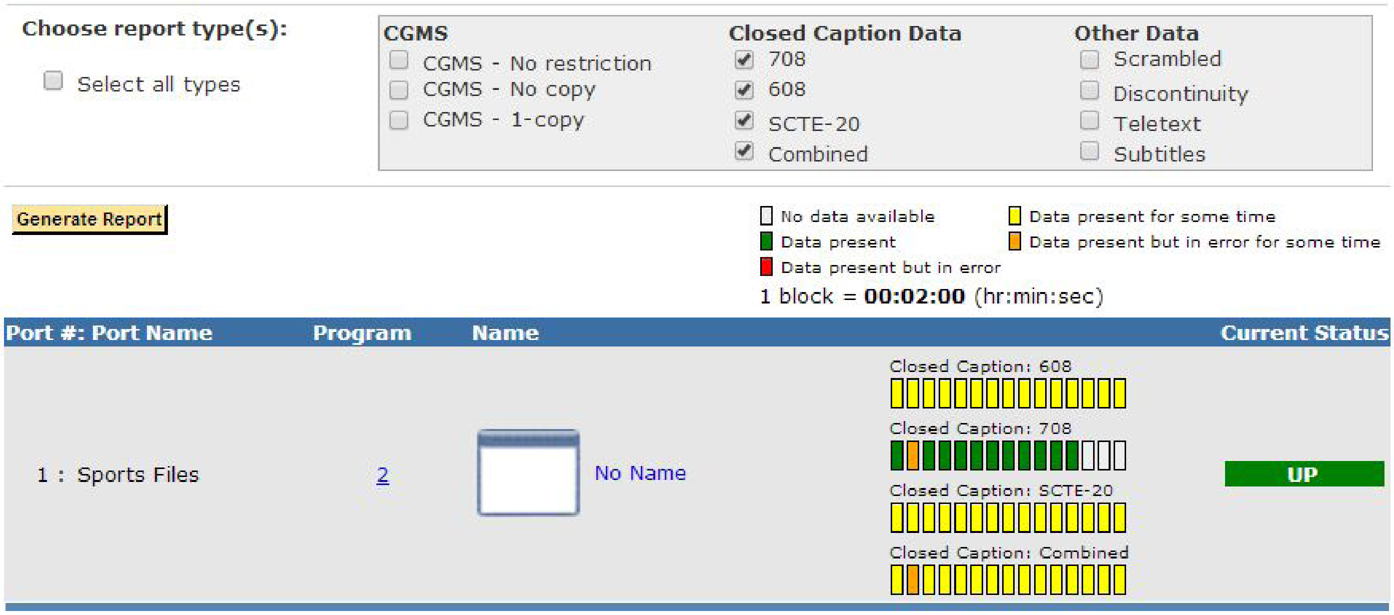


Figure 12. Closed Captioning Report Setup and availability bars.

Regulatory Compliance

Many government agencies require digital video service providers to also provide additional services beyond audio and video. One such requirement is for closed captioning (or subtitling/teletext) services. Another requirement is for audio loudness.

Closed Captioning

In the case of Closed Captioning (CC), or Subtitling/Teletext, many governments require this service for the hearing impaired. If required, there can be a hefty fine for failing to carry such services. A monitor should have the ability to detect the presence and absence of such services. These results, like all other details, should continuously be written to a 60-day database available to anyone with a browser. Figure 12 shows the supported formats, as well as an example of 708 CC in a digital video service.

An example of compliance testing is to know if 85 percent of all content is including closed captions. Figure 13 shows a summary of such a test. This figure shows that about 150 digital video services are in compliance, yet over 300 are still failing to run closed captioning over 85 percent of the time.

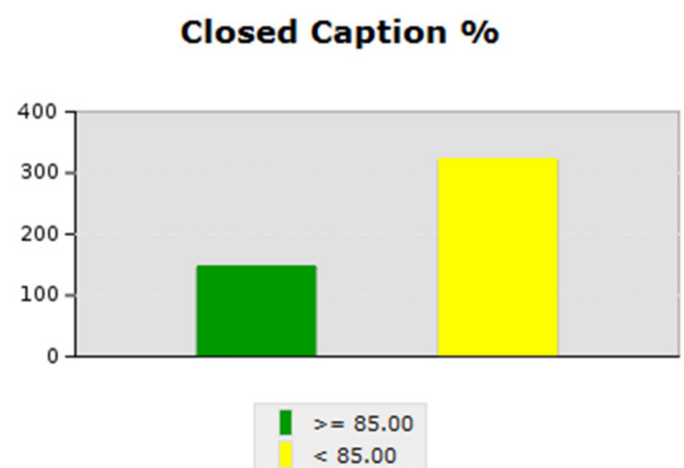


Figure 13. Percent of digital video services with closed caption support over 85% of the time.

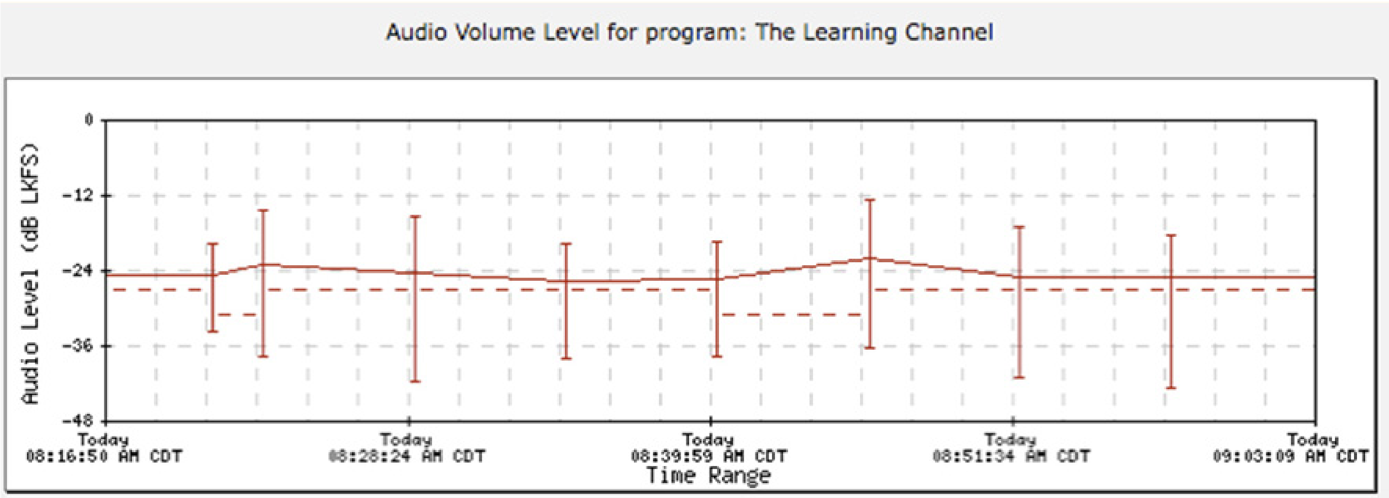


Figure 14. Dynamic DialNorm and Audio Loudness.

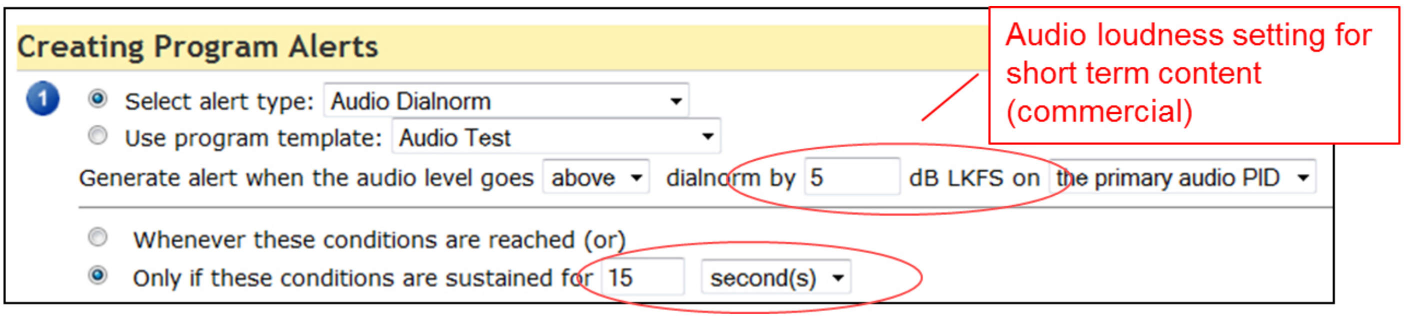


Figure 15. Configuring Audio Loudness Program Alerts.

Audio Loudness

Another important regulatory compliance requirement around the world today is for audio to be within a small range of the DialNorm value. The ITU BS 1770 standard describes the formulas used to calculate short term and long term audio loudness levels. The ATSC A/85 (2013) Recommended Practice document further restricts the limits to a window from 3 to 10 seconds for a short term test, whereas the EBU R 128 document recommends 3 seconds for the short term measurement window.

These standards are designed to address the difference in loudness values between programs, as well as between advertisements. Failure to comply can also carry a hefty fine when not maintained. A Video Quality Monitor should have the ability to monitor loudness on every audio element on every program in every TS. Figure 14 shows a dynamically changing DialNorm (dotted line) value and its associated Loudness measurements over time.

One use-case example for Audio Loudness testing was to configure a trigger to alert anytime that the loudness values deviated more than 5 LKFS (Loudness, K-weighted, relative to Full Scale) for over 15 seconds. See Figure 15.

This setup was configured for a specific group of channels and then ran 24x7. As seen in figure 15, the DialNorm may change from program to program, or during commercial insertion. As the DialNorm changes, the monitor uses that new reference value to measure the delta to the measured loudness over that same time period.

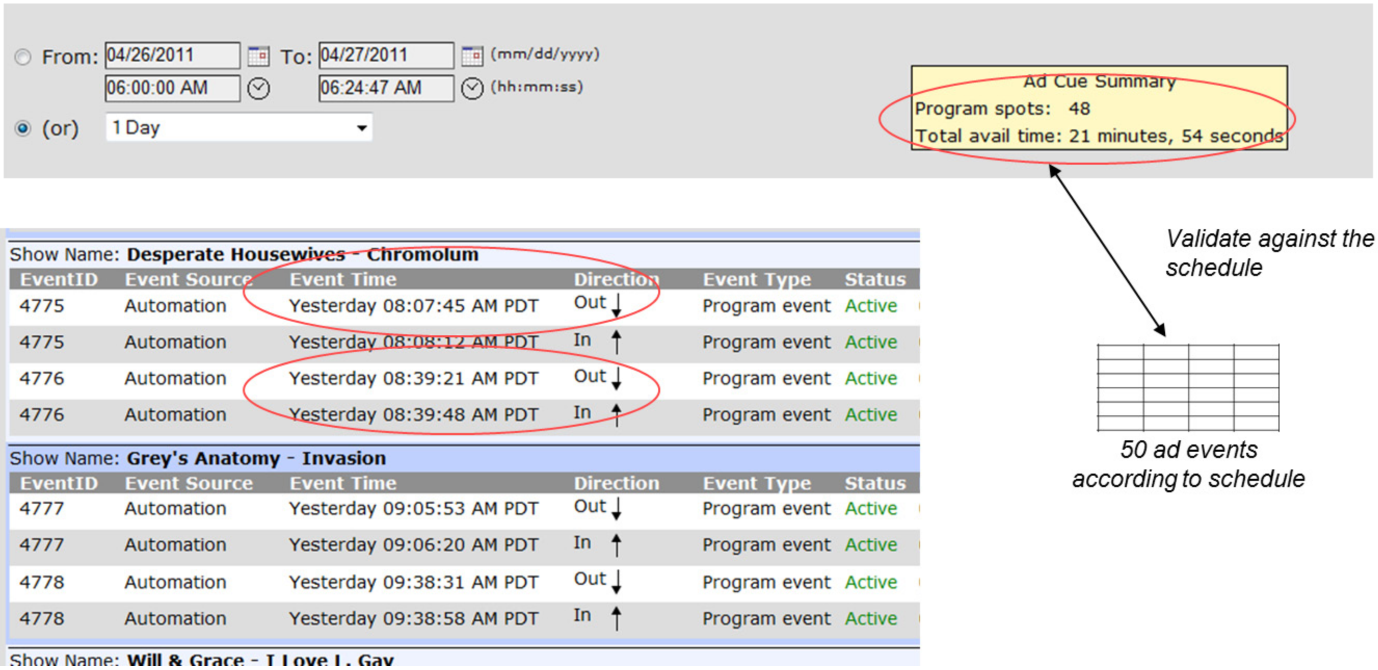


Figure 16. SCTE 35 Ad Cue summary.

Ad Verification

Today, an average of 2% of digital advertisements fail to air or air incorrectly due to scheduling, insertion, and other errors. In addition, advertisements often suffer the same audio and video quality issues that plague regular programming. As a result, monitoring and auditing capabilities are critical to successful ad delivery.

A monitor should provide the most complete digital ad insertion monitoring capabilities by combining real-time monitoring and alerting with historical auditing across the entire channel lineup in all advertising zones. The monitor should also deliver extensive data including historical thumbnails which improve digital ad insertion on any platform, allowing engineering teams to ensure proper function of insertion technology by identifying and correcting system errors when they occur.

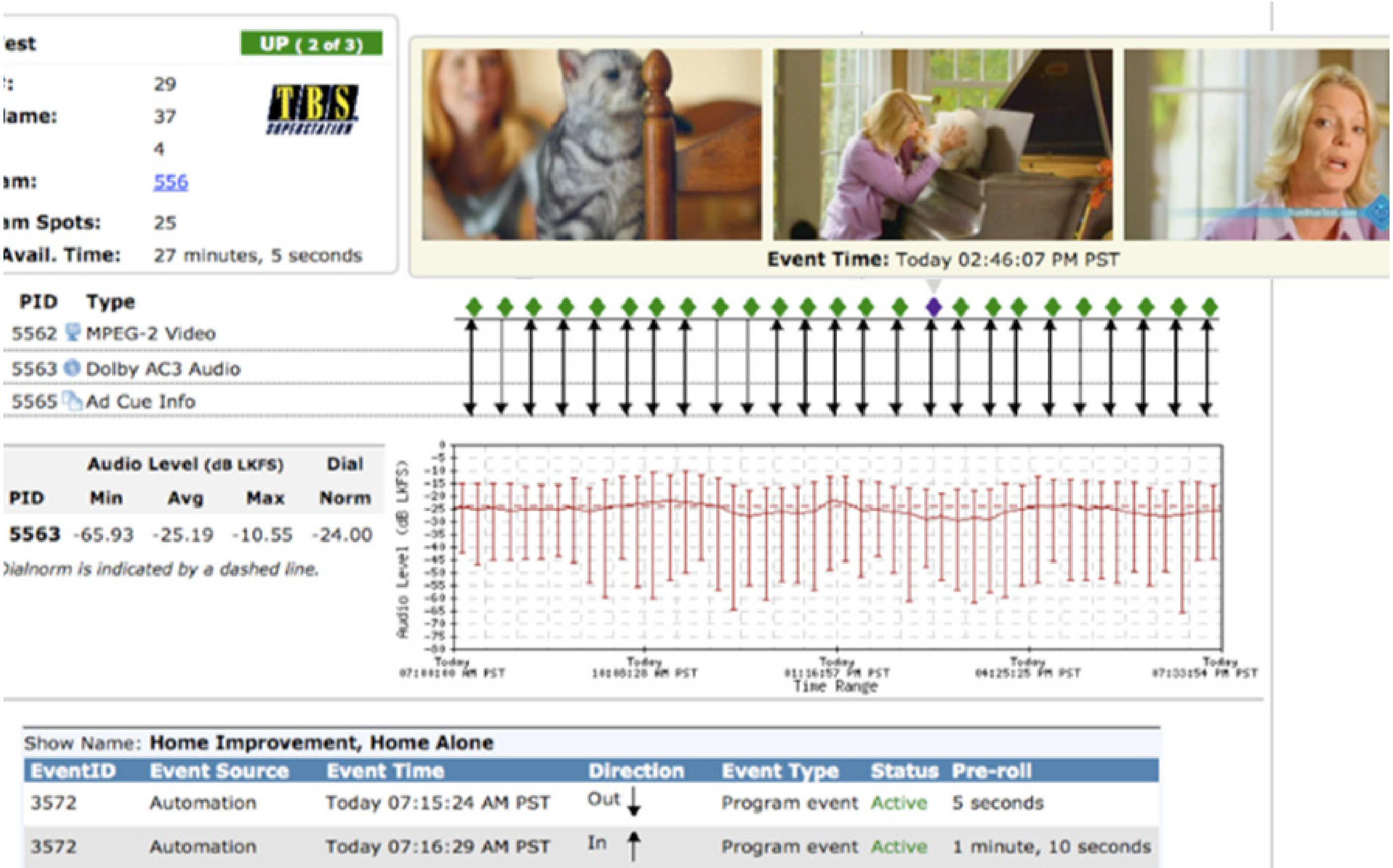


Figure 17. Video thumbnail around the SCTE 35 Ad Cue event.

In addition, by performing ad insertion verification, ad sales groups are able to provide higher levels of customer service, resulting in greater revenue potential. By strategically placing monitoring probes in each of your ad zones, you should be able to monitor and be alerted on all insertion opportunities network-wide, as well as issues that arise from problems. Figure 16 shows an example of the SCTE 35 commands in a digital video service showing when to trigger an ad-insert. The summary also shows that 48 ads were detected even though the expectation was for 50 ads

An example that helps in Ad Verification is to show a video thumbnail just prior, during, and after the Ad Cue trigger from SCTE 35. Figure 17 shows the SCTE 35 triggers and audio details, but also includes three video thumbnail surrounding the selected key event.

RF Stats

				Pre-RS BER			Post-FEC erred TS packets		
Port Name	Freq	Current Activity	Const.	Min	Avg	Max	Min	Avg	Max
675MHz-RF1	675 MHz	UP		0.00E+0	4.23E-5	2.91E-4	0.0/sec	43.4/sec	475.0/sec
753MHz-RF1	753 MHz	UP		0.00E+0	1.35E-5	2.64E-4	0.0/sec	0.6/sec	16.0/sec
669MHz-RF1	669 MHz	UP		0.00E+0	2.49E-6	5.58E-5	0.0/sec	0.1/sec	5.0/sec
57MHz-RF1	57 MHz	UP		0.00E+0	2.16E-6	4.15E-6	0.0/sec	0.0/sec	0.0/sec
63MHz-RF1	63 MHz	UP		0.00E+0	0.00E+0	0.00E+0	0.0/sec	0.0/sec	0.0/sec
69MHz-RF1	69 MHz	UP		0.00E+0	0.00E+0	0.00E+0	0.0/sec	0.0/sec	0.0/sec
177MHz-RF1	177 MHz	UP		0.00E+0	0.00E+0	0.00E+0	0.0/sec	0.0/sec	0.0/sec
183MHz-RF1	183 MHz	UP		0.00E+0	0.00E+0	0.00E+0	0.0/sec	0.0/sec	0.0/sec
189MHz-RF1	189 MHz	UP		0.00E+0	0.00E+0	0.00E+0	0.0/sec	0.0/sec	0.0/sec
195MHz-RF1	195 MHz	UP		0.00E+0	0.00E+0	0.00E+0	0.0/sec	0.0/sec	0.0/sec

Figure 18. RF Monitor measuring BER on more than 100 RF QAM channels from a local cable TV service provider.

RF Monitoring

QoS starts at the physical layer and measures parameters such and signal level, noise, and forward error correction (FEC). All digital RF transmissions (e.g., 8PSK, QPSK, 8VSB, COFDM, QAM, etc.) assume a lossy environment and add additional data for redundancy and error correction (i.e., inner-FEC). These additional overhead rates range from 9/10ths (very little) up to and beyond ½ (almost two for one, or full redundancy) depending upon the RF standard and how much noise or interference is expected to be received or recovered from. Interleaving is another good means to prevent loss of data (or to aid in error recovery), but does not add any additional overhead to the stream. Interleaving works best by taking a short burst of errors and spreading them out over longer amounts of time making the FEC more effective. If the bit error ratio (BER) for the received transport stream (after demodulation and inner-FEC) is less than about 5x10E-3, then it is assumed to be quasi-error free (QEF) due to the Reed/Solomon (R/S) portion of the transport being able to correct up to eight errors per TS packet (five errors for 8VSB). The reason for calling it quasi-error free is due to the statistical nature of random errors where we might rarely find a short burst of nine or more errors in a single TS packet causing the R/S algorithm to pass a TS packet to the video/audio decoders with one or more bit errors. Figure 18 shows different RF ingest points (usually satellite and terrestrial) as well as the common egress QAM RF feed going out to the many set top boxes. Each of these RF ingest and egress points need to be monitored for QoS and preferably a post-FEC BER of 0.0. Figure 18 is from a QAM receiver measuring over 100 RF channels in parallel from 57 MHz up to 1000 MHz. It is important to note that the "Post-FEC Avg" column was selected and sorted showing the worst offenders at the top of the list. In this specific case, channel EIA-104 at 675 MHz is receiving a huge amount of RF impairments leading to a very high BER in both Pre-RS and Post-FEC. In this case, it appears that the TS from 675 MHz is getting about 43 TS packet errors every second.

Another place to see when BER negatively affects a TS is in ETR290 Priority 2.1. This test looks at the Transport Error Indicator bit (one bit after the TS sync byte) which is set by every RF digital demodulator. If the bit is a “1” value, then we know for a fact that the TS packet has one more bit errors inside the 188-byte TS packet. This is a bad sign, but it could be even worse if it happens to land inside an anchor video frame (i.e., I-frame) being used to display many other video frames. If an error rarely occurs in an audio TS packet, or a bi-directional video frame, then the error will probably be missed by the viewer, or at worst, only occur for a small fraction of a second. See Figure 18 for an example of a demodulated TS with errors (ETR290 2.1 failures).

There are usually two key points in the network where RF monitoring is important to any broadcaster of Cable, Terrestrial, or Satellite digital video services. Those two points are at the ingest where source content is brought into the system (by dish or aerial antenna), as well as the egress where the signal leaves the system. The most important point to RF testing is signal or transport integrity. This is achieved by monitoring the RF Level, noise, and most importantly, the Post-R/S BER (should be always 0.0). It is usually OK if the pre-R/S BER is worse than 5x10E-3 as long as the post-R/S BER is zero, and the ETR290 Priority 2.1 test is always green/ good.

Another good reason to measure the RF signal at ingest and egress is to make sure that we stay as far away from the digital cliff as possible. This means maintaining high levels of signal power, low levels of noise, and minimal pre-R/S BER. As long as these tests stay within predefined values, then we can be sure that the stream is transmitted and received error-free.

Width	Height	Bit rate
1280	720	3 Mbps
960	540	1.5 Mbps
864	486	1.25 Mbps
640	360	1.0 Mbps
640	360	750 Kbps
416	240	500 Kbps
320	180	350 Kbps
320	180	150 Kbps

Figure 19. An example of eight different ABR formats and rates available from within a manifest file.

Even though we have concluded that the stream was transmitted error-free, there may have been audio, video, or multiplexing errors embedded inside the stream that are hidden to any RF or ETR290 testing. In this case, it would be advisable to also measure the audio and video protocol for correctness and decodability. The additional test (QoE) is only required on the RF-ingest side because the egress side should have already been tested for compliance prior to modulation and transmission.

New Requirements for Monitoring OTT & Adaptive Bit Rate

Over the top (OTT) technology is new and growing quickly. Where the previous sections discussed digital video services being broadcast from one to many, OTT is more of a one to one service, usually over the HTTP broadband network. It also includes dynamic bandwidth (bandwidth) allocation (slightly decreasing or increasing every few seconds) depending upon bandwidth availability at the users’ PC, tablet, or mobile phone. This dynamic change in bandwidth is called Adaptive Bit Rate or ABR. Figure 19 shows an example of the many possible video formats and rates.

System Status

Engine Status:	UP
NTP Status:	UP
Database Used:	4%

Device Status

LAN 1 (web interface)	UP
LAN 3 (ABR)	UP

Data Activity Status

Current total input rate:	112.301 Mbps

Origin Servers

Edit

Origin Server	Current Bitrate	Bandwidth Limit
10.0.3.46	113.548 Mbps	300.000000 Mbps

Current Input Bitrate								
Port #	Name	Device	Current Bitrate	Format	Encrypted	VOD/Live	Rep. Count	Status
0	Show Time -1	ABR	9.813 Mbps	HLS	No	Live	7	UP
1	Show Time -2	ABR	9.745 Mbps	HLS	No	Live	7	UP
2	Show Time -3	ABR	9.761 Mbps	HLS	No	Live	7	UP
3	first bipbop	ABR	826.536 Kbps	HLS	No	Live	4	UP
5	NTSC Test - 1	ABR	826.689 Kbps	HLS	No	Live	4	UP
6	NTSC Test - 2	ABR	826.310 Kbps	HLS	No	Live	4	UP
7	NTSC Test - 3	ABR	826.724 Kbps	HLS	No	Live	4	UP
10	Impaired 404 & 302	ABR	19.524 Mbps	HLS	Yes	Live	6	UP
11	Impaired 404	ABR	20.092 Mbps	HLS	Yes	Live	6	UP
12	Encrypt. -1	ABR	20.031 Mbps	HLS	Yes	Live	6	UP
13	Encrypt. -2	ABR	20.029 Mbps	HLS	Yes	Live	6	UP

Figure 20. ABR monitor with 13 unique ABR services.

In order to make this shift quickly and seamlessly, the content must be compressed to up to 16 different rates, and then divided into small chunks of time (e.g., 2-second chunks). The link between the service provider and end-user-equipment negotiates for the best estimate of bandwidth for the next few seconds. This scenario relies on a manifest file describing the content and available rates. The end user does not see any of the negotiations, but instead should simply be able to view the highest quality video within the browser or application.

To make sure that all of this goes off without any problems, the ABR monitor will check each manifest file as well as the many supporting rates over time. This process can be performed actively or passively. The active approach will attempt to watch every defined video over every rate and create a report showing the results of the video over rates and time. Figure 20 shows the ABR monitor actively monitoring several video services. In each case, the service will include the same content or video program over several different bit rates.

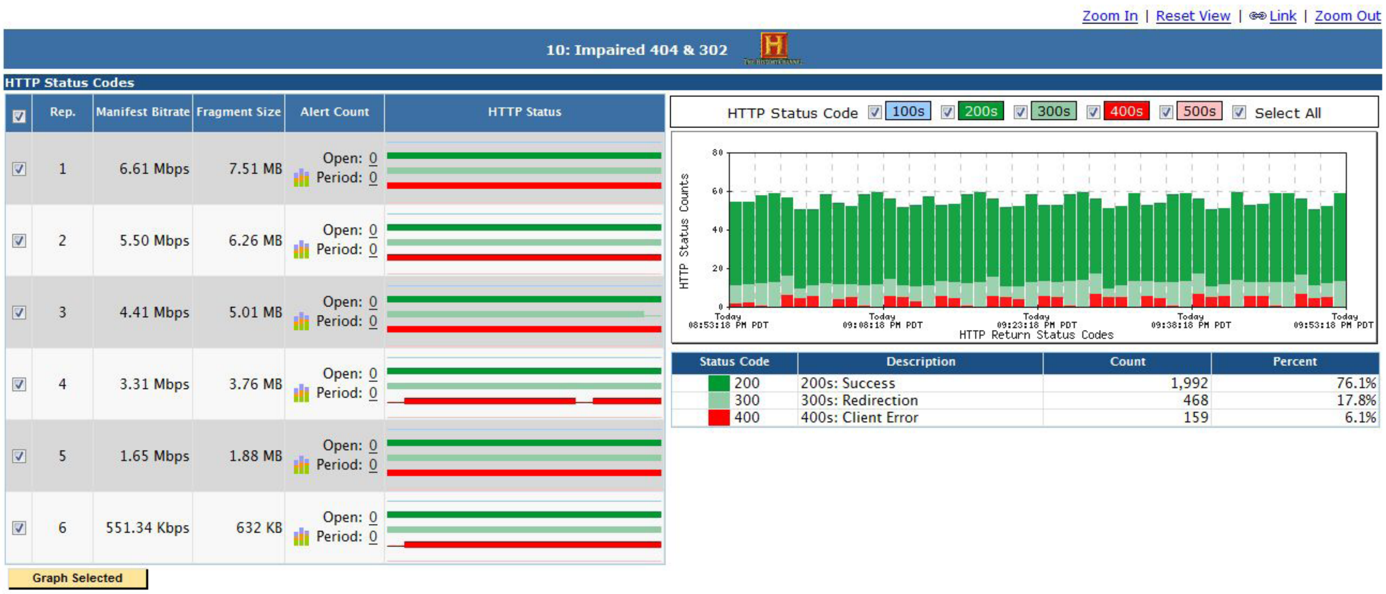


Figure 21. Multiple formats and rates for a single service with occasional HTTP failures.

For the passive process, the ABR monitor will only monitor the selected stream based upon the end user request (only one of the many rates listed in the manifest file).

As mentioned earlier, each service is divided into small chucks of time allowing viewers to dynamically switch to a higher or lower bandwidth depending upon how much bandwidth is currently available. Figure 21 is an example of one specific service that offers six different video formats and bit rates from 6.6 Mbps down to 550 kbps. The plot is over several hours showing that most of the HTTP handshakes were successful, but a few were redirected to another server, and also a few 400-series client errors (e.g., Page Not Found).

Since the quality of any ABR service is heavily dependent upon the source material, it is wise to also measure QoS, QoE, and PVQ on each upstream digital video service.

Summary

To summarize Digital Video Service testing and monitoring, we need to place high importance on testing QoS to ensure that the transmission link is working well, but not to rely solely on this one metric. Next, we must rely on QoE because we know that it is possible to deliver a bad video or audio element in a TS and get a perfect QoS score. Therefore, QoE testing will verify that the audio and video elements are decodable on any compliant TV or set top box. Lastly, we must monitor audio loudness for differences in audio levels, as well as video over compression which is legal, but negatively affects to quality of the video.

These testing and monitoring requirements will help keep viewers happy and will reduce the amount of calls from subscribers complaining about adverse video services.

According to MRG Cable & IPTV Operator Surveys, the four top issues causing people to call in and complain were Macroblocking, Blackout, Freeze, and Audio Silence. Figure 22 shows these rating from the survey.

Top Video Error*	Operators
Macroblocking	89.5%
Blackout	88.4%
Freeze	84.2%
Audio Silence	52.6%

Figure 22. Viewer Reported Errors – Poor QoE.

These top four errors account for 54% of the total number of view complaints. Of these errors, 60% were caused by the operator, and 40% were caused in the home. Therefore, proactively monitoring and measuring each service from RF/IP to individual pixels will help to keep the customers happy which will reduce subscriber loss in today's highly competitive markets and will also reduce operational expenses.

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For Further Information
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