IMPLEMENTING THE NCTA-CEA PSIP AGREEMENT

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ABSTRACT

In ATSC-compliant DTV broadcasts, PSIP data provide DTV receivers with tuning information, electronic program guide data, as well as other information supporting a variety of functions. When the DTV broadcasting signal is received by a cable provider, multiplexed and carried on a cable network, the PSIP data need to be preserved and transformed to comply with cable standards. Otherwise, cable-ready DTV receivers may not be able to tune to the signal. In light of this need, the NCTA and CEA have reached an agreement regarding the carriage of PSIP on cable. This paper explores the issues surrounding the adaptation of PSIP data to the cable environment, including the consequences of merging multiple terrestrial transport streams into a single cable transport stream. The paper also presents a sample design and implementation of a system to support PSIP carriage on cable as highlighted by the NCTA-CEA agreement.

INTRODUCTION

In DTV broadcasts, a single MPEG-2-compliant transport stream (TS) can simultaneously carry multiple video, audio, and/or data programs [1]. In ATSC-compliant broadcasting, metadata describing the contents of the transport stream multiplex are carried by PSIP – the Program and System Information Protocol [2]. The PSIP data consist of collections of "table sections", which are also encapsulated into MPEG-2 TS packets. These packets have unique PID values that can be used to distinguish the PSIP tables from each other, as well as from the audio, video, and data streams.

The PSIP tables are defined in ATSC standard A/65A [2]. These tables enable a number of important features for digital television (DTV) receivers:

- Tuning to programs by virtual channel numbers, rather than physical broadcast bands;
- Selecting language tracks;
- Creating interactive electronic program guides;
- Applying "V-chip" restrictions on viewing based on content advisory ratings.

The ability for a DTV receiver to tune to the terrestrial broadcasting signal based on virtual channel number rather than physical frequency band is very important for terrestrial broadcasters. Network broadcasters typically have one frequency band for broadcasting an analog signal and a different frequency band for broadcasting a digital signal. They have often invested substantial resources over the years in brand recognition for their analog channel number. Moreover, a DTV broadcast may consist of multiple programs, so it is necessary in many cases to identify multiple "virtual channels" within a single digital broadcast band.

The PSIP standards identify virtual channels (VCs) by the combination of "major channel number" (mandated to be equal to the analog channel number for stations with existing NTSC licenses) and "minor channel number." . The virtual channel numbers allow DTV receivers to tune the DTV signal using the same analog channel number, even though the physical channel is at a different frequency. In addition, PSIP data provide details about alternative language tracks, content advisory ratings, and audio and video streams within the broadcast bands.

PSIP data also support interactive electronic program guides (EPGs) in standard, off-the-shelf TV sets and set-top boxes (STBs) by supplying information on upcoming programs. The standards and mechanisms described thus far allow the user to purchase a standard DTV receiver, hook it up to an antenna, turn it on, and have it work over-the-air with a minimum of manual configuration.

When a DTV signal is carried on cable to the consumers, the PSIP information needs to be preserved in order for consumers to retain the ability to tune to the signal using a cable-ready DTV receiver, analogous to using an antenna. For analog signals, consumers can purchase "cable-ready" TVs that can receive signals from an already-established cable connection. The same holds true for digital television; consumers will expect equivalent commercially available "cable-ready" DTVs or STBs that they can deploy without direct intervention from their cable provider. This is especially important for those consumers that only want the free or low-cost, entry-level "antenna extension" service to view the unscrambled DTV programs. These services do not require the use of the Point of Deployment security module (POD). These consumers will not be able to access the out-of-band channel navigation information and must rely on the in-band PSIP information for tuning and EPG services.

NCTA-CEA CABLE PSIP CARRIAGE AGREEMENT

With the intention of achieving this type of environment, the FCC issued a Report and Order on Cable Carriage of DTV (Docket 98-120), which in paragraph #83 requires carriage (if present) of PSIP data related to the primary video service.

To meet the needs of PSIP carriage on cable and to make the data meaningful for cable-ready receivers, an agreement has been established between the Consumer Electronics Association (CEA) and the National Cable Television Association (NCTA). The agreement describes the carriage of PSIP on cable in support of consumer digital receiving devices (digital receivers) connected directly to the cable TV system [4]. The intent is that consumers will be able to purchase a cable-ready receiver that can process unscrambled cable channels immediately, as well as play "host" to a cable-system specific decryption processor referred to as a POD module.

Key provisions of the NCTA-CEA agreement include:

- If a digital transport stream includes services carried in-the-clear, that transport stream must include VC data in-band in the form of ATSC A/65 (PSIP), if present in the stream.
- VC table data are also sent out-of-band to the POD module in the receiver.
- VCs are identified by a one- or two-part channel number, and a textual channel name.
- At least twelve hours of PSIP event data must be included, if received from the broadcaster.
- The cable provider has the option to limit the total bandwidth for PSIP data to 80 Kbps for a 27 Mbps multiplex and 115 Kbps for a 38.8 Mbps multiplex.
- Event data may be transported in-band and/or out-of band. The in-band data may be used to augment out-of-band data at the receiver.
- For access-controlled services, the out-of-band SI channel number may or may not match the channel number identified with in-band PSIP data.
- The channel number identified with out-of-band SI data should match the channel number identified with in-band PSIP data, for in-the-clear services.

The NCTA-CEA agreement does not preclude the possibility that cable providers may choose to implement alternative agreements with specific stations, station groups, or networks. These "private agreements" could have cable providers including different amounts of PSIP data from different terrestrial/broadcast sources, with different types of manipulations and bandwidth limitations allowed for each.

One implementation challenge from the PSIP agreement involves the handling of PSIP data when multiple transport streams containing PSIP data are multiplexed in cable plants. Terrestrial DTV channels have fixed bandwidth of approximately 19.39 Mbps, but digital cable systems use modulation methods that allow carriage of 27 Mbps or even 38.8 Mbps per transport stream. In addition, cable providers may want to select which programs (or VCs) from a given transport stream to carry. In order to optimize the usage of cable bandwidth, the cable providers naturally want to combine programs from several terrestrial transport streams together in one multiplex.

However, traditional MPEG-2 multiplexers are not designed to handle the PSIP data. Thus, a new PSIP-aware device needs to be developed that can process the PSIP data from the input transport streams and generate the in-band PSIP and out-of-band service information (OOB SI) using the input PSIP data according to SCTE standards.

DESIGN OF METADATA PROCESSING SYSTEM FOR CABLE HEAD END

Comparison of Terrestrial PSIP, Cable In-Band PSIP, and Cable Out-of-Band SI

The terrestrial PSIP metadata consists of a number of tables:

Table 1. Terrestrial PSIP Tables

Table	Description
Master Guide Table (MGT)	gives PIDs, sizes, and version numbers for all other PSIP tables.
System Time Table (STT)	gives current time, convertible to wall clock time at receiver.
Rating Region Table (RRT)	describes system(s) for rating broadcast content, referenced by "content advisory descriptors" in EITs (not sent when RRT is fixed, as in U.S.).
Virtual Channel Table (VCT)	provides details about the VCs in the stream, including channel name and number (different forms for terrestrial and cable PSIP).
Event Informa-tion Tables (EITs)	describe upcoming program "events," including title, time, captioning services, rating information.
Extended Text Tables (ETTs)	give extended descriptions of VCs and events.
Data Event Tables (DETs)	describe upcoming data "events,".
Directed Channel Change Table (DCCT)	provides definitions of virtual channel change requests.
DCC Selection Code Table (DCCSCT)	carries code values & selection criteria names for reference from DCCT.

These tables are encapsulated as private data into MPEG-2 TS packets and multiplexed along with the video, audio and data streams. The tables are identified by PID and table ID. The PID for MGT, STT, RRT, VCT is 0x1FFB, the so-called PSIP base PID. The PIDs for EITs and ETTs can be arbitrarily selected as long as they do not conflict with other PIDs in the same transport stream. The MGT provides the information necessary to discover what PIDs have been used for the EITs and ETTs. The DETs, DCCT and DCCSCT will not be discussed in this paper because they are beyond the scope of current PSIP carriage agreements.

In the cable environment, the service information is carried in two forms – in-band PSIP and out-of-band SI. The cable in-band PSIP differs in some subtle but significant ways from the terrestrial PSIP described above. Cable metadata relies much more on information in the PMT. For example, both the caption service descriptor and the content advisory descriptor (when present) must be carried in the EITs and may optionally be included in the PMT in the terrestrial world. For cable, these descriptors (when present) must be located in the PMT, and may be carried in the EITs. Additionally, in cable the AC-3 audio descriptor is found in the PMT, and so is optional in the cable EITs.

Another difference is in the VCT. The VCT comes in two forms, one for terrestrial broadcasts (the TVCT) and one for cable broadcasts (the CVCT). They are mostly similar with a few differences. Both list the virtual channels that appear in the broadcast stream and give information for each one including: Channel name, Channel number (two-part for TVCT, one- or two-part for CVCT), MPEG-2 program number (used by receivers to coordinate with entry in PAT), Service type (video, audio, or data-only), and Source_id (used to coordinate VCs with EIT entries). The TVCT supplies PID values of all the video / audio / data streams in the channel.

Terrestrial broadcasters may include the CVCT in their transport streams, in addition to the mandatory TVCT. Cable providers will have instances when they receive the CVCT within a terrestrial stream and pass it through, and other occasions when they will need to generate it locally based on the content of the TVCT and other tables. In terrestrial broadcasts, it is required to include a service location descriptor in the TVCT. This descriptor identifies the various elementary streams (video, audio, and data) included in the complete program. However, the CVCT does not require the presence of a service location descriptor—the information is expected to be present in the PMT.

The OOB SI is defined in SCTE standard DVS 234[3]. While similar in nature to PSIP, the DVS 234 tables are optimized for the cable environment. Tuning relies much more heavily on the data in the PMT. Aggregate EITs (AEITs) and ETTs (AETTs) are used to reduce the number of PID values that the POD host will need to process (MGT table types and corresponding tag values associate and distinguish the various table sections, rather than multiple PID values). Other notable differences include:

- The SI base PID value is 0x1FFC (in contrast to 0x1FFB for ATSC PSIP).
- The Network Information Table (PID 0x1FFC) delivers the Carrier Definition Subtable (CDS) and the Modulation Mode Subtable (MMS). CDSs define number of carriers used in the system and their frequency locations. MMSs define the modulation format (e.g. QPSK or 64QAM) for each carrier in the system.
- Two alternative types of Virtual Channel Table, Short-form (S-VCT) *and* Long-form (L-VCT), may be present in the transport stream, depending on selected profile (see Table 2).
- The Network Text Table (PID 0x1FFC) carries Source Name Subtables to associate names with each service listed in an S-VCT.
- The S-VCT and L-VCT deliver the Virtual Channel Map, Defined Channels Map, and Inverse Channel Map – the keys to channel navigation using the OOB metadata. VCTs also identify the physical cable carrying the transport stream. The L-VCT also includes carrier frequency and modulation mode information.
- Up to 30 days of event information may be carried in AEITs and AETTs. These use a maximum of four PIDs.
- Multiple MGTs corresponding to distinct channel maps may be included in the transport stream, distinguishable within the POD module (the POD identifies the "correct" MGT using the included map_id value and discards the others).

In-band PSIP Processing

According to the Agreement, when DTV services are carried over cable in-the-clear, PSIP data must be provided in-band if PSIP data is available in the original input signal. When multiple transport streams that contain PSIP data are multiplexed in the cable head-end, care must be taken to preserve the PSIP data from input streams and merge the data for the multiplexed output transport stream. As shown in the previous section, all PSIP data packets have the same base PID 0x1FFB, and use standard protocols to arrange EITs, ETTs and DETs. Thus, simply merging the streams is unlikely to work. Intermingling packets from different transport streams with a common PID value (for example PSIP's 0x1FFB) results in a stream that is not MPEG-2 compliant, and is certain to confuse receivers.

In order to meet the requirements of both the PSIP agreement and in-band cable PSIP carriage standards, the metadata processing system must provide the following two functions:

- Resolving the conflicts of PSIP data between multiple terrestrial streams and merging the data for a single output transport streams.
- Making sure the new PSIP data for the output transport stream complies with cable standards.

To do these, the metadata system must extract the PSIP data from the input transport streams, decode it, and parse the PSIP data to obtain the semantic contents. The decoded PSIP data are then modified to reflect the characteristics of the new output transport stream. Next, the PSIP data from different inputs are consolidated and merged into a single set of PSIP data. Finally, the new PSIP data are re-encoded into MPEG-2 packets and multiplexed back into the output transport stream with consolidated video and audio packets.

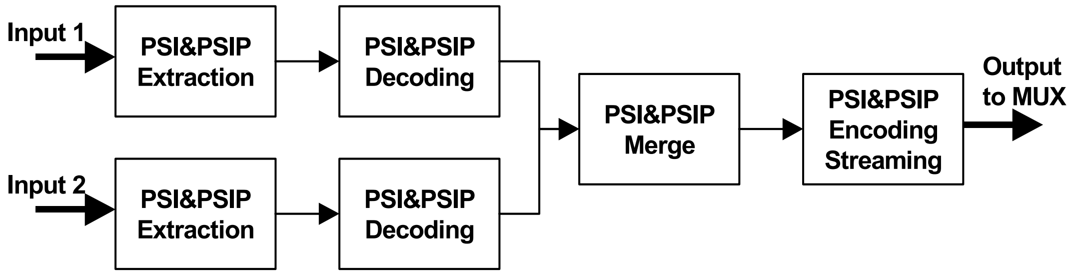

Figure 1: Flow chart of in-band PSIP processing

Figure 1 illustrates the flow chart of the in-band processing routine.

Specific changes have to be made for certain individual PSIP tables. In the VCT for each input Transport Stream, the list of Virtual Channels needs to be decoded. The description of each Virtual Channel will be translated with a new virtual channel number and the frequency of the output ransport Stream. The channel numbering system in cable can be different from that of terrestrial broadcasts. Terrestrial DTV channels are designated by a two-part, major-minor channel number to preserve branding and viewer familiarity, as described above. Broadcasters are likely to want to preserve their major channel numbers onto the cable system, much as they do on analog systems today. However, cable providers will sometimes have to re-map terrestrial broadcasters' channel numbers within the cable system. Cable providers typically do not use the two-part numbering scheme, and may want to convert the two-part number to a one-part number to coordinate it with the out-of-band guide information, though this is not recommended. Once the translation is made, the VCs from different input streams will be merged together to form a single CVCT for the output transport stream.

The EITs from the various input streams must be consolidated. Terrestrial broadcasters are required to carry at least four EITs, namely EIT-0, EIT-1, EIT-2, and EIT-3 that cover 12 hours of programming information. Additional EITs are optional; the number of additional EITs carried will vary between broadcasters. The ATSC recommended practices suggest carrying at least 3 days worth of EITs. In addition, for each EIT group, multiple instances of the tables may exist, each of which is related to a single VC. Because EIT PIDs are arbitrarily selected by each broadcaster, EIT packets from different input sources may have different or overlapping PIDs.

To process the EITs, the MGT from each input transport stream must be decoded in order to find all the EITs contained in the transport stream. Each EIT is decoded to find its association to a specific VC. When EITs from multiple transport streams are merged, the source_id in the EITs may need to be modified in order to resolve any conflicts. In addition, if the input transport streams contain more than four EITs, the additional EITs may be filtered out to reduce bandwidth. Finally, all EITs will be encoded into a new set of PIDs.

The cable operators have the option to carry ETTs or block ETTs. If the carriage of ETTs is selected, the ETTs have to be processed in much the same way as the EITs are.

Due to the changes in EITs and ETTs, the MGT for the output transport stream essentially has to be regenerated to reflect the presence of the EITs and ETTs, new PID selections, and table lengths of all PSIP tables. In addition, the RRT and STT may be updated if necessary.

Because of changes to the program line-up after transport stream re-multiplexing, it is obvious that the PAT and PMT will also require modification or regeneration. Although MPEG-2 multiplexers are designed to handle any PAT and PMT changes, the difference between terrestrial PSIP and cable in-band PSIP may require additional functionalities that do not exist in traditional multiplexers. For example, under certain situations, some descriptors may need to be copied from PSIP tables to the PMTs.

Finally, the system must provide a bandwidth estimation and reduction function in order to meet the bandwidth requirement specified by the PSIP agreement. There are several optional features that will affect the PSIP bandwidth, including the number of EITs, whether or not to include ETTs, as well as the time interval of EITs, that are not specified in the PSIP standards. Furthermore, multiple tables with the same PID may be packed into a single MPEG-2 packet. Finally, compression technology may be used to further optimize the bandwidth usage.

Out-of-band Service Information Generation

Cable systems have traditionally sent EPG data in an out-of-band (OOB) channel that describes all the programming available to the viewer in a single feed. Cable providers will continue to deliver guide information in the OOB channel in the digital domain, but most of the presently used methods are proprietary. Off-the-shelf cable-ready DTV receivers need a standards-based mechanism for delivering out-of-band metadata.

The metadata processing system will generate the OOB SI according to DVS 234. Although the cable OOB SI delivers information similar to in-band PSIP, the protocol used to format the data is significantly different from that of terrestrial or in-band cable PSIP, as described previously. The cable OOB SI contains several unique tables, including the NIT, NTT, S-VCT, and Aggregated EITs and ETTs.

The NIT and NTT are easy to generate and do not change once they are created. Both S-VCT and L-VCT are created to include all virtual channels in a cable network. In addition, links between DTV services in input streams and VCs in the output channel map will be maintained.

To generate the aggregated EITs and aggregated ETTs, a similar process to that of in-band PSIP processing will be used. First, the EITs and ETTs in the input streams will be decoded. The decoded tables will be updated for any changes in the program source_id. Finally, the aggregated EITs and ETTs are created by combining multiple tables from different sources into single aggregated tables.

However, not all OOB SI tables may be created and delivered depending on the profiles selected by the cable operator. DVS-234 defines six profiles for delivery of the service information via the out-of-band channel, described in Table 2.

Table 2. DVS 234 Metadata Delivery Profiles

Profile	Attributes
1 – Baseline	uses Short-form VCT, Modulation Mode, and Carrier Definition subtables for navigation
2 – Revision Detection	builds on Profile 1 by adding a revision detection mechanism
3 – Parental Advisory	builds on Profile 2 by adding RRT support for compliance with FCC-mandated content advisories
4 – Standard EPG Data	adds AEITs and AETTs to Profile 3 for non-proprietary EPG support
5 – Combination	allows navigation based on Long-form VCT, in addition to Profile 1 navigation
6 – PSIP Only	navigation is restricted to Long-form tables as in terrestrial PSIP

None of the mechanisms described thus far preclude the use of the proprietary service selection and navigation systems frequently used in cable today. These proprietary systems are likely to remain in the mix for the foreseeable future, supported by system-specific decryption functions in POD security modules. During this interim period, proprietary system suppliers will likely develop methods for ingesting the most-timely metadata available – delivered to the head-end "live" by PSIP in the case of terrestrial broadcasts.

IMPLEMENTATION EXAMPLE

Figure 2 illustrates the metadata processing system in the cable head-end environment. 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 merged into a higher bandwidth transport stream and are then modulated by a QAM modulator before being sent out to customers via the cable plant. Depending on the bandwidth of the input streams, a variable number of transport streams can be multiplexed into a single output stream.

To protect the investments already made by the cable operators, the system we implemented works together with the MPEG-2 multiplexers, leaving those multiplexers responsible for the audio and video streams, while the metadata processing system is responsible for processing PSI and PSIP data.

The metadata processing system takes either full transport streams or "composite" SI streams – created by the multiplexers – as inputs. 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 encrypted streams may not include PSIP. The metadata processing system monitors each of the incoming streams in real-time and provides detailed information about the contents of the stream, the association between MPEG-2 programs and virtual channels, and program guides.

When multiple streams containing PSIP data are multiplexed into a single transport stream, the system processes the PSIP and creates new in-band PSIP data for the output stream. As described previously, the system decodes the original PSIP data obtaining the semantic contents, translates the data to a form consistent with the local cable environment and merges the metadata at the content level. The resultant PSIP tables are then encapsulated into MPEG-2 packets. A streaming device, which is a part of the metadata processing system, outputs the PSIP MPEG-2 packets based on the standard table requirements taking into consideration the bandwidth limitations prescribed by the Agreement. The output PSIP data stream from the metadata system is then multiplexed back into the output transport streams along with audio and video and other elementary streams. This forms the in-band PSIP data required by the NCTA-CEA Agreement.

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 in the cable network, as well as any VCs the cable provider chooses to include for the purposes of discovery. 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 DVS 234. For incoming streams that do not contain PSIP, the system allows the input of the VC information so that it can be included in the OOB virtual channel map.

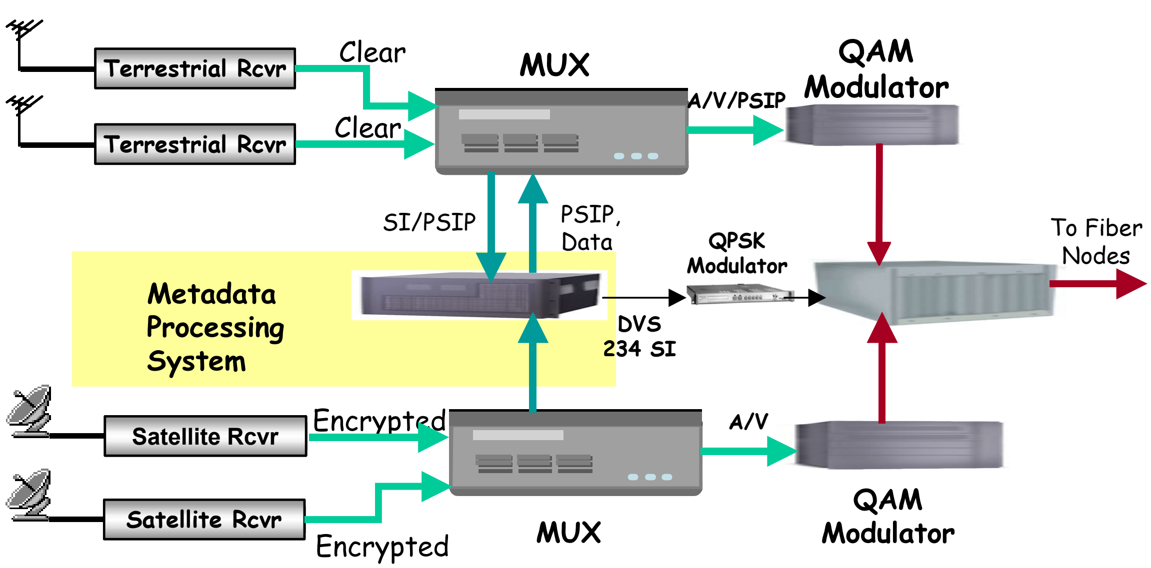

Figure 2: Metadata Processing System in Cable Head-End Environment

The metadata system also provides control of the associated multiplexers. Since typical multiplexers are not designed to handle PSIP structures, it is important that the metadata processing system can be tightly coupled with a multiplexer to provide direct control for handling PSIP packets. In addition, because the metadata system has the complete information about the elementary components of the input and output streams, the system can be used to automatically set up multiplexer functions, such as PID pass-through, PID blockage and PID mapping. The control feature is useful for the cable operator since it precludes the need to manually discover and manipulate the elementary stream PIDs.

In the future, the metadata processing system could also be linked to the proprietary program guide service to perform real-time updates 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 sporting event, 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 could be used to update the cable guide.

SUMMARY

PSIP data in DTV channels provide broadcasters a tool for maintaining their analog brand and promoting their services through EPG information. Therefore, there is a strong incentive for broadcasters to include rich, timely PSIP data in their DTV transmissions.

When DTV services are delivered through a cable system, the PSIP data in the original broadcast signal must be updated and carried though the cable network so that consumers with off-the-shelf cable-ready DTV receivers can view DTV services in the clear. This is a key motivation for the FCC Report and Order mentioned above, and drove the NCTA and CEA to create a PSIP carriage agreement. In addition, service information that is based on SCTE standards and contains the authoritative, up-to-the-minute program guide information has clear advantages over proprietary EPG systems.

Cable providers need a device capable of handling PSIP and PSI data from multiple transport streams. An external metadata processing system, as presented in this paper, minimizes the impact on the cable head-ends, while still allowing them to comply with industry standards, carriage agreements, and FCC mandates. The metadata processing system in the cable head-end manipulates, aggregates, and harmonizes metadata for inclusion in the in-band and out-of-band channels. By directly ingesting terrestrial PSIP data, the cable system delivers relevant, accurate metadata to the viewer and enables off-the-shelf commercial receivers while maintaining compatibility with legacy receiver equipment.

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