# Troubleshooting and Monitoring

## Recommendations for TV Everywhere Deployments

### Combining QoE and QoS for Maximum Quality Assurance Throughout the Network

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TV Everywhere is clearly the future of television as cable operators, their competitors and content providers all race to build the infrastructure necessary for delivering any program (linear or on-demand) to any device at any time and over any access network. The new technology necessary to deliver TV anywhere content brings new challenges and to ensure customer satisfaction, it is vital that cable operators are able to deliver a "TV Like" viewing experience to each targeted device.

In cable's competitive environment, ensuring the best possible quality of experience (QoE) – one free from video and audio errors that disrupt the viewing experience – will be critical to keeping existing customers and to building significant subscription numbers. Operators must be able to assess performance and identify causes when quality is subpar across all points in the end-to-end adaptive bitrate streaming infrastructure. Not only will this be essential to maintaining subscriber satisfaction, but it will also be critical to convince content providers and their advertisers that they will benefit from funneling high-value first-run and on-demand content into TV Everywhere services over managed networks.

This paper will explain the technology behind TV Everywhere, Adaptive Bitrate (ABR) Streaming, the types of adaptive streaming technologies that are available, ABR profiles, and how and why there has been a shift away from classic progressive streaming protocols towards HTTP-based ABR delivery.

The paper will then examine the need for QoE monitoring of both linear and on-demand ABR-based TV Everywhere services by looking at some of the architectures operators are currently using for their TV Everywhere deployments. Recommendations will be provided for operators to show where and what needs to be monitored for both linear and on-demand content at various points in the network in order to ensure the best quality of the viewing experience for subscribers.

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## Adaptive Bit Rate Streaming and its Challenge

Adaptive Bit Rate (ABR), which is an HTTP based video streaming technology, is the key enabling technology for delivering the TV Everywhere experience. It is designed to eliminate buffering issues by providing multiple versions of the same content encoded at multiple bit rates (and corresponding quality). The client side player will determine the available bit rate and will request the appropriate content to meet current bandwidth availability. As the video program streams are usually "segmented" or "fragmented" such that only a short sequence of the content is streamed from the server side, the next batch of segments is requested at the optimum bitrate when the bandwidth availability changes. Sophisticated middleware allows the session to be paused and seamlessly transferred from one play out device to another (e.g., from mobile to TV) and continues to play out from the pause point at the most appropriate bitrate for the new device. In summary, ABR enables delivery of program streams that immediately adapt to the bandwidth that is available and best suited for the end-user viewing device.

With this new technology and complex delivery method, cable operators must be able to assess performance and identify causes when quality is subpar at any point in the ABR network infrastructure. Not only will this be essential to maintaining subscriber satisfaction, but it will also be critical to convince content providers and their advertisers that they will benefit from funneling high-value first-run and on-demand content into TV Everywhere services over managed networks.

The new parameters associated with ABR quality assurance (QA) include the following:

- Transcoding – Operators are employing a wide range of vendor approaches to supporting the basic requirements of ABR transcoding, where for every class of device there is a range of bit rates that must be assigned to each content stream, whether it's fed live from an original encoding source or from file storage. Typically this entails generating up to a dozen combined H. 264 video streams encoded at various rates using either purpose-built hardware or software running on off-the-shelf processors.
- Fragmentation – ABR requires the fragmentation of video delivered with each user session into chunks of a given time duration. The fragmentation process varies depending on what type of device is requesting the content. Unfortunately, each of the most popular ABR streaming modes – Apple HLS, Microsoft Smooth, Adobe HDS and MPEG-DASH – employ incompatible approaches to constructing fragments, timing the sequence, and when communicating manifest files to clients.
- This means that an operator intending to reach all connected devices that use ABR, including TV sets, game consoles, computers, tablets and smart phones, must eventually support multiple types of fragmentation as well as different resolutions, profile and bitrates, thereby requiring multiple transcoded outputs from any given TV program or movie.

In any event, under current circumstances, a video service provider attempting to achieve end-to-end quality assurance with an all-encompassing multiscreen service would have to tabulate and analyze fragment-by-fragment performance on at least the three currently dominant fragmentation modes across all streams.

- Content Protection – Just as different types of devices operate natively with different types of ABR fragmentation systems, they also come equipped to support different types of digital rights management systems. This means that each fragment over each ABR stream must be assigned an encryption key that will communicate with the embedded device DRM client. Premium service QA will have to provide verification that the digital rights management (DRM) processes are working.
- Other Points of QA Associated with Multiscreen Services – While not directly associated with different ABR and device categories, there are additional processes coming into play in the multiscreen distribution environment that will require monitoring and analysis, including dynamic advertising, subscriber and device authentication and enhanced feature performance tied to companion device apps, e-commerce, advanced content discovery mechanisms, social networking and much else.

Again, the challenges above may be daunting, but they can be overcome and should become easier to address as new QoE and QoS tools and techniques become available.

## QoE + QoS = Maximum QA for ABR-based Video Network Infrastructure

To ensure the best possible QoE for viewers, it's necessary for operators to employ a comprehensive approach to quality assurance (QA). In this paper, a comprehensive QA solution for operators' ABR-based services is described that employs a two-stage approach. The first stage is to use the latest QoE monitoring tools and techniques to ensure the quality of programming from ingest all the way through the critical transcode process. After being transcoded and the resulting H.264 streams have been packaged into the four ABR streaming formats (Apple HLS, Microsoft Smooth Streaming, Adobe HDS and MPEG-DASH), the second stage is to employ quality of service (QoS) techniques to ensure that all media assets are properly cached and ready to be delivered immediately upon request.

Cable operators who use ABR streaming to deliver multi-screen services should consider using monitoring tools to implement QA procedures at the most crucial points in the network.

## Stage 1: QoE Monitoring During "Content Preparation" (Refer to Figure 1a)

Fortunately for operators, there are already proven QoE tools and techniques that can be immediately employed to provide considerable QA for their ABR-based services. Advanced QoE monitors are already being used by operators large and small to identify picture and sound quality errors in the programming they ingest in their headends. Additional monitoring can also be done after other critical processes, such as transcoding, caching, and streaming to ensure the integrity of their programming all the way from the content provider to the network edge. One key step in the complete ABR streaming process for which established QoE monitoring methods are in use is transcoding.

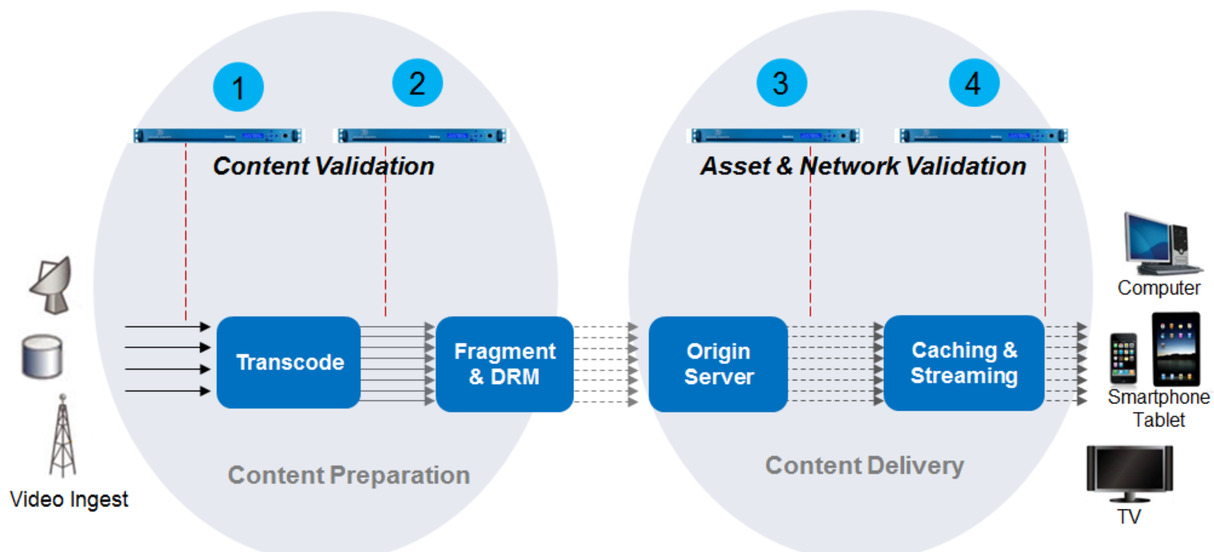


**Figure 1a.** Multiscreen, Multipoint Video Monitoring

## Transcoding: Where it Could all go Wrong

Transcoding content ingested in MPEG-2 into the H.264 codec, used for multi-screen TV Everywhere services, is perhaps the most critical step in the entire ABR streaming process. Previously the key was to ensure that the MPEG-2 programs are error-free prior to transcoding since packet errors in particular are then encoded into the new format and look like valid packet streams. But now in addition it's absolutely vital that the MPEG-2-to-H.264 transcoding process itself doesn't create errors because they will be multiplied greatly as 6-12 profiles of each stream are typically created to support delivery of the program to smartphones, tablets, PCs and other devices at different profiles, bit rates and resolutions.

Here, the critical challenge is to perform comprehensive quality analysis on each H.264/AAC stream in real time, which is much more difficult than analysis of MPEG-2 video. Due to both complexity and the use of entropy bit stream encoding, H.264, as well as the fact that encoding errors are more subtle, H.264 content requires seven to 10 times the computational resources required to analyze MPEG-2 for video quality impairments. One of the critical components to watch for in the H.264 macroblock encoding process is over-compression, which commonly happens with motion-intensive action sequences in sports and other programming. Such artifacts – resulting in blurred or soft, washed-out images – are virtually undetectable once the signals are encrypted, which is why the transcoding output must be directly monitored independently of what comes next in the ABR processing train.

Further complicating matters is that with transcoding there are multiple streams for each piece of programming that must be monitored with respect to ancillary content feeds, such as synchronization of closed captioning.

Given that transcoding is the first step in the ABR streaming process, it is also arguably the most critical, as any errors introduced here will be carried through all the way to the end user. So while a service provider can flawlessly perform the fragmentation, packaging and delivery-- involving caching and streaming-- the result could still be a flawed viewing experience for the subscriber.

To ensure the transcoding process is being done correctly, service providers should monitor MPEG-2 streams prior to transcoding and then monitor each of the resulting H.264 streams post-transcode. In this way, service providers can determine if the transcoder is introducing errors or if the content being ingested already contains the errors. This will help identify the underlying source of any errors, which is critical to resolving the issue and ensuring an optimal QoE.

## Choosing a Monitor

Fortunately, well-defined "best practices" and proven solutions exist for comprehensively monitoring both MPEG-2 and H.264 streams.

There are several key characteristics service providers should look for in their TV Everywhere QoE monitoring solutions:

- Obviously, the ability to credibly analyze and report on video and audio quality for all of the MPEG-2 and H.264 streams is required, as is scalability to monitor all of the resulting H.264 streams created by the transcode process.
- Additionally, these QoE monitors should be capable of gauging and reporting the actual severity of errors based on how much they will impact subscribers. Simply put, not all errors are created equal, and one-time "blips" that are imperceptible to subscribers do not require the same attention that significant and recurring errors require. Identifying actionable errors – often before they impact subscribers – is a key advantage for service providers.
- Finally, the ideal QoE monitor will also employ historical reporting capabilities that log errors and associated network conditions at the time of the errors. These reporting features can help service providers tremendously in diagnosing recurring errors, which in turn leads to faster fixes, and enables service providers to address serious "garbage in, garbage out" situations before they can dramatically reduce viewers' QoE.

### Stage 2: Content Delivery Monitoring (Refer to Figure 1b)

As we have reviewed, extensive QoE monitoring of content from acquisition through the critical transcoding process (during "Content Preparation") is vital to ensuring the best possible video and audio quality.

After this point, there are two places (marked 3 and 4 in the oval box) when QoE monitoring techniques are not applicable due to the inability of QoE monitors to examine encrypted content. But more importantly, there is no need to perform this CPU intensive QoE monitoring task again if the QoE monitoring has already been implemented. For example, if an audio stream with the correct audio loudness gets packaged into a segment, there are no devices after the packaging process (during content delivery) that could materially change the audio loudness. After the video and audio content has been verified to free of viewer-impacting errors (which happens during the content preparation stage), QoS tools and techniques are needed to verify that the ABR video assets have been properly "published" to the origin servers and caching servers, and are ready for retrieval and immediate viewing by the subscriber.

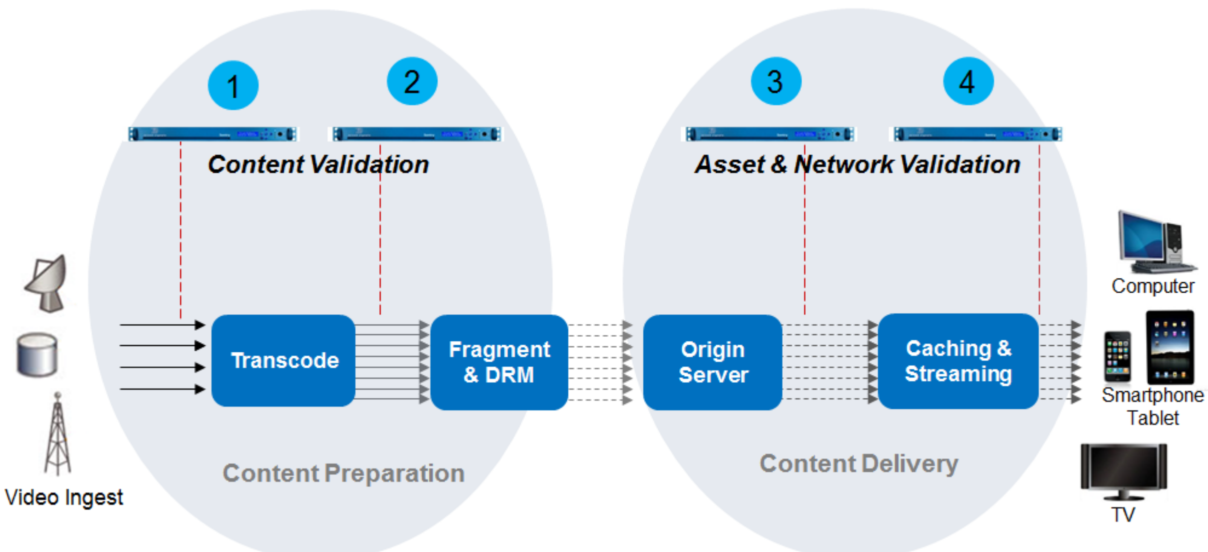


**Figure 1b.** Multiscreen, Multipoint Video Monitoring

### Active Monitoring

The characteristics for an effective QoS monitoring tool for ABR QA include the ability to proactively validate all assets, bitrate profiles and manifest files based on a HTTP fragment fetching engine. Additionally, it should be able to detect and alert operators to any mismatch in the bitrate of the sub streams, identify missing segments (HTTP errors) and note excessive segment-fetching latency. This is called "Active" monitoring or validating, as it is actively fetching hundreds, or even thousands of streams concurrently in real time. This method will simulate video flow just like a large group of subscribers will, and it can be configured in such a way to validate video asset availability and network performance against a specific segment of the network or a cluster of servers. An active monitor is also ideal for testing and performing QA on the entire network and servers, from Origin (point 3 on the diagram) all the way to the edge of the network (point 4 on the diagram). An active monitor can validate ABR video asset availability at any point on the network. An active monitor is a good first line of defense for cable operators to consider as the issues it identifies, are not unique to a particular session, but will more likely happen to all the subscribers when they make similar requests. For example, if there is a particular segment that is missing, every subscriber requesting this video segment will likely see black or frozen video.

## Passive Monitoring

As the name implies, the passive monitor is a completely different but a complimentary QoS monitoring tool to the active monitor. While the active monitor simulates video flows to validate asset availability and network performance, the passive monitor only "passively" analyzes subscriber requested video on the network without generating any video traffic. Similar to the active monitor, a passive monitor will be able to generate reports on alerts for user impacting events. However these reports and alerts are session-based and it is not always guaranteed that the same error will happen again in another session. In general, it is recommended to first use the active monitor to ensure the video asset availability and then use a passive monitor as a way to troubleshoot any subscriber/session specific event when it occurs.

## Conclusion

TV Everywhere and other ABR-based services are clearly critical to operators remaining competitive in an increasingly competitive multichannel – and now multi-device and multi-access network – world.

Ensuring an optimal QoE for subscribers will be crucial to remaining competitive and currently a two stage QA approach that combines deeply probing QoE monitoring during the Content Preparation stage, along with advanced QoS monitoring during Content Delivery stage. Here, an active monitor is used to validate content readiness and availability, and a passive monitor is used for session based troubleshooting.


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## Abbreviations and Acronyms

**ABR** Adaptive bitrate is a technique used in streaming multimedia over video delivery networks.

**DRM** Digital rights management

**DASH** Dynamic Adaptive Streaming over HTTP

**H.264** H.264 is a standard for video compression commonly used for the recording, compression, and distribution of high definition video.

**HTTP** Hypertext Transfer Protocol is an application protocol for distributed, collaborative, hypermedia information systems.

**MPEG-2** MPEG-2 is a standard for the generic coding of moving pictures and associated audio information.

**QA** Quality assurance, is ensuring the quality of a product (video) being delivered.

**QoE** The quality of experience a viewer receives from video service providers.

**QoS** The quality of service a subscriber receives from video service providers.

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