SONY

network connection

File Interchange Format

MXF

Technology Enabler for IT-Based Broadcast Operations

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Meta-data applications

workflow innovation

AV contents

INTRODUCTION

This paper describes the implementation of MXF-based operations (Material eXchange file Format) in the TV studio environment. The first proposal for MXF was presented at a technical meeting of the Pro-MPEG Forum in Beaverton, Oregon, in July 1999. This first proposal consisted of simply a wrapper of the AV streams for program exchange in an IT environment. After this submission, the specification of MXF was expanded to carry rich meta-data. After completion of its technical work in the Pro-MPEG Forum, MXF was submitted to SMPTE for further standardization. MXF is expected to become one of the most important methods for carriage of meta-data and AV contents for the television industry. This paper further specifies the characteristics and advantages of MXF for multimedia operations in an IT environment.

At present the broadcast and production industries face significant changes due to the introduction of IT technologies. The use of IT technology has the potential to create efficiencies and improvement of data workflow in the television production environment, with the addition of significant cost reductions. It is believed that the first wave of IT technology will be realized by the use of MXF and rich meta-data to create workflow innovation. This paper discusses the harmonization of MXF file transfer and meta-data applications.

The initial work for the creation of a unified file exchange scheme, MXF, was established by the Pro-MPEG Forum, but currently the AAF (Advanced Authoring Format) association and the EBU (European Broadcasting Union) have joined not only the standardization activities but also the development of toolkits. This document describes the concept of an MXF development toolkit and the roadmap for future MXF products.

MXF represents a key technological development in the migration to advanced production systems that make use of extensive meta-data. This paper specifies how MXF/AAF and meta-data work together in an IT-based production system, and further clarifies its advantages for end-users.

WHAT IS MXF?

File Interchange Format

Program materials are usually stored in the form of packaged media. A/V tapes are used mostly for this purpose. Program materials are then ingested and transferred to servers via the digital interfaces, such as, SDTI-CP, i.LINK®,*. This type of operation is known as "legacy style" and is illustrated in the upper part of Fig. 1. In this case, a data transfer is carried out on a peer-to-peer connection. In other words, dedicated devices store the program materials and the exchange operation is performed on a standalone basis.

Once the program materials are ingested onto the file servers, these materials can be handled as files. The files are transferred and shared via the network connecting the file servers. In this case the key technologies are the interchangeable file format and the IP network. The compatibility of data files is very important to guarantee interoperability among the devices that constitute the production system. The first objective of the MXF format is file interchange via a network connection. This operation is specified as "network style" in the lower part of Fig. 1.

The networking operation provides several benefits to users. For example, operators can share all program contents that are ingested as files. This means each production operator can collaborate with others flexibly. In the near future, therefore, the "legacy standalone" work style will migrate to the network style by the gradual conversion of physical media packages to ingested multimedia data files.

It should be noted that in the case of package media, exchange interoperability is guaranteed by strict adherence to a given tape-based standard - because the A/V signal format is tightly related to the physical layer of the media. However, in the case of ingested data files, the format is logical and separated from the physical specification of the media. Currently there are some open and proprietary methods for file format specification, such as AVI, OMFI, Quicktime™, DPX, GXF, etc.

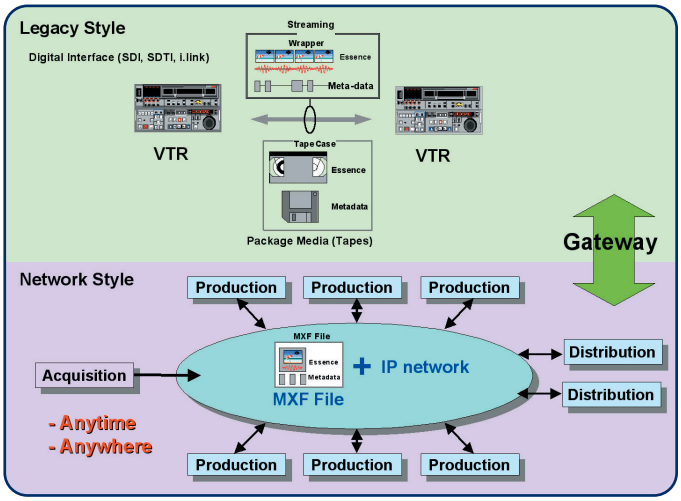

Fig. 1 Program Material Ingestion and File interchange among servers

In today's television operations, complete programs are mostly exchanged by package media, because it can simply guarantee the interoperability between equipment of the same standard. However, as the TV industry migrates to end-to-end applications of IT technologies, file exchanges will replace package media. Therefore, the urgent need for a flexible and open multimedia file format satisfying the requirements of end-users and standards organizations is needed. To achieve the latter, MXF has been submitted to SMPTE for its consideration.

The basic objective of the MXF file format is the exchange of (intermediate or final) program material in IT-based environments.

*i.LINK is a trademark of Sony used only to designate that a product contains an IEEE 1394 connector. All products with an i.LINK connector may not communicate with each other. Please refer to the documentation that comes with any device having an i.LINK connector for information on compatibility, operating conditions and proper connection. For information on any Sony device having an i.LINK connector contact Sony at 1-800-686-7669.

Compression Independent Format

MXF has been defined as a flexible wrapper for Video, Audio streams and meta-data. Fig. 2 depicts the basic file structure of MXF. MXF can contain AV streams in the File Body. Rich meta-data can be included in the header as well as in the body of the file. The initial standardization process focussed on the wrapping of Type D10 (MPEG-ES, SDTI-CP based) and DV-DIF streams (common format for DVCAM™ and DVC-Pro™ VTRs). The MXF file format keeps a neutral position towards the type of compression scheme (DV, MPEG, etc.) and source signal format (525/625-line, SDTV/HDTV, etc.) in use for the program material. Furthermore, the MXF body is expandable for various other types of AV stream formats. Currently uncompressed source body, MPEG PS/TS/PES body and Type D11 stream (HDCAM®) body are under discussion in the Pro-MPEG Forum.

The SDTI-CP (Type D10 VTR compatible MPEG-ES), DV (DVCAM and DVC-Pro) and HDCAM (Type D11 VTR) streams will use an intermediate container format, called MXF Generic Container, before final encapsulation by the MXF wrapper. This GC (Generic Container) is a common packet format which can include lots of useful meta-data. Existing stream formats don't have extensible meta-data space so that this common meta-data carriage will support interoperability functions for various compression schemes currently only implemented in stream form. The details of GC will be described in Meta-data Format MXF section.

The concept of compression independence provides an important advantage for users of MXF. Even if a receiver unit cannot decode the body format, the decoder can at least recognize the meta-data in the MXF file header for content identification. This means the search for content material using meta-data is available without decoding the file body.

MXF removes the boundaries between compression schemes and the source signal format.

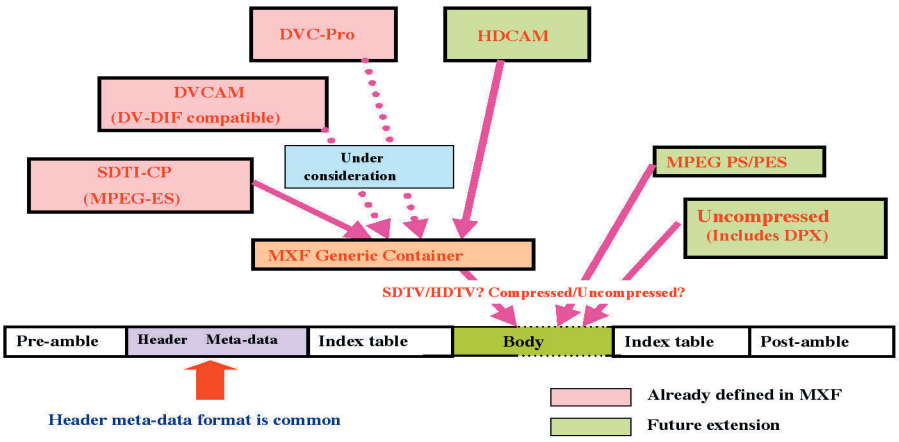

Fig. 2 Compression independent format

Since the initial activities for the development of MXF, the members of the Pro-MPEG Forum have expanded the capabilities of the format, with special emphasis on interoperability with the Advanced Authoring Format (AAF). Pro-MPEG had a joint meeting with members of the AAF association in May 2000. At this meeting, Pro-MPEG members decided to make MXF a defined subset of AAF. At present, members of the AAF association and the EBU have joined the team of MXF developers, which include many broadcast, manufacturer and academic organizations. Pro-MPEG, AAF and the EBU share the opinion that the technical advantages brought by MXF will lead to its adoption as the common interchange file format for IT-based production applications.

Since these three organizations do not have as part of their charter the creation of industrial standards, they decided to submit their developmental work on MXF to SMPTE for final standardization. The first proposed draft standard to SMPTE was submitted in March 2001. The relationship among these activities is depicted in Fig. 3 below.

The four organizations in Fig. 3 have conducted good collaborative technical work and are supportive of the standardization activities of MXF. Therefore MXF promises to become the next generation standard for program exchange with the support of these key standardization groups.

One of the important applications of MXF is its use in archive systems. Users are very sensitive to the selection of the file format for the archive system, because they cannot easily change the file format after starting the archiving process. It would be extremely difficult and costly to convert a large database of program material at a later time. With this consideration in mind, MXF provides the confidence needed in a "future-proof" file format, for users to commit to archive their materials. In particular, MXF is an advanced, open standard, and many manufacturers have pledged their support to this standard. In the near future, even if users want to change their archiving systems, they will easily find alternatives due to the interoperability of the MXF file format.

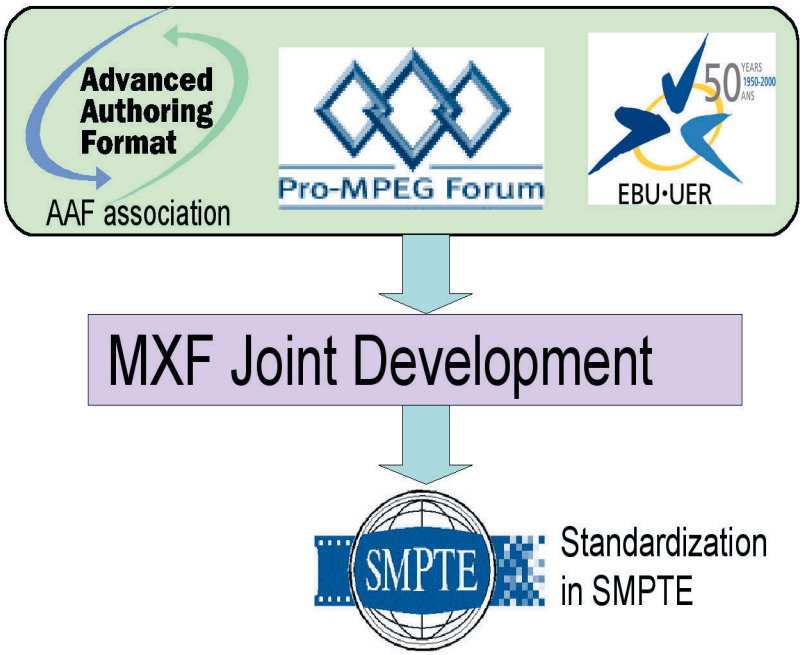

Fig. 3 Relationship of the organizations regarding MXF development and standardization

MXF is a Subset AAF

As said earlier, Pro-MPEG forum and AAF association members agreed to develop MXF as a subset of AAF. The AAF file format has been developed for high performance authoring applications, including non-linear editing and multi-layer compositional work. This relationship is shown in Fig. 4.

AAF allows for a very flexible description of its contents and specifies all edit processes during a non-destructive edit operation. This description can include all EDL-like (Edit Decision List) information, special effects and various elements of rich meta-data. While AAF offers a high level of versatility and performance for authoring work, it is, however, too flexible and rich for the purpose of file interchange. If AAF files are exchanged, numerous constraints are required for file interoperability. Therefore, from an AAF viewpoint, a simpler version of AAF (i.e. with limited functionalities and specific exchange characteristics) is required for file interchange. MXF is suitable for this purpose.

On the other hand, MXF is a new format in the industry, requiring a relation to an existing format. AAF is the only available file format with capabilities to handle rich meta-data. Therefore, MXF has been developed as a subset of the AAF format - just like a light version of AAF.

MXF allows the description of an editing operation for a cut edit only, but it cannot specify complex special effects. In MXF the sequence of body contents is placed in the presentation order. This comes from the required functionality of streaming of the file contents over synchronous stream interconnections. During the standardization process, the EBU requested the inclusion of specific meta-data for use by broadcasters, which is known as "Geneva Scheme meta-data." While this meta-data is very useful for broadcast operations, the current specification of AAF does not include it. However, since AAF is a very flexible and expandable file format, it is expected that the Geneva Scheme for meta-data will be adopted by AAF in future revisions of the format.

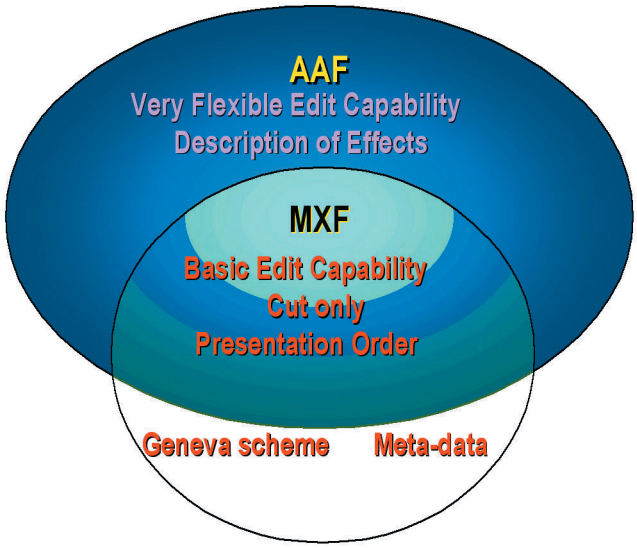

Fig. 4 Relationship between AAF and MXF

Geneva Scheme Meta-data

The Geneva Scheme meta-data is specified in part 4 of the MXF documents. The purpose of this scheme for meta-data is to add content descriptions scene by scene. This document is simply a collection of various types of existing meta-data. For example, the Location information, Language information, Image formats, Scripting descriptions, Contracts and Rights, Sub-title descriptions, Owner information, etc. This document will become a dynamic standard, which means it will be expanded in functionality by future revisions of its meta-data set.

The Geneva Scheme meta-data is the first step for the global exchange of meta-data for contents description. The Geneva Scheme meta-data is therefore a key advantage for the use of MXF file format.

Relationship of MXF and AAT

Both AAF and MXF are file formats, but their functionalities do not conflict with each other. AAF is a very flexible format that is suitable for complex edit operations; it is, however, very difficult to exchange AAF files between different manufacturers' devices. Therefore, an acceptable standard file format is necessary for the exchange and archive of program materials. This concept is specified in Fig. 5. MXF is a file format specifically designed for simple exchange and archive of final, complete, material packages.

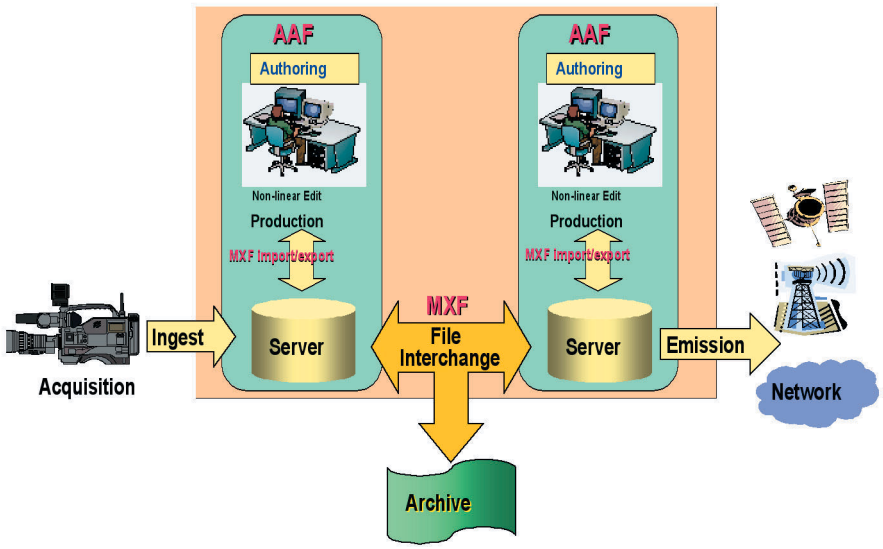

Fig. 5 The relationship of AAF and MXF format

Inter-Island Format

Different types of file formats are used in today's production environments. Each processing island adopts a different format based on different operational policies and technical requirements. There is, however, no standard for file interchange among these processing islands. In order to implement file exchange, a neutral and advanced format is necessary. This neutral characteristic defines an intermediate common file format, which can be converted to and from all the existing file formats with a minimum of computational efforts.

This is one of the strengths of MXF and is shown in Fig. 6. MXF can carry the equivalent information contained within an OMF, GXF or any other type of file format. At the same time, MXF is a subset of AAF, for optimum interoperability with this powerful authoring file format. Therefore, the choice of MXF as an inter-island exchange format is a good choice, for it not only resolves today's interoperability problems but also leads to the implementation of highly efficient, IT-based, production environments.

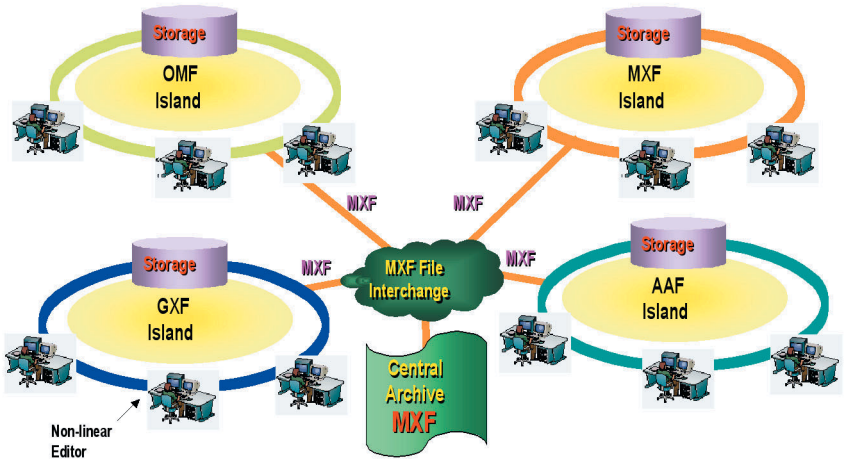

Fig. 6 Inter-island format for various production formats

One of the typical models of IT-based production system is shown in Fig. 7 below. All work servers are connected via an IT-based network (i.e. IP network). In addition, the ingested materials are stored on near-line archives as MXF files, as well as shared with Production and On-Air systems. These near-line MXF files will also be stored in long-term archive systems. The ingested MXF files can then be transferred to the branches (affiliates) or other studios for re-purposing applications.

In order to design this type of system, the key technologies of MXF/AAF and meta-data are required as part of its infrastructure. The meta-data element UMID (Unique Material IDentifier) is also essential to maximize the relationship (linkage) between the MXF/AAF file and more extensive external meta-data. UMID specifies the identification of each program material contained in the files, on a frame-by-frame or, scene-by-scene basis, or any other form. UMID is just a pointer to link the packaged program segments to any associated external meta-data. Of course, MXF can carry rich meta-data, however, users have valuable legacy meta-data in their own formats. This UMID linkage system supports the use of such external meta-data in conjunction with the ingested/archived program materials.

This meta-data friendliness is key for the migration to a future IT-based system.

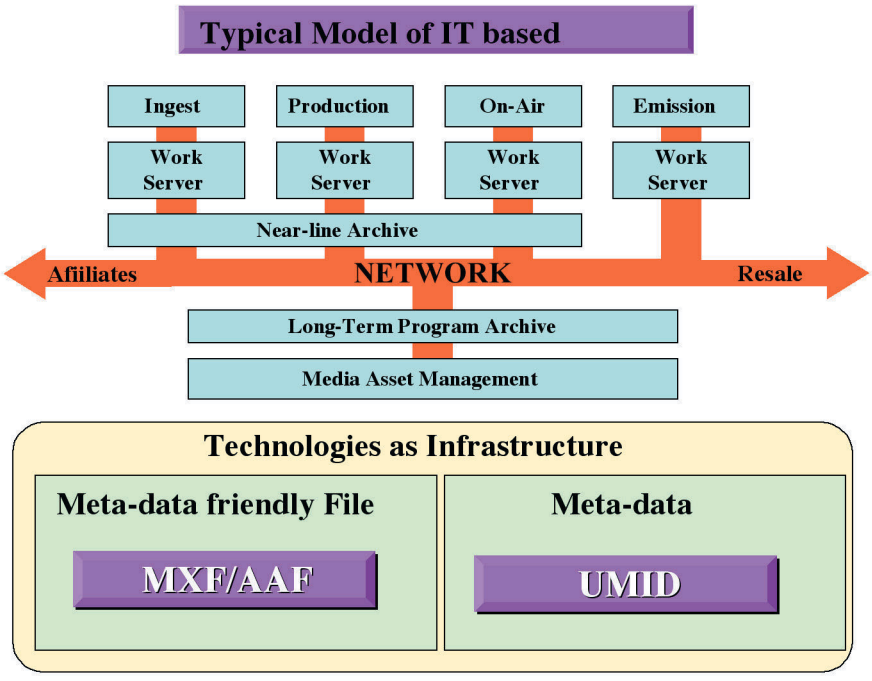

Fig. 7 Typical Model for IT based Platform

Meta-data Format in MXF

MXF can contain meta-data in the header and the body portions of the file. Header meta-data consist of EDL-like information, Content identification meta-data, Scene/Shot meta-data, Descriptive meta-data (Geneva scheme meta-data), etc. These descriptors represent side information for the whole of the file, shots and scenes. On the other hand, MXF adopt a GC (Generic Container) as the intermediate container for the body. All AV streams and meta-data are encapsulated into this GC. The GC consists of the following items: System Item, Video Item, Audio Item and Auxiliary Item. The essential item is the System Item. The System Item contains specific parameters for the processing of AV streams and meta-data. The basic packing of GC is on a frame-by-frame basis. The meta-data that requires frame accuracy (e.g. time code, UMID, etc.) should be stored in the System Item. Also, if a larger space for meta-data is required, Auxiliary Items are available to carry the additional meta-data.

Non-linear editors are required to edit both types of meta-data (header & body). The general idea for the edit operation is to utilize the intermediate format as shown in Fig. 8. XML is a human-readable language, which is useful to record the header meta-data description. Hence, non-linear editors will use the XML file as the first output of the edit process description. On the other hand, the body streams are stored in Audio/Video servers where frame accurate meta-data is multiplexed/de-multiplexed via SDTI-CP and/or, i.LINK interfaces. Those XML files and AV streams are used to generate an MXF file.

Since MXF is just a file interchange format, manufacturers don't have to store the contents of an MXF file in its native file structure. MXF import/export operations are, therefore, very important to enable interoperation between different manufacturers' machines.

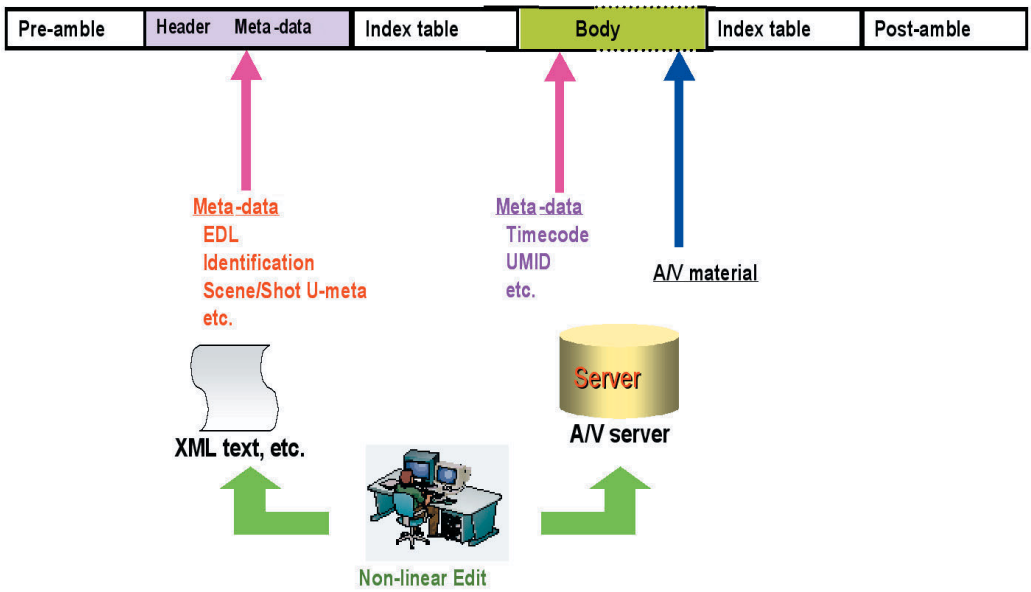

Fig. 8 Meta-data format in MXF

How to Operate Meta-data in MXF Editing Process

The expected meta-data operations are shown in Fig. 9. The acquisition process is the first step for the generation of meta-data in the production chain. For example, camcorders will record the conventional SMPTE12M timecode along with UMID meta-data. UMID meta-data is attached to every shot for the purpose of material identification. Those shot materials (AV streams and meta-data) are ingested onto servers in the form of an MXF file. The program shots are stored as File Packages in the MXF file. File packages are just shot materials, which have different timelines. Once these MXF files are stored into servers, non-linear editors can start editing the file packages. The file packages are mapped onto the single timeline that defines the Material package in MXF. Non-Linear editors will add some meta-data for the description of scenes and generate EDL-like data. These are included in the header meta-data of MXF files. This edit process will be repeated to generate the final complete package, as specified in Fig. 9.

The relationship between File package and Material package is depicted in Fig. 10. All File packages are generated during the acquisition process as program materials. Some meta-data (for example, shot meta-data) have already been attached to each File package.

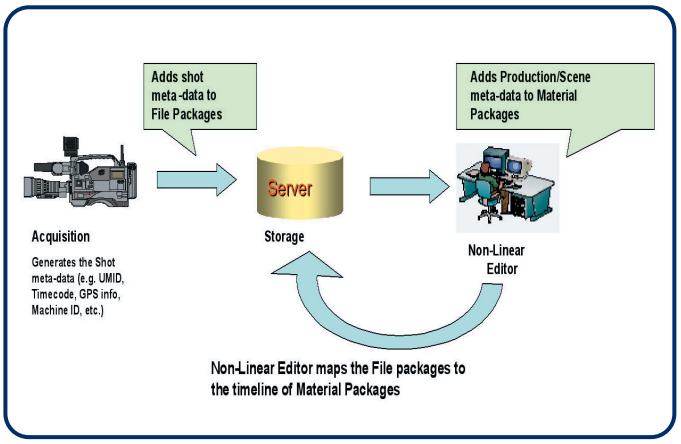

Fig. 9 Meta-data operation in MXF

Non-linear editors will generate the single timeline for the reference of the edit process. This is defined as Material packages. File packages are cut and mapped onto this reference timeline that defines the Material package. Non-linear editors can define some scenes on their timeline independently from the boundaries of shots in File packages. Non-linear editors can also attach meta-data to each scene. Finally the mapping decisions are converted to EDL-like data and stored in the MXF header meta-data. This is, in broad terms, the editing process for MXF and associated meta-data.

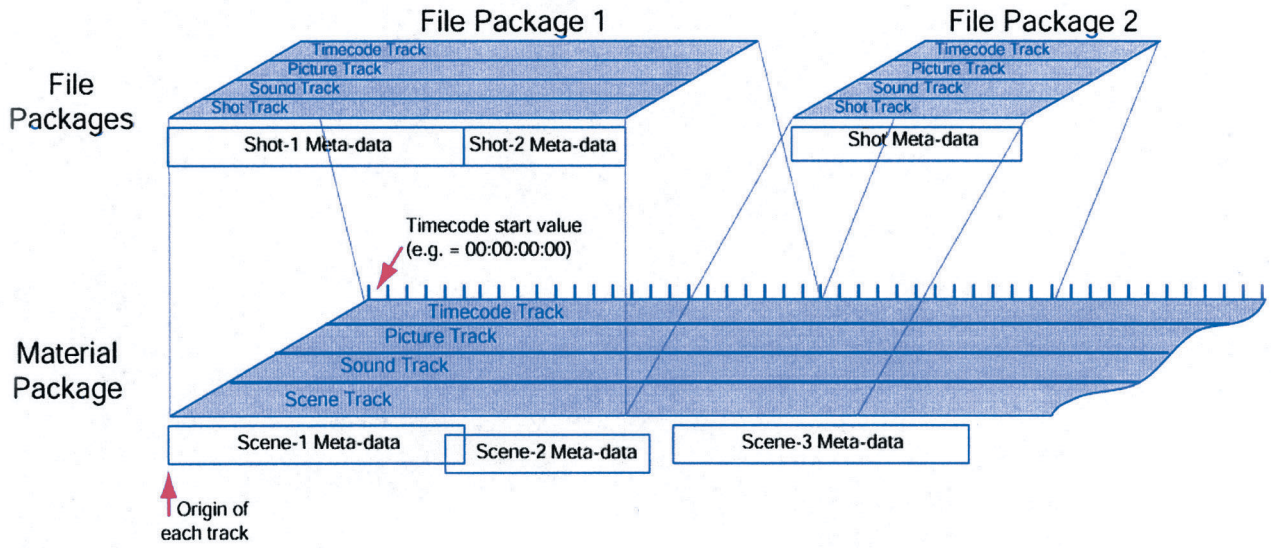

Fig. 10 Meta-data operation in MXF

UMID Linkage between MXF File and External Meta-data

According to our model for an IT-based system, the edited files are stored into the near-line and deep archive modules. MXF files basically contain UMID information; therefore UMID data can be used to link the MXF essences and the external meta-data. The basic idea is shown in Fig. 11, which describes the linkage (synchronization) between the external meta-data database system and essences in an AV server. MXF header meta-data is duplicated and stored in the external MXF database. For example, a user can then search the AV contents from this external database. The found data contains the search keys (UMIDs), so that the corresponding program entity can be retrieved from the AV servers (archive systems).

This is just an example, but this external meta-data database can also include user specific data such as scripts, text, subtitles, closed captions, XML files, etc.

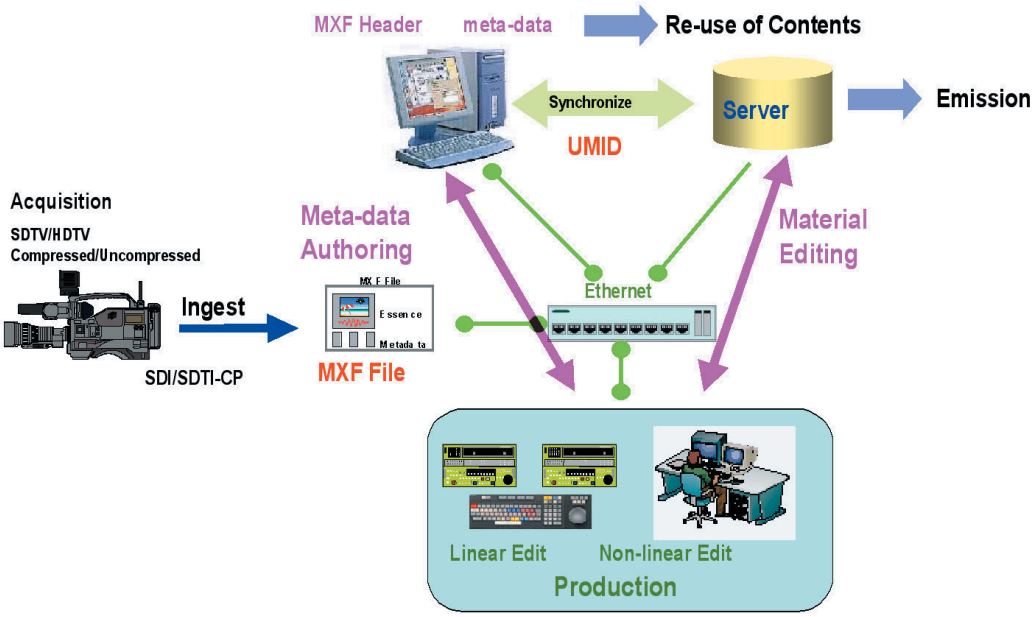

Fig. 11 UMID Linkage between MXF file and External meta-data

MIGRATION to IT PRODUCTION WORLD

Current and Future Production Model

Fig. 12 shows a comparison between the current production model and a future, IT-based model. It can be seen that the basic difference is the workflow of the production process.

The workflow of the current production system follows a sequential process, because all operations are pipeline oriented. In addition, all production processes are connected and share materials via the archive system. However, in the case of IT-based production systems, all data are handled by means of file-based processes and all files are shared among the horizontal production operators. These production operators can process their creative work concurrently without knowledge of the storage location of their materials. In essence, all file operations are managed with shared files, providing an innovative workflow improvement for end users and high efficiency in the production process.

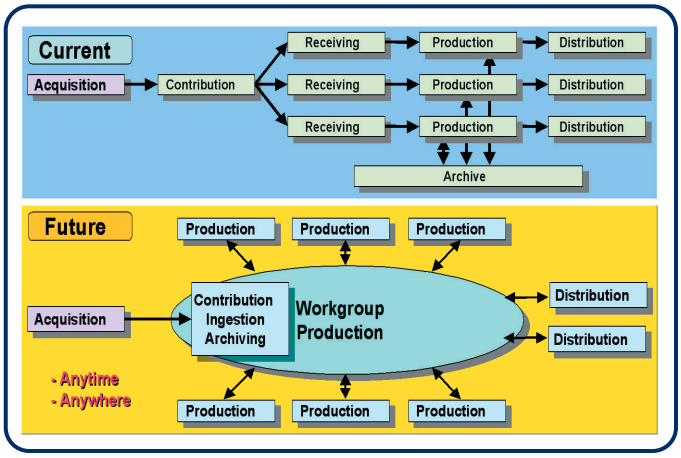

Fig. 12 Current and Future production model

How to Improve the Operation Flow for Broadcast Production

IT-based production will improve the following areas in the current workflow:

- **Concurrent production work with file sharing**
  Creators can process their work independently with minimum waiting time. In addition the created files can be shared with worldwide production locations creating opportunities for effective collaboration work.

- **Re-use and re-sale of archived contents**
  IT-based production will generate archived files on a daily basis. Meta-data will catalogue this material for re-use and re-sale in a convenient manner. MXF will be used as the file interchange standard for this purpose.

- **Management of large amount of AV assets with meta-data**
  UMID information will be stored inside MXF files. External meta-data databases will be associated with AV materials by using UMID data. This mechanism will improve the use of asset management systems.

- **Reliable contents transfer**
  File transfer technology via IP networks will improve the reliability of content transfer. Error-free file transfer will improve the ingestion process of incoming material.

Interoperability and Migration

The MXF format is defined as a wrapping format for existing stream-based material via digital interfaces, e.g. SDTI, i.LINK, etc. Current digital stream formats (Type D10/D11 stream, DV DIF, etc.) can be easily converted to MXF files. The migration process from stream-based interfaces to network connections will occur in a gradual manner, balancing the preservation of legacy investments and the acquisition of new IT-based equipment.

The Pro-MPEG forum has made very effective demonstrations at NAB-2000/2001 to prove the harmonization of the SDTI and MXF worlds. This is shown in Fig. 13. SDI/SDTI signals and MXF files can be exchanged between different manufacturers' equipment while maintaining material interoperability. The matured interoperation of SDI/SDTI/MXF data formats has been shown to work well, with numerous benefits for the entire production process. Therefore, it is the hope of many, that these standards will be supported by many leading manufacturers of professional broadcast equipment.

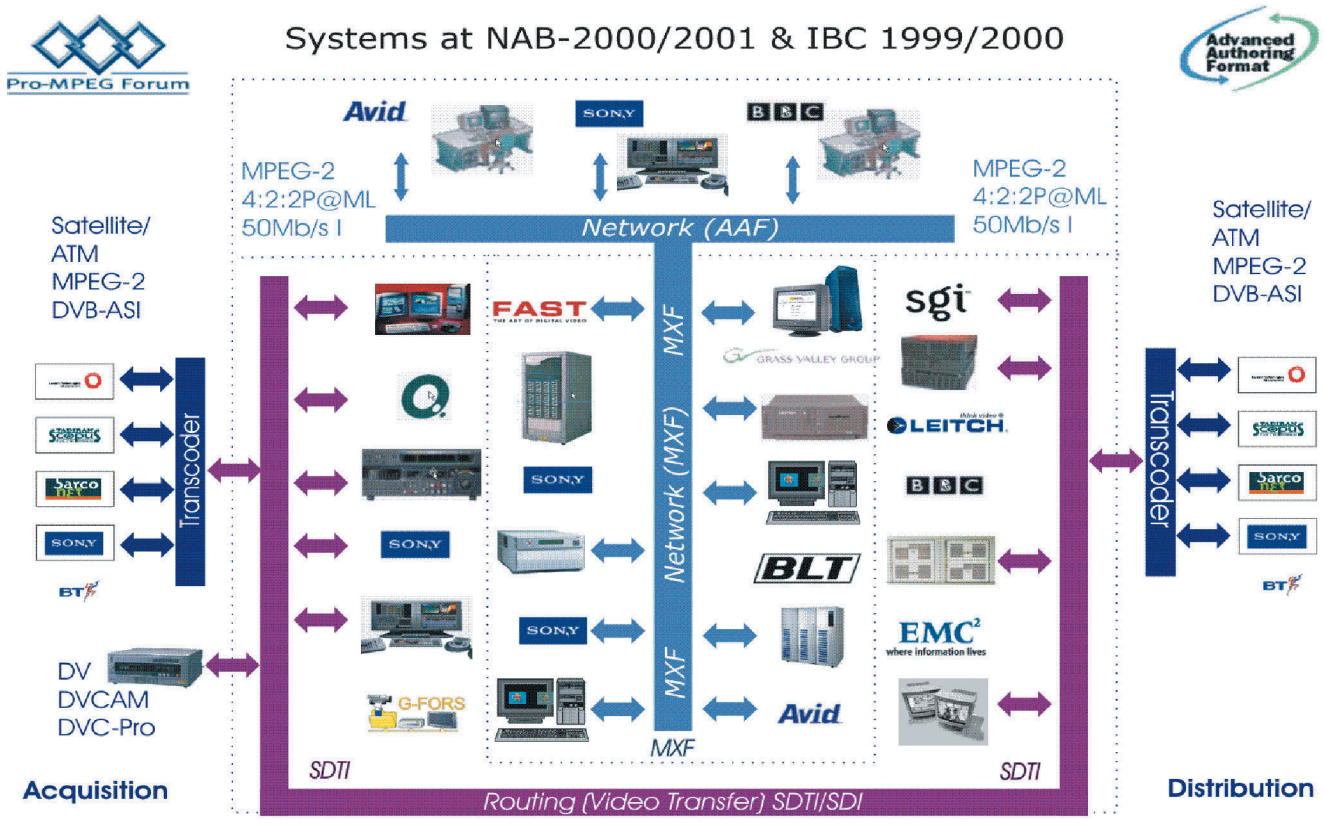

Fig. 13 Interoperability of MXF and SDTI equipment = Migration to the Future

AAF SDK Approach

As mentioned above, MXF is defined as a subset of AAF. The AAF association has developed an SDK (Software Development Kit) for developing AAF systems. Therefore, with some constraints added to the AAF SDK, it will result in an SDK for MXF. The notable difference between AAF and MXF is the binary notation employed in their definitions. In the case of AAF, a Microsoft® Structured Storage notation is recommended. But in the case of MXF, a KLV (Key-Length-Value, defined by SMPTE 336M) protocol is used for binary notation. Therefore, a translation of binary format is required. Fortunately, the AAF SDK has a plug-in mechanism to implement this capability.

Currently Sony is developing the plug-in for MXF support in collaborative work with the AAF association.

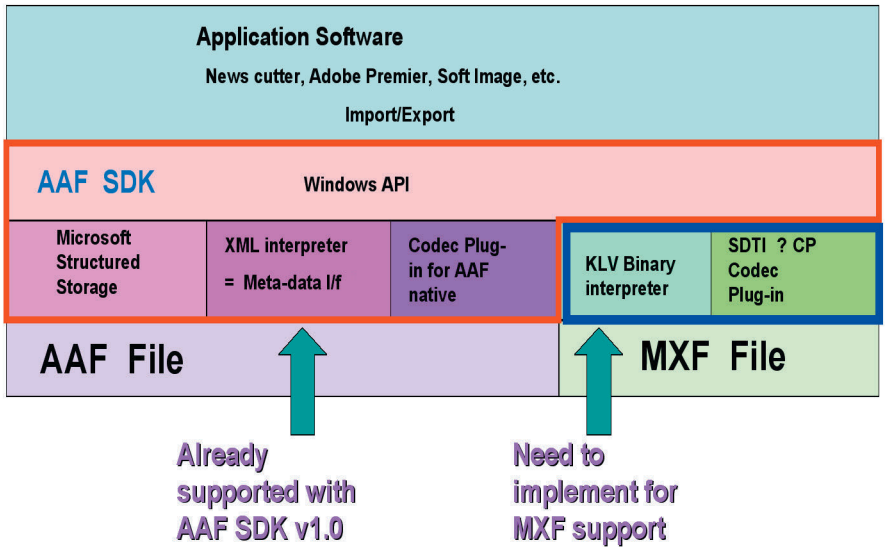

Fig. 14 MXF support by AAF SDK

MXF Reference Software Project

The EBU PITV group has started the development of MXF reference software. Their purpose is to accelerate the product level implementation by distributing the source code of the reference MXF file generators and MXF sample files. Their approach is very flexible, because the meta-data description is specified by means of an XML dictionary. They assume the use of future extensions to support evolving sets of meta-data.

MXF Support with AAF SDK

The rough structure of the software module in the AAF SDK is shown in Fig.14. The AAF SDK provides the application interfaces required by the upper layers of software by means of Windows® API. The AAF SDK can output the file in several formats, such as Microsoft Structured Storage, XML, etc. In order to support MXF file import/export functions in the AAF SDK, a KLV Binary interpreter is necessary to import/export the MXF file directly to/from AAF modules. In addition, the codec plug-in for MXF bodies is also necessary.

Basic AAF capability has already been implemented in the released of AAF SDK Ver.1.0. Sony is planning to implement the additional modules shown above to support MXF import/export functions. These additional modules will be provided as a plug-in for the AAF SDK.

CONCLUSION

MXF/AAF and meta-data are key technologies for the implementation of IT-based production applications. These technologies will provide significant levels of improvement in data workflow for all acquisition, production, and asset management operations.

The first step towards the practical implementation of an IT-based production will start by the multi-manufacturer adoption of the MXF file format. The introduction of Sony's e-VTR at NAB'02 will help the migration to IT-based production by bridging linear, digital VTRs to the IT networking world. Valuable assets stored in $^1/_2$" tape form will then be converted, with minimum efforts, to MXF files, for communication over IT networks.

Annex A. Bibliography

1. **SMPTE 336M**	Data Encoding Protocol Using KLV
2. **SMPTE 330M**	Unique Material Identifier (UMID)
3. **SMPTE 298M**	Universal Labels for Unique Identification of Digital Data
4. **SMPTE 326M**	SDTI-CP Format
5. **SMPTE 331M**	SDTI-CP Element & Meta-data Definitions
6. **SMPTE RP204**	SDTI-CP MPEG-2 Decoder Template
7. **ISO/IEC 13818-2:**	Amendment 2: (MPEG-2, 4:2:2P@ML).
8. **SMPTE 356M-2001,**	D10 Type Stream Specifications: MPEG-2 4:2:2P@ML for 525/60 and 625/50
9. **SMPTE 322M**	Format for Transmission of DV Compressed Video Audio and Data over a Serial Data Transport Interface
10. **SMPTE 314M**	Data Structure for DV-based Audio, Data and Compressed Video, 25 Mb/s and 50 Mb/s
11. **SMPTE xxxM**	MXF format document
12. **SMPTE yyy.1M**	MXF Operational Pattern 1
13. **SMPTE yyy.2M**	MXF Operational Pattern 2
14. **SMPTE abc**	MXF Descriptive Meta-data Set 1
15. **SMPTE zzz.mM**	DV Essence Container
16. **SMPTE zzz.nM**	CP Essence Container
17. **SMPTE RPxxx**	MPEG-2 Interoperability Ranges (tbc)

Meta-data applications

IT environment

File Interchange Format

network connection

AV contents

workflow innovation

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