IMPLEMENTING AND VERIFYING OFF-AIR DTV CARRIAGE CONTRACTS IN CABLE HEADENDS

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Abstract

Cable-carriage of off-air DTV broadcast streams may involve the selection and transformation of different components of the stream. Carriage agreements may specify constraints on these processes. This paper lists some of the more common technical aspects of carriage agreements and describes how they can be implemented conveniently and with low operational cost. Systems that can be used to implement the agreement can also be used to monitor and verify compliance with such carriage agreements. An integrated solution is described to meet these needs.

1. INTRODUCTION

A typical ATSC terrestrial DTV broadcast stream contains one or more video programs, audio programs, and/or data programs. It also contains the Program and System Information Protocol (PSIP) metadata used by DTV receivers for tuning, electronic program guides (EPG), and other functions[1],[2]. Because a terrestrial broadcast stream has lower bit rate than a QAM-modulated cable signal, and because cable operators may sometimes carry only a selected subset of services that appear in an off-air broadcast stream, off-air DTV broadcast streams are typically re-multiplexed in the cable headend. In the re-multiplexing, the cable operators often make various changes to the original signal, such as filtering out unwanted programs, elementary streams, data packets and/or optional metadata. In addition, the cable operators may transcode input video and audio streams to reduce the bit rate in order to maximize the usage of cable bandwidth.

Cable operators face two problems when performing such re-multiplexing:

1. The modifications to the original signal may be governed by various regulatory requirements and industry wide agreements, as well as by carriage contracts between the terrestrial broadcasters and cable operators. Moreover, it is possible that a cable operator may have different carriage agreements with different broadcasters. Thus, it may be necessary to apply different policies to different signals in the same cable headend multiplex.
2. There is increasing desire to retain PSIP metadata in off-air broadcasts when passing them through a cable plant, in order to accommodate “cable-ready” consumer DTV receivers. However, most of the MPEG-2 multiplexers used in cable headends are not designed to handle the PSIP metadata.

This paper describes a headend system architecture that can be used by cable operators for processing PSIP and other metadata while simultaneously enforcing and verifying carriage agreements between terrestrial broadcasters and cable operators. Such a system can work in conjunction with one or more MPEG-2 transport stream multiplexers to produce output streams that are fully compliant with carriage agreements and the various metadata standards including the ATSC PSIP standard, and the ANSI/SCTE 65 2002 standard[3].

2. Technical Components of Carriage agreements

Carriage agreements negotiated between the local broadcaster and the cable operator may contain many technical elements. Some of the more common ones are described below. Later we present ways in which these elements can be implemented and monitored.

1. Specific video and audio services in the broadcast stream that will be carried may be specified. This can range from all services being carried to only a single (primary service) being carried. The services to be carried can be specified in the agreement by the MPEG-2 program number, stream packet identifiers (PIDs), and/or virtual channel number used by the broadcaster.
2. In the case where multiple services are to be carried, the agreement may specify if the broadcaster can allow services to disappear and appear, or if there are restrictions – e.g., if the services must be present at all times, perhaps in the form of a low bit rate "barker" channel.
3. The agreement may specify whether the operator can reduce the bit rate of, or modify in any way, the packetized elementary stream (PES) structure of the services which usually results in increased compression/reduced image quality. This operation is usually implemented by exercising the transcoding/rate-muxing features of a multiplexer, and sometimes by decoding the signal to uncompressed baseband and then re-encoding the signal.
4. If bit rate reduction is to be allowed on any service, the agreement may specify upper and lower limits of the incoming and outgoing bit rates.
5. An MPEG-2 program in the incoming stream may contain multiple elementary streams, e.g. one video, two audio (one of which could be a secondary audio program/SAP). The program may also contain one or more data streams that are associated with the A/V program. The agreement may allow only specific elementary streams to be carried, e.g., only the main audio track and no data even if it is program-related.
6. The stream emitted by a local broadcaster may contain services that have no A/V content at all and only carry data. Carriage of data–only services may be (dis)allowed. These services may be specified similar to the manner in which A/V services are specified. Additionally, specific descriptors in MPEG-2 Program Specific Information (PSI) and descriptions in ATSC DST's may be used to identify and refer to specific content types.
7. The agreement may disallow carriage of streams that contain encrypted or proprietary content that cannot be received by all cable customers on a non-subscription basis.
8. The carriage agreement may stipulate the amount of in-band EPG information (in the form of ATSC A/65 compliant PSIP data in the incoming stream) that will be carried. The minimum amount is likely to be as specified in the February 2000 NCTA-CEA PSIP agreement [4],[5].
9. However, the agreement may exceed the minimum requirement described in the NCTA-CEA PSIP agreement, and can specify the following parameters per service carried:
    - Number of hours/days of program event titles
    - Number of hours/days of program descriptions

- o Various EPG table cycle times or bit rates

10. The agreement can specify branding as signaled by in-band EPG data. Specifically, whether one-part of two-part virtual channel numbering will be used and what the specific number will be. The short name and description of the virtual channel can also be specified.
11. The off-air signal typically has content advisory information, and closed-captioning signaling information carried in the EIT's. The cable operator may additionally require that these be signaled in the MPEG-2 PSI tables, or may agree to copy these descriptors (during multiplexing) in the headend from the EIT's to the PSI tables – if legacy digital STB's require this information to be in the PSI tables.
12. If the cable operator can support updates to out of band EPG data - either standards-based or proprietary in format – the agreement could specify if the in-band EPG data will feed the out-of-band EPG data. This The latter is used to drive EPG's in operator provided STB's, and in future POD-host equipped retail, digital-cable-ready TV's and STB's.

3. IMPLEMENTATION OF AGREEMENTS

DTV services arrive at the cable head-end over satellite and terrestrial links, as well as via other means (over an ATM network, for example). Multiple transport streams originating from different sources are typically multiplexed into a higher bandwidth transport stream, and are then modulated by a QAM modulator before being sent out to customers via cable. Available multiplexers can select audio/video services from each incoming stream and create a new, output transport stream with only the desired services. Depending on their source, some incoming transport streams may contain PSIP data while others may not. For example, transport streams received from off-air terrestrial broadcasts will typically contain PSIP, while streams originating from cable networks (offered as premium, hence scrambled services) may not include PSIP.

Available multiplexers can implement some of the elements of carriage agreements listed in the previous section. However, currently available multiplexers are designed to handle the grooming and bit-rate modifications of the audio and video services only. Metadata such as the ATSC PSIP tables are typically ignored by present-day multiplexers, and are either blocked from passage, or are erroneously passed through – without the needed modification to reflect the program and A/V PID grooming that the multiplexer implements. Also, the multiplexers are meant to be used in a relatively static configuration, and are neither easily easily, automatically nor dynamically reconfigurable to handle some of the cases described in the previous section.

A more general approach for implementing the various elements of cable carriage agreements described above is to use a separate metadata processing system that can process and interpret the in-band metadata in the off-air stream to (1) transform and generate new metadata, and (2) trigger pre-programmed control actions that instruct the multiplexer to implement needed service selection and A/V bit rate modification actions. Figure 1 illustrates the metadata processing system in the cable head-end environment.

The metadata processing system monitors each incoming streams in real-time and provides detailed information about the contents of the stream, including the existence of various services, such as data services, that are not easily discovered by a traditional multiplexer. To protect the investments already made by the cable operators, the system should work with existing MPEG-2 multiplexers.

The metadata processing system can either get the relevant metadata (i.e., PSIP/SI/PSI) directly from the input transport streams, or can have them passed to it from the multiplexers. The latter can be achieved by a private or standards-based protocol to exchange desired information between the multiplexer and the metadata processing system. By decoding the MPEG-2 PSI tables and the PSIP tables, the metadata processing system can identify every component in the transport stream and tell whether it is a video, audio, data or PSIP/PSI packet. Thus, a cable operator does not need to continuously and manually monitor and analyze the transport stream content to effect a multiplexer control action. The system can automatically identify the PID streams that show up in the transport stream, determine the actions such as re-mapping, blocking or passing through each PID stream according to the carriage policy parameters, and send appropriate control commands to the multiplexers.

When multiple streams containing PSIP data are multiplexed to a single transport stream, the system needs to process the different incoming PSIP streams and create new in-band PSIP data for the output stream. The system decodes the original PSIP data, obtains their semantic content, translates the data, and merges the metadata at the table level. The tables can be played out as MPEG-2 transport packets either by the metadata processing system, or the system can send the tables to a multiplexer for it to play out MPEG-2 packets at table-specific rates. Note that not all multiplexers can support download and playout of externally specified tables. The table playout rates should take into consideration the bandwidth limitations indicated in the carriage agreement. The output PSIP data stream from the metadata system is multiplexed into the output transport streams along with audio and video and other elementary streams. This forms the in-band PSIP data required mainly by cable-ready DTV receivers for tuning to in-the-clear streams.

In addition to handling in-band PSIP, the metadata processing system also generates an OOB SI stream. The aggregated SI data contains the information for all the “in-the-clear” virtual channels (VCs) in the cable system, as well as any scrambled services that the cable provider chooses to include for the purposes of discovery by POD-enabled cable-ready DTV receivers. For incoming streams that contain PSIP data, the system optionally extracts the EIT and ETT data and converts them to the aggregated SI format described in SCTE 65 2002 [3], sometimes also referred to as SCTE DVS 234. For incoming streams that do not contain PSIP, the system allows manual or programmatic input of the VC information so that it can be included in the OOB virtual channel map.

In addition, the metadata processing system may also export information to the cable operator’s proprietary program guide service to perform real-time update of the service information. Typically, the database used by the cable operator for EPG service is days or weeks old. When a program, such as a sports game, runs over time, the EPG information following the overrun program event is out-of-date. If the incoming stream contains updated PSIP information, this information can be used to update the cable guide.

4. OPERATIONAL ISSUES

The operation of the metadata processing system consists of specifying the following parameters during the initial setup phase:

1. Mapping of specific input programs/PIDs to specific output PID's, or blockage of specific input PIDs/MPEG-2 programs. This operation should be performed only once. A tight integration between the metadata processing system and the multiplexer control system will ensure consistency between PID grooming and metadata grooming.
2. Mapping of an incoming virtual channel's major-minor channel number to an outgoing/cable channel number. Mapping may specify either a two-part or single-part channel. In addition, the channel name can also be changed if desired.
3. The number of hours of EPG data to be passed through.
4. The frequency of optional PSIP tables being played out, mainly EITs and ETTs, as defined by the actual table interval time or limitation on the PSIP bandwidth.
5. Enable/disable the copying of various descriptors from the on-air event's EIT to the PMT. For example, the content advisory descriptor that may be only in the EIT should be copied to the PMT.
6. Allow/disallow transcoding or bandwidth reduction by the multiplexer for a specified transport stream, program, or elementary stream. If allowed, then specify the maximum/mimimum bit rate for that program/elementary stream.

The control information can be entered with the help of a simple user interface and the data can be saved in a format that is easy to view and edit, e.g., using XML. This XML file may capture an agreement that may be in force at multiple locations, e.g., a nationwide agreement between a broadcast network and an MSO. Instead of duplicating the manual configuration process at every location, the metadata processing system should be able to export and import the XML file (corresponding to a specific agreement) for easy implementation of the contract elsewhere.

5. MONITORING & VERIFICATION

A low cost approach for monitoring and verifying compliance with various carriage agreements within a headend is of high value to a local system's operations. To reduce cable headend operations burden and minimize the equipment cost, it is desirable to have the monitoring device be the same as the metadata processing system described above, so that all aspects related to carriage contract implementation can also be verified and monitored continually by a single system. Thus, the system should provide convenient user interfaces for contract specification, metadata transformation & generation, multiplexer configuration, stream monitoring/visualization, and configuring error-based alarming.

5.1 Error Monitoring

In addition to monitoring compliance with carriage agreements, cable operators may need to monitor input streams to prevent errors from being propagated to their customers. Typical errors that may be present in a DTV broadcast stream include:

1. Missing, invalid, or infrequent PSIP and PSI tables. Because of these metadata errors, DTV receivers may not be able to tune channels or block unwanted programs properly. Furthermore, the on-screen program guide may be missing or incorrect.

2. Missing video or audio elementary streams.
3. PCR jitter, which can cause incorrect synchronization of the audio and video signals, sometimes resulting in a “lip sync” problem.
4. Video and audio buffers overflow or underflow, which can cause ragged, stuttering video and audio.

Depending on the type of errors found, the cable operators may have different options to deal with the erroneous conditions in the transport stream. Some errors may be fixed or filtered out by the metadata processing system and multiplexers. For example, PSI and PSIP tables are normally regenerated by the metadata processing system. Therefore, certain syntax errors, inconsistent data, and incorrect table time intervals may be automatically corrected. Other type of errors may be corrected with some level of manual intervention. In addition, some errors may be filtered out if they are associated with data that are not critical. For the errors that cannot be easily fixed, the cable operators may need to contact the original broadcasters so that the problems can be promptly addressed. Since transport stream errors can also be introduced in cable headends, comprehensive stream monitoring (at various points in the path of a stream from ingest to emission) can be used to detect the occurrence and cause of errors – such as equipment failure or operator error during provisioning, reconfiguration, maintenance, etc.

Besides error monitoring, another important reason for cable operators to monitor input streams is to know the exact content and bandwidth usage of an input stream so that they can optimize bandwidth usage in their backbone and QAM feeds to the home. For example, when the program lineup changes in an input stream and leaves significant unused bandwidth, the cable operator can detect and use the available extra bandwidth to offer other services.

5.2 Contract Verification

A monitoring system at the headend that continually checks for compliance with carriage agreements is of high value to the local systems operations. All of the technical components of carriage agreements described in section 2 above can be verified automatically as described in table 1.

Different stream monitoring strategies may be applied in cable headends. One possible approach is to check the input or output streams periodically and manually using a stream analyzer. However, this approach only shows a snap shot of the stream and requires tedious routine inspections that result in high operational cost. An alternative approach is to monitor multiple streams simultaneously and use the system to verify carriage contract compliance automatically. This approach is the most cost-effective. The operator is only required to enter the contract items that are to be monitored in a standard template using a simple user interface, he can repurpose the contract specification file used for implementing the contract. To meet the needs of automatic contract verification for multiple off-air feeds, the monitoring system should provide the following features:

1. Allow multiple inputs and performs simultaneous analysis on different streams in real-time.
2. Provide remote user interface for displaying and analyzing data.
3. Provide an alarming function to inform the cable operators or the original broadcasters once any errors are detected in the stream.

4. Provide a recording function that is automatically triggered by defined error conditions in a transport stream for further analysis.

6. SUMMARY

Whether the cable operator implements must-carry type of contracts or private carriage agreements, a large number of technical parameters must be addressed in implementing the agreement. The technical issues will only continue to become more numerous and complex as penetration of DTV increases and service providers and content providers seek to innovate and expand offerings. In the near future the deployment of retail, cable-ready DTV receivers based on OpenCable and related standards, and the launch of interactive services will create these additional technical requirements.

Current digital cable headends are equipped to deal with only a limited number of these technical issues. Equipment deployed today can only groom and rate-shape audio and video programs, and they also require static channel line-ups. In-band PSIP metadata is ignored and cannot be correctly transformed. The ability to handle this new type of stream element, as well as the ability to handle frequent and periodic changes to incoming stream composition, requires new types of stream processing, monitoring and operational support systems.

Triveni Digital has developed and deployed the StreamBridge system to meet a critical need in this area. StreamBridge is designed to be a low cost, highly integrated system to facilitate the bridging of off-air streams to digital cable systems. This system is designed to analyze the composition of incoming streams, comprehend carriage contracts specified in convenient XML format, instruct multiplexers in the headend to implement appropriate grooming and rate-shaping actions, and monitor/verify the resulting streams for carriage contract compliance. The system is scalable and a single unit can support a large number of multiplexers / transport streams. The StreamBridge system provides remote user interfaces, and can interface with multiplexers that are not co-located. The system software can be easily upgraded to evolve with changing standards, operational needs, and other headend equipment changes.

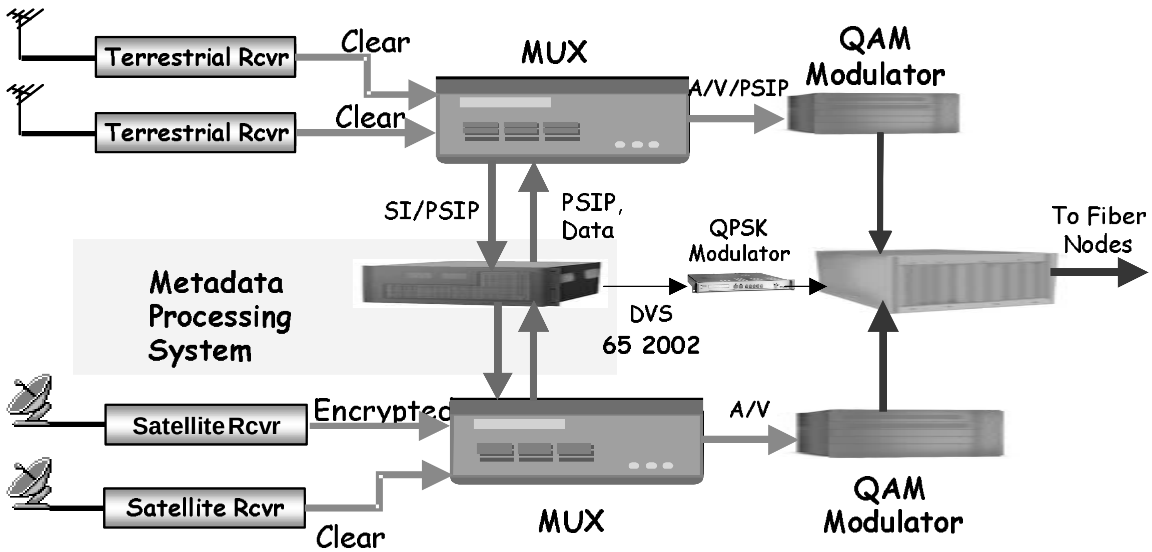

Figure 1: Metadata Processing System in Cable Head-End Environment.

Table 1. Common technical contract items and related monitoring parameters

Contract Item	Monitoring Parameters
No bit rate reduction	Monitor and compare the bit rate of specified elementary stream.
No video trans-coding	Periodically compare the input stream with the corresponding portion of the output stream for changes in bit rate.
Meet minimum bit rate requirement	Monitor the bit rate of specified elementary stream and compare it with a specified value.
Carry specified program or all programs	Discover the specified programs in the input stream. Identify the same programs in the output based on program number, PMT PID or virtual channel mapping information.
Carry specified elementary stream or all streams of a program	Discover the specified elementary streams in the input stream. Verify that the specified elementary stream is present in the output stream based on PID mapping information.
Carry specified data program	Monitor that the data program is present in the output stream.
Carry required PSIP data	• Verify the presence of the virtual channel in the virtual channel table. • Verify the number of EITs present in the transport stream is the same as specified. • Verify the presence or absence of ETTs as specified. • Perform cross table analysis to check the data among different PSIP tables and between PSIP and PSI tables are consistent after re-multiplexing.
Verify channel branding	Check if the correct virtual channel name, major and minor channel numbers are present in the output VCT.
Verify the bit rate of PSIP data.	Identify the PSIP data that are related to the particular input broadcast streams. Calculate the bit rate of all PSIP data that belong to the input stream and compare it to a specified value.
Carry required descriptors	Analyze the tables that carry the descriptor and verify that the specified descriptors are present and correct.

REFERENCES

[1] Program and System Information Protocol for Terrestrial Broadcast and Cable (Revision A) and Amendments 1A, 2 and 3, ATSC Document A/65A, 31 May 2000.

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[3] Service Information Delivered Out-of-Band for Digital Cable Television, ANSI/SCTE 65 2002.

[4] NCTA-CEA PSIP Agreement, February 2000

[5] Memorandum of Understanding Among Cable MSOs and Consumer Electronics Manufacturers, 12 December 2002

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