PSIP Generation for DTV Broadcasts

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Abstract

PSIP tables are essential in DTV broadcasts. If they are missing or incorrect, DTV receivers often can't tune to the signal. This paper discusses the problem of generating PSIP data and inserting it into a DTV broadcast stream. An overview of the different PSIP tables is given, including the function of each table and the inter-relationships among the tables. Issues discussed include the interfaces between PSIP generators and DTV encoders/multiplexors, manual entry and editing of descriptive information about the virtual channel lineup and upcoming programming, automated import of programming information from listing services, and interfaces to traffic and automation systems.

Introduction

The PSIP tables are defined in the ATSC Program and System Information Protocol (PSIP) standard [1], together with its corrigenda and amendments [2][3]. 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
- Built-in interactive electronic program guides
- So-called "V-chip" restrictions on viewing based on content advisory ratings
- Automated setting of wall clock time

DTV stations typically have one broadcast band (or physical channel) on which they broadcast an analog signal and another broadcast band on which they broadcast a digital signal. They have often invested substantial resources over the years in brand recognition for their analog channel number. For example, station WRC in Washington, DC, is widely recognized as "NBC4". If viewers were forced to tune to DTV signals by the physical broadcast band number (channel 48 in the case of WRC), then the benefits of the analog channel branding would be lost.

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.

For these reasons the ATSC standards provide for a virtual channel to be identified by "major channel number" and "minor channel number." For stations with existing NTSC licenses, the **major** channel number for both analog and digital channels is mandated by the standard to be equal to the station's analog channel number. The **minor** channel number for the analog channel is mandated to be 0, and the **minor** channel number for a digital channel may be any number between 1 and 99 for an ATSC digital television service or ATSC audio-only service, or any number between 1 and 999 for other types of services, such as data broadcasting.

The mappings from virtual channel numbers to physical broadcast bands and specific audio and video data streams within those broadcast bands are provided by PSIP data.

A DTV program may contain language tracks in multiple languages. The information about what language tracks are available is provided by PSIP data.

Printed from a paper delivered at the NAB Broadcasting Engineering Conference, Apr. 8-13, 2000.

One big advantage of cable and satellite systems over analog terrestrial broadcasts is the increasing availability of interactive electronic program guides (EPGs), supported by proprietary set-top boxes. For digital terrestrial broadcasts this feature can be supported by standard, off-the-shelf TV sets and set-top boxes. What makes this possible is information on upcoming programs provided by PSIP data.

For a DTV set to enforce viewing restrictions based on content advisory ratings, it is necessary to be able to find out the advisory ratings associated with each program. This information is provided by PSIP data.

A perennial problem with home appliances these days is that whenever the power goes out, the homeowner has to go all over the house resetting the time on alarm clocks, stoves, radios, microwave ovens, TV sets, stereos, etc. In the DTV world the current time is transmitted once a second in every broadcast channel, so the DTV set can reset its clock by itself (and with future home networks will be able to reset the clocks on the other appliances as well). This time information is provided by PSIP data.

However, in order for DTV sets to carry out these functions, the DTV broadcasters must ensure that the PSIP data that they generate and broadcast is complete and accurate.

ATSC Broadcast Stream

The ATSC broadcast stream (or transport stream) in a single physical broadcast band may contain multiple programs. Each program may contain any combination of video, audio and data streams. There is typically at most one video stream in a given program, but there are often multiple audio streams (for example, sound tracks in multiple languages), and/or multiple data streams.

Each video, audio, or data stream consists of a sequence of so-called "transport packets," which are interlaced to form the entire broadcast stream. Each transport packet contains 188 bytes, the first 4 bytes of which make up a packet header. One field in the packet header is a 13-bit "packet identification" or PID. Packets belonging to the same video, audio, or data stream have the same PID value, and different streams have different PID values. Thus, the PID values of the transport packets can be used to sort out (or demultiplex) the sequences of packets belonging to the different video, audio, or data streams.

The PSIP data consist of collections of "tables," which are also packed into sequences of transport packets. These also have PID values which can be used to separate the PSIP tables from each other and from the audio, video, and data streams.

One problem facing a DTV receiver is how to figure out what is in the broadcast stream and how to find it (i.e., how to find out what PID values correspond to what video streams, audio streams, data streams, and PSIP tables).

The combination of the MPEG-2 systems standard [4] and the ATSC PSIP standard [1][2][3] provides the necessary information to do this.

System and PSIP Tables

There are four "system tables" defined in the MPEG-2 systems standard:

- Program Association Table (PAT)
- Program Map Table (PMT)
- Conditional Access Table (CAT)
- Network Information Table (NIT)

In addition to these, there are six tables (or in some cases collections of tables) defined in the ATSC PSIP standard:

- Master Guide Table (MGT)
- System Time Table (STT)
- Rating Region Table (RRT)
- Virtual Channel Table (VCT)
- Event Information Tables (EITs)
- Extended Text Tables (ETTs)

There are several other tables currently in the ATSC standardization pipeline (Data Event Table, Directed Channel Change Table, Directed Channel Change Selection Code Table), but this paper deals only with those tables already in the standards.

The PAT lists the virtual channels (which MPEG-2 calls "programs") in the transport stream, and gives the PID values where the PMT for each channel can be found. It also gives the PID value for the NIT if one is present. The transport packets containing the PAT always have PID value 0x0000, so a receiver always knows how to find it. The PAT is supposed

to be included in the broadcast stream at least once every 100 milliseconds.

The PMT for each virtual channel lists all the video, audio, and data streams for the channel and gives their PID values. It may also contain descriptors giving additional information about the streams. The PID value for each PMT is given in the PAT. Each PMT is supposed to be included in the broadcast stream at least once every 400 milliseconds.

The CAT gives the PID values for conditional access information, to be used by conditional access modules.

The NIT can be used to give miscellaneous information about the broadcast network. To date it seldom appears in ATSC broadcasts, since there is no real need for it in an ATSC context.

The MGT gives the PID values, sizes, and version numbers for all the other PSIP tables. The transport packets containing the MGT always have PID value 0x1FFB, so a receiver always knows how to find it. The MGT should be included in the broadcast stream at least once every 150 milliseconds.

The STT gives the current time, as the number of GPS seconds since 12:00 am January 6, 1980. Assuming the viewer has told the DTV receiver what time zone it is in, it can convert this to wall clock time. The STT always appears in PID 0x1FFB. It should be included in the broadcast at least once a second.

An RRT describes the content rating system(s) used to rate the broadcast content. For stations close to an international border, where their viewing area may include more than one rating region, there may be more than one RRT included in the broadcast. The ratings in the RRT(s) are referenced by "content advisory descriptors" associated with individual TV programs. Thus, a DTV receiver can let the user specify the ratings in the RRT(s) for which viewing should be restricted, and can then check the content advisory descriptors to enforce the restrictions. The RRT always appears in PID 0x1FFB. It should be included in the broadcast at least once a minute.

The VCT comes in two forms, one for terrestrial broadcasts and one for cable broadcasts. However, they are nearly identical. Both list the virtual channels which appear in the broadcast stream and give a good deal of information about each one, including:

- Channel name
- Channel number (major-minor combination)
- MPEG-2 program number (allowing receiver to match channel with corresponding entry in PAT)
- Conditional access flag (restricted yes/no)
- Service type (video, audio, or data-only)
- Source_id, a surrogate ID which is used to match up entries in the EITs with the channels to which they belong
- PIDs of all video/audio/data streams in the channel (duplicating information in the PMT)

Thus, it is the VCT which enables tuning by virtual channel number, and which allows the DTV receiver to display the channel name to the end user, both in EPG displays and in the corner of the screen when a viewer first tunes to a channel. The VCT always appears in PID 0x1FFB. It should be included in the broadcast at least once every 400 milliseconds.

The EITs contain information about upcoming TV programs (called "events" in the PSIP standard) in the virtual channels of the broadcast stream. There are up to 128 EITs, designated EIT-0 through EIT-127. (Actually, each EIT-j is really a group of tables, one for each virtual channel, but each group is often informally referred to as if it were just a single table.) Each contains information about the events in a three hour period, starting at midnight, 3:00 am, 6:00 am, etc., GMT. EIT-0 covers events in the current 3-hour period, EIT-1 covers events in the next 3-hour period, etc., so that the entire set covers events up to 384 hours, or 16 days, ahead. Any event which overlaps the time period of an EIT will be described in the EIT. The information in the EIT includes:

- Event title
- Event start time
- Event duration
- List of closed caption services for the event, if any, and their languages
- List of content advisory ratings for the event

Thus, it is the EITs which enable the basic grid displays in electronic program guides. The PID for each EIT-j is given in the MGT. At least EIT-0 through EIT-3 are supposed to be included in the broadcast stream (i.e, a minimum of 12 hours of

programming). It is recommended that EIT-0 appear at least once every 500 milliseconds.

The ETTs give extended text descriptions of virtual channels and events, with ETT-V giving information on the channels in the VCT and ETT-0 through ETT-127 giving information on the events in EIT-0 through EIT-127, respectively. There may be multiple descriptions in different languages for any virtual channel or event.

Thus, the ETTs enable electronic program guides to provide extended information on individual TV programs, such as a synopsis of the plot, list of key performers, etc. The PID for each ETT is given in the MGT. All ETTs are optional. However, they can be a powerful tool for broadcasters to provide viewers with information which will attract them to the broadcaster's programming.

An interesting issue is how many EITs and ETTs to include in the broadcast stream and how often to transmit them. If all EITs and ETTs are included, and if they are transmitted every 500 milliseconds, this may require a substantial fraction of the entire broadcast bandwidth. While program information in an EPG can be a valuable tool for attracting viewers to a channel, this is probably much more effective for programs coming up in the next few hours than for programs several days in the future. Some high-end receivers will scan all channels whenever they are turned "off" and cache the EIT and ETT data. For these receivers the frequency of transmission of the EITs and ETTs may not be too critical. Other receivers will not cache any EIT and ETT data. For these receivers the frequency of transmission will have a pronounced effect on the EPG response time. Broadcasters will have to assess the trade-offs and determine how much programming data to transmit and how often to transmit it.

PSIP Generator Features

The basic functions of a PSIP generator are to gather the data which goes into the PSIP tables, format the data correctly into transport packets, and insert them into the broadcast stream at suitable intervals.

Ideally, the gathering of the data can be automated, so that little or no staff effort is required to maintain the PSIP generator. However, it is inevitable even then that a user interface on the PSIP generator will be needed at least once in a while in order to configure the system and to handle data updates when glitches occur in other components of the automated data gathering process.

Thus, at a bare minimum a PSIP generator must provide the following:

- Convenient user interface for configuration of the system and for data input/update
- Correct formatting of data into PSIP tables and packing of tables into transport packets
- Interface to encoder(s) and/or multiplexor(s) for insertion of packets into the broadcast stream

Moreover, a number of other features are extremely important for economical and reliable operation of the broadcast station:

- Automated import of programming data from listing services
- Automated interfaces to the broadcast station's traffic and/or automation systems
- Merging of data from multiple sources
- Access controls
- Remote user interface
- Fault tolerance

User Interface. The most important feature of a user interface for a PSIP generator is that it be easy to learn and easy to use. In particular, station staff should not be required to have any detailed knowledge of the ATSC or MPEG-2 standards in order to use the PSIP generator. They should be able to operate entirely in the application domain with which they are familiar. Moreover, modern point-and-click user interface technology should be used to maximize convenience and efficiency.

In the United States the station staff should not have to enter any data for the RRT at all, since it is static. It should simply be pre-loaded into the PSIP generator (although an override should probably be available if the user really wants it).

All the station staff should have to do for the STT is make sure the system clock is set and maintained correctly on the PSIP generator's computer. Ideally this will be done automatically by means of an interface to a GPS receiver or atomic clock or other similarly accurate time source.

The station staff should not even need to be aware the MGT exists, since it is just a roadmap to the other tables.

The engineering staff should be able to describe the virtual channels which will be broadcast, giving their names, major-minor channel numbers, etc., without having to know anything about the coding of this information into the fields of the VCT.

The programming staff should be able to describe the programs (events) which will be broadcast on the various channels by entering the title, start date/time, end date/time, textual description, etc., of each program, without having to know anything about EITs or ETTs.

The programming staff should be able to manage channel configuration changes by simply indicating when each channel will be on-air and off-air, and let the PSIP generator translate this automatically into VCT version changes at the appropriate times.

A PSIP generator should provide special operations for such common occurrences as inserting a special news bulletin or coping with a program which overruns its time slot (as often happens with sports events). In these situations the staff should be able to indicate which program should have the time deducted from it, the current program or some later program down the line, and the PSIP generator should adjust all the start times and end times accordingly.

Some knowledge of the existence of the PSIP tables is inherently needed for specifying how often the various tables should be transmitted. However, a PSIP generator should have reasonable default values for this, so that the engineering staff do not necessarily have to address this issue early on. Moreover, if they do want to address this issue, it should be possible to specify the frequencies by means of a few carefully chosen parameters, rather than having to specify the frequency individually for each of the 260 different tables (RRT, STT, MGT, VCT, 128 EITs, 128 ETTs).

PSIP Data Formatting. Formatting the data correctly is absolutely essential for interoperability with the diverse DTV receiver products coming onto the market place. It seems like an obvious and straightforward requirement, but it is not as easy as is sounds. The relevant ATSC and MPEG-2 standards are very complex, with many subtleties. Achieving correct formatting requires that the implementers of the PSIP generator have an intimate knowledge of these standards.

In practice, many DTV stations are finding when they go on the air that not all brands of DTV receivers can tune in their broadcasts successfully, even when the receivers are in a location where the RF reception is very clear. In almost all cases the problem is that the PSIP data in their broadcasts are incomplete or incorrectly formatted. Many DTV receivers can cope with some minor deviations from the standards, but different receivers vary widely in the nature of the deviations which they can handle.

Encoder/Multiplexor Interfaces. Once the PSIP generator has the data formatted into transport packets, the next task is to get the transport packets into the broadcast stream. This is normally done by feeding the transport packets into the encoder or multiplexor.

It is extremely valuable for a PSIP generator to be able to interoperate with as many different encoder and multiplexor products as possible, so that the broadcaster is not locked into any particular encoder or multiplexor vendor. As products evolve and the needs of the broadcaster evolve, the encoders and multiplexors of choice may change.

Import from Listing Services. Manual entry of programming information is an extremely labor intensive process (and therefore a very expensive and error prone process). It is highly desirable for a TV station to have an automated way to get this data into the PSIP generator.

Most TV stations have an arrangement with one or more program listing services wherein they provide programming information to the listing service, the listing service augments it with information they receive directly from the content originators (such as movie and episode synopses), and then the listing service provides it to various newspaper, cable service, and/or web site TV guides. If the PSIP generator can simply import this data from the listing service at regular intervals, perhaps via an Internet link, it can save the broadcaster a great deal of expense and trouble.

Traffic/Automation System Interfaces. More and more TV stations are installing advanced traffic systems and/or automation systems to streamline their operations. Often these systems contain the definitive information about what programs are to be shown when, especially in the case of last minute program changes and overruns.

An interface between the PSIP generator and the traffic system and/or automation system can both simplify operations and ensure that PSIP data is accurate and up-to-date. Depending on the preferred mode of operation of the broadcaster, either the PSIP system or a traffic/automation system could be the primary point of data entry, with the data then propagated to the other system(s).

Data Merging. The "best" source for PSIP data may be different for different categories of data. For example, the listing service may be the best source for descriptive information on movies and weekly shows. The traffic /automation system may be the best source of data on the precise start times and end times of programs. The station's news room may be the best source for descriptions of the lead articles for the nightly news.

Thus, the PSIP generator should be able to merge the data from different sources, allowing the station staff to specify reconciliation rules – which source should have priority for different categories of data.

Access Controls. It is clear that complete and accurate PSIP data will become increasingly critical to successful DTV broadcasting. Thus, PSIP data will increasingly need the same protection as any other mission critical data. In particular, it should not be possible for just anyone to stroll past the console of the PSIP generator and fiddle with the data.

Access should be restricted via the usual login procedures, so that only authorized personnel can make changes.

Remote User Interface. Different portions of the PSIP data may need to be maintained by different departments in a station. For example:

- The engineers may need to maintain information about certain technical features of the broadcast stream, how often the PSIP tables are transmitted, etc.
- The programming staff may need to maintain information about the program lineup.
- The master control operator may need to maintain information about last minute changes to programming.
- The news room may need to maintain descriptions of the lead stories in the nightly news, etc.

Thus, it is important to allow access to the PSIP generator from a number of different locations throughout the station, and possibly from other remote locations, such as roving news vans.

Suitable access controls are obviously especially important when such remote access is possible. It should be possible to define different roles with different access permissions for different categories of users. Each user would then be assigned to a role, so that when a user logs in, the user is restricted to the activities appropriate to that user's role.

Fault Tolerance. As more and more DTV receivers are sold, and the DTV viewing audience gets larger and larger, it becomes increasingly important for DTV broadcasters to attract those viewers and provide them with the best possible viewing experience.

However, if a station's PSIP data goes missing from its broadcast, then DTV receivers may not be able to show any of its channels in EPG displays or even tune to them. A failure of the PSIP generator may be even more serious than a failure of an encoder.

Thus, it becomes increasingly important for PSIP generators to be fault tolerant.

Future PSIP Requirements

As mentioned earlier in this paper, there are a number of additional PSIP tables in the standards pipeline which PSIP generators will likely need to support in the near future:

- Data Event Tables (DETs)
- Directed Channel Change Table (DCCTs)
- Directed Channel Change Selection Code Table (DCCSCT)

Also, there is a move underway in the ATSC standards community to enable enhanced EPG functions such as media-rich descriptions of channels and events (rather than just textual descriptions), channel logos, and searches on event categories.

The basic idea is that the EPG will increasingly become the primary portal to broadcast content. Many broadcasters will pack multiple virtual TV channels in their broadcast band and/or include a large number of audio-only and/or data-only channels in their broadcast band. Thus, the total number of channels available to the viewer will be very large, and channel flipping will no longer be a feasible way to select channels, even for terrestrial broadcasts.

As this evolution takes place, an important key to the success of a broadcaster will be the ability to use the EPG as an advertising medium. It will be crucial for PSIP generators to support this functionality.

Summary

DTV audiences are growing, and competition for these DTV viewers will soon become very keen. To improve or even maintain audience share, DTV broadcasters will have to provide reliable, high quality broadcasts. Complete and accurate PSIP data are an important component of such broadcasts.

Therefore, it is crucial that broadcasters select a PSIP generator which will enable them to maintain complete and accurate PSIP data in their broadcast with minimum staff effort, and which will continue to evolve as the industry evolves.

This paper has described the nature and value of the PSIP data, and has discussed a number of the specific factors which broadcasters should consider when selecting a PSIP generator.

References

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