White Paper

Efficient QC in IMF Workflows

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1. INTRODUCTION

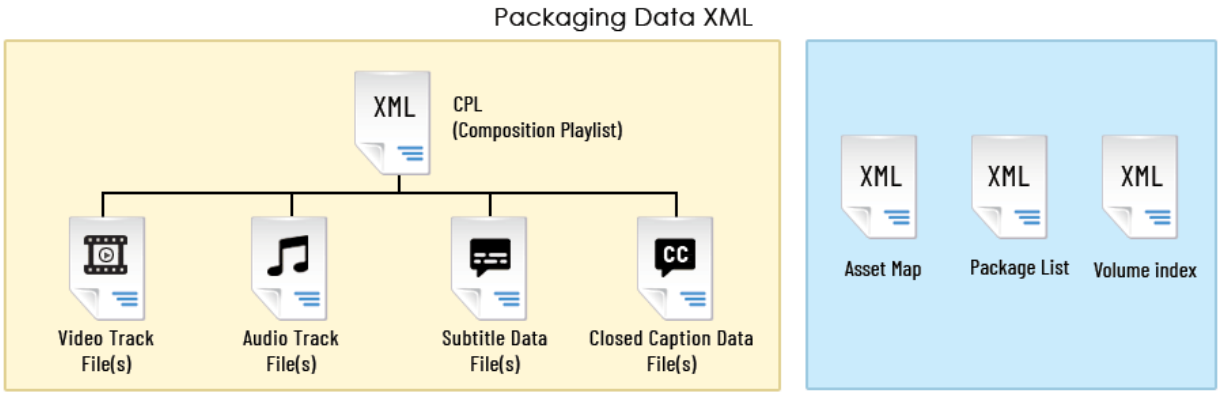
In a short span of 10 years, the Interoperable Master Format (IMF) has established itself as the industry's de facto standard for both production and distribution workflows. It provides numerous advantages in terms of interoperability, storage, distribution, and workflow automation.

At the core of any IMF package lies an XML-based Composition Playlist (CPL), which defines audio, video, and data tracks localized for a specific region or application. As the popularity of IMF continues to grow, it has become crucial for content creators to ensure full compliance with IMF specifications for any package. IMF follows several concepts — such as CPL, PKL, AssetMap, multiple application types, and versioned packages — which can make adherence to specifications somewhat challenging. Consequently, it is essential to employ automated file-based QC solutions, that offer comprehensive and efficient quality control for both original and versioned IMF packages. Efficient QC helps in enhancing interoperability and overall workflow efficiency.

2. ADVANTAGES OF IMF

IMF has been embraced by some of the largest content creators in the industry for several key reasons:

1. The creation of a single, high-quality interchangeable master file
2. Streamlined creation and management of multiple versions of the same content
3. Reduced storage requirements
4. Increased efficiency in the content exchange
5. Low-cost, fast distribution: IMF lowers the cost of making and storing multiple masters and assets for the same piece of content, improving time to market and streamlining global distribution

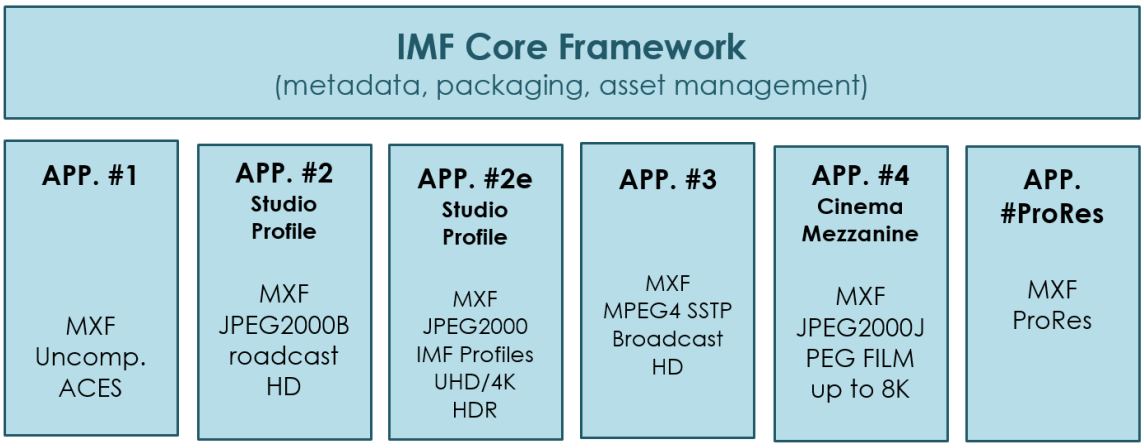


With the above advantages, IMF's adoption is set to grow in coming years. Moreover, with the growing popularity of UHD/HDR, we can expect further acceleration in IMF's adoption.

3. WHY IS QC FOR IMF IMPORTANT?

With the increasing adoption of IMF and its complex structure, it becomes extremely important that we perform comprehensive QC of IMF packages (IMP). Just imagine if we have an unverified original IMP, with which multiple versioned IMF packages have been generated. In such a scenario, if the base IMP contains multiple issues, these issues will propagate downstream to versioned packages. This has the potential to disturb the whole content chain. Therefore, it is important to perform comprehensive verification of the base IMP, followed by incremental verification for each versioned package. Such an approach will ensure the delivery of quality IMP to consumers, and seamless interoperability and distribution.

IMF is based on the SMPTE ST-2067 series of specifications, which is defined with a very modular approach. The specification defines the core framework and the various implementations — called applications — derived from this core framework. This is depicted in the diagram below.



The core framework defines the basic components of IMF, but it is left to the individual manufacturers to define and deliver the final mix. Each IMF mastering tool can define its own folder structure, file naming conventions, relative path in which the final version will be stored with respect to the original version, and more. This gives manufacturers flexibility but could

become an interoperability nightmare for content aggregators. The independent and modular architecture of IMF has the advantage of introducing new applications without affecting the core framework, but it also increases the risk of violating standard constraints. Therefore, it becomes important for an automation tool to ensure compliance with codec specifications defined in the respective applications, while simultaneously ensuring integrity with the core framework.

In the next couple of sections, we'll explore how comprehensive QC should be performed for both original and version IMF packages.

4. QC OF ORIGINAL IMF PACKAGES

Content creators must perform in-depth analysis of an IMF package using an automated content verification system — one that is continuously aligned with the latest developments and adopts the trends of an evolving IMF specification. It should perform integrity checks on the IMF structure XMLs, ensuring that the core framework isn't violated, and deep analysis of the underlying video and essences.

Complex Composition Structure

One of the major driving factors of implementing IMF workflows is solving versioning issues and eventually optimize storage and network bandwidth. Each unique version is defined as a playlist and represented in the IMF package as a CPL. The CPL is not designed to contain an essence, but rather to reference external track files that contain the actual essence. This allows multiple compositions to be managed and processed without duplicating the essence in common. The original version or main package is self-contained, and the CPL refers to external essences that all reside within the package.

Thus, an IMF package can be complete, containing all the referenced constituents, or it might depend on previous packages for one or more video and audio main essences. An IMF package might point to a single timeline, or it might have multiple compositions for various language versions in the same package. An automated QC tool should understand the various flavors of IMF and optimize its analysis to perform thorough checking at a maximum speed.

The QC solution should also ensure that the IMP contains all the relevant files. The size of essence files, especially video files, can often run into terabytes, and such files have a high chance of becoming corrupted during transfer. Calculating the file size and checksum for each file, and ensuring that its value matches with what is encoded in the PKL file, is important for the overall integrity of an IMP.

Metadata Consistency

The CPL defines the playback timeline for the composition and includes metadata applicable to the composition. There is an overwhelming amount of IMF metadata contained in the various XML files (CPL), including the MXF container of each video, audio, and data essence, and the actual essence itself. The first challenge is to read and assimilate the metadata available at various levels of the distributed content structure, and the second is to ensure that it is consistent at all levels. For example, video resolution will be present in the CPL file, in the MXF header metadata, and in the underlying MJPEG2K/ProRes video essence. It is important that these three values are consistent so that any third-party application that depends on the metadata at any level can operate properly. An automated QC tool will fulfill the critical responsibility of ensuring metadata consistency at all levels of content structure.

In-Depth Verification of Video Audio Essence

The in-depth verification of underlying video, audio, and subtitles is equally important. Each essence needs to be checked for compliance with MXF and corresponding audio/video/subtitle specifications. Duration and metadata values like framerate and resolution for each essence should match, as per the CPL. Each essence should be fully decodable without any conformance error.

Once the above checks are executed, a comprehensive quality check of audio and video should be performed to ensure high quality. Video essence should be checked for valid color gamut, RGB levels, freeze frames, black frames, color bars, PSE, and. more. Likewise, audio needs to be checked for loudness, silence, test-tones, and audio clicks. Checks like PSE, loudness, and color bars are often required for meeting regional regulations. Moreover,

combining essences from multiple tracks can often result in issues like audio clicks, loudness, and color mismatches. A good QC solution should support all these checks to ensure the delivery of high-quality content.

Playback

Unlike a regular media file that can be played back using freely available tools like VLC Media Player, QuickTime Player, or others, IMF packages have a componentized structure and comprise at least eight to ten individual files (and possibly many more) that are linked through underlying XMLs. The usual media players often find it tricky to play back the intended IMF timeline that is contained in the CPL.

It is also difficult to play back an error segment identified during content analysis and sync it with an external video, audio, or data essence. Therefore, the right automated QC tool should include IMF playback capability to make it a complete solution. An automated QC tool must be accompanied by a playback option to easily visualize the various errors specific to different components/essence identified during content analysis.

With globalization, good quality captions/subtitles are critical to any content. Hence it is important that a good QC solution should perform comprehensive QC of captions. It includes support for various formats, checking for consistent metadata, conformance and other quality issues like right language, dropout, completeness, synchronization etc.

Processing Modes

Different applications for IMF relate to the production and distribution of finished content. These will always be high-res files with high bitrate and maximum resolution. For an IMF package, the overall size of the media files will be very large and will depend upon the compression format, frame rate, bitrate, and other parameters of the underlying video and audio essence. For example, the size of a one-hour 4K media file can vary from a few hundred gigabytes to a few terabytes. For IMF packages of such a large size, processing these media files can be very time consuming; thus the processing speed of the automated tool becomes very important.

High-speed content analysis can be a challenge for a QC tool. To some extent, it can be achieved by using high-quality and modern decoders, but this approach has its limitations. To overcome this challenge, the right QC tool will need to use different analysis strategies, such as in-depth analysis or shallow analysis of the content. In the case of high-level analysis, only the header metadata will be parsed and validated, skipping the essence decoding. On the other hand, an in-depth analysis will do the complete decoding and metadata validation. This approach gives users an opportunity to choose a QC strategy that fits their schedules and delivery commitments.
A good QC solution should also act as a hybrid QC solution that implements organizational QC policy to support a combination of automated and manual QC checks – the result is a well-integrated and efficient broadcast workflow.

The performance aspect becomes more important as media companies move their workflows to the cloud. For a couple of reasons, the strategy of first downloading the IMP package locally and then verifying it may not work for the cloud. For one, downloading a large IMP package running into the terabytes may require a lot of time and disk space. This will pose challenges if the QC solution is also installed on the cloud, since local storage will incur extra costs. In these cases, it is important that a QC solution can verify the file directly from the cloud without having to download it first. Furthermore, a good QC solution should support multiple cloud locations, like Amazon, Google, and Azure, to ensure and should also have the feature of auto scaling to scale up/down the system dynamically depending on the QC requirements.

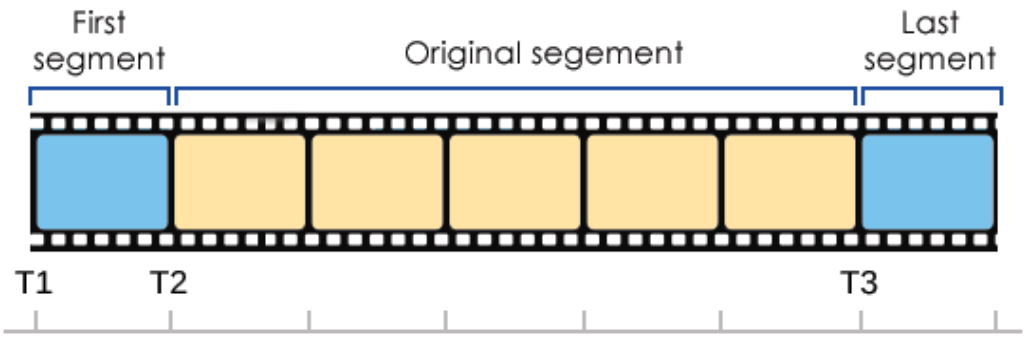
5. QC OF VERSIONED IMF PACKAGES

It is the responsibility of the QC tool to leverage the power of IMF and perform efficient verification of versioned packages. Let's take a simple example in which an IMF package consists of one video and one English audio. For Spanish audiences, the content provider creates a version package with an additional Spanish audio inserted. When this versioned IMF package is submitted to a QC solution, it is important for the solution to only QC the newly added track without verifying the original package. This will ensure QC of only newly added tracks or segments, thus maintaining the efficiency introduced by any IMF workflow.

A good QC solution should therefore be able to identify the difference between versioned and original packages and only verify that difference.

In addition to the above performance directive, a QC solution should be able to address the below complexities related to versioned packages:

- The CPL present in a version file can refer to essences that might reside in a different folder or storage location, and are only traceable through UUIDs. The problem becomes worse when a version file must be delivered that has essences referring to multiple packages spread across various storage locations. Further compounding the problem is the complexity of varied folder structures and file naming conventions for content coming from multiple production houses. A good QC solution should be able to locate all the required essences, provided the necessary directory paths are given as input
- Identification of duplicate tracks/segments: Once duplicate tracks and segments are identified, the QC solution should skip their analysis to save time and critical resources. If possible, analysis results for duplicate tracks should be copied from earlier reports and merged with the new reports. This will make reports for versioned packages provide a complete picture to the user
- Assignment of correct timestamps for verification: Consider a situation in which an original video track has been modified for a version package by adding a video segment in the beginning and towards the end. In such a scenario, it is expected that the QC solution will skip the analysis of the original track and only perform detailed analysis on the first and last segments. All the errors reported for the last segment should correspond with the timeline defined in the CPL. For example, the timestamp for the last segment in the below case should start from T3 and not T2, as depicted below. This approach will ensure the sanity of reported errors.



6. CONCLUSION

For content aggregators or postproduction houses, it is difficult to keep track of a complex and evolving standard like IMF, and to continuously upgrade their setups or workflows to suit the dynamic environment.

We now understand that IMF is critical for uniform and efficient delivery of content. The nexus of XML files gives the necessary functionality to hold the content timeline, update content location as needed, store content hash values to ascertain content integrity, and store only the changes in order to optimize storage and network bandwidth. Even so, the IMF system introduces complexity that requires a continually evolving automated QC tool that is always up to date. The solution should perform in-depth analysis of IMF structure and video, audio, and data, with minimal human intervention.

Interra Systems offers leading machine learning (ML)- and artificial intelligence (AI)-driven, file-based QC solutions, such as BATON, which offers comprehensive quality checks and verification efficiency in a flexible environment. BATON meets all the above stated requirements, from analyzing various flavors of IMF to deep analysis of audio video essence. As the most widely deployed QC solution in IMF workflows, BATON has the most extensive audio and video quality checks to ensure delivery of pristine content for all downstream applications. Finally, our BATON Player application can play back all flavors of IMF content to enable hybrid QC and validation of errors reported by the BATON application.