IMPLEMENTATION OF DVB SIMULCRYPT ETSI TS103197V1.3.1 ARCHITECTURE

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ABSTRACT

An increasing number of broadcasters are finding it necessary to migrate their digital head-ends to support open standards defined by the DVB Simulcrypt Head-end Architecture. A motivating factor for this is to enable the support of multiple Set-Top-Box populations.

This paper will examine the practical issues and limitations involved in the design and implementation of a DVB Digital Head-end to deliver pay TV services, utilising system components and interfaces defined under the new ETSI TS 103197 v1.3.1 "DVB Head-end implementation of DVB Simulcrypt".

In particular we examine the function of the EIS component defined within ETSI TS103197 v1.3.1 "DVB Head-end Implementation of DVB Simulcrypt" and the information required by this component to effectively operate within a broadcast head-end. The paper highlights the limitations of the current technical specification and the practical issues this presents to the broadcaster. PSI and ECM timing issues within a Simulcrypt Head-end are examined, in relation to support of existing STB populations.

INTRODUCTION

Broadcasters are no longer able to implement complex broadcast solutions on proprietary interfaces due to costly development and lengthy deployment timescales. A definite push towards implementation of open solutions on standardised open interfaces can be seen within the industry. Broadcasters are demanding an ever-increasing level of functionality and flexibility from head-ends, and are turning to the newly defined DVB head-end architecture, as a solution to the problem of integrating complex system components.

With increasing demand to differentiate services offered to consumers, broadcasters are looking to introduce more than just traditional digital TV, with the delivery of pay-per-view (PPV) functionality, rich interactive content and PVR technologies to the home.

This paper will highlight the main issues in implementing a digital head-end solution using conditional access systems, based on the currently defined ETSI TS103197v1.3.1 Technical Specification. In particular focus will be given to the role of the EIS and the synchronisation of Program Specific Information (PSI) with scrambling state changes in a dynamic environment.

DVB HEAD END ARCHITECTURE

The DVB have defined a standard head-end architecture identifying functional components and interfaces commonly required. In order to fully understand the issues involved in implementing a solution based on the DVB Architecture, a brief explanation of the functional components and their interfaces is given below.

In the DVB-Simulcrypt system architecture, the EIS is the functional unit in charge of holding and distributing schedule information with the head-end.

It should be noted that the functionality grouped under the term EIS may be distributed over multiple platforms. The EIS will configure the compression system through the Mux Config Component and provide scrambling control through the Simulcrypt Synchroniser (SCS) with Program Specific Information (PSI) being updated by the PSI / SI Generator ((P)SIG) on receiving updates from the EIS or Mux Config.

The Mux Config component is responsible for the configuration of the compression systems and for redundancy control. The Mux Config will receive configurations from the EIS through the EIS<>Mux Config interface and activate these at the appropriate time. The Mux Config can also trigger changes in the multiplex configuration to the (P)SIG using the Mux Config<>(P)SIG interface.

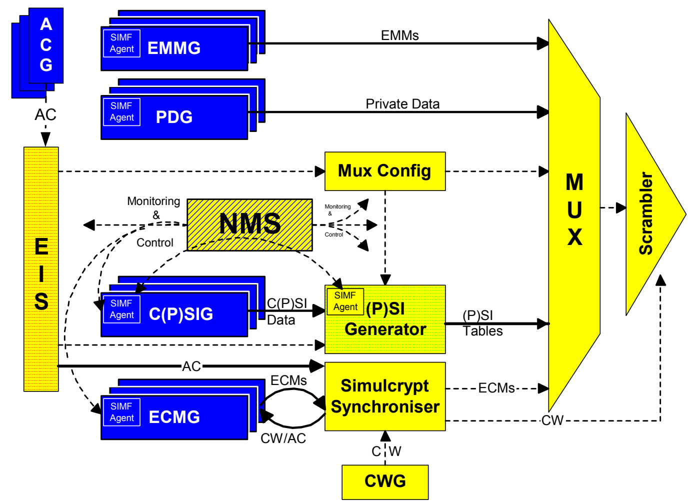

Figure 1 - SimulCrypt System Architecture

The Simulcrypt Synchroniser is responsible for obtaining the Entitlement Control Messages (ECMs) from the ECM Generator (ECMG) using the SCS<>ECMG interface. The SCS requests control words (CW) from the Control Word Generator (CWG) and is sent Access Criteria (AC) from the EIS through the EIS<>SCS interface. The Access Criteria contains information stating how the ECM should be built by the ECMG. The SCS sends the CW and AC to the ECMG and receives the ECM in return.

The (P)SIG unit represents the functionality of a Program Specific Information Generator (PSIG) and Service Information Generator (SIG). The (P)SIG will receive the necessary information from either the EIS through the EIS<>(P)SIG interface or the Mux Config through the Mux Config <>(P)SIG interface to build the PSI tables for injection into the multiplexer using the (P)SIG <>Mux interface.

The ECMG is responsible for the correct generation of ECMs on receiving the control words and access criteria from the SCS through the SCS<>ECMG interface.

The Entitlement Management Message Generator (EMMG) is responsible for generation of the EMMS and transfer to the multiplexer using the EMMG<>Mux interface.

The Private Data Generator (PDG) is responsible for the generation of Private Data (PD) and transfer of the data to the multiplexer using the PDG<>Mux interface.

In order to understand what is required from each of these components and their interfaces a brief explanation is given of the events required for an addition of a new scrambled service.

- The EIS will build and download a new Service Configuration to the MUX Config for activation at time *t* in the future. The EIS has knowledge on the capacity of each multiplex through the Mux Config and will add the service to a multiplex with available capacity.
- The EIS will generate and send a SCG provision message and ECM group message to the SCS with activation time *t*. These two messages contain all the relevant information for the SCS to scramble the service at time *t*.
- The EIS will generate the changes required to the PSI at activation time *t* and transfer this information to the PSIG, or the Mux Config will send updates to the PSIG directly. The PSIG will be required to play these out prior to activation time *t*, to allow the STB time to locate the ECM, and for the smart card to generate the control word ready to descramble the service.
- The EIS will inform the Service Information Generator (SIG) of the new service with activation time *t*. The SIG will build and transfer the SI to the multiplexer for insertion into the transport stream at time *t*.
- The SCS will open a Channel if one does not already exist with the ECMG, and set-up a new stream for the transfer of the ECM in advance of time *t*. The SCS will provide the CW generated by the CWG, and AC provided by the EIS, to the ECMG for generation of the ECM stream.
- The SCS will inject the ECM stream into the multiplex relative to the scrambling of the elementary streams within the CWG (Control Word Group) constituting the service or services. The off set value used for the injection of the ECM streams (transition delay start) is provided by the ECMG during channel set-up. The availability of the transition delay start is dependent on the functionality of conditional access system, as it is an optional parameter within the specification.
- The SCS will scramble the service at time *t*.
- The EMMG will transfer EMMs to the multiplexer for injection into the transport stream using the EMMG<>Mux interface. If the new service requires a new entitlement to the smart card population this must be distributed in advance of time *t*.

In detailing the stages to scramble a service it should be noted the all the components within the head-end should be synchronised to a single time source. All system components should be synchronised to a common time source, such as UTC. This does not preclude schedules being entered using local time.

Now that we have set the expectation of the components and their interfaces we can examine the practical limitations of the current standard and the defined interfaces.

THE MISSING INTERFACES

In summary, the following interfaces are required for a fully functional system.

EIS<>Mux Config, allows configuration of the multiplex with the service line-up.

EIS<>SCS, allows the EIS to control scrambling of the services.

EIS<>PSIG, allows the EIS to communicate the PSI required in the transport stream.

Mux Config<>(P)SIG, enables the Mux Config to communicate changes in PSI.

SCS<>ECMG, transfer of ECMs from the ECMG on receiving CW and AC.

EMMG<>Mux, transfer of EMMs to the multiplexer.

ACG<>EIS, provision of Access Criteria from multiple CAS to the EIS.

PDG<>Mux, transfer of PD to the multiplexer.

The EIS<>Mux Config, EIS<>(P)SIG, Mux Config<>(P)SIG and ACG<>EIS interfaces are currently undefined in the standard.

A brief explanation of the missing interfaces is given.

EIS<>Mux Config

The interface between the EIS and Mux Config is currently undefined. This isolates the EIS from the compression system and restricts the EIS to only being able to provide scrambling control. In not defining the EIS<>Mux Config interface the EIS is unable to control the configuration of the compression system. This means that the EIS cannot schedule service line-up changes and define or allocate PIDs that should be used for the service line-up. Therefore manual synchronisation is required between the EIS and Mux Config for the service plan and PID definitions.

EIS<>(P)SIG

In not defining the EIS<>(P)SIG interface the EIS can not communicate PSI or SI changes to the (P)SIG. This means that any changes to the service line-up and or scrambling state requires a manual synchronisation of the PSI/SI on the (P)SIG. Therefore it is not possible to implement service map or scrambling state changes, without manual synchronisation of the Mux Config and PSIG as well. This has forced EIS providers to develop a PSIG integrated with the EIS using proprietary interfaces.

Mux Config<>(P)SIG

The Mux Config<>(P)SIG interface allows the Mux Config to communicate PSI/SI changes to the (P)SIG. The Mux Config needs to inform the (P)SIG of changes in the transport stream. e.g. when a redundant multiplexer becomes active for a particular transport stream the PSIG will have to load the correct PSI/SI to the new multiplexer unit. This interface is not required if the EIS<>Mux Config interface is present. In summary if this interface is not defined then the EIS must generate the PSI to maintain synchronisation within the system.

ACG<>EIS

The ACG interface allows each Conditional Access System (CAS) to provision the EIS with Access Criteria dynamically as required. This removes the need to manually enter access criteria into the EIS for each conditional access system per new event type.

Practically the main problems caused by the lack of definition of these interfaces are:-

(a) Synchronisation of the Program Specific Information PSI, with service changes.

(b) Entering Access Criteria per an event requires input of access criteria into the EIS, or the EIS being able to generate the Access Criteria automatically.

PRACTICAL ARCHITECURES

Now that we have highlighted the missing interfaces and the effect this has on a head-end we can redefine the practical architectures possible. In identifying the main issues it can be clearly seen that the location of the PSIG is critical in the head-end solution.

This can be seen in Figure 2, which shows the EIS isolated within the current architecture and only able to configure the SCS for scrambling control.

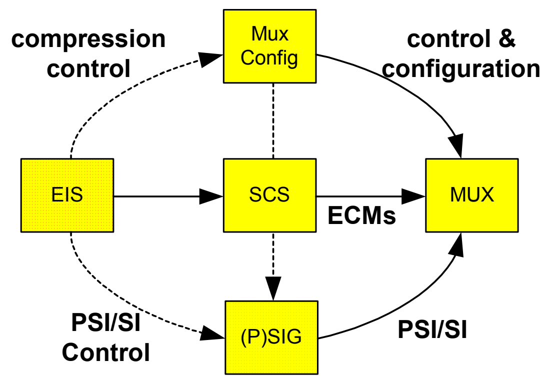

Figure 2 - Component Interactions

Reasons for PSIG Alignment

The PSIG is responsible for generating the PSI. To correctly build the PSI, knowledge of the transport stream and any specific conditional access information is required.

One natural alignment comes from the need to build the PSI to reference the elementary streams contained within the transport stream known by the Mux Config, and another from the requirement to add conditional access descriptors and any proprietary conditional access information, known only by the conditional access provider.

Therefore only two possible architectures are viable.

(a) Combined Mux Config with PSIG with manual intervention on scrambling state changes, or

(b) Combined EIS with PSIG with a static service plan line-up.

Combined Mux Config Solution

The Mux Config is responsible for configuration of the transport stream. The compression vendor will provide the Mux Config component, which is directly related to the compression hardware and its supported features. Most Mux Config systems are configured locally while some have proprietary interfaces allowing remote configuration and management.

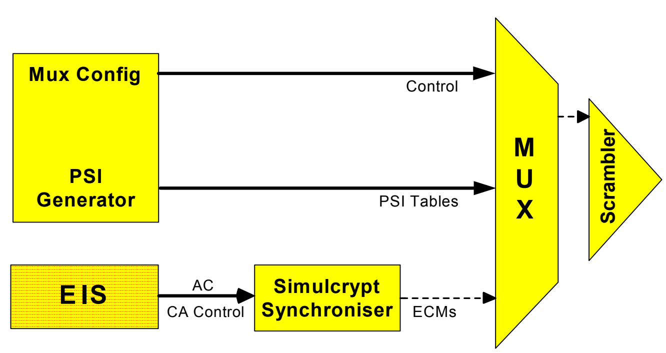

Figure 3 - Mux Config Solution

Many compression vendors provide basic EIS functionality within their compression control solutions. In order to implement a system capable of scrambling with DVB compliant conditional access systems, compression vendors were obliged to implement a means of provisioning access criteria to the Simulcrypt

Synchroniser, since this was not defined in the initial ETSI TS103197 standard.

Compression vendors will usually have solutions for the Mux Config, PSIG, SCS, Scrambler and Multiplexing component. Often the Multiplexer will contain the scrambler and potentially a SCS and CWG although these might be separate units.

The PSIG functionality has been historically embedded into the Mux Config system provided by the compression vendors. Most compression system controllers provide generation of PSI since any compliant MPEG-2 transport stream requires a standard level of PSI to be present. This requires that Mux Config providers understand how to add CA specific descriptors into the PSI for scrambled services until the EIS<>PSIG interface has been standardised.

In practice then, a functional unit combining Mux Config and PSIG functionality must also include aspects of the EIS, in order to maintain synchronisation of scrambling control changes with PSI changes, on scrambling transitions.

Combined EIS Solution

The EIS is the central component responsible for scheduling configuration updates to all downstream head-end components.

In practice compression vendors and conditional access vendors have solutions providing EIS functionality, although an EIS aligned with the Conditional Access system is generally preferable since this removes the requirement for the Conditional Access providers to pass confidential information on the AC generation to the EIS provider.

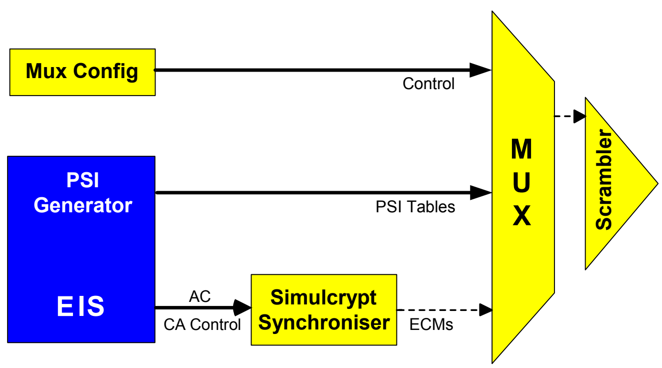

Figure 4 - EIS Solution

The advantage in a single supplier providing the EIS and PSIG is the provision of a proprietary interface between the functional components for synchronisation of PSI when scheduling scrambling changes.

The disadvantage in this architecture is that careful operational checks need to be put in place to avoid misalignment of the service map on the Mux Config and EIS components. A mismatch here will result in un-referenced PID's or 'apparently' missing PID's in the output transport stream. Fortunately many broadcasters have semi-static service line up so it is possible to manage this limitation of the system, by the use of careful operational procedures.

In having the EIS and PSIG integrated, dynamic conditional access functionality is provided, this in turn allows for revenue generating pay-per-view services to be delivered.

IMPLEMENTATION PRACTICALITIES

The following practical issues must be taken into consideration when implementing a system.

(a) System Synchronisation

(b) EMMG/PDG Configuration

System Synchronisation and Timing Issues

Synchronisation within a head-end must be maintained between all system components running on schedules or required to perform tasks to an activation time. In particular the EIS, PSIG, Mux Config, ECMG, EMMG and Multiplexer should be synchronised. The synchronisation of these units is fundamental to the compliance of the transport stream and correct operation of the STB.

Time Synchronisation

A point which is often over looked when designing and implementing a system is time synchronising of the different functional process running within the head-end. All system components should be running from a single clock source. Co-ordinated Universal Time is recommended with head-ends for time synchronisation since this is not affected by seasonal time changes.

Correct Timing Sequence of Events

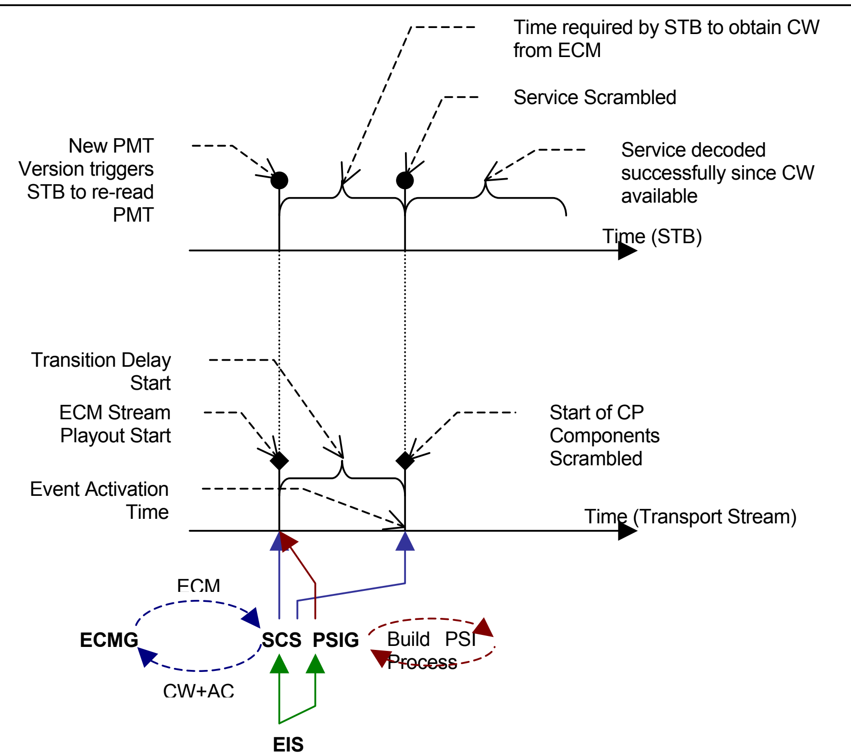

Figure 5 - Correct Transition Timing

In Figure 5 the correct sequence of actions prior to scrambling can be seen. The EIS will send a SCG_provision message to the SCS with an activation time in the future, the SCS inserts the ECM stream into the transport stream prior to the scrambling change. The delay between the insertion of the ECM stream and the scrambling of the elementary streams is defined by the parameter transition_delay_start defined within the DVB Standard and is configurable on most CA vendor ECMG units, although it is an optional parameter.

To enable the STB to decode the service, the PMT version must be updated, and available to the STB. The STB then reads the new PMT for the service, to obtain the ECM PID. The ECM must also have been inserted into the transport stream sufficiently in advance of the start of scrambling to enable the STB to obtain the CW.

Incorrect PSI and Scrambling Synchronisation

The PSI must be synchronised to reflect the state of the transport stream, since a mismatch will result in service disruption. The affect on a STB can vary dramatically from a minor service disruption to a complete lack of service availability. Figure 6 shows an example of incorrect PSI timing. The cause of this could be that the PSIG is not synchronised with the rest of the system. The result would be an interruption to service for one CP.

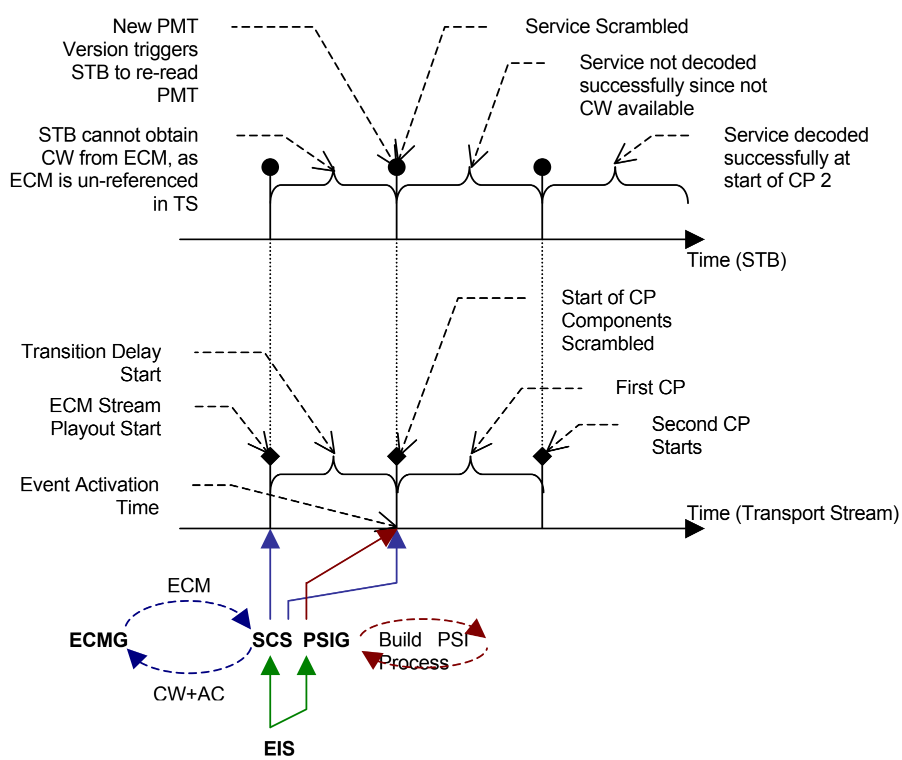

Figure 6 - Incorrect Transition Timing

This timing sequence is incorrect for the reason that the PSIG signals the ECM in the stream at the time the service is scrambled, not allowing the STB enough time to find the ECM and generate the CW. The transition_delay_start parameter is not taken into account.

Incorrect ECM Transition timing parameters

Figure 7 details the scenario where the value of the transition_delay_start parameter is badly configured. The affect of not adjusting the timing parameter values sent to the SCS at channel establishment, is that the STB may have insufficient time to produce the control word, ready for de-scrambling. This would result in a period where the service is unavailable.

Adjustment of the timing parameters, should take into account the requirements of the entire STB population, and be done for every conditional access system used within the head-end.

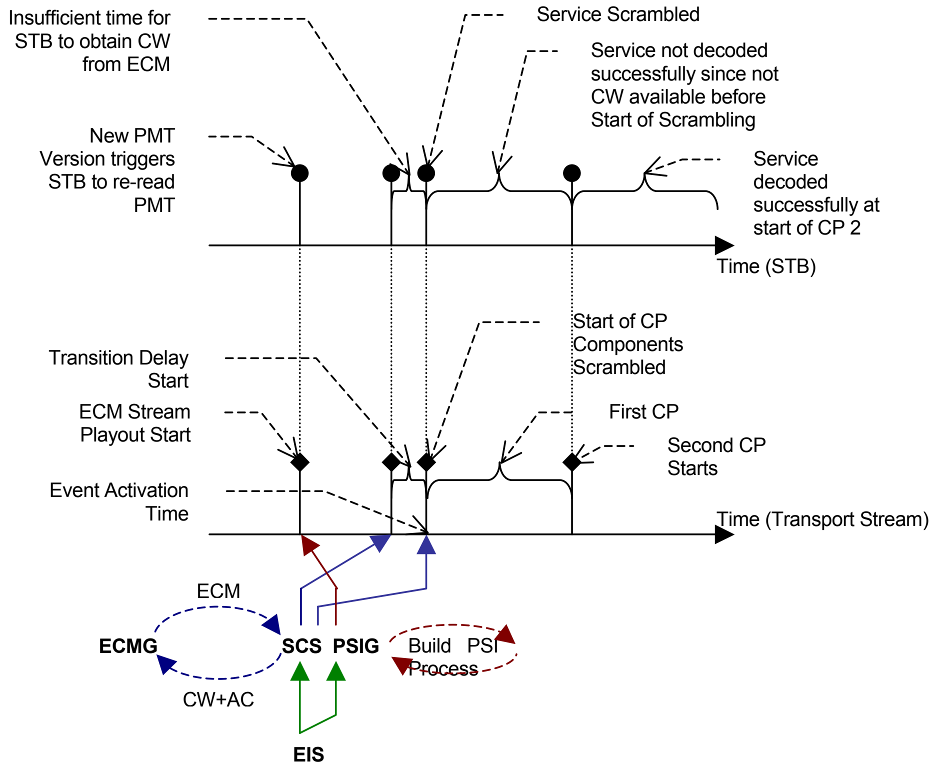

Figure 7 - Incorrect Transition Timing

EMMG/PDG Configuration and Delivery

The multiplexer must perform two major tasks in handling EMM and Private Data (PD) connections. The incoming datagrams must be allocated a PID within the outgoing transport stream and formatted into MPEG-2 packets. This raises two important implementation issues, how shall the compression system allocate an EMM stream to a PID and how should the datagrams be packetised, if they are delivered in section format by the EMMG/PDG.

A dynamic solution is not possible since the PSIG must be informed of the allocation of the PID values, which is not possible without the Mux Config<>PSIG interface. Therefore EMM and PD streams must be pre-allocated PID values so that the PSIG can correctly build the PMT and CAT tables.

One method of mapping an EMM/PD stream to a PID would be to link the PID to the client_id/channel_id/stream_id combination since this is unique within a head-end.

However this raises the issues with respect to the interpretation of the uniqueness of client_id / channel_id / stream_id combinations within head ends with redundant EMMG's, PDG's and multiplexers. See the section on operational behaviour for more details.

The EMM and PD traffic is bursty in nature and the component bit rates may vary over time. However the Mux Config component is responsible for the bandwidth management of the transport stream. Therefore a maximum value must be set for the EMM and PD component bit rate. If this maximum value is exceeded then the stream should be disconnected, in order to protect the output transport stream from going over rate.

OPERATIONAL BEHAVIOUR

The standard defines the structure of the interfaces and the functionality provided, the actual implementation of the interfaces is left to vendors interpretation. This creates various implementations of the same interface, which result in operational restrictions during integration. Broadcasters cannot simply pick-n-mix components based on compliance to the technical specification but must actually ensure interoperability between the selected vendors equipment based the functionality desired.

In particular redundancy handling should be carefully examined during system design for the following components:

(a) EMMG,

(b) ECMG and SCS,

(c) EIS.

EMMG Connections and Redundancy Handling

The first area where the differing interpretations of the specification can lead to confusion is on the EMMG interfaces.

The redundancy handling on EMMG units is the responsibility of the CA vendor. Some vendors have made one or both of the following assumptions, that make implementation within the head-end of combined multiplexer and EMMG redundancy complicated to set-up.

- Each EMMG unit/process regardless of being within a redundant pair will have a unique client ID.
- Each Client ID /Channel ID combination may only connect to one physical multiplexer IP address.

Assuming the following system requirements, where the head-end contains 1+1 EMMG redundancy, the Mux Config is controlling 1+1 multiplexer redundancy, and where only one EMM component is required. The EMM stream should be provided by the setup of only one stream within the EMMG <> Mux interface. However due to interpretation of the technical specification a total of 4 unique client ID combinations may have to be defined to support a single EMM stream, given the redundancy possibilities.

In this example the first multiplexer must have two connections defined one from each of the unique client ID's allocated to the main and standby EMMG functional components. Given that the second multiplexer has a unique IP address, two more connections must be defined on the second mux also with unique client ID's.

This case is an example were the conditional access vendor has assumed that each EMMG unit will have a unique client_id regardless of being a redundant pair and that each connection to a multiplexer will have a unique client_id and channel_id.

This when combined with functionality such as data transfer by TCP or UDP, can impact on the network link capacity requirements, between the EMMG and multiplexer, particularly if UDP transfer is not available.

ECMG and SCS Redundancy

Two factors are important to bear in mind with respect to the ECMG and handling of multiplexer redundancy and ECM's, in order to reduce the outage time on redundancy switching.

(a) What should an SCS do on loss of communication to the ECMG unit/s?

(b) How to handle m+n multiplexer and SCS redundency.

Firstly the SCS should always extend the CP if communication is lost with an ECMG unit. This ensures that although no new ECM's can be received, that the output of the system remains scrambled and the service remains viewable. As soon as communication to all associated ECMG units is re-established, a new CP will begin and the CW's will start to cycle from odd to even.

Secondly, the question is raised on how to handle multiplexer redundancy whilst minimising the effect on the STB. The SCS can be implemented on the multiplexer or as a standalone unit. Assuming the SCS is implemented on the multiplexer, there is no defined method of handling CW and ECM synchronisation between main and redundant multiplexers within the head-end, in the eventuality of a multiplexer redundancy switch. Some compression system vendors have proprietary interface between multiplexers to handle this in a 1+1 mux redundant architecture, which result in no interruption to service on switch over.

However within an m+n multiplexer redundant scheme, some outage is inevitable, because the spare multiplexer cannot pre-provision ECM's for all other head-end multiplexers, and may only set-up the connection to the ECMG once it has become a online mux. The effect on the transport stream and services will be a period of clear output, plus an outage in the region of 1 CP whilst the STB generates the new CW from the new ECM.

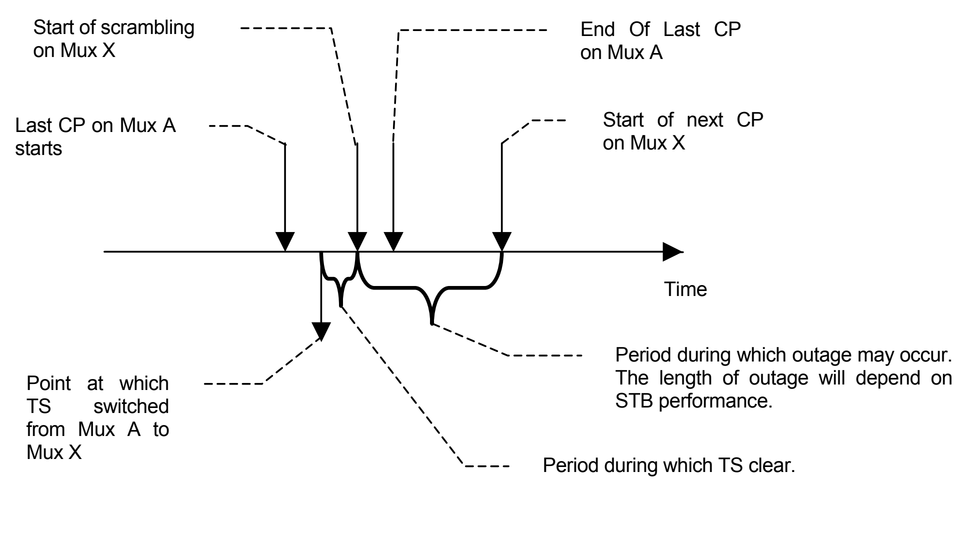

Figure 8 - Service outage on TS redundancy switch

EIS Redundancy

Broadcasters wishing to implement a system based on the DVB head-end architecture should also carefully examine other aspects of head-end redundancy, as the current specification does not give clear guideline for redundancy switching schemes of critical head-end components.

For example, the transport stream integrity should be maintained in the eventuality of an EIS channel closure to the SCS, or a redundancy switch of the EIS component. In closing the EIS<>SCS channel the SCS should not close the streams associated to that channel down, as this would stop scrambling. Operational behaviour in the event of errors or un-expected operation is not detailed within the technical specification.

SUMMARY

In summary we can see that implementing a head-end solution based on the DVB Architecture requires careful implementation and consideration in using the interfaces and components defined. It is not simple matter of picking different components from different vendors and bolting then together to form a working solution.

It should be noted that although some interfaces are currently un-defined in the standard, that the DVB are actively working on defining these interfaces to close the gaps in the architecture and that implementing a system based on the DVB solution allows the Broadcaster the flexibility to alter compression vendor and/or conditional access vendor at a later date.

It should also be noted that implementing a system based on these interfaces is typically quicker than using proprietary bespoke interfaces between each combination of conditional access and compression vendor.