PSI & SI

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Agenda

- Transport streams
  - packets, sections, tables, PES, demux
- DVB SimulCrypt
  - architecture, synchronization, ECM, EMM, scrambling
- Standards
  - MPEG, DVB, others

Transport streams

packets and packetization

Standard key terms

- Service / Program
  - DVB term : service
  - MPEG term : program
  - TV channel (video and / or audio)
  - data service (software download, application data)
- Signalization
  - set of data structures in a transport stream
  - describes the structure of transport streams and services

- Transport stream
- « TS », « multiplex », « transponder »
- continuous bitstream
- modulated and transmitted using one given frequency
- aggregate several services

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MPEG-2 transport stream

- Structure of MPEG-2 TS defined in ISO/IEC 13818-1
- One operator uses several TS
- TS = synchronous stream of 188-byte TS packets
  - 4-byte header
  - optional « adaptation field », a kind of extended header
  - payload, up to 184 bytes

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MPEG-2 transport stream

- Multiplex of up to 8192 independent elementary streams (ES)
  - each ES is identified by a Packet Identifier (PID)
  - each TS packet belongs to a PID, 13-bit PID in packet header
  - smooth muxing is complex, demuxing is trivial
- Two types of ES content
  - PES(Packetized Elementary Stream) : audio, video, subtitles, teletext
  - sections : data structures

MPEG-2 Transport Stream

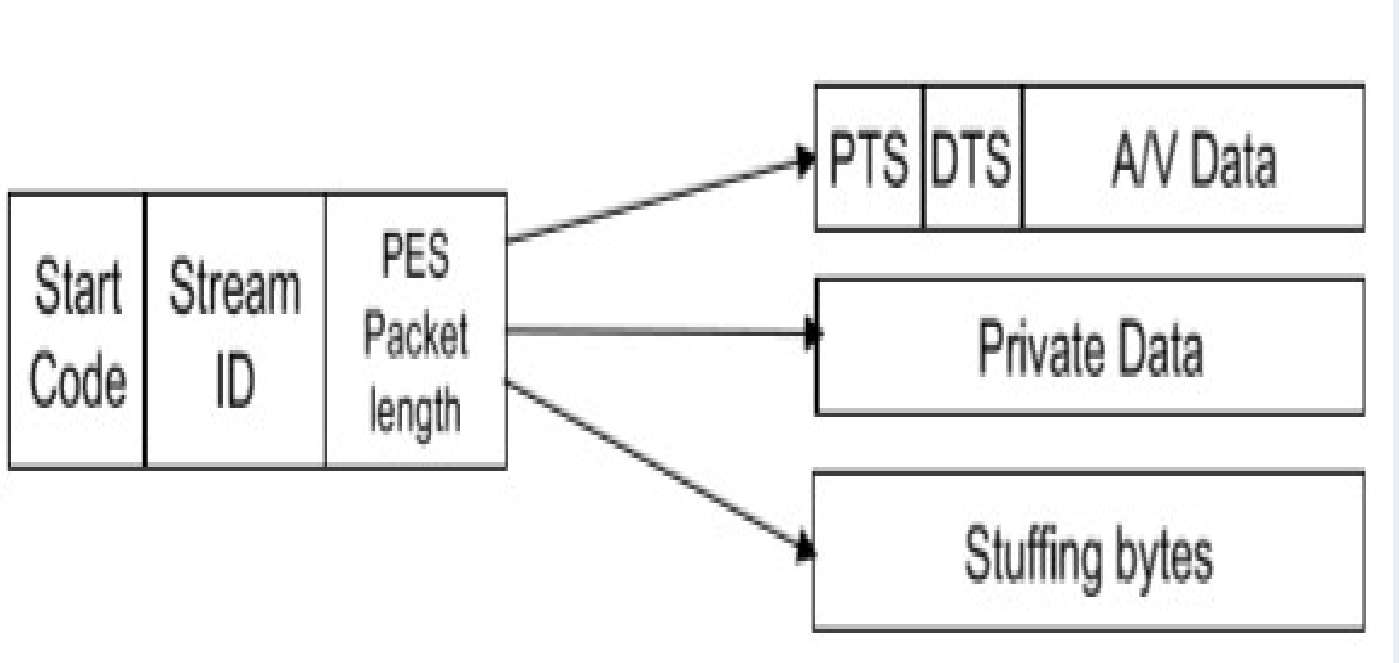
- MPEG-2 TS = multiplexing format
- For several TV channels
  - N * (Video + Audio(s) + Data) with different time bases
- Special Case: one program
  - Single Program Transport Stream (SPTS)

1 transport stream = sequence of transport packets

- Fixed size (188 bytes)
  - Helps integration with error correction tools
- Detection of data packet starts
- Synchronization after packet loss

MPEG-2 Transport Stream

- Two ways of transporting data
- Sections: meta data, EPG, etc…
  - Carousel
- PES Packets: audio, video
  - PTS+DTS, Clock
  - RAP, Size



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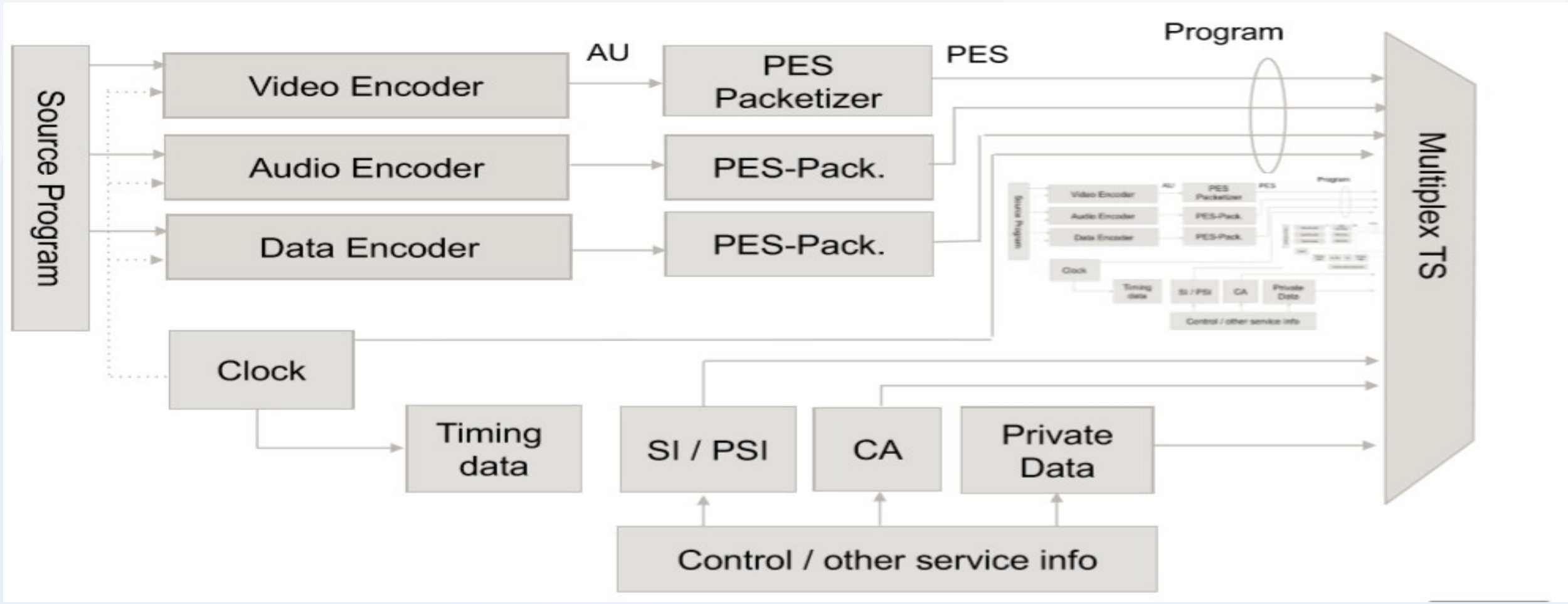
MPEG-2 Transport Stream



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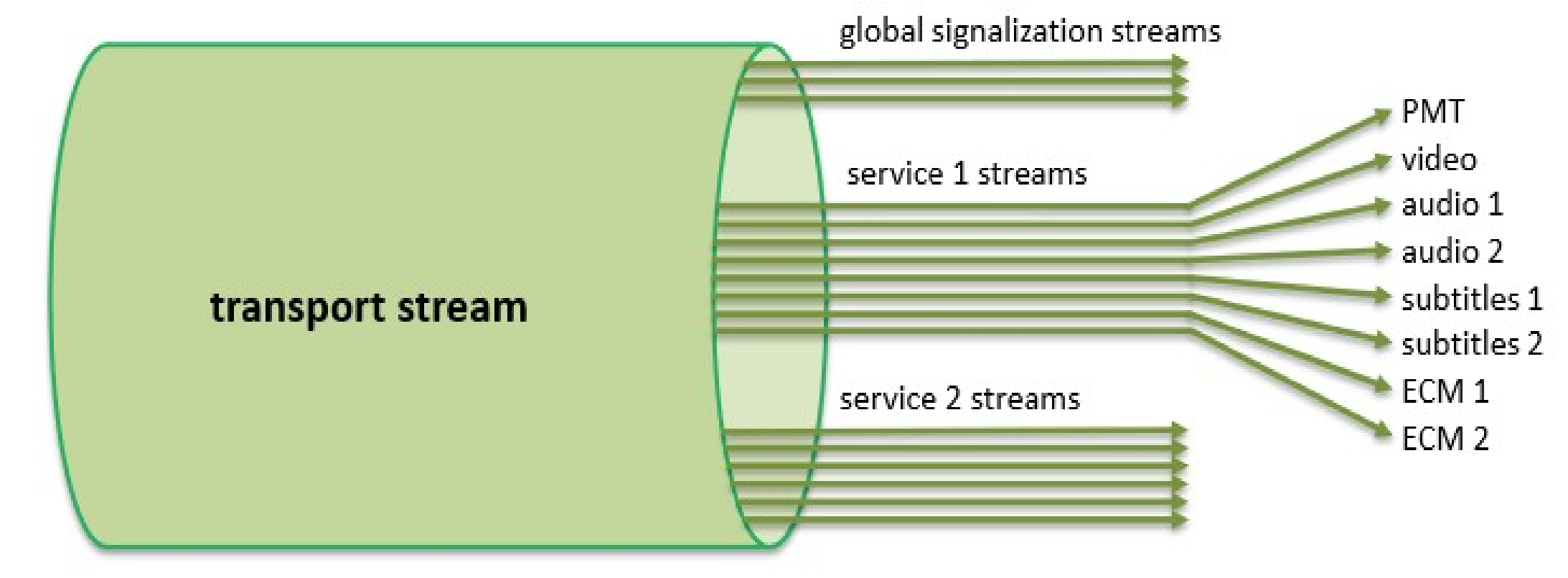
Multiplex of elementary streams

- Two types of ES content
  - PES, Packetized Elementary Stream : audio, video, subtitles, teletext
  - sections : data structures
- A transport stream is a multiplex of elementary streams
- elementary stream = sequence of TS packets with same PID value in header
- one set of elementary streams for global signalization
- describe the TS, the network, the operator, the services, the events, EMM's, etc.
- one set of elementary streams per service
  - a service is typically a TV channel

Multiplex of elementary streams



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TS packet

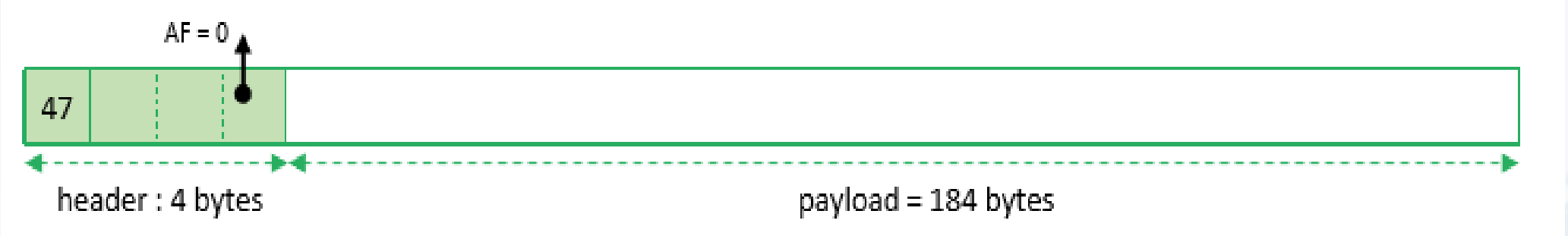
4-byte header includes :

- Sync byte = 0x47
- PID : 13 bits
- Continuity counter : 4 bits
- Payload Unit Start Indicator (PUSI) : 1 bit
- Transport scrambling control : 2 bits
- Adaptation field presence : 1 bit
- Payload presence : 1 bit

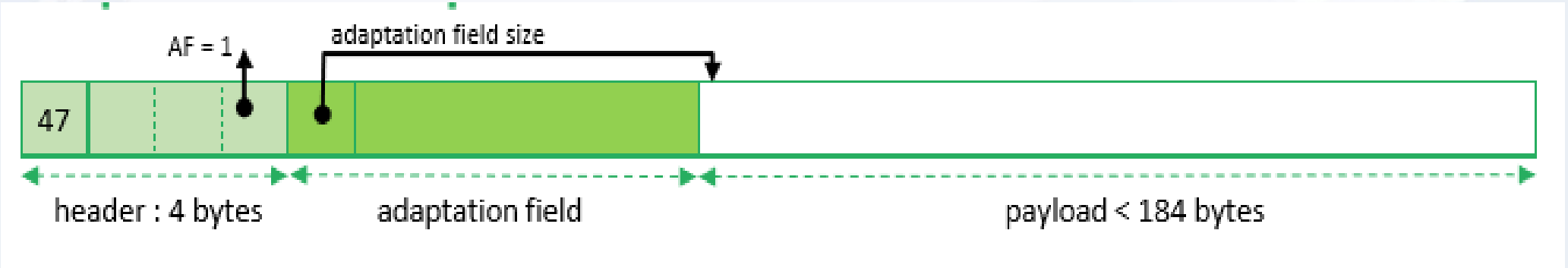
- Adaptation field may include :
- Program Clock Reference (PCR / OPCR)
- Private data
- Stuffing

(for PES stream padding)

- TS packet without adaptation field



- TS packet with adaptation field



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Multiplexing and demultiplexing

- Elementary stream = concatenation of all payloads of all TS packets with same PID
- Elementary stream transport
- packetization = cutting ES into packets payloads with same PID
    - setting Payload Unit Start Indicator (PUSI) in TS header on « unit » boundary
- multiplexing = mixing with packets from other PID's to build a complete TS
- demultiplexing = extracting all packets with same PID from TS
- depacketization = rebuilding ES from packets payloads with same PID
- using PUSI to resynchronize on « unit » boundary

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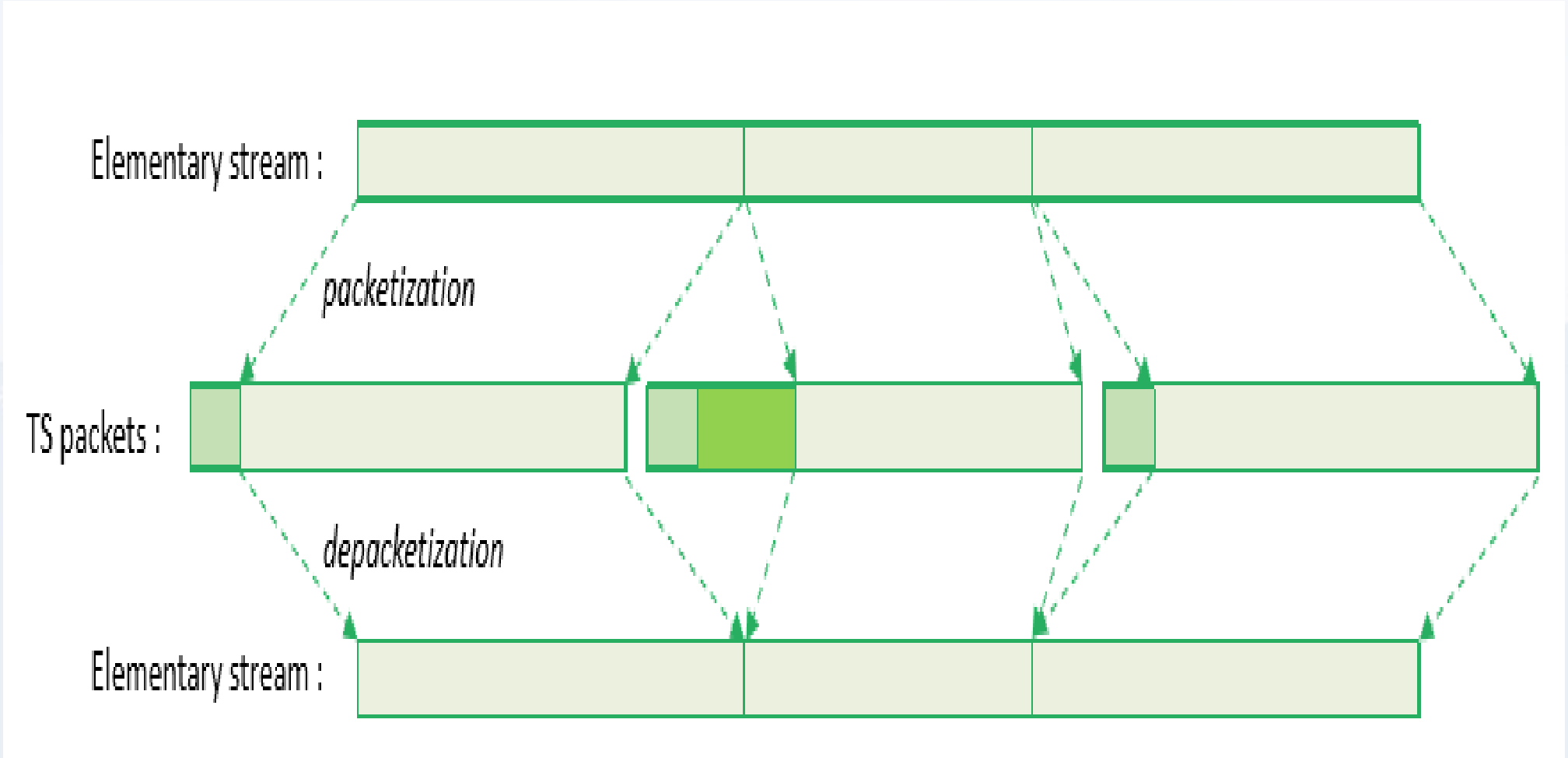
Elementary stream :
packetization
TS packets :
depacketization
Elementary stream :

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Packetized Elementary Stream (PES)

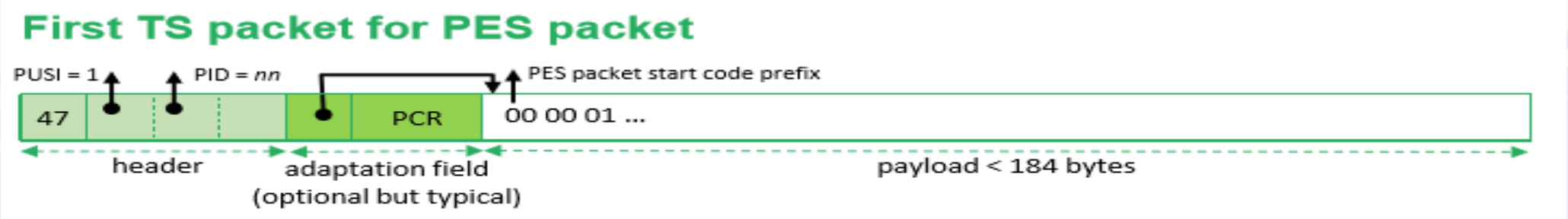
- A stream of PES packets
  - up to 65536 bytes per PES packet
  - start of PES packet identified by PUSI bit in TS header
- PES packets can contain
  - video : MPEG-2 (H.262), AVC (H.264), HEVC (H.265), etc.
  - audio : MPEG-2 Layer 2, AAC, HE-AAC, AC-3, DTS, DTS-HD, etc.
  - DVB subtitles (text or bitmap)
  - teletext (deprecated but still used)

Packetized Elementary Stream (PES)

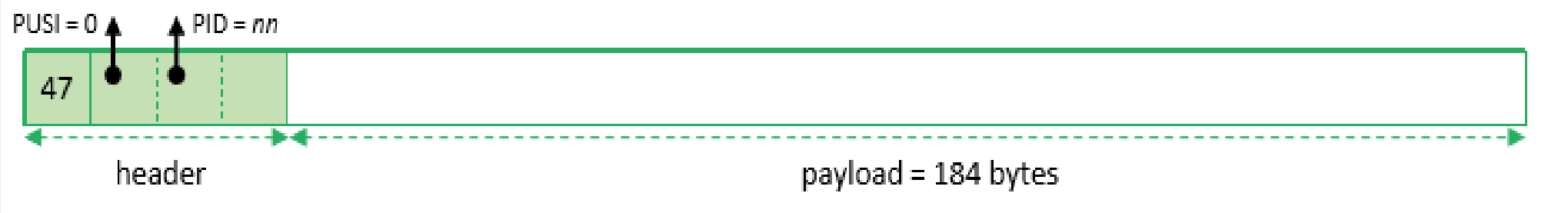
- One elementary stream contains one single type of content
  - video
  - audio for one language (with or without « audio description »)
  - multi-channel audio (stereo, 5+1, etc.) within same PID
  - subtitles for one language (with or without « for hard of hearing »)
  - exception : one teletext stream is a multiplex of several text streams (« pages »)

Typical PES packetization

- First TS packet for PES packet



As many intermediate TS packets as required for current PES packet
(multiplexed with TS packets from others PID's)



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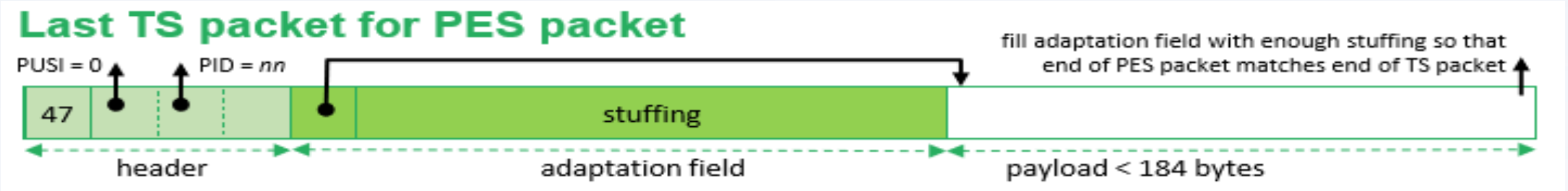

PES streams robustness

TS packet loss is tolerated in audio and video streams

- video « macro-block » effect
- audio « glitch » effect
- quality of recovery based on decoder implementation

TS packet loss detection based on continuity_counter

- 4-bit field in TS packet header
- cannot detect loss of an exact multiple of 16 TS packets
- resynchronization on next TS packet with PUSI

But video / audio decoders can resynchronize within PES packet

- video / audio bitstream formats usually contain synchronization patterns
- example : NAL unit boundary in AVC encoding

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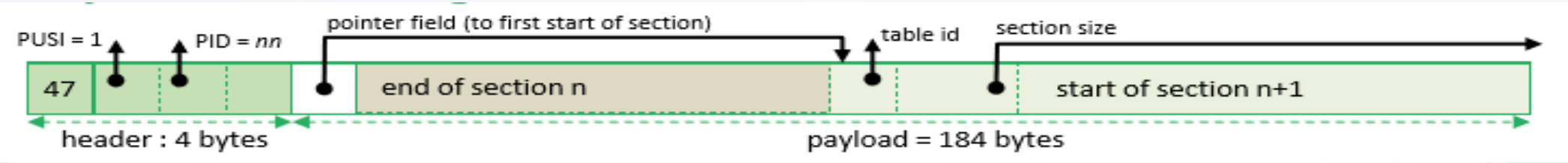
Sections streams

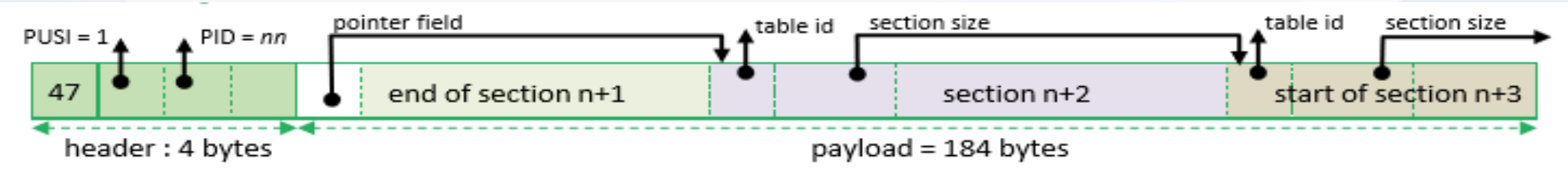
- Contain data structures named « tables »
- A table is split into one or more « sections »
    - section = smallest data unit, up to 4096 bytes
    - standard header and type-specific payload
    - table type identified by table_id in header
    - two types of section syntax : « short » and « long »
    - based on 1 bit in header
- Each type of table defines its own syntax
    - use long or short sections
    - payload bitstream syntax

Typical section packetization

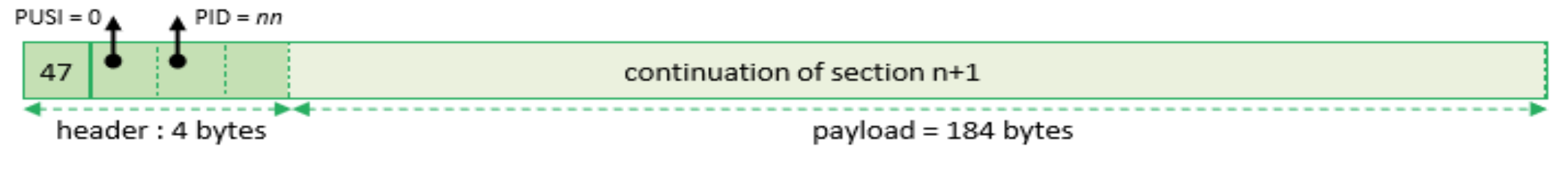
- TS packet containing the start of section n+1



- As many intermediate TS packets as required for section n+1 (multiplexed with TS packets from others PID's)



- Last TS packet for section n+1, start of next section



Tables with short section

- One section per table
    - section and table are equivalent
- Each table brings new information
    - CAS EMM / ECM
    - date and time information (TDT / TOT)
- No standard integrity check
    - except section length in section header
    - some table-specific mechanisms
    - cryptographic integrity in EMM / ECM
    - CRC32 in TOT

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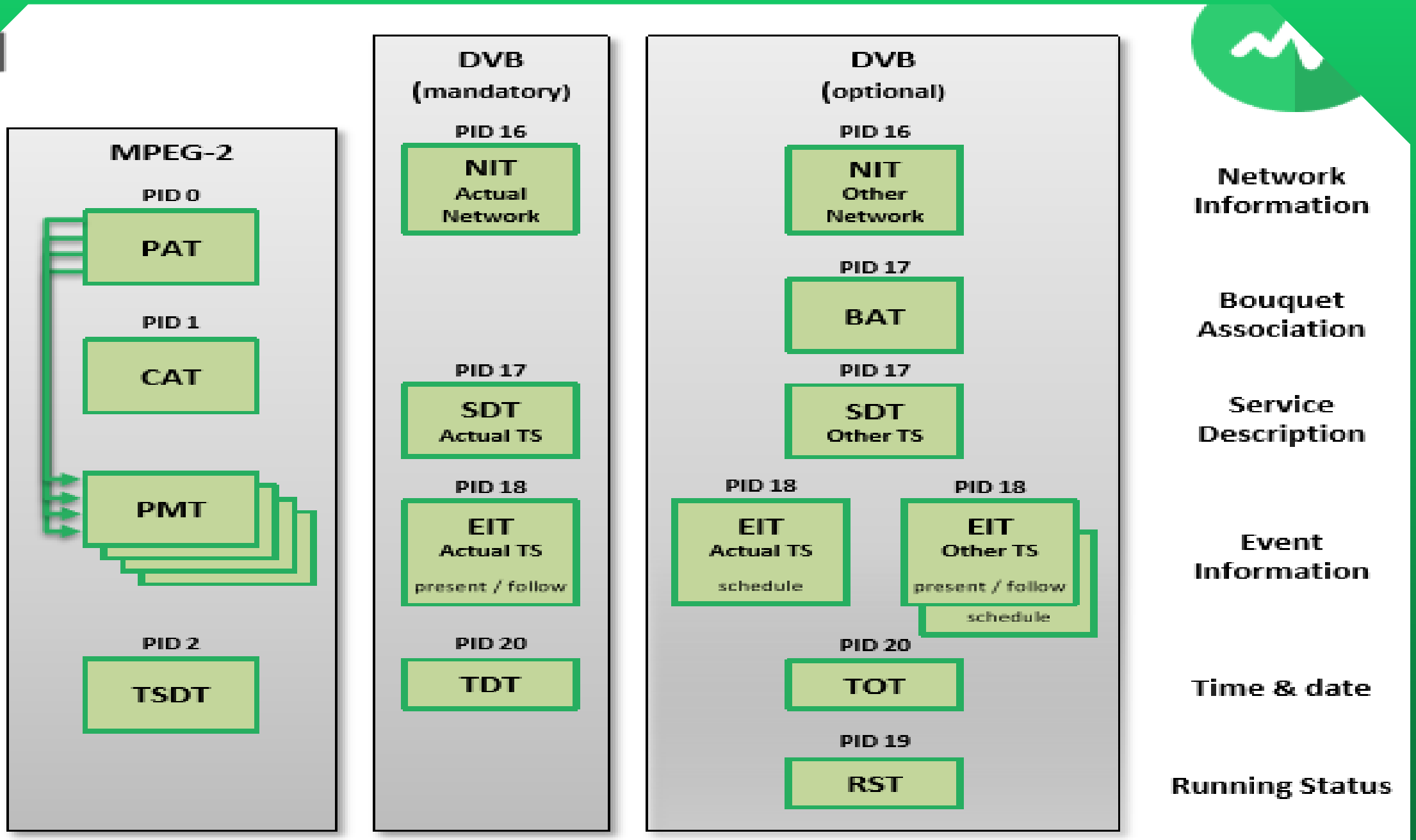
Tables with long sections

- Up to 256 sections per table
    - need to receive all sections to rebuild the complete table
- Same table repeatedly cycled
- Content change notification
    - version number in long section header
    - each table is repeatedly broadcast with same version number
    - version number changes when table content changes
    - STB software sets demux filters to be notified of new tables only
- Integrity check
    - CRC32 in each section
    - section rejected in case of corruption, can be detected at demux level
    - resynchronization on next TS packet with PUSI

Descriptor

- standard substructure with standard header and type-specific payload
- most tables use generic « lists of descriptors »

- Signalization: PSI / SI
  - PSI : Program Specific Info.
  - MPEG-defined
  - ISO / IEC 13818-1
  - TS structure: PAT, PMT
  - CA : CAT
- SI : Service Information
  - DVB-defined
  - ETSI EN 300 468
  - private sections in MPEG terms


MPEG-2
PID 0
PAT
PID 1
CAT
PMT
PID 2
TSDT
DVB
(mandatory)
PID 16
NIT
Actual
Network
PID 17
SDT
Actual TS
PID 18
EIT
Actual TS
present / follow
PID 20
TDT
DVB
(optional)
PID 16
NIT
Other
Network
PID 17
BAT
PID 17
SDT
Other TS
PID 18
EIT
Actual TS
schedule
PID 18
EIT
Other TS
present / follow
schedule
PID 20
TOT
PID 19
RST
Network Information
Bouquet Association
Service Description
Event Information
Time & date
Running Status

PSI-SI introduction

- PSI & SI – what are they ?

Program Specific Information (PSI)

- Defined in the MPEG-2 systems specifications
- Provide information required to decrypt and display chosen event
- PAT, PMT and CAT are three main tables in PSI

Service Information (SI)

- Information on available services
- Frequencies which carry these services
- Common interest categories/groups for these services
- Events in a service
- Network details of service help manage revenue flow to service providers

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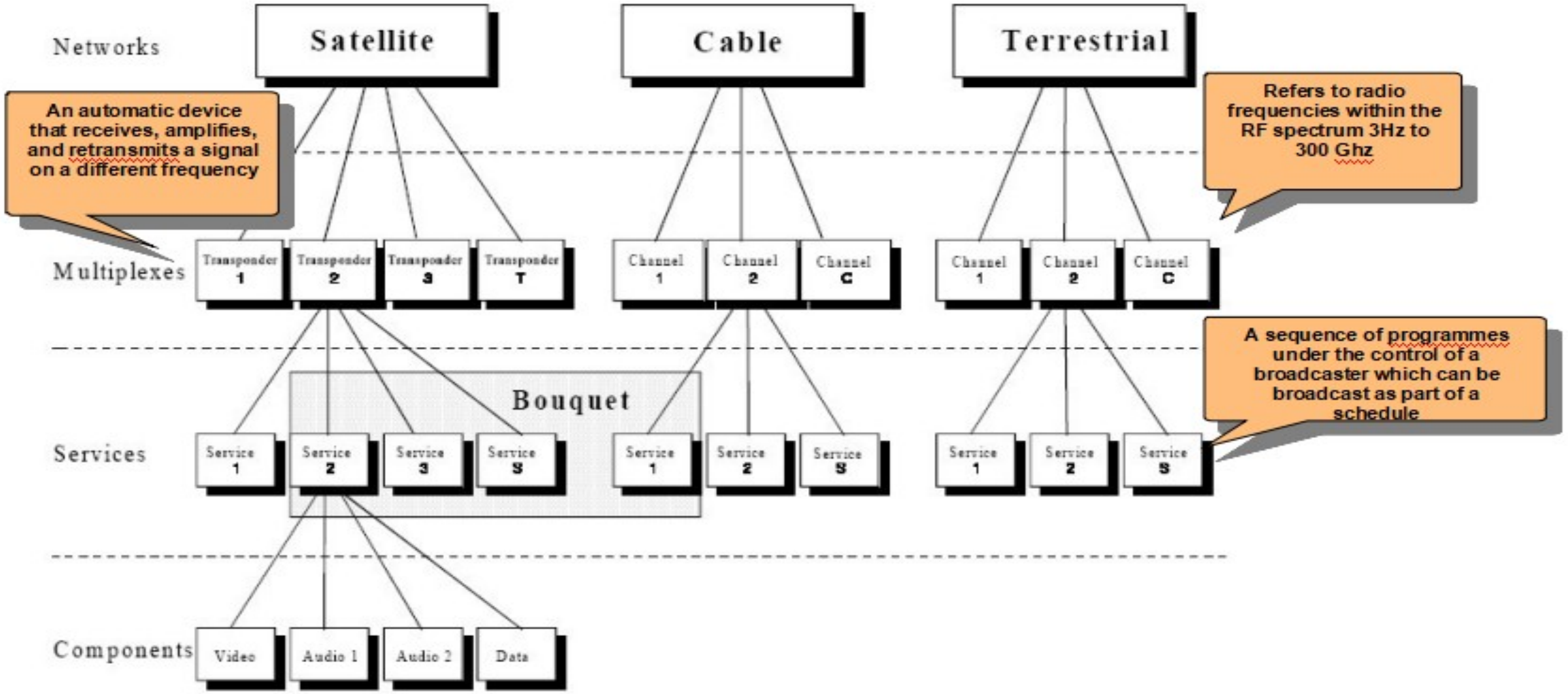
Impacts of errors

- Errors in Audio – Video
- Cause annoyance to people watching the TV
- Some glitches that users might put up with

- Errors in Service Information
- Improper data display (EPG, etc) could make it difficult for users to make purchasing decisions
- Immediate loss of revenue for service provider

DVB Service delivery model



Why is PSI/SI required?

- Automatic Tuning of receiver upon selection
  - TSID and channel number are required to tune
- Program location
  - Program in BROADCASTING: set of elements having common start and stop times
  - Program in MPEG: collection of elementary streams with same PCR_PID and program number
- EPG (Electronic Program Guide)
- API (Application Programming Interface)
- CA (Conditional Access)

Table Structure – PSI & SI (MPEG-2 & DVB)

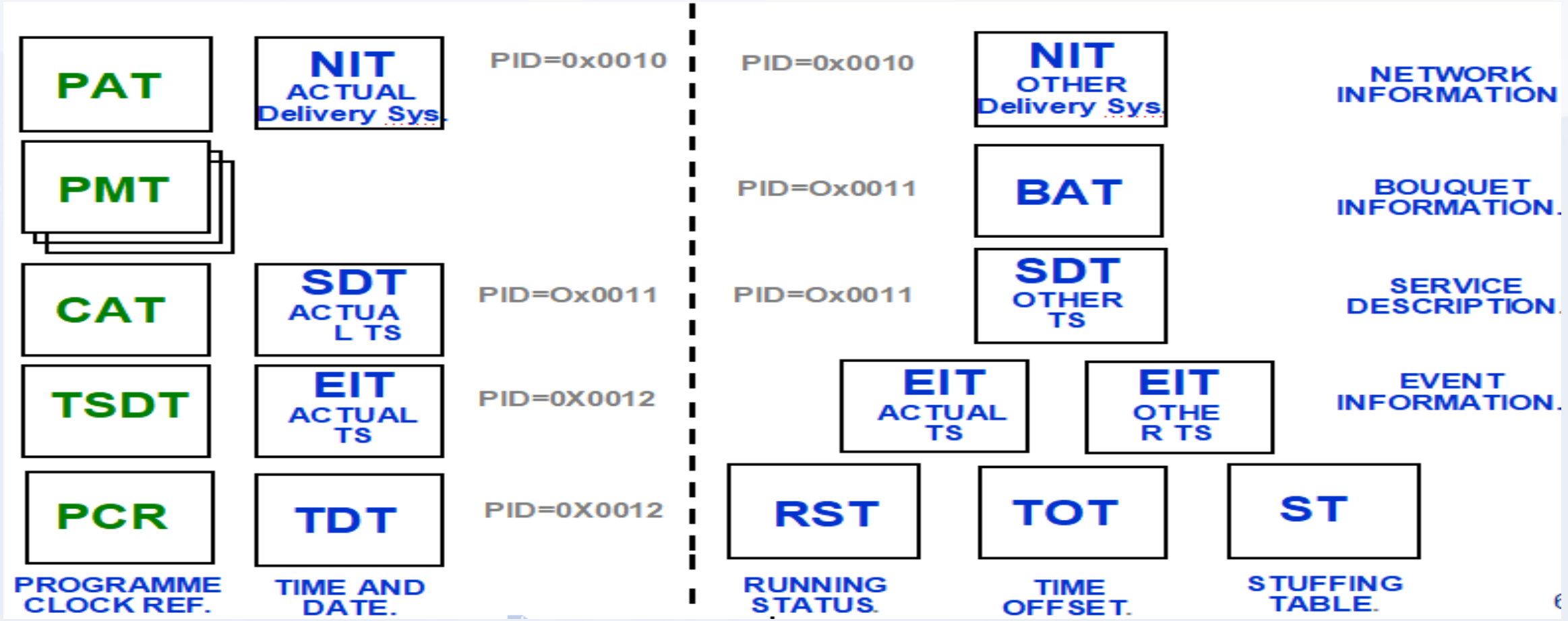


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Table Structure – PSI & SI (MPEG-2 & DVB)

Service information tables in a DVB system.

Mandatory (MPEG)	Mandatory (DVB)	Optional (DVB)	Reserved PID
PAT			0x0000
PMT (one per service)			
CAT			0x0001
	NIT-actual	NIT-other	0x0010
	SDT-actual	SDT-other	0x0011
	EIT-present/following (actual)	EIT-schedule (actual & other) EIT-present/following (other)	0x0012
	TDT		0x0014
		TOT	0x0014
		BAT	0x0011

Example table associations- DVB

Program Association Table

(in TS Packets with PID=0)

Program Number	*Transport Packet PID*
0	122
1	60
....	....
....	....
20	200

Network Information Table

(syntax not defined in MPEG-2 Systems)

Delivery Network Information

Program Map Table for Program #20

(in TS Packets with PID=200)

PES Streams	*PID*
Video	500
PCR	500
Audio 1	510
Audio 2	520
ECM	530
Private Stream (TXT)	540

Conditional Access Table

(in TS Packets with PID=1)

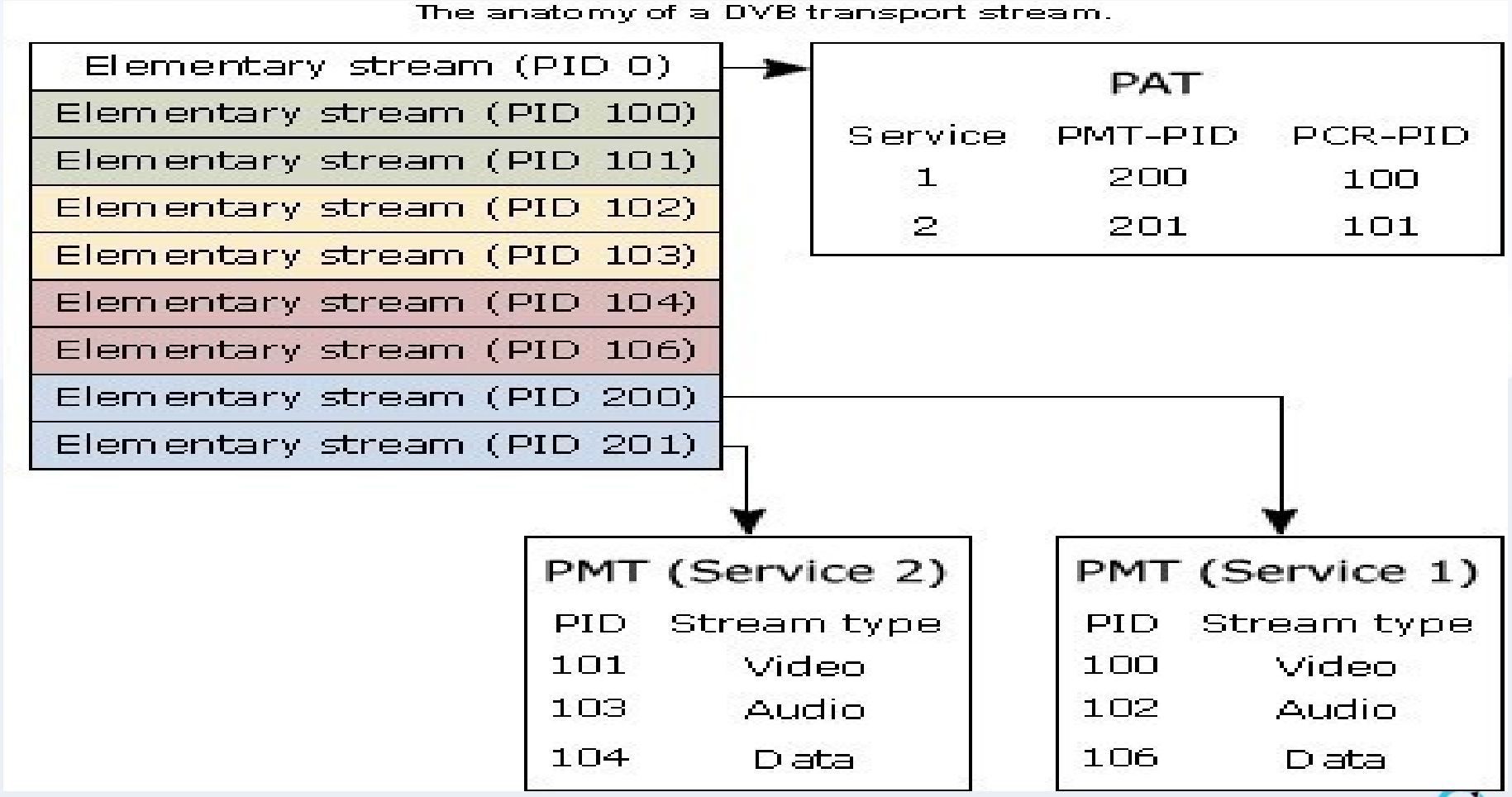
Scrambling Management Information

MPEG-defined PSI

- PAT : Program Association Table
  - repeated in PID 0
  - list of « services » in the TS, ie. TV channels or data channels
  - service id and PMT PID

- PMT : Program Map Table
  - technical description of one service
  - list of elementary streams in the service
  - PID, type (audio, video, etc.), additional info using a list of descriptors
  - list of ECM streams for this service
  - There is one PMT per service, but there may be more that one PMT on the same PID.

Structure of PAT and PMT tables



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MPEG-defined PSI

- CAT : Conditional Access Table
- repeated in PID 1
- list of EMM streams on this TS
- CAT not present when no EMM on TS
- This table controls the scrambling of a service.
- It associates one or more CA systems with their EMM (Entitlement Management Message) stream and any other extra data that may be required.

PMT with CAT information

PMT

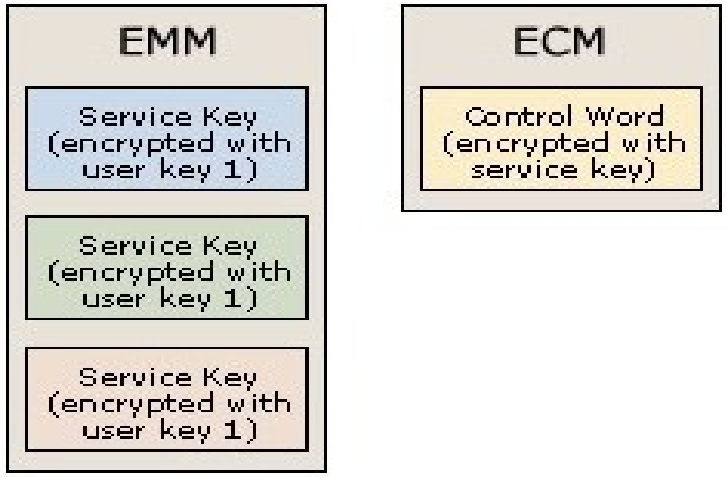
program number = 712
PCR_PID = 0x01C7

descriptor tag = 0x09
CA system ID = 15 (Cardex)
PID = 0x011A (ECMs)

stream type	PID	elementary stream descriptors
audio (ENG)	0x1B00	descriptor tag = 0x09 CA system ID = 37 (Tarhex) PID = 0x011B (ECMs)
video	0x1B01	descriptor tag = 0x09 CA system ID = 37 (Tarhex) PID = 0x011C (ECMs)
audio (SPA)	0x1B02	Descriptor tag = 0x09 CA system ID = 37 (Tarhex) PID = 0x011C (ECMs)

This has the controlword that is sent to CA module on receiver side to descramble the channel

Encapsulating code words and service keys in ECMs and EMMs.



DVB-defined SI

- SDT : Service Description Table
  - editorial description of the services in a TS
  - either in « actual » TS or « other » TS
  - provides a name, language codes, running status and country availability.

This DVB SI table describes the characteristics of available services.

It is located on PID 0x0011. Two types of SDTs are specified by DVB, the SDT Actual and the SDT Other.

The SDT Actual is a mandatory table that describes the services within the transport stream currently being accessed.

The SDT Other describes the services contained in other transport streams in they system.

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DVB-defined SI

- BAT : Bouquet Association Table
  - commercial operator description and services
  - several commercial operators may sell the same services
  - This DVB table describes a set of services grouped together by a broadcaster and sold as a single entity. It is always found on PID 0x0011.

- NIT : Network Information Table
  - technical description of a network
  - either « actual » network or « other » network
  - list of TS in this network
    - usually with frequency and tuning parameters
    - used for fast network scanning

DVB-defined SI

- list of services in each TS
    - service ids and « logical channel number »

NIT:

The DVB table that contains information about a network's orbit, transponder, etc. It is always located on PID 0x0010.

DVB specifies two types of NITs, the NIT Actual and the NIT Other.

The NIT Actual is a mandatory table containing information about the physical parameters of the network actually being accessed.

The NIT Other contains information about the physical parameters of other networks. The NIT Other is optional.

DVB-defined SI

- EIT Event Information Table
- Present/Following information allows events on a service such as classifications like “running”, “not running”, “paused”, “starts in a few seconds”.
- Schedule information is arranged by table, sub-table, segment and section into 3 hours blocks within which the program guide information can be transmitted.
- In general, the EIT information may be scrambled, although different countries may provide regulations which restrict this practise.

DVB-defined SI

- editorial description of events
- either in « actual » TS or « other » TS
- EIT « present / following »
- short description of current and next event on each service
- used to display information banner on screen
- EIT « schedule »
- long description of all events in the forthcoming days
- used to display the EPG
- optional, depends on operator’s good will and bandwidth availability
- complete 7-day EPG for a large operator uses several Mb/s
- sparse EIT schedule sections, rarely complete tables

DVB-defined SI

- EIT Actual (DVB) :
- Event Information Table. This table is part of the DVB SI. It supplies the list of events corresponding to each service and identifies the characteristics of each of these events.
- Four types of EITs are defined by DVB :
- 1) The EIT Actual Present/Following supplies information for the present event and the next or following event of the transport stream currently being accessed. This table is mandatory and can be found on PID=0x0012.
- 2) The EIT Other Present/Following defines the present event and the next or following events of other transport streams in the system that are not currently being accessed by the viewer. This table is optional.
- 3)The EIT Actual Event Schedule supplies the detailed list of events in the form of a schedule that goes beyond what is currently or next available. This table supplies a schedule of events for the transport stream currently being accessed by the viewer.
- 4) The EIT Other Event Schedule supplies the detailed schedule of events that goes beyond what is currently or next available. This table supplies a schedule of events for other transport streams in the system that are not currently being accessed by the viewer. The EIT Schedule tables are optional

DVB-defined SI

- TDT Time and Date Table
  - Provides UTC (Universal Time) coded as MJD (Modified Julian Date)
- TOT Time Offset Table
  - Is used to provide time offsets to give local time.
- RST Running Status Table
  - These are sent out only once to update the status of an event. The RST updates this information and allows timely automatic switching to events
- ST Stuffing Table
  - Used to replace or invalidate tables.

DVB SimulCrypt
one network, several conditional access systems

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Standard key terms

- CAS : Conditional Access System
- CW : Control Word
    - content encryption key for video & audio
- EMM : Entitlement Management Message
    - CAS-specific message to manage rights, smartcards, subscribers
    - sent to some identified set of subscribers, possibly only one
- ECM : Entitlement Control Message
    - CAS-specific message to control a scrambled service
    - sent to everyone willing to watch the service

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DVB SimulCrypt

- Enforce coexistence of multiple CAS to protect the same content
  - DVB-defined standard
- Use-cases
  - one broadcast operator, multiple commercial operators
  - transition between CAS generations
- Broadcast
  - very simple architecture
  - common scrambling
  - multiple EMM and ECM streams with standard signalization
- Head-end
  - complex architecture
  - multiple CAS equipment
  - common synchronization

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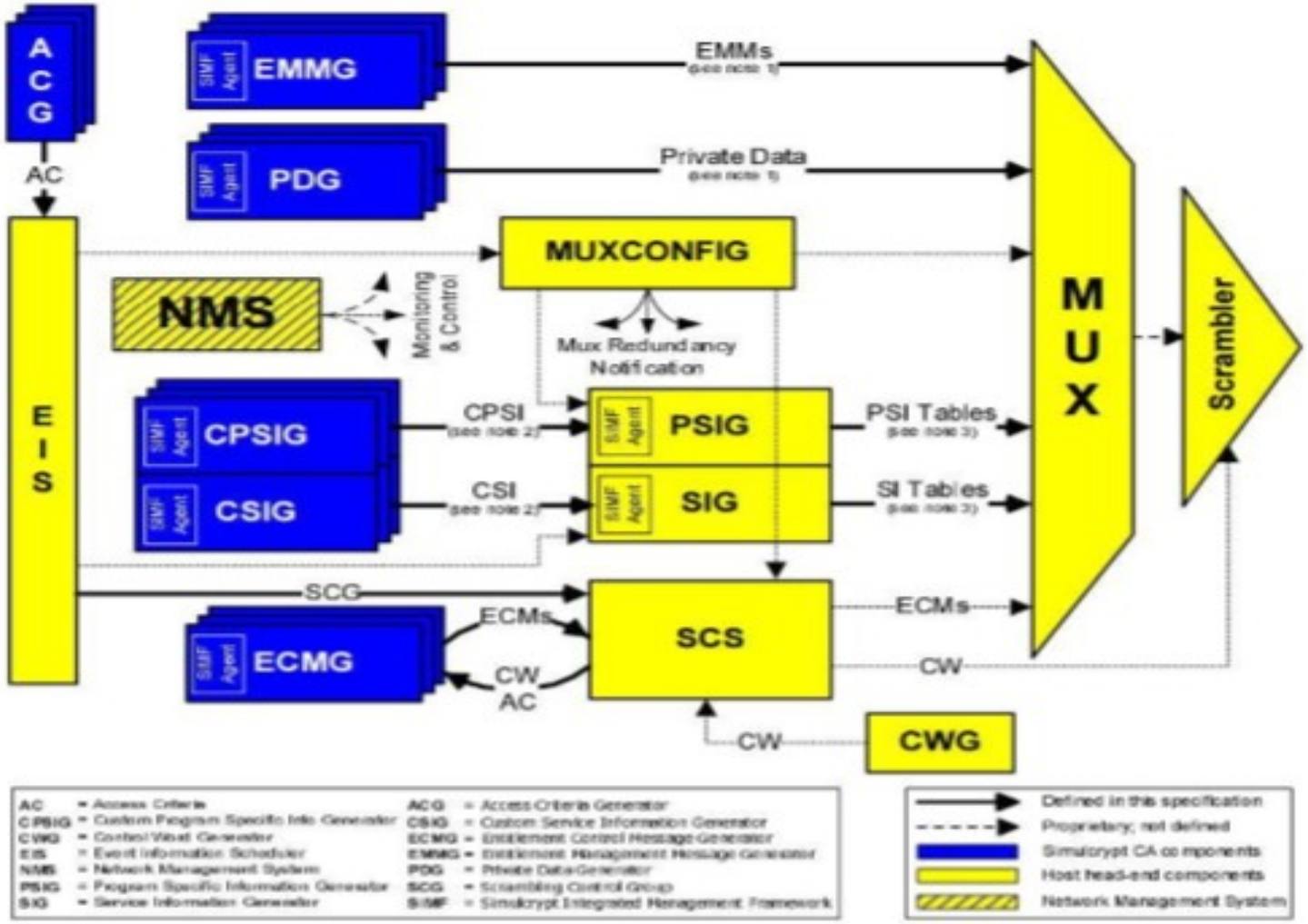
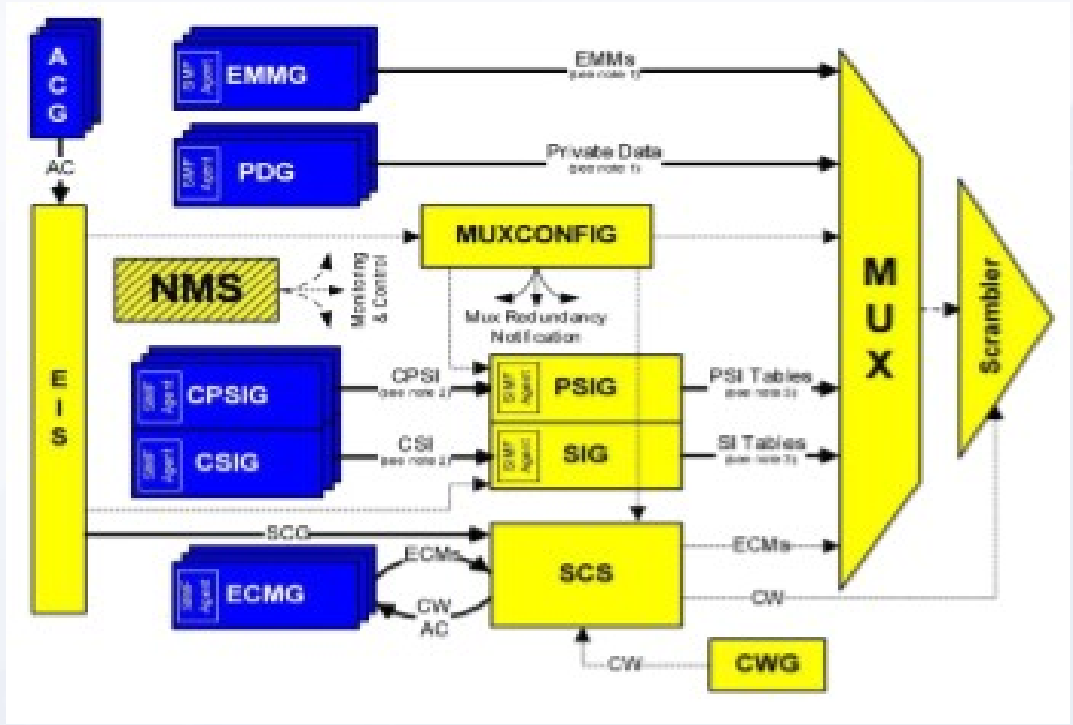
DVB SimulCrypt head-end diagram

Extracted from
DVB standard
ETSI TS 103 197



DVB SimulCrypt head-end

- Interface between two worlds
- one « MUX system » vendor
    - yellow components
- multiple CAS vendors
    - blue components



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- DVB SimulCrypt protocols
  - specified between components of distinct worlds
  - protocols within the same world are not specified
  - proprietary, vendor specific
  - consistent nested tag-length-value (TLV) structures
  - using logical « channels » and « streams »
  - except ACG <=> EIS protocol (XML protocol)
  - EIS <=> SCS protocol is specified
  - so that EIS and SCS may in fact come from distinct vendors
- TSDuck plugins
  - scrambler interacts with any standard ECMG
  - datainject interacts with any standard EMMG or PDG

EMM signalization

- Using CA_descriptor in the CAT of the TS
- standard part of CA_descriptor: CA system id, EMM PID
    - CA_system_id are allocated by DVB
    - http://www.dvbservices.com/identifiers/ca_system_id
- private part of CA_descriptor: CAS-specific
    - used by the CA software in the STB
- Number of EMM streams is CAS-specific
    - for instance, one EMM stream may contain all EMM's for
        - one operator
        - one EMM type (e.g. individual, group, global)
        - or any other configuration
        - when they exist, operator id and EMM types are CAS-specific concepts
        - they are usually identified in the private part of the CA_descriptor

ECM broadcast

- An ECM usually transports a CW pair and access criteria
  - specific to one or more audio or video streams
  - specific to one CAS
- Each service (i.e. channel) has dedicated ECM streams
  - per scrambling group
  - per CAS
  - base mechanism for DVB SimulCrypt
- Scrambling group
  - a set of audio or video elementary streams scrambled with the same CW
  - subtitles are usually not scrambled in practice (but could be in theory)
  - usually, all audio and video streams of a service are in the same scrambling group
  - in rare cases, audio and video streams are scrambled with distinct CW

ECM signalization

- Using CA_descriptor in the PMT of the service
  - standard part of CA_descriptor : CA system id, ECM PID
    - same as EMM signalization
  - private part of CA_descriptor: CAS-specific
    - used by the CA software in the STB
    - CA_descriptor private part is usually different in CAT (EMM) and PMT (ECM)
    - sample content : operator id, public subset of access criteria
- Two possible positions for CA_descriptors in PMT
  - at program level
    - only if one single scrambling group
  - at stream level
    - mandatory if different ES use different CW
    - take precedence over program level if both are used for same CA_system_id

Scrambling synchronization

- During one crypto-period (CP) number N
    - typically 10 seconds
    - scrambling using same CWN
- ECMN carries CWN and CWN+1
    - initial ECM broadcast delayed from start of CP (CAS specific)
    - ECMN is repeated several times during CPN (typically 10 ECM/s)
    - if first ECMN+1 is missed, the descrambler already knows CWN+1 anyway

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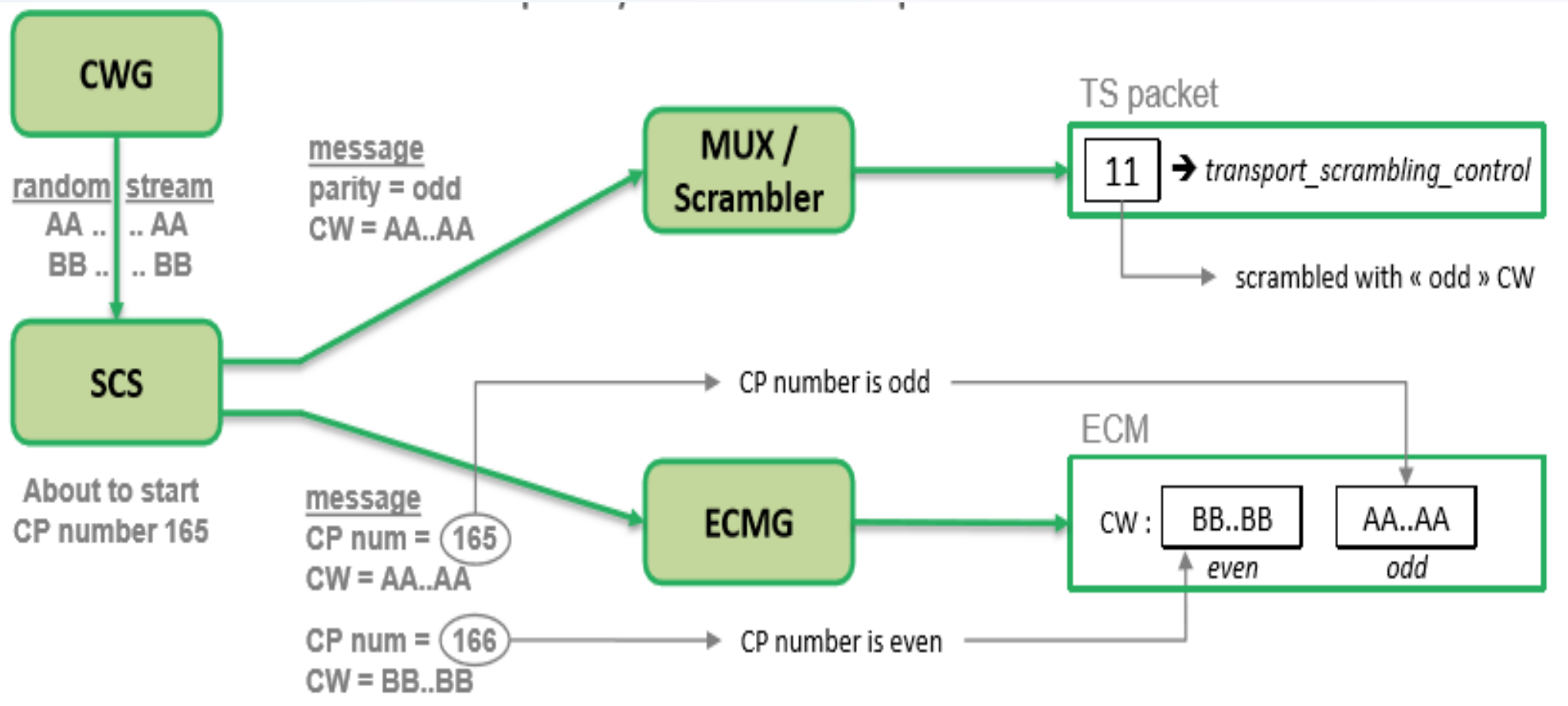
Scrambling synchronization

- The CA software configures the descrambler with both CWN and CWN+1
- either N or N+1 is « even », the other one is « odd »
- TS packet header contains 2-bit transport_scrambling_control
- used by the descrambler to select the appropriate CW
- 00 : clear, do not descramble (MPEG-defined: ISO 13818-1)
- 10 : use even CW (DVB-defined: ETR 289)
- 11 : use odd CW (DVB-defined: ETR 289)
- Implemented in TSDuck plugin scrambler

Scrambling synchronization

- Based on crypto-period (CP) number
    - CP numbers are sequentially allocated by SCS
    - the full CP number stays on head-end
    - its parity is used in TS packets and ECM’s

Scrambling synchronization



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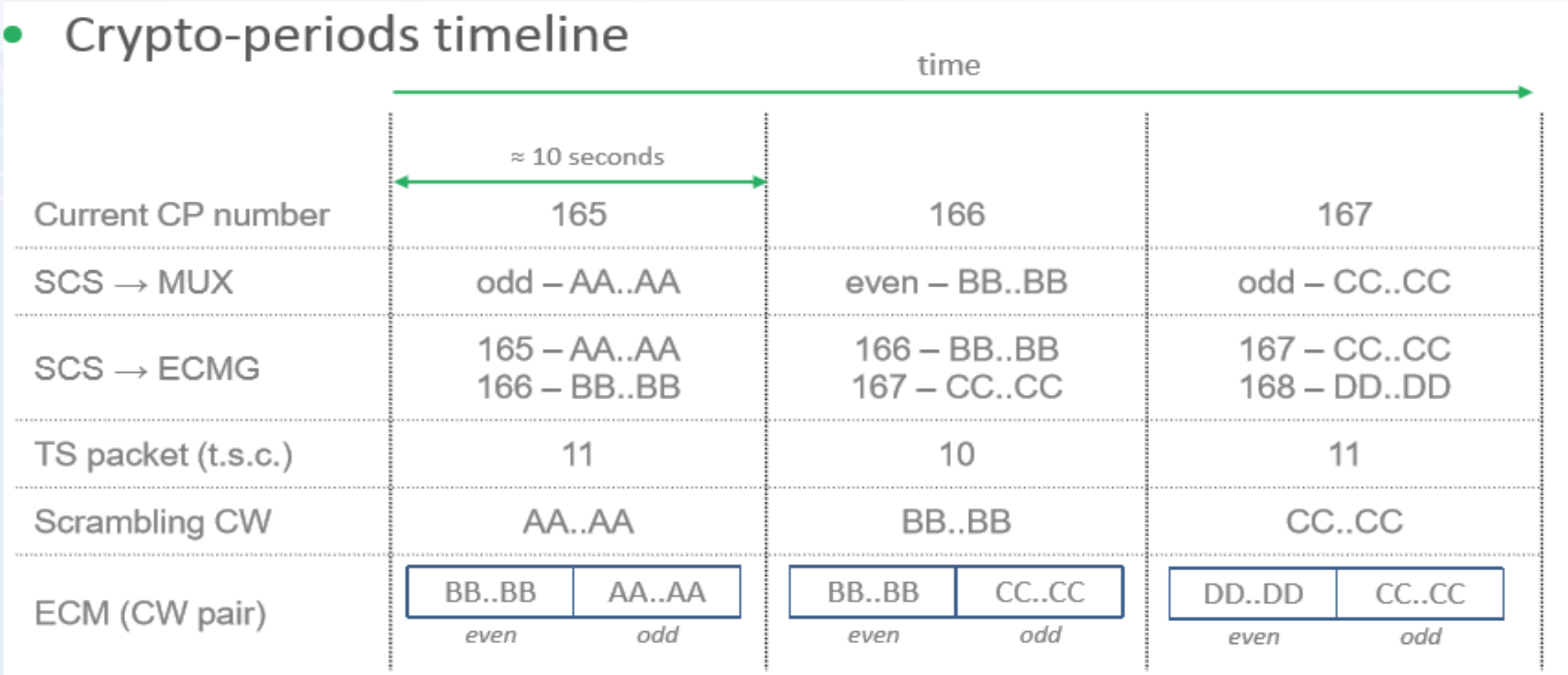
Scrambling synchronization

- Crypto-periods timeline



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TS vs. PES scrambling

- ISO 13818-1 defines two possible levels of scrambling
- TS level
  - each TS packet is scrambled individually
  - clear TS header and adaptation field, scrambled TS payload
- PES level
  - each demuxed PES packet is scrambled individually
  - TS packet header marked as clear
  - PES packet header contains similar 2-bit PES_scrambling_control
  - clear PES header, scrambled PES payload

TS vs. PES scrambling

- In practice, only TS-level scrambling is used
  - PES-level scrambling is technically much more difficult
    - scrambling is performed on multiplexed TS
    - ETR 289 specifies sub-scrambling of 184-byte super-blocks
    - PES packet boundaries not aligned on crypto-period boundaries
  - PES-level scrambling is never used in practice

EMM & ECM tables

- CA-private in DVB-defined range
    - ETSI ETR 289 defines the range of private CA table ids
        - 0x80 – 0x81 : ECM
        - 0x82 – 0x8F : « CA private »
    - defined as « short sections »
        - no versioning
        - each section is an independent new table

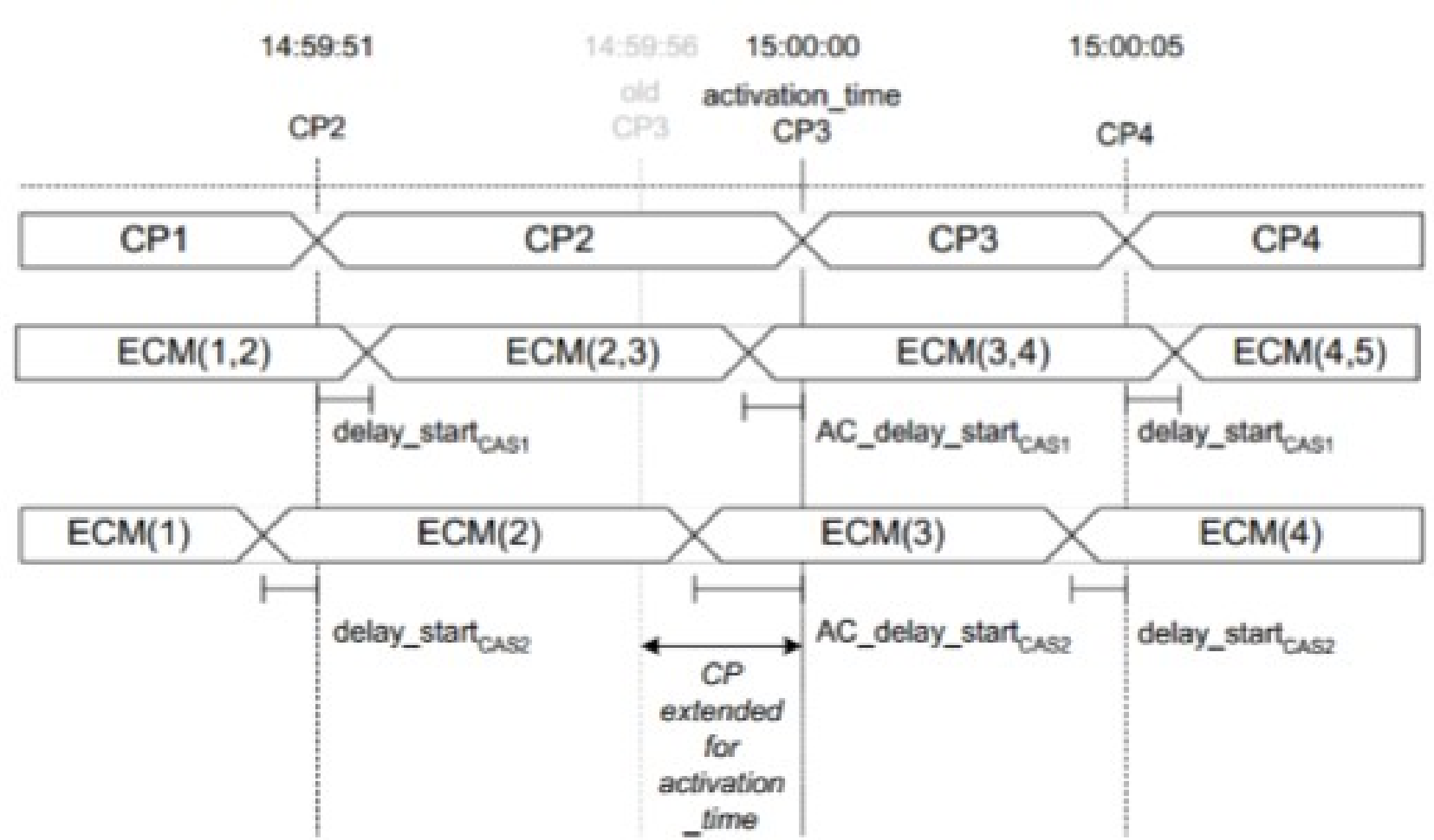
EMM & ECM tables

- Typical usage
  - 0x80 and 0x81 alternating with crypto periods
  - ECM table id change used as trigger by CA software to submit ECM to smartcard or TEE
  - ECM table id and CP number do not necessarily have the same parity
  - 0x82 – 0x8F used for EMM's
  - CAS-specific
  - typically one table id for each EMM type, easier to filter in STB

Access criteria transition

- Use case : restricted event or pay-per-view event transition
- Scenario :
    - the ECMG of each CAS had sent its own timing requirements to SCS
    - SCS synchronizes the generation of the ECM from each CAS

Access criteria transition



Extracted from DVB standard ETSI TS 103 197

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Clear-to-scramble transition

- Use case : Pay-TV channel with public periods in the clear
- Scenario :
    - the ECMG of each CAS had sent its own timing requirements to SCS
    - SCS synchronizes the generation of the ECM from each CAS

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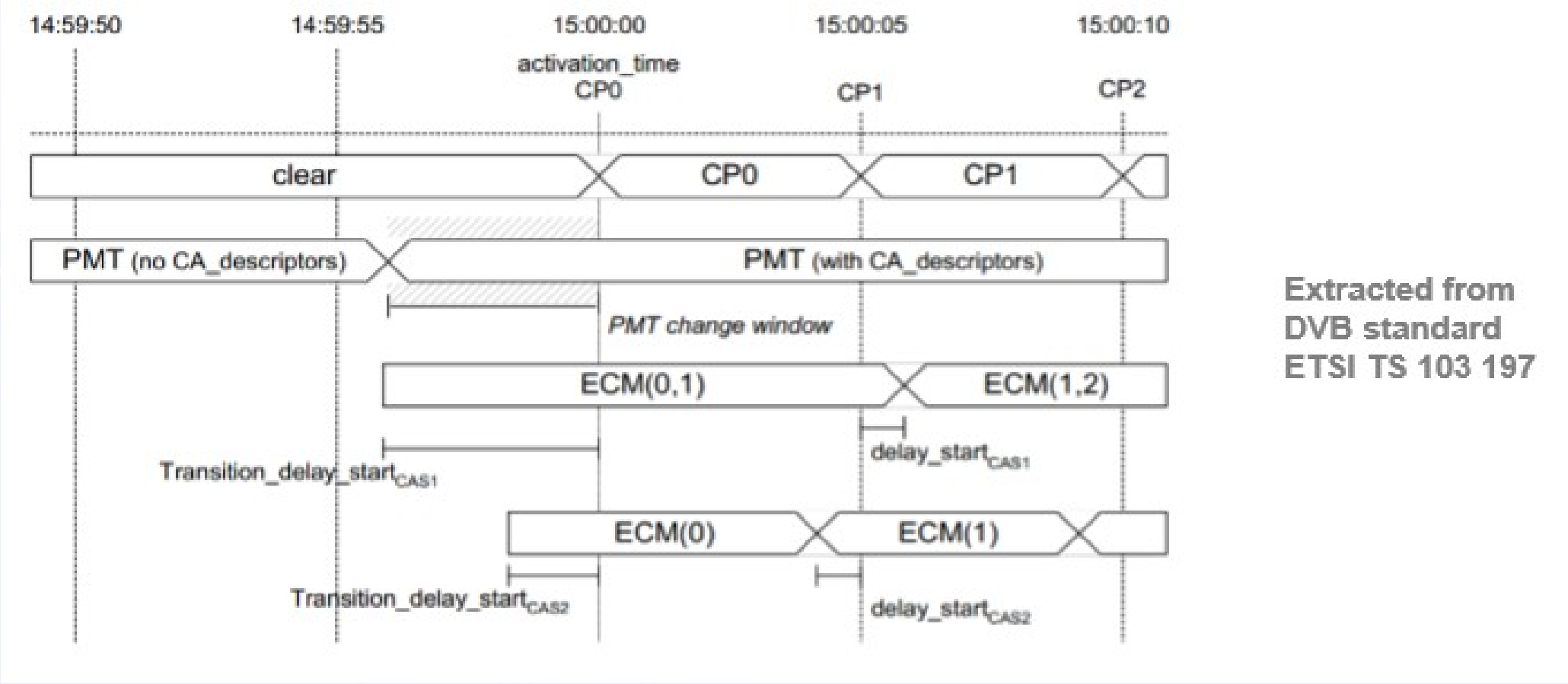
Clear-to-scramble transition



Extracted from DVB standard ETSI TS 103 197

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DVB CSA-2

- DVB Common Scrambling Algorithm
  - DVB proprietary algorithm
  - supposed to be « secret »
  - fully described in Wikipedia
  - open-source implementations online (libdvbcsa)
- Algorithm
    - 64-bit key (also known as « Control Words » or CW)
    - first pass : block cipher in reverse-CBC mode
      - use CW as key
      - block size : 64 bits
      - residue ignored

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How are the tables packed into transport streams?

- Concept of Sections
- Syntatic structure used to map MPEG-2 & SI tables into TS packets
- Sections within each table limited to 1024 bytes, except EIT (4096b)
- Elements of a section
  - Table ID – which table is being referred to
  - Table ID extension – which subtable is being referred to
  - Section number – applies only to sub tables
  - Version number – indicates newer versions of table sent earlier
  - Current next indicator – ‘now’ or ‘next’ – either table to be used for current event transmissions or for future!
- Mapping of these tables into TS packets (ordering, stuffing, etc)

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Service information acquisition and storage

- Mode of transmissions and receptions
- Data and object carousel way of transmitting schedules
- SI parser on receiver end, which extracts PAT, PMT, SDT, EIT table information to retrieve mainly the list of services and events

- Storage considerations
- Embedded database to store information from these tables particularly the EIT and SDT to reproduce on EPG screen when requested by user
- Customized databases, or choice of DBs like SQ-Lite (self-contained, serverless, zero-configuration, transactional SQL database engine)
- Compression – any technique or using libraries such as zlib
- Persistency of the DB cache into flash in file format

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Table Sections

Pointer

Name	Number of bits	Description
Pointer field	8	Present at the start of the TS packet payload signaled by the payload_unit_start_indicator bit in the TS header. Used to set packet alignment bytes or content before the start of tabled payload data.
Pointer filler bytes	N*8	When the pointer field is non-zero, this is the pointer field number of alignment padding bytes set to 0xFF or the end of the previous table section spanning across TS packets (electronic program guide).

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Table header repeated until end of TS packet

Name	Number of bits	Description
Table ID	8	Table Identifier, that defines the structure of the syntax section and other contained data. As an exception, if this is the byte that immediately follow previous table section and is set to 0xFF, then it indicates that the repeat of table section end here and the rest of TS packet payload shall be stuffed with 0xFF. Consequently, the value 0xFF shall not be used for the Table Identifier
Section syntax indicator	1	A flag that indicates if the syntax section follows the section length. The PAT, PMT, and CAT all set this to 1.
Private bit	1	The PAT, PMT, and CAT all set this to 0. Other tables set this to 1.
Reserved bits	2	Set to 0x03 (all bits on)
Section length unused bits	2	Set to 0 (all bits off)
Section length	10	The number of bytes that follow for the syntax section (with CRC value) and/or table data. These bytes must not exceed a value of 1021.
Syntax section/Table data	data N*8	When the section length is non-zero, this is the section length number of syntax and data bytes.

Table syntax section

Name	Number of bits	Description
Table ID extension	16	Informational only identifier. The PAT uses this for the transport stream identifier and the PMT uses this for the Program number.
Reserved bits	2	Set to 0x03 (all bits on)
Version number	5	Syntax version number. Incremented when data is changed and wrapped around on overflow for values greater than 32.
Current/next indicator	1	Indicates if data is current in effect or is for future use. If the bit is flagged on, then the data is to be used at the present moment.
Section number	8	This is an index indicating which table this is in a related sequence of tables. The first table starts from 0.
Last section number	8	This indicates which table is the last table in the sequence of tables.
Table data	N*8	Data as defined by the Table Identifier.
CRC32	32	A checksum of the entire table excluding the pointer field, pointer filler bytes and the trailing CRC32.

Descriptor

Name	Number of bits	Description
descriptor tag	8	the tag defines the structure of the contained data following the descriptor length.
descriptor length	8	The number of bytes that are to follow.
Descriptor data	N*8	Data as defined by the Descriptor Tag.

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MPEG-2 TS –Sections

Data Transport

- Data Blocs or « tables », of any type
- No real-time constraint
- Supports data repetition or update (carousel)
  - Version number

Table fragmentation: sections

- Maximum size: 1024 or 4096 bytes
- Current and total fragments: 8-bit
  - Max 256 sections / table
- 1 table < 256 KB or 1 MB
- Transport integrity: CRC32

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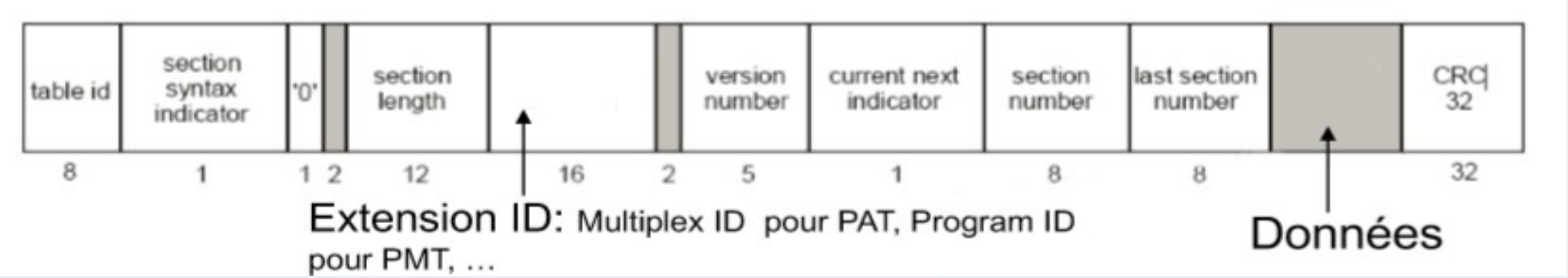
MPEG-2 TS –Sections

Table Multiplexing

- TableID
- Allows sending of different tables on a single PID



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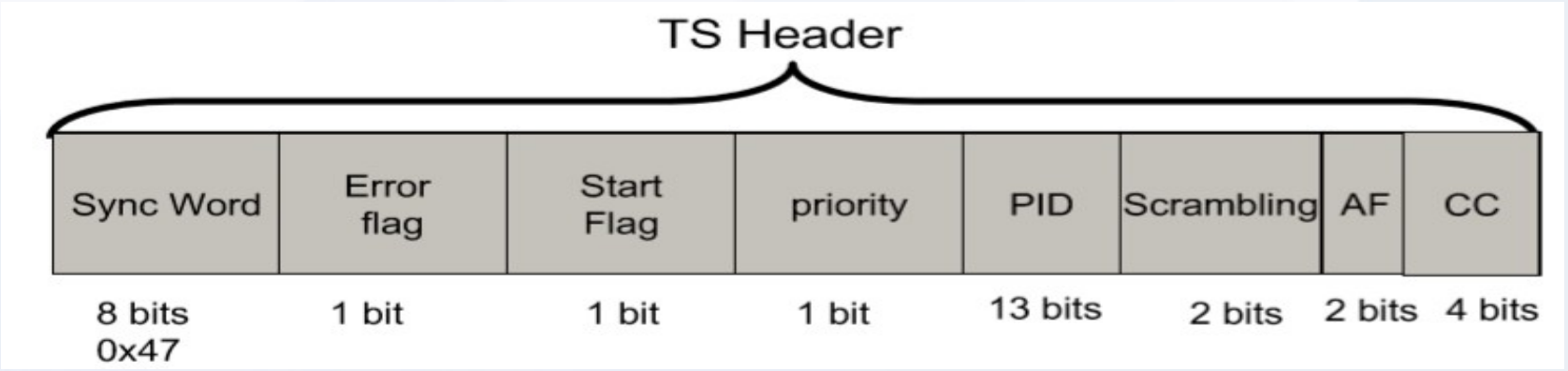
TS_Header_Field

- Fixed packet size
- 188 bytes
- **Header 4 bytes:**
- Synchronization word (1 byte): synchronization recovery when losses
- Error flag: if errors are still present in the TS packet
- Packet Identifier (PID): packet destination
  - (13 bits: max 8192 destinations)
- Start flag: PES or Section first byte in this packet

TS_Header_Field

- Scrambling indicator
- Adaptation Field
- For header extensions
- Random Access Point (RAP) indication
- Clock (PCR)



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MPEG-2 TS Timing

Each program carries a clock

- Program Clock Reference (PCR)
- PES Timestamps relate to this clock

Constraints:

- PCR shall be send often to compensate receiver clock drifts
  - MPEG-2 <100 ms
  - DVB: < 40 ms (i.e. once per frame @ 25 Hz)