REAL-WORLD PSIP SOLUTIONS

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ABSTRACT

2002 is going to be the DTV year: about a thousand TV stations are to rollout their digital architecture if they are to comply with FCC deadlines. The minimum equipment required is a transmitter, an encoder and "some" PSIP.

PSIP is the ATSC standard A/65, Program and System Information Protocol [2]. PSIP provides more than tuning, branding and program guide information. It provides one of the differentiators that may well drive the mass market to adopt the digital technology.

We will first give an overview of what PSIP is and why it is needed. Then we will explore a certain number of challenges posed by PSIP, and the solutions that Thales came to engineer over the last 3 years to overcome them. Finally, through several real-life station architectures, we will show what solutions are available and how to design a system that can grow with a station. Among other things, we will review how the scheduling information can be remotely downloaded to a set of stations. We will also explore the balance between the flexibility of a software implementation and the robustness of a hardware solution.

WHAT IS PSIP?

The transport layer of an ATSC DTV signal is based on the MPEG-2 standards. MPEG-2 system [1] defines a multiple-program packet-based transport stream. It also defines a basic set of tables called Program Specific Information (PSI) that allow a receiver to tune to the individual components of a program (video, audio and data).

PSIP (Program and System Information Protocol), ATSC standard A/65, adds some tables to meet some specific US DTV requirements:

- **Tuning**: although most of this functionality is already provided by the PSI tables, PSIP adds some tuning information like the carrier frequency, whether the channels are actually active or not… A new functionality, called Directed Channel Change, allows a broadcaster to direct enabled receivers to automatically tune to a specific channel if certain conditions are met.

- **Branding**: PSIP provides a two-part channel number that links each digital channel to the analog channel of the station. It also provides a short (7 characters) channel name, a long channel name and a channel description.

- **Program guide**: the most appealing functionality of PSIP, but also the most difficult to implement, is an electronic program guide that enables a viewer to know what program is currently running and what will be aired in the next few days. For each program the viewer can know its title, start time, duration, description, ratings, audio tracks and close captioning.

MPEG-2 PSI Tables

The MPEG-2 system standard defines the following tables:

- The Program Association Table (**PAT**) lists the currently available programs and contains the Transport Stream ID or TSID.

- The Program Map Table (**PMT**) lists, for each program, the currently available video, audio and data components. Optional descriptors can give additional details about a program or a component.

- The Conditional Access Table (**CAT**) lists the conditional access systems in use in a stream and points to the subscribers rights information. If all channels are in the clear, no CAT is needed.

ATSC PSIP Tables

The ATSC standard A/65A [2] defines the following tables:

- The Master Guide Table (**MGT**) lists and points to all other PSIP tables present in the stream.

- The Virtual Channel Table (**VCT**) repeats the Transport Stream ID found in the PAT and lists all the virtual channels that can be found in the stream, whether they are currently active or not. Optionally it may list virtual channels found in other physical channels, including the analog channel of the station. For each virtual channel, the VCT contains the branding information and repeats some of the tuning information found in the PMT.

- The Directed Channel Change Table (**DCCT**) contains Directed Channel Change requests. Each request specifies a source virtual channel, a destination virtual channel and some switching conditions. A receiver currently tuned to the source channel switches to the destination channel provided that the conditions are met and that the viewer has enabled this function.

- The Rating Region Table (**RRT**) describes the rating system used in one or several regions in which the stream is transmitted. In the US, the rating system is standardized [4] and is understood by receivers and therefore the RRT does not need to be transmitted. Actually it is too complex to be accurately described in the RRT!

- The Directed Channel Change Selection Code Table (**DCCSCT**) may be used to add some selection codes (geographical or genres) to the predefined tables stored in the receivers.

- The System Time Table (**STT**) transmits the current UTC time and date to the receivers. It also contains some information about the current daylight savings status and the next transition.

- The Event Information Tables (**EIT**) are the main tables used for the electronic program guide. Each table contains the schedule information for a 3-hour period. The first four tables (12 hours) are mandatory.

- The Extended Text Tables (**ETT**) provide additional descriptions for the virtual channels (channel ETT) or the programs (event ETT).

WHY DO WE NEED PSIP?

Each of the 3 functions of PSIP makes a good argument for using PSIP:

- **Tuning**: some receivers do not even tune to a transport stream without PSIP. The Directed Channel Change function enables several possibilities, like multiple versions of the same ad for different geographical areas or for different categories of viewers.

- **Branding**: PSIP allows a station to name and describe its channels. And the major channel number is the analog channel number, which allows the station to capitalize on years of communication investments.

- **Program guide**: thanks to PSIP, viewers can know what is the title, start time, description of the current and future events directly on their TV set. And it also works for the analog channel. This is one of the easy benefits of converting to digital!

PSIP BUILDING BLOCKS

Several pieces of equipment may be involved in the PSIP management of a station.

PSIP Generator

The most obvious of them is the PSIP Generator, like Thales' Pearl. Its function is to gather all the necessary information in a central place and build the PSIP tables and optionally the PSI tables accordingly.

This process is dynamic because the EPG must be kept up to date. Since each EIT table contains 3 hours of schedule, one table becomes obsolete every 3 hours and must be replaced by a new one. The MGT must be updated accordingly. If the PSIP Generator is also in charge of the PMT tables and these tables contain program-dependant information like the content advisory descriptor, this can generate updates every few minutes.

It is important that the PSIP Generator be able to manage and cross-carry the information for several streams. At the very least, it must be able to generate an EPG for the station's analog channel.

Multiplexer

In a typical station, the Multiplexer receives the individual program elements from various sources (encoders, video and data servers) and combines them into a fully ATSC-compliant transport stream. Being in charge of assembling the final stream, the Multiplexer plays a central role in the PSIP management function.

The multiplexer may be a dedicated hardware unit with transport stream inputs and outputs, like Thales' Amber. But it may also be a piece of software running on an industrial PC. Thales has a patented and award-winning software multiplexing kernel called OpenMux®. This kernel provides the inherent flexibility of software solutions and is the foundation for a whole series of products ranging from a video server to an interactive data server. This makes it possible to combine the PSIP Generator with an interactive data server and an IP encapsulator on the same hardware platform.

Rebrander

A "Rebrander" is a piece of equipment dedicated to performing the operation called re-branding. It consists of customizing an ATSC transport stream by changing the Transport Stream ID, carrier frequency, major and minor channel numbers, short and long channel names and the channel descriptions. An example is Thales' Gypsum. Of course, this function is also available in the full-blown Multiplexer, Amber.

A Rebrander is useful in some centralized architectures that we discuss later in this paper.

PSIP PROBLEMS AND SOLUTIONS

It is very important that the PSIP information be accurate and coherent. Otherwise the receivers may not be able to tune to the station's signal. Even worse, this may prevent viewers from tuning to another station's signal! Although not extremely complex, the PSIP standard must be properly implemented. PSIP poses several problems for which Thales proposes practical solutions:

Sending PSIP reliably and cost-effectively

The most common way of sending PSIP is to have a software-based PSIP Generator running on a PC. A PCI card outputs an ASI transport stream to the Multiplexer. Although using a PC makes sense because of its ease of use and flexibility, this poses two problems:

First, if the PC fails, no PSIP is transmitted. And PC's are not especially reputed for their reliability. Having a redundant PSIP generator is a possible but expensive solution.

Second, an ASI link is expensive: it means having a specific PCI card in the PC and an additional input in the Multiplexer. Moreover, it means one more cable between the two pieces of equipment, which must be close to each other.

Thales has developed a solution, first used by 34 Raycom Media stations: the emission Multiplexer does not simply pass through the PSIP transport packets. It actually stores the PSIP tables in its internal memory, then carousels, packetizes and multiplexes them. This takes care of the reliability problem because the Multiplexer is a dedicated piece of hardware. Even if the PSIP Generator PC fails, the Multiplexer is still able to transmit valid PSIP for several hours. After that, the Electronic Program Guide is no longer available but the branding and tuning information is still correctly sent, guaranteeing that the signal can be received.

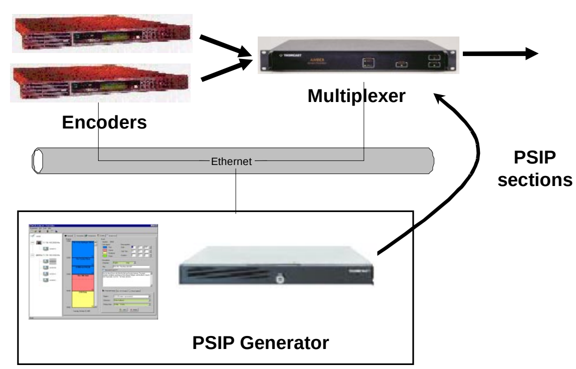

Figure 1: Ethernet PSIP link

The cost issue is addressed by replacing the dedicated ASI link between the PSIP Generator and the Multiplexer by the existing Ethernet network and exchanging table updates instead of a transport stream. During normal operation, it only requires a transmission every 3 hours, when the current time reaches the 3-hour EIT boundary. Therefore this generates minimal traffic on the network. Additionally, this reduces the requirements for the PSIP Generator to a 1U industrial PC compared to 2U when there is an ASI output.

Of course, the PSIP Generator can still have one or more ASI outputs, which can even be used at the same time as one or more Ethernet outputs.

Entering the schedule information

Some stations have to or want to enter their schedule information manually. That may be because they do not have a database with all the necessary information or because they do not have any way of communicating that information to the PSIP Generator. Even when they do, there are cases when the information needs to be manually changed, often at the last minute. It is therefore very important that the human interface of the PSIP Generator be efficient, easy to understand and flexible. It does not hurt either if it looks nice.

Given the fact that the program grid of a station is largely repetitive, from one day to the next or from one week to the next, it is nice to have the ability of defining "recurrent" events. These are events that are automatically inserted by the PSIP Generator in the schedule, following a predefined pattern like "week-days" or "every Monday". It must be easy to modify one instance, all instances or stop the recurrence after a given instance. When a new recurrent event is defined, it is important that the PSIP Generator automatically check that there is no conflict with any other event, recurrent or not.

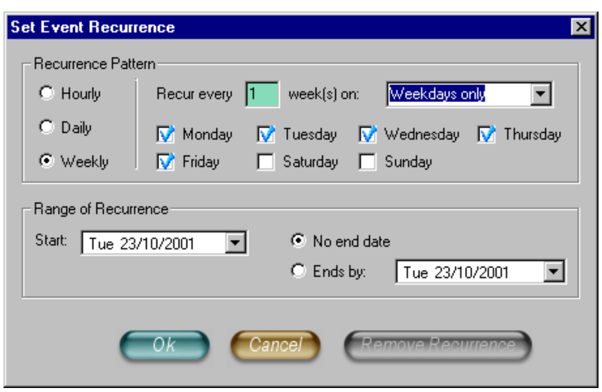

Figure 2: Recurrent events

There are cases when several virtual channels have exactly the same contents. A very frequent example is when the analog channel of a station is "simulcast" in a digital standard definition virtual channel. Another case is when a group of stations (e.g. a state network) broadcasts the same contents from several transmitters but "brands" the virtual channels differently. It would be inefficient to have to enter the same schedule information several times. To that effect, Thales provides the "linked channels" functionality in its PSIP Generator. The concept is to define the schedule once, for a master channel, and then "link" all other channels to it. Each change made to the "master" schedule is automatically performed on the "linked" channels.

Sometimes, last minute adjustments must be made to the schedule because of an event over or under-run. Very often the next events in the schedule have a fixed duration and must be shifted accordingly, up to an event that can "absorb" the duration change. This has to be done quickly, without requiring every event to be individually adjusted.

Importing the schedule information

Most of the time, the information needed by the PSIP Generator is already available in the station in various places: program management system, database, traffic system, automation system and even MPEG-2 encoding system. Each PSIP Generator vendor, including Thales, has developed several bridges to various proprietary interfaces. This is an inefficient approach and there is now a need for an open solution to interface the PSIP Generators with more data sources.

The requirements of such an interface include the ability to authenticate a data source, to make incremental changes to the PSIP information, to resolve conflicts between several sources and to be extensible to accommodate for the future revisions of the PSIP standard.

This is why Thales has developed an open interface based on the increasingly popular and extensible XML format, combined with the simple and widely used File Transfer Protocol (FTP). This interface has been successfully and very quickly implemented by Myers Information Systems in their ProTrack traffic system, as well as other vendors and customers. Indeed, this interface is so easy to implement that any station that has a proprietary database can very quickly interface it to the PSIP Generator.

However, for a program management system or traffic system manufacturer, it would not be very efficient to interface to every PSIP Generator’s proprietary format.

This is why Thales is participating in an ongoing industry effort within the ATSC Implementation Subcommittee to standardize an interface between the various systems in the station.

Scheduling the "inactive channels"

Some broadcasters want to allocate dynamically their bandwidth between a High Definition program and several Standard Definition ones. For example, during prime time, one HD and one SD programs are broadcast, and the rest of the day four or five SD programs are broadcast. Or one SD program is shut down during the night and replaced by a data service.

This means that some channels are sometimes "inactive". This is signaled with PSIP through the "hidden" flag of the VCT. When they handle that situation automatically, the PSIP Generators do it by scheduling this flag. Of course, the encoding and multiplexing system must also be reconfigured. If everything is not perfectly synchronized, or if there is a last minute change, there is a very high risk that the VCT will be inconsistent with the contents of the stream. This is likely to prevent viewers from tuning to an active channel that is declared as inactive.

The solution proposed by Thales consists of handling the "hidden" flag automatically with the Multiplexer. Indeed, since the Multiplexer is the piece of equipment in charge of building the broadcast stream, it knows exactly which programs are currently active and which are not. This information comes either from the management system or from the actual input transport streams. It is therefore very easy for it to make sure that the "inactive" channels are correctly signaled within the VCT.

Synchronizing the PSIP and PSI tables

The PAT and PMT tables provide all the necessary information for the decoder to tune to individual program components (video, audio or data). The service location descriptor in the VCT contains almost the same information. Some receivers rely on the PMT for tuning, while others rely on the VCT. Therefore, the consistency of these tables must be ensured.

In the case of locally generated programs, the PSIP Generator could ensure this by communicating with the encoders, but this means developing a protocol and upgrading all the legacy encoders. If there are some remultiplexed programs (e.g. from a network), only the remultiplexer knows all the information, through the incoming PMT's.

This is why Thales generates the service location descriptor of the VCT in the remultiplexer, using the incoming PMT's. This solution also works with legacy encoders because they all generate their own PMT. This solution has the great advantage that there is no need for an interface between the PSIP Generator and the encoders or the automation system, and is the only solution in the case of remultiplexed programs.

Computing the service location descriptor and the "hidden" flag of the VCT from the incoming PSI tables is a function that Thales calls "dynamic PSIP" in its Remultiplexer. This function is available whether the VCT comes from the PSIP Generator, a transport stream input or is generated by the Multiplexer itself.

Delaying a stream

All times contained in a stream, either in the System Time Table or in the Event Information Table are expressed in UTC time. The decoder is in charge of displaying the local time, using a time offset entered by the viewer. Therefore, the EPG of a stream sent in several time zones is always correctly displayed (except if the title of a program is "News at noon" of course!).

If a broadcaster decides to delay a stream then all the timing information becomes wrong. Correcting this in the delaying equipment is quite difficult because the EIT's must be sent in fixed 3-hour slots, the boundaries of which must be synchronized with the UTC time. It is therefore necessary to rebuild entirely the EIT's.

Thales proposes a simple solution to this problem, using the already described linked channel feature of the PSIP Generator. An optional time offset parameter allows the linked channel to be delayed from the master channel. This can be used for NVOD (Near Video On Demand) applications when multiple channels in a stream carry the same but time-shifted contents. But this can also be used to delay a complete linked stream from a master stream before broadcasting it in another time zone. The PSIP Generator feeds simultaneously the Multiplexer of the master stream and as many time delay devices as necessary.

PSIP STATION ARCHITECTURES

There are many different ways to create a digital stream and therefore many different ways to generate the corresponding PSIP. In this section we explore several real-life station architectures and show how PSIP is handled in each case.

PSIP Re-branding

The simplest architecture is when a station receives a complete and fully ATSC-compliant transport stream, including the Electronic Program Guide. It can come from the network (e.g. the PBS satellite feed) or from a central studio for a group of stations. The stream must be customized for the station to prevent tuning problems with the receivers (TSID) and to brand the stream locally (major channel number, channel name…) but the only thing that needs to be changed is the branding information.

There is no need for a PSIP Generator therefore a Rebrander like Thales' Gypsum will do the job. In many cases the station is actually an unmanned transmitter site and the reliability of the Rebrander becomes a critical factor. A dedicated hardware-based unit with redundant power supplies is a must. It must also be possible to monitor it remotely.

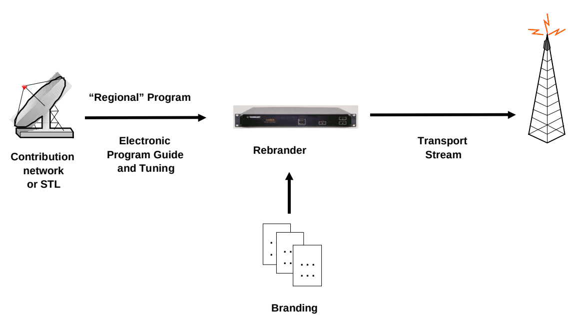

Figure 3: Re-branding architecture

Gypsum provides an additional security mechanism: in case of a failure of the main input stream it can automatically switch to a second input stream. This stream can come from a redundant link or be received off-air from a neighboring station of the same group.

If there is a need to add or drop a program, then the Amber Multiplexer can be used because it also features a re-branding mode.

Static PSIP

Many stations faced with the digital transition want to start with the simplest possible system and grow progressively. Translated to PSIP this means that they only want to send the mandatory tuning and branding information but no Electronic Program Guide. This is called "static PSIP".

No PSIP Generator is needed in this case, and some Multiplexers, including Thales' Amber, are able to send all the mandatory tables with no additional equipment. Although the PSIP tables are called "static" because they contain no Electronic Program Guide, the "dynamic PSIP" feature of Amber ensures that they are dynamically made consistent with the contents of the stream even when it changes.

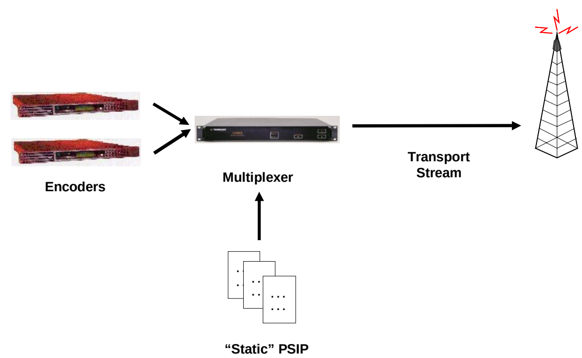

Figure 4: Static PSIP architecture

This is the low cost PSIP solution. But the good news is that it can be easily upgraded to full PSIP by simply connecting a PSIP Generator. The Multiplexer becomes then both a PSIP Injector and a backup for the PSIP Generator, leveraging the initial investment.

Manually Entered Schedule

As soon as there is a need to generate an Electronic Program Guide, the PSIP Generator becomes necessary. It injects the PSIP tables into the emission multiplexer either via an ASI link or via Ethernet, which, as we have seen, is cheaper and more reliable.

The simplest solution to feed the schedule information into the PSIP Generator is by entering it manually. Although this is not the most efficient way, features like linked channels and recurrent events make it feasible if they are properly implemented.

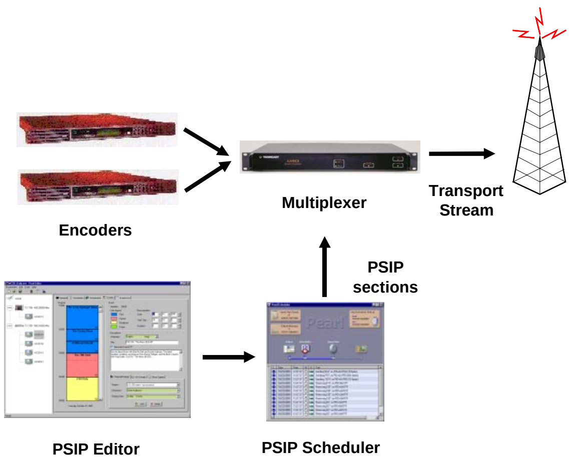

Figure 5: PSIP Generator

When used in conjunction with the "dynamic PSIP" feature of Amber, there is still the possibility of making dynamic changes to the encoding system (e.g. adding an audio channel, shutting down a virtual channel…) while automatically maintaining the consistency of the PSIP tables.

In some "CentralCasting" scenarios there may actually be a single PSIP Generator that feeds simultaneously several Multiplexers with different sets of PSIP tables.

Listing Services

The first step in automating the Electronic Program Guide is to download it from a listing service like Tribune Media Services. In exchange for an affordable monthly fee this saves the burden of entering the information manually.

The importation process takes typically place every night automatically. It requires that the PSIP Generator have an Internet connection to access the FTP server. For security reasons, it is important that this connection be on a different Ethernet port than the management network.

Of course, the information from such a listing service may not be up to date. It is therefore still very important to be able to do last minute adjustments.

Fully Automated Electronic Program Guide

Most stations already have the schedule information available in an electronic format. It may be in a program management system, a traffic system, an automation system, a proprietary database or a combination of several of them.

In this architecture, the PSIP Generator must accept the data through an open interface. In some cases it has to arbitrate conflicts between several sources. This is where the XML protocol developed by Thales is used. True interoperability between various vendors will be achieved when this protocol is augmented by a new standard protocol being developed within the ATSC.

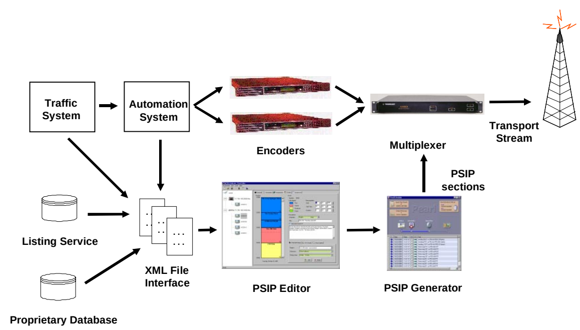

Figure 6: Automated Station

Remultiplexed Streams

Things get even more complicated when some programs are locally encoded and some are remultiplexed. If the PSIP Generator cannot import the schedule for the remultiplexed programs through another source, the remultiplexer has to combine intelligently the information that comes from the local PSIP generator and the one that comes from the remultiplexed streams.

CONCLUSION

No single solution solves every problem… From the simple re-branding case to the full-blown automated PSIP architecture, there is a wide range of complexity.

To meet the requirements of these various architectures, the products involved in PSIP management are getting more and more sophisticated, flexible and mature.

In particular PSIP involves more than a PSIP Generator. The Multiplexer is at least as important. Using a PC-based PSIP Generator tightly coupled with a hardware-based Multiplexer provides a good balance between flexibility and reliability.

Moving some intelligence into the Multiplexer guarantees the consistency of the PSIP and PSI tables without requiring complex bi-directional interfaces with various systems in the station.

What’s more, by using carefully designed and flexible products a station can seamlessly and safely grow from the simplest system to the most efficient and automated architecture.

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4 EIA-766, “U.S. Region Rating Table (RRT) and Content Advisory Descriptor for Transport of Content Advisory Information Using ATSC A/65 Program and System Information Protocol (PSIP)”, September 1998