REIMAGINING THE POSSIBILITIES OF PROXY WORKFLOWS FOR MEDIA PRODUCTION

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INTRODUCTION

"Proxy" is defined by Merriam-Webster as "the agency, function, or office of a deputy who acts as a substitute for another." In audio-video terms, a proxy is a copy of digital data that acts as a substitute for another. There is a difference between the dictionary definition and digital media usage.

In the dictionary sense, a proxy is effectively viewed as the person on whose behalf the proxy acts—such as a delegated person who votes on behalf of a company shareholder who can't attend a meeting. A decision by the proxy cannot be differentiated from a decision by the original person.

In the digital media sense, a proxy is also effectively viewed as if it is the original data, but usually the proxy is not expected to be identical to the original content. For example, you can create high-quality proxy media that's a fraction of the size of the original 4K camera file for better editing performance.

Typically, proxy media is used to reduce storage requirements, network bandwidth, and CPU load. Most facilities have limited compute resources; therefore, reducing demand for processing digital media can allow more contributors to make use of those limited resources, provided that the proxies are good enough to allow for effective decisions. The added value of a proxy workflow is to allow audio and video to be processed in scenarios where the original content is either not available or not accessible in the user's work context.

Avid has a long history of offering proxy workflows in both its enterprise and post-production solutions. With Avid NEXIS® | EDGE, a powerful new solution that brings in-house and remote contributors together in a collaborative workflow environment, Avid implements a different proxy methodology, which provides improved simplicity and metadata consistency.

To help you understand how this new proxy workflow works and can benefit you, we'll first describe the foundations of the Avid approach to handling multiple representations of content. Then we'll cover how the proxy workflow approach for Avid NEXIS | EDGE maximizes flexibility and workflow productivity.

ESSENCE IDENTIFICATION AND ASSOCIATION

There are several aspects to a proxy workflow that must be effective for that workflow to be productive. The most important of these aspects is the association between an original essence file and its proxy alternatives.

Association is a relationship between entities. For example, let's say that a high-res video file (such as DNxHD SQ) is transcoded to a low-bitrate version (such as H.264 3Mb/s). We can establish a relationship between the two file names and use that relationship to, say, respond to a command to load the high-res file by having the loading software instead substitute the associated proxy file for the high-res file.

That association, however, is fragile. If either or both files are moved and/or renamed, the relationship will be broken and will need repair. This kind of repair can be risky if done manually, i.e., via user selection. If the wrong file is used to re-establish the association, a bad user experience will likely result.

A more durable association can be made when the identity of an essence file is self-evident. If the reference to a file can be made from a value that can be reliably and reproducibly derived from the data in the file itself, then the identity "follows" the file and does not depend on the current name or folder.

Avid uses two kinds of durable identity methods for essence files. The first is used for MXF files. MXF uses Unique Material Identifiers (UMID[1]), which can be extracted from files to establish identity of the content. Another method is to compute a "hash key" that is a unique string generated from the bytes in the file.

C4ID[2] is a similar method that reproducibly computes a unique identification value from a given file. When a file is moved, its identity can be recovered by reading it from the file (UMID) or by re-computing its hash value. In either case, any referencing systems can automatically track the movement of the essence and update the references to reflect the new location.

The value of self-evident identity comes from the reliability of its associations between both metadata and essence, as well as between alternate essence files for the same content. The difference between file identity and content identity is expressed in the AAF and MXF data models' definition of source.

1. Defined in SMPTE ST 330:2011
2. http://c4id.com

CONTENT IDENTITY

MXF and AAF represent streams of digital samples, plus associated descriptive metadata, in a top-level File Package (FP). These samples must be immutable for the FP UMID to be meaningful. This means that different representations of the same content must have different identities. As a result, it is not possible, using FP UMIDs, to independently link the different representations together. Similarly, a hash approach will yield different identities for different essence implementations and cannot be used as an independent linkage value.

If the relationship between two versions of content cannot be determined independently from each version, then other means must be used to establish the connection. This can be done as a by-product of transformative functions. For example, when a transcode is executed, the input and output are known at the same time, and a linkage can be established as part of that operation. Another likely method is to have a user manually establish the connection between the versions. But there are obvious limitations to this approach.

Fortunately, MXF provides a mechanism to solve this problem.

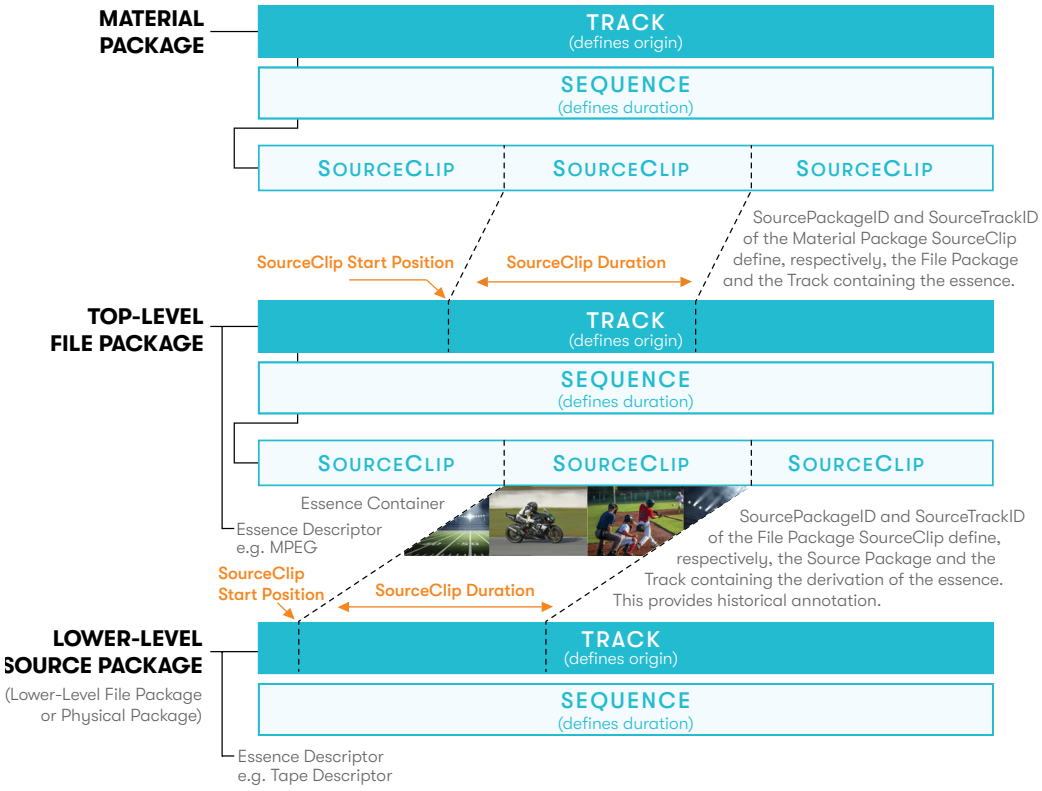

FIGURE 1: HEADER METADATA PACKAGES[3]

3. SMPTE ST 377-1:2019

The lower-level Source Package (SP or, in Avid terms, Physical Source Package) uniquely identifies the content that is captured in a file. It is intended to represent an abstract concept of images and/or sounds that are either naturally captured or synthesized. In either case, a file package is a digital instance of the images and/or sounds, and different instances can link to the same SP to signify that they have equivalent images and/or sounds. In other words, a person can watch and listen to any set of files derived from the same source and perceive that there are no content differences between them.

MXF and AAF have analogous object models that can be leveraged to link metadata (AAF) with essence (MXF). The following table maps the MXF package concepts above to AAF:

MXF	AAF
Material Package	Master Mob
Top-Level File Package	File Source Mob
Lower-Level Source Package	Physical Source Mob

In general, Avid products create MXF essence on disk storage systems along with accompanying metadata in AAF format (or similar, e.g., bins) where the IDs in the metadata structures match the IDs in the MXF files. By tracking the MXF IDs on storage, it is always possible to find the right essence when loading project metadata assets.

INDEPENDENT ESSENCE ASSOCIATION

With MXF (and AAF), the source identity can link various representations of content together. An asset system that wants to find content alternatives can know what to look for by examining the source identity and then matching that to the essence identities that have been inventoried from storage.

The term “independent” means that essence instances and metadata can all be processed in any order, with the same result at the end. It is not required, for example, to have metadata in hand before registering an essence instance of the content that the metadata represents. Likewise, different instances (e.g., low-bitrate and high-quality) can be created and destroyed without the need for coordination. This allows workflows to focus on the key elements of the assigned tasks without needing to know about systemic data dependencies.

Avid NEXIS | EDGE stores the association data in a neutral database, which has the sole purpose of handling relationships between different kinds of objects. Having a relationship database means that the existing data sources don’t have to be modified to know about each other. Implementing relationships with a graph database allows excellent flexibility in describing the relationships without requiring a complex fixed schema.

CONTENT IDENTITY ORIGIN AND FLOW

While the processing of essence and metadata can be done independently, there is one basic aspect of the media workflow that must be maintained; the content identity must be managed properly to tie together different instances of the content. Content versions are typically generated serially, starting with an original set of essence and metadata. In the serial workflow, alternative versions are made from the original, allowing the processing component to carry the content identity to the new output.

In some cases, alternative versions are created simultaneously at capture time, typically in a single device. Here, the device can use the same content identity in each output.

In either scenario (serial or concurrent creation), it is critical to maintain relationships via content identity across all instances for the system to be most effective.

IMPLEMENTING ASSOCIATIONS

Avid NEXIS | EDGE uses a graph model to store information about associations between essence streams. Graphs use nodes, edges, and properties to carry data.

Nodes represent items, and edges are directional relationships between nodes.

FIGURE 2: ASSOCIATION INFORMATION STORED BETWEEN ESSENCE STREAMS

Both nodes and edges can have properties (key-value pairs). For essence association representations, the nodes are AAF or MXF elements (or other relevant items), and the edges connect the objects.

The following graphic is an example visualization of some associated nodes in a graph:

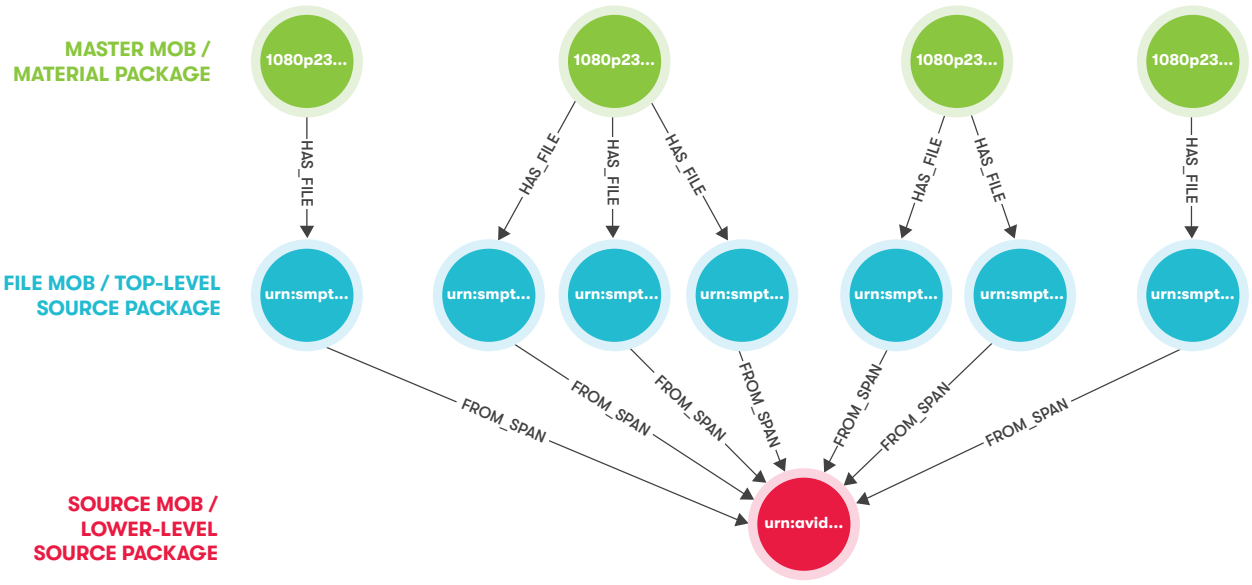

FIGURE 3: VISUALIZATION GRAPH OF ASSOCIATED NODES

In this diagram, the upper layer (green) represents clips, the middle layer (teal blue) represents files, and the lower layer (red) represents sources. Here, the clip nodes are connected to the file nodes via edges that have the tag HAS_FILE. A tag is like a type and denotes the meaning of the edge. The file nodes are connected to the source via a FROM_SPAN edge that marks not only the content identity but also the span of that source that was used to create the file.

Properties of a file include a list of the tracks from the source that are contained in the file. Files can also be associated with a descriptor that identifies the technical aspects of the essence stored in those files, but that is not shown in this diagram.

Graphs are processed using a pattern-matching language. By looking at the graph, one can imagine how to traverse from, say, a high-resolution file to an appropriate proxy file. Follow the edge into the source and then reverse-follow edges until a file is found with a descriptor that matches the requirements of the context under which the query was made.

Regarding the lifecycle of the graph, we can look at an insertion of nodes and edges representing a clip ingested from a camera card.

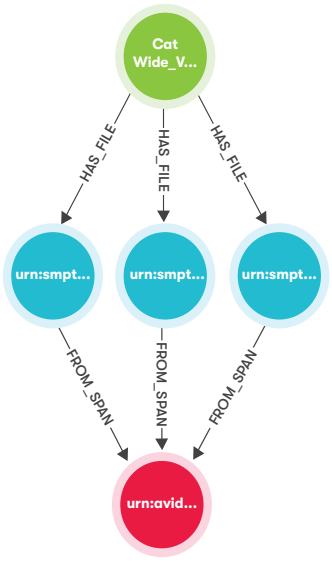

FIGURE 4: VISUALIZATION GRAPH OF INGESTED CAMERA CARD CLIP

In this example, the files are mono-essence, so there is a file for video and one file for each audio track. The nodes and edges are constructed from either AAF (or similar) metadata for the clip or the essence files themselves.

When a proxy alternative essence is created, the file can be processed to construct nodes and edges in the graph for that essence. Insertion into the graph is like an "upsert," where nodes and edges are only created if they don't already exist. In this case, the source node was inserted when the original essence was processed, so the new proxy file node will simply associate with the existing source node.

The following diagram shows the addition of the proxy essence:

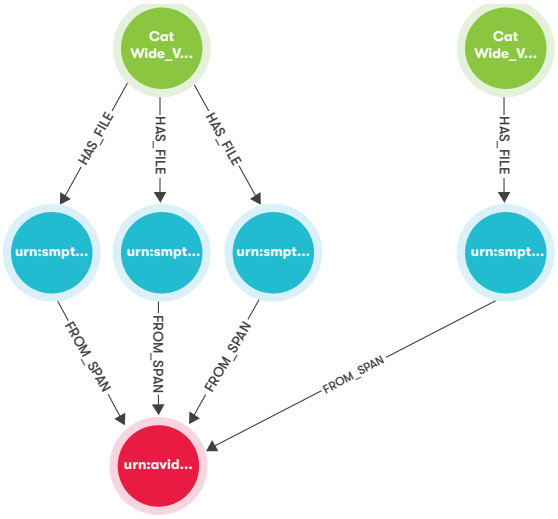

FIGURE 5: VISUALIZATION GRAPH OF PROXY ESSENCE ADDITION

The order can be reversed (proxy, then original) and the graph will end up the same. This allows for flexible workflows. For example, the original content can be offloaded from the system while keeping the proxies online. When the original files are brought back online, the associations will be restored to their previous state.

IDENTIFICATION

Currently, all native MXF essence and bin metadata objects are represented in the graph by UMIDs. When a non-native file is ingested, the file's bytes are used to compute an AAF clip with repeatable UMIDs that establish the essence and source identity (the source is the ingested file). Once the correct process is applied, the system treats the input essence file as if it was native MXF. If the file is not ingested but is simply registered as an alternative, the file cannot be independently associated with other clips. The association could be made using the file name, but that is not reliable.

A better method is to derive a hash of the file and build an association between the hash value and an existing source UMID. If the mapping data is preserved, the non-native file can be reinserted into the graph reliably. An example of this is a QuickTime file with an existing proxy. The procedure used to compute a source UMID from the high-res file will not result in the same UMID when the existing proxy is processed separately. Thus, the existing proxy must be associated with the high-res asset using the alternate method.

PROXY USE AND MANAGEMENT

Avid Media Composer® already has a method of substituting various forms of essence in the editing process. This method requires several manual actions to be performed to accomplish the substitutions. First, you must create a new transcoded clip from an original clip, usually keeping the transcoded essence separate from the original essence. Then you typically unmount the storage for the original essence to prevent interference. Finally, you need to perform a relink operation on a sequence to change the media references in that sequence from the original clips to the transcoded clips, completely replacing the original references.

This process has some important limitations. The primary limitation is that the process only applies to sequences. You cannot relink a clip to another essence. Another limitation is that the sequence metadata is modified, so the references to the original material are lost. Finally, the alternate versions are separate independent assets that have their own metadata and must be explicitly managed. In general, this impacts the potential of a collaboration between different systems.

The sequence-changing nature of the relink does not allow effective sharing if

different users need to use different essence alternatives. Another factor that inhibits collaboration is that asset duplication can result in metadata that is not consistently available. If you add metadata to a clip after transcoding, the new metadata will not be present in the transcoded version.

The main goal of the Avid NEXIS | EDGE approach is to dramatically improve collaboration and simplify the use of essence alternatives. Instead of requiring destructive changes to sequences, essence alternatives are identified via runtime queries of the backend. Specific alternative essences are chosen while loading the player—after metadata has been processed. This approach is called late binding and it does not require any changes to asset storage. Instead of forcing you to manage copies of essence, you can work solely on the original content asset, keeping a single set of metadata that will not become fragmented.

To make this function simple for users, the alternative essences are hidden. You will not see separate clips as you do today. In fact, the only artifact of the proxy creation process is an essence file. This essence file does contain a minimum set of metadata to identify the content. When the proxy file is created, a notification is processed, causing the new file's metadata to be analyzed. The analysis algorithm extracts the content identity and creates a corresponding association in the database. The editing application can query the Avid NEXIS | EDGE server to find content alternatives, either when playing assets or when managing storage. If a clip is no longer needed, then it's possible to find and delete any associated proxy content. It's even possible to use the database to detect unused proxy content and delete it automatically.

WORKFLOWS

The primary goal of the Avid NEXIS | EDGE proxy workflow is to allow ultra-simple switching between essence that requires a LAN environment and essence that is more suitable to remote access over the Internet. You only need to select your access mode and can then continue working normally. If remote-suitable essence does not exist, the system allows you to initiate creation of the proxy alternatives that you need.

Once this has been successfully completed, the editing system automatically makes these proxies available to you. This is not limited to remote access workflows; you can even select remote-suitable essence when in the LAN environment to conserve storage and network bandwidth.

This first goal is not the only anticipated use of the proxy workflow. The concepts can be extended to allow functions such as the following:

- EDIT PROXY FIRST—In this workflow, proxy content is created near-simultaneously with original rushes. Here, the proxies and original metadata (bins) can be uploaded to the editorial facility (or to the cloud) much more quickly than the high-res content. Shot selection, annotation, and rough

cutting can be done on the proxy, and when the high-res arrives in the facility, the bins will automatically link up without having to modify any sequences or lose any metadata.

- RE-GRADING CAMERA RAW FILES—In this workflow, re-grading shots can result in new "proxy" content that can be tagged so that you can switch back and forth to see the differences in the color grading.
- AUTO-CONFORM—In this workflow, the associative capability of the database can facilitate an automatic conform from editorial material to final graded masters.

CONCLUSIONS

Enabling a more dynamic and flexible content association system with reliable content and essence identity allows for simpler and more effective use of essence in editorial systems. Simplifying content management enables you to keep your storage more fully utilized with less operational burden. This approach not only helps with broadening access to content over less-capable networks, but also shows a path toward newer functions that improve collaboration and productivity.

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