



Introduction to Digital Television

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Introduction to the Digital Television

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ANALOG TV - YUV (YCrCb) Components

$$Y=f_{\text{linear}}(R,G,B)$$

⇒ (luminance) Black and White TV

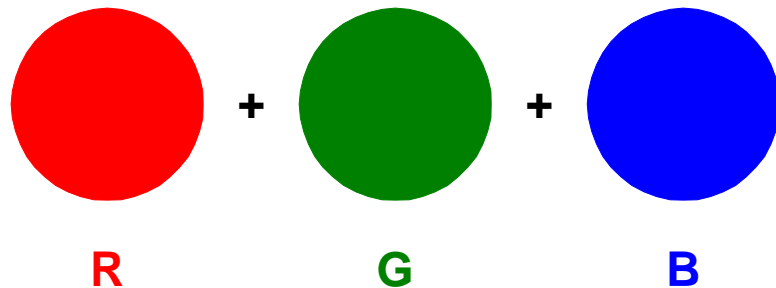
$$Cr=R-Y=f_{\text{linear}}(R,G,B)$$

⇒ (Color difference or chrominance R)

$$Cb=B-Y=f_{\text{linear}}(R,G,B)$$

⇒ (Color difference or chrominance B)

Y image ⇒



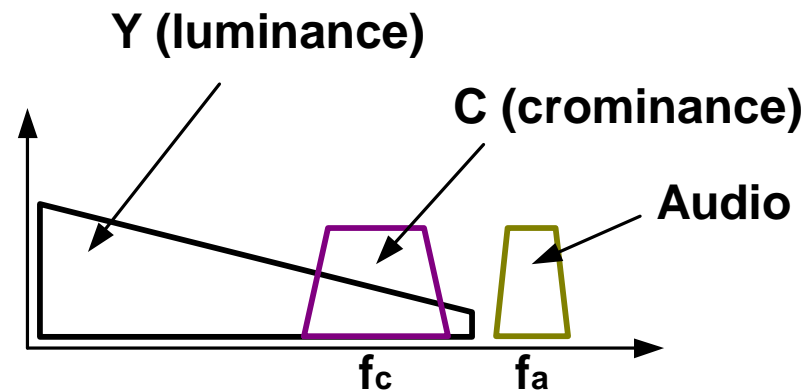
= any color

(Y+Cr+Cb) image ⇒



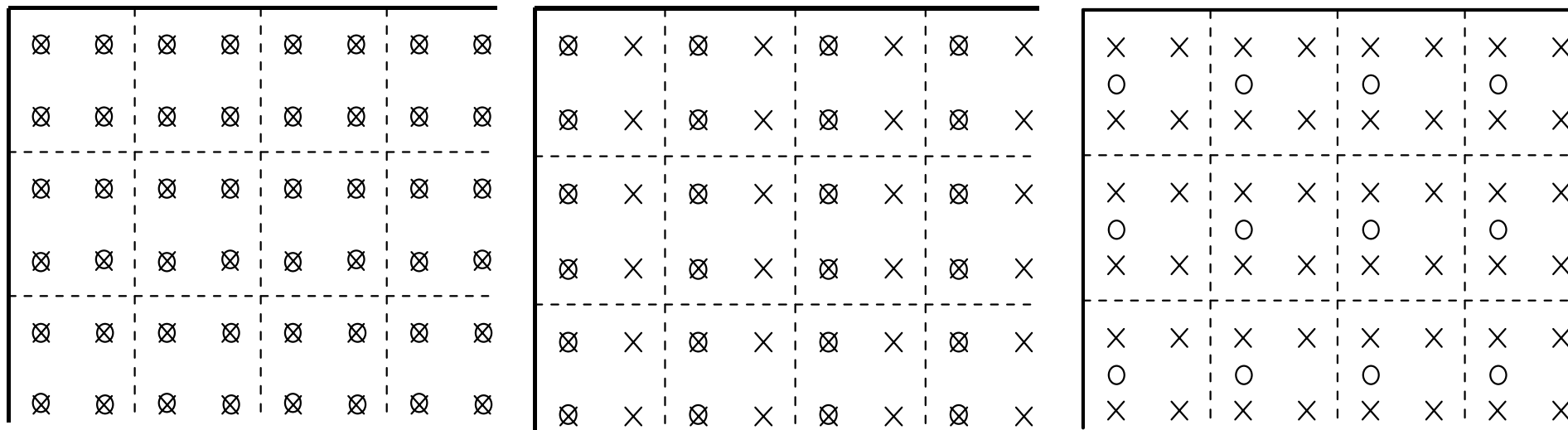
TV Spectrum

- Compatibility between BW TV and Color TV leads to cross-colour and cross-luminance interferences.
- Quadrature modulation, $C(\text{chrominance}) = \cos(2\pi f_c t + \theta(t))$, $\theta(t) = f(C_r, C_b)$.
- NTSC (National Television System Committee)-USA.
- PAL (Phase alternating Line)-Portugal.
- SECAM (Sequentiel Couleur Avec à Mémoire)-France.
- D2-MAC (Multiplexed Analogue Component)-England.



Digital TV - ITU-R BT.601-5

4:4:4 , 4:2:2 and 4:2:0 (not defined in BT.601) Formats

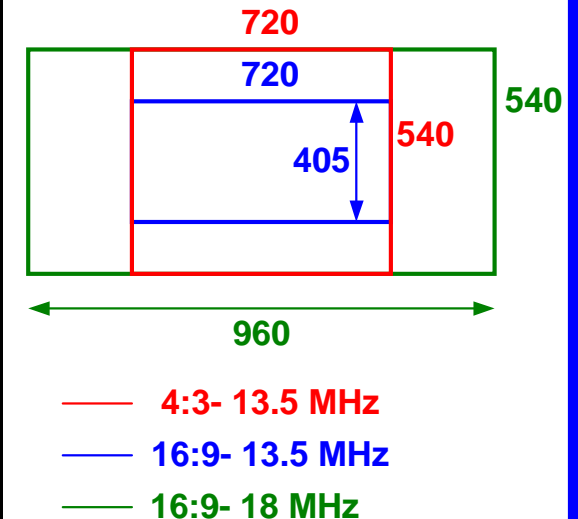


x - Represent luminance samples

0 - Represent chrominance samples

ITU-R BT.601-5

<i>Aspect Ratio</i>	<i>4:3 or 16:9 – 13.5 MHz</i>		<i>16:9 – 18 MHz</i>	
System	525-line, 60 field/s 4:2:2 (4:4:4)	625-line, 50 field/s 4:2:2 (4:4:4)	525-line, 60 field/s 4:2:2 (4:4:4)	625-line, 50 field/s 4:2:2 (4:4:4)
Number of samples per total line: - Y (luminance) - Cr, Cb (each color dif.)	858 (858) 429 (858)	864 (864) 432 (864)	1144 (1144) 572 (1144)	1152 (1152) 576 (1152)
Sampling frequency: - Y (luminance) - Cr, Cb (each color dif.)	13.5 MHz (13.5 MHz) 6.75 MHz (13.5 MHz)		18 MHz (18 MHz) 9 MHz (18 MHz)	
Number of samples per digital active line: - Y (luminance) - Cr, Cb (each color dif.)	720 (720) 720 (720)		960 (960) 480 (960)	



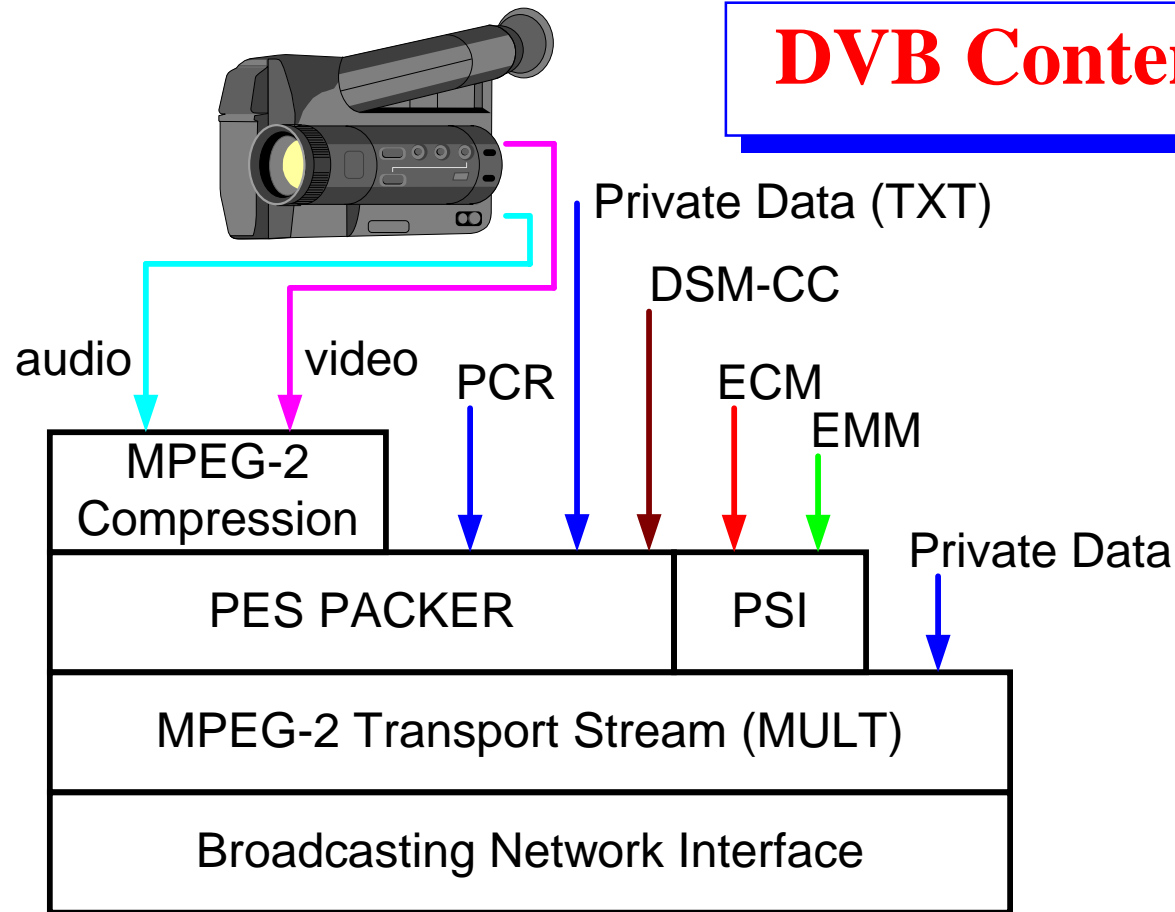
ITU-R BT.709-3

- **The Standard recommends that for the new implementations particularly where interoperability with other applications, including digital television and computer imagery, is important, the system of an active image format of 1920 pixels by 1080 lines is preferred.**

System (Aspect ratio 16:9)	1125/60/ 2:1(1:1)	1250/50/ 2:1(1:1)	1125/60/ 2:1	1250/50/ 2:1
Number of samples per total line: -Y (luminance) -Cr, Cb (each color dif.)	2200 1100	2376 1188	2200 1100	2304 1152
Sampling frequency: -Y (luminance) - Cr, Cb (each color dif.)	74.25 MHz (148.5 MHz) 37.125 MHz (74.25 MHz)		74.25 MHz 37.125 MHz	72 MHz 36 MHz
Number of samples per digital active line: - Y (luminance) - Cr, Cb (each color dif.)	1920 960		1920 960	
Numer of active lines per picture:	1080 (Square pixels)		1035	1152



DVB Content Plane



PCR- Program Clock Reference
ECM - Entitlement Control Message
EMM - Entitlement Management Message
TXT- Teletext
DSM-CC - Digital Storage Medium Command and Control

Broadcasting Network Interface

- **Satellite - DVB-S (ETS 300 421)**

 - QPSK

- **Cable - DVB-C (ETS 300 429)**

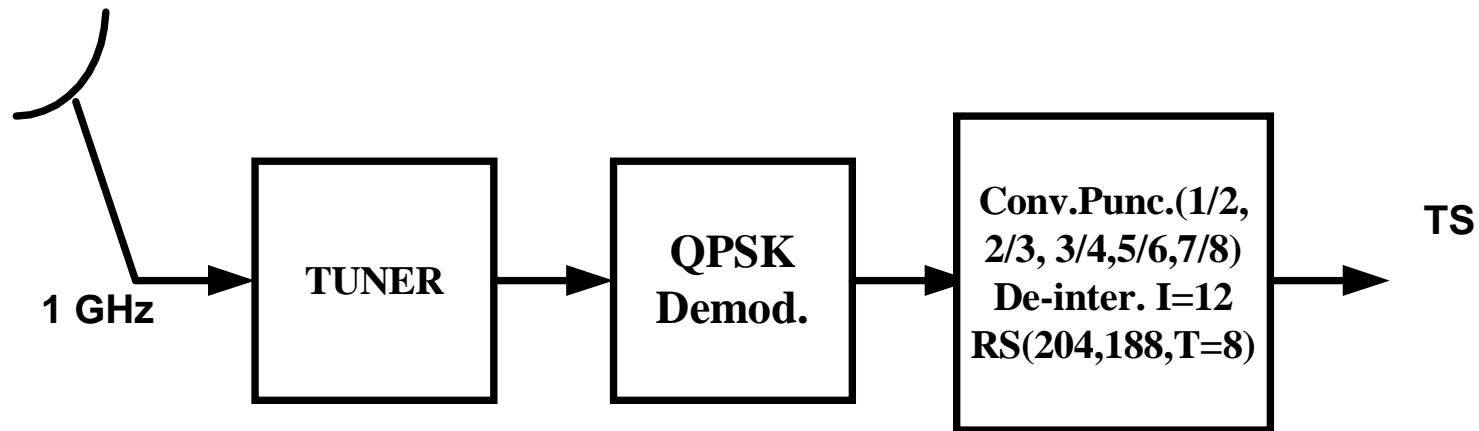
 - 16-QAM, 32-QAM, 64-QAM

- **Terrestrial - DVB-T (ETS 300 744)**

 - 1512 carriers (2k mode), 6048 carriers (8k mode)

 - QPSK, 16-QAM, 64-QAM, Non-uniform 16-QAM, Non-uniform 64-QAM

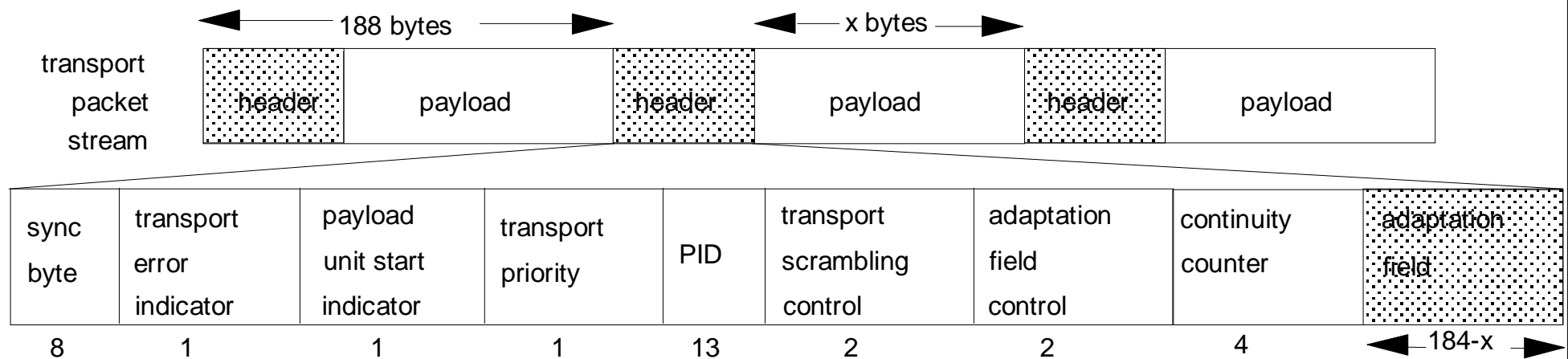
Satellite Interface - ETS 300 421



<i>EUTELSAT HOT BIRD (13^o East)</i>	<i>Television Channels</i>	<i>POL</i>	<i>FEC</i>	<i>TS (MsY/s)</i>	<i>Access</i>	<i>Lang.</i>
10.722 GHz	FKR, MTA, HB4/2OU, HB4/3OU, 3ABN	H	3/4	29.9	Cryptoworks	multi
10.796 GHz	Infosport, Regions, Mezzo, Festival, Histoire, Télétoon, Odyssée	V	2/3	27.5	Viaccess	French

Transport Stream (TS) Packet

- MPEG-2 defines fixed size transport packets with a fixed length of 188 bytes consisting of a 4 byte header information, a variable length adaptation field and the payload



TS Packet Header

- **sync_byte** (8 bits) ⇒ The sync_byte is a fixed 8 bit field whose value is '0100 0111' (0x47) and is used to identify the start of a TS packet. Sync_byte emulation in the choice of values for other regularly occurring fields, such as PID, should be avoided.
- **transport_error_indicator** (1 bit) ⇒ When set to '1', it indicates a bit error in this TS packet.
- **payload_unit_start_indicator** (1 bit) ⇒ This flag indicates that the first byte of this TS payload is the start of an unit access (e. g. a PES packet or a PSI section as explained later).
- **transport_priority** (1bit) ⇒ when set to 1, it indicates that this TS packet is of greater priority than other packets having the same PID which do not have this bit set to '1'.

TS Packet Header

- **PID** (13 bits) \Rightarrow Packet Identifier is one of the most important field in the TS header. It identifies TS packets carrying data from the same elementary stream (e.g. video stream from 'Sport TV' programme). Some PID values have special meaning as described in the following table,

value	description
0x0000	Program Association Table
0x0001	Conditional Access Table
0x0002-0x000F	reserved
0x00010 ...	Available for PES streams, program_map tables, network tables, or for other purposes.
0x1FFE	
0x1FFF	Null packet

TS Packet Header

- **transport_scrambling_control** (2 bits) ⇒ It indicates the scrambling mode of this TS packet payload. The Transport Stream packet header, and the adaptation field when present, shall not be scrambled. It must be set to '00' in the case of a null packet.

value	description
00	not scrambled
01	user defined
10	user defined
11	user defined

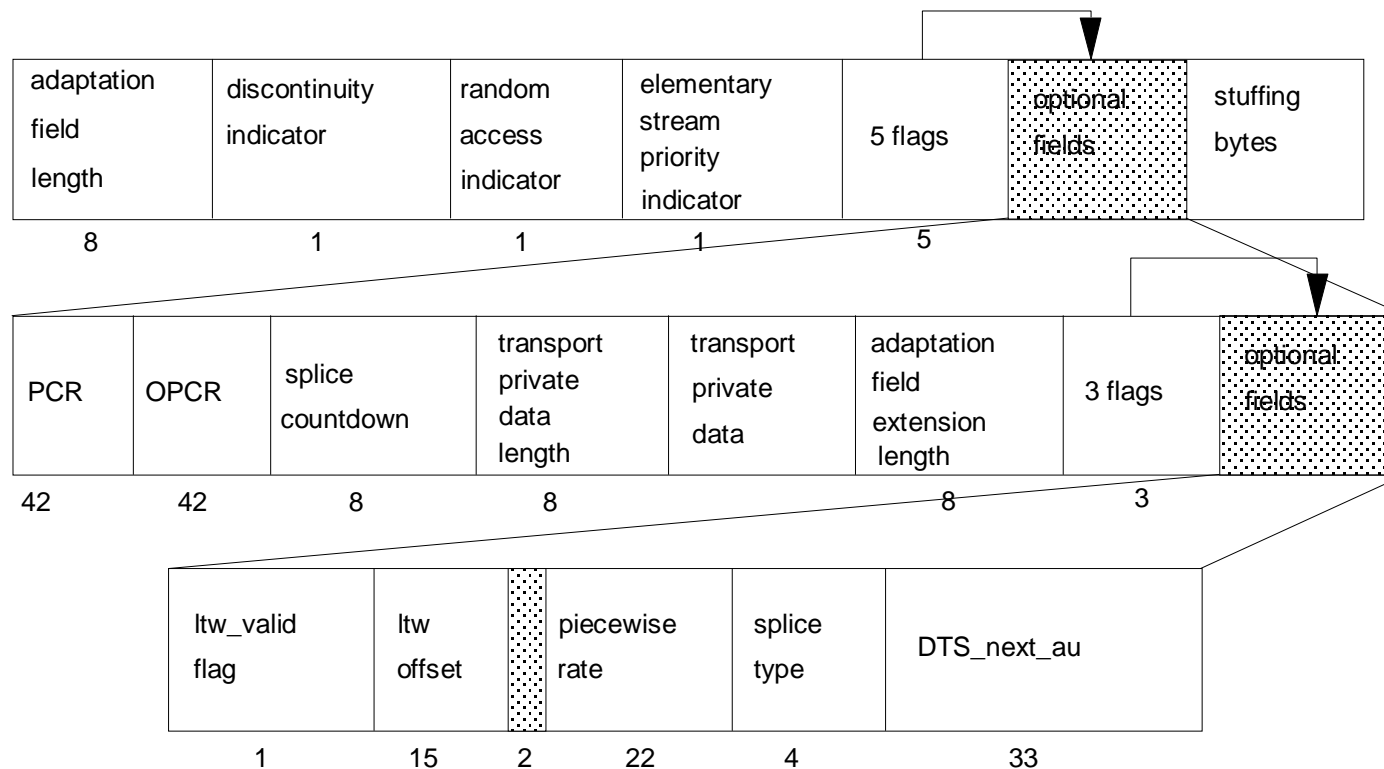
TS Packet Header

- **adaptation_field_control** (2 bits) \Rightarrow This field indicates whether this TS packet header is followed by an adaptation field and/or payload.

value	description
00	reserved for future use by ISO/IEC
01	no adaptation_field, payload only
10	adaptation_field only, no payload
11	adaptation_field followed by payload

- **continuity_counter** (4 bits) \Rightarrow The continuity_counter is a 4 bit field incrementing with each Transport Stream packet with the same PID. The continuity_counter wraps to 0 after its maximum value. It shall not be incremented when the adaptation_field_control of the packet equals '00' or '10'. It can be used to find packet loss.
- **Adaptation_field** \Rightarrow This field (see its description in the next slide) is followed by N contiguous bytes of data (payload) from the access units (PES packets, PSI sections, etc). The number of data_bytes, N, is equal to 184 minus the number of bytes in this adaptation_field.

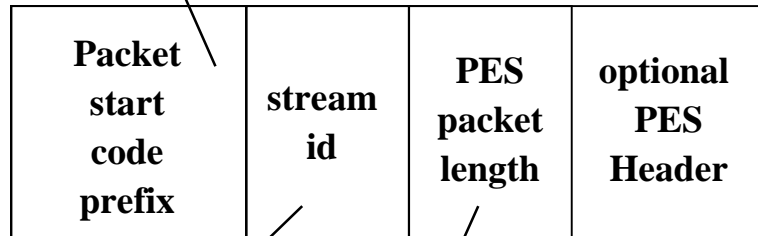
Adaptation Field



- **adaptation_field_length** (8 bits) ⇒ This field specifies the number of bytes in the adaptation_field immediately following the adaptation_field_length.

PES Packet Header

0x 00 00 01



24

8

16

1011 1100

⋮

1111 1111

stream_id	Description
1011 1101	Private_stream_1
1011 1111	Private_stream_2
110x xxxx	MPEG-2 or MPEG-1 audio stream number x xxxx
1110 xxxx	MPEG-2 or MPEG-1 video stream number xxxx
1111 0000	ECM_stream
1111 0001	EMM_stream
1111 0010	DSM-CC_stream

The number of bytes in this PES packet following the last byte of this field

Program Specific Information (PSI) tables

- Four tables defined by MPEG-2 Systems,
 - ⇒ Program Association Table (PAT)
 - ⇒ Program MAP Table (PMT)
 - ⇒ Network Information Table (NIT)
 - ⇒ Conditional Access Table (CAT)

Relation Between PSI Tables : Example

Program Association Table
(in TS Packets with PID=0)

<i>Program Number</i>	<i>Transport Packet PID</i>
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)

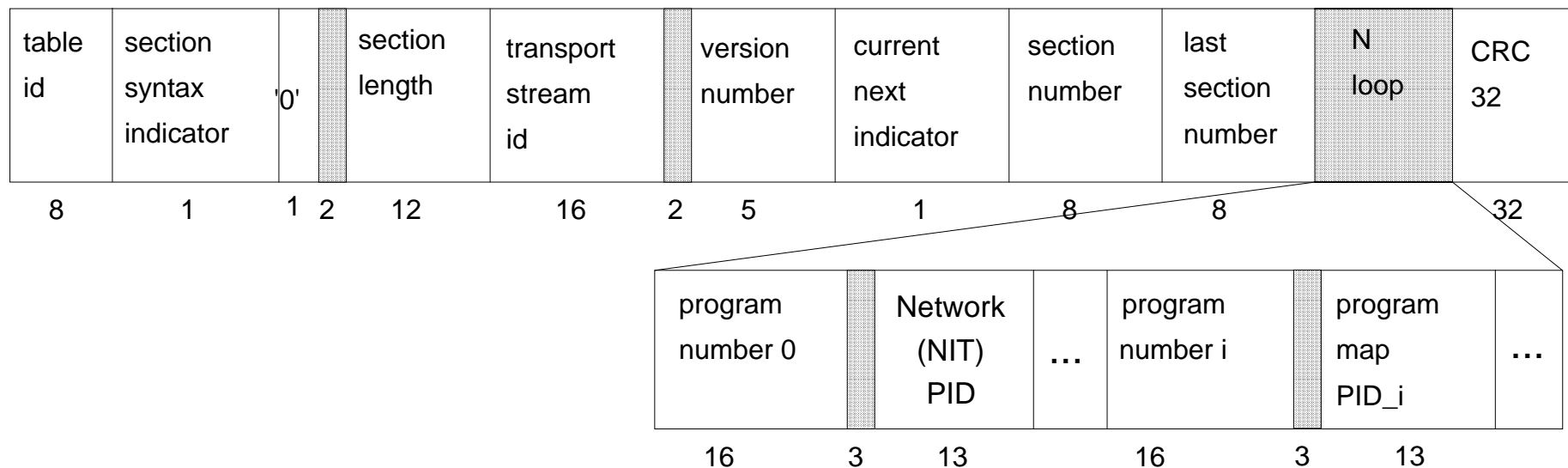
<i>PES Streams</i>	<i>PID</i>
Video	500
PCR	500
Audio 1	510
Audio 2	520
ECM	530
Private Stream (TXT)	540

Conditional Access Table
(in TS Packets with PID=1)

Scrambling Management
Information

Program Association Table (PAT) - PID=0

- The overall table is to be split into one or more sections with the following syntax (section number),



- Program number 0 => NIT PID

Program Association Table (PAT) - PID=0

- **table_id** (8 bits) ⇒ This field identifies the content of a TS PSI section,

value	description
0x00	program association section
0x01	conditional access section
0x02	TS_program_map_section
0x03-0x3F	ITU-T Rec. H.222.0 ISO/IEC 13818 reserved
0x03-0x3F	user private
0xFF	forbidden

and according to the above Table_id assignments, is set to 0x00.

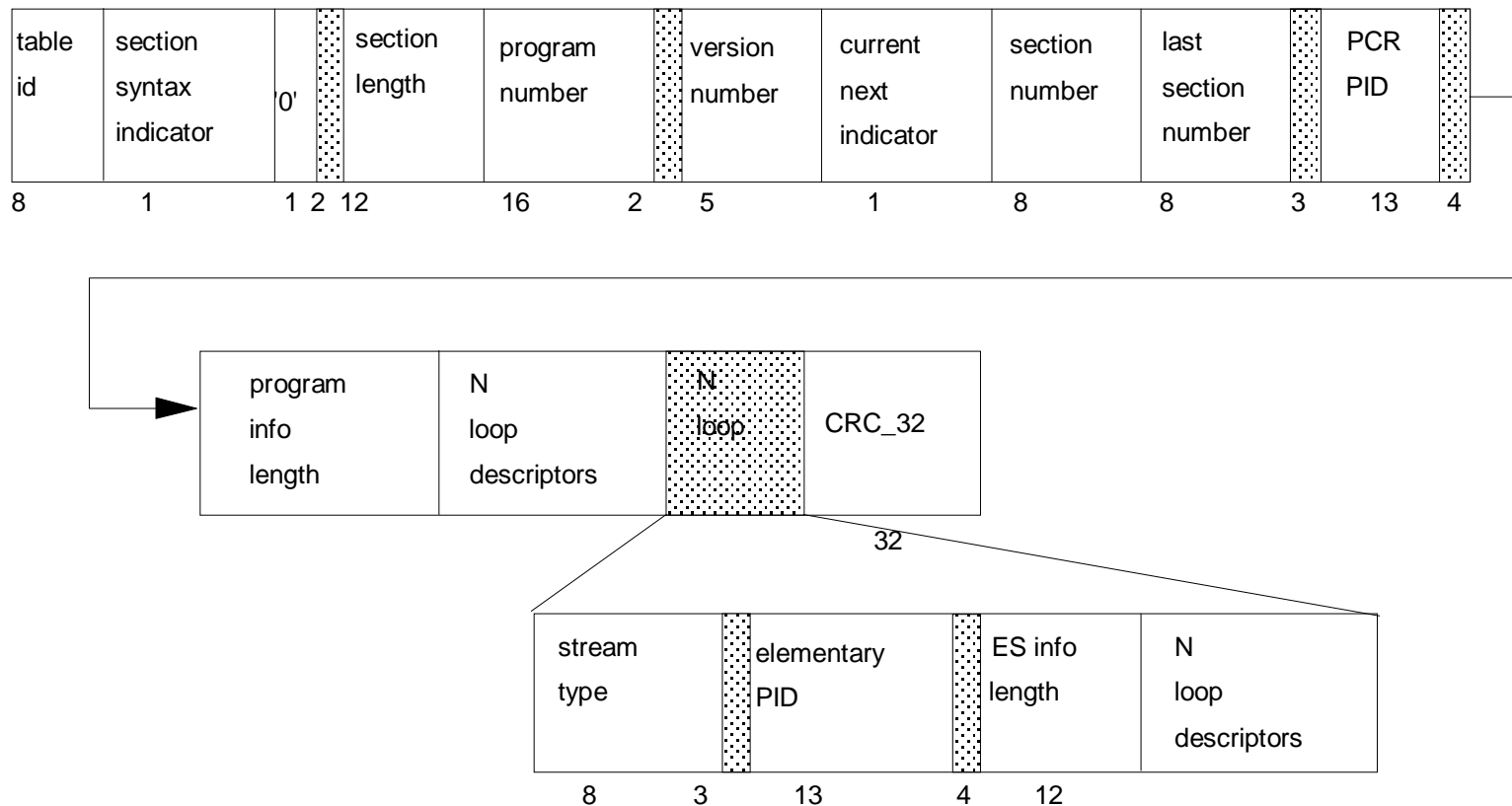
- **section_syntax_indicator** (1 bit) ⇒ Set to '1'.
- **section_length** (12 bit) ⇒ It specifies the number of bytes of this section, starting immediately following this field and including the CRC. The value in this field shall not exceed 1021.

Program Association Table (PAT) - PID=0

- **transport_stream_id** (16 bits) ⇒ It serves as a label to identify this TS from any other multiplex within a network. Its value is defined by the user.
- **version_number** (5 bits) ⇒ This field indicates the version number of the whole Program Association Table. The version number shall be incremented by 1 whenever the definition of the Program Association Table changes. Upon reaching the value 31, it wraps around to 0.
- **current_next_indicator** (1 bit) ⇒ When set to '1' indicates that the Program Association Table sent is currently applicable. When the bit is set to '0', it indicates that the table sent is not yet applicable and shall be the next table to become valid.
- **section_number** (8 bits) ⇒ It gives the number of this section. The section_number of the first section in the Program Association Table shall be 0x00. It shall be incremented by 1 with each additional section in the Program Association Table.
- **last_section_number** (8 bits) ⇒ It specifies the number of the last section (that is, the section with the highest section_number) of the complete Program Association Table.

Program MAP Tables - PID=selected by PAT (encoder)

- Each table provides the mappings between the program number and the program elements that comprise it. Each table has only one section, identified by the program_number field, with the following syntax.



Program MAP Tables - PID=selected by PAT (encoder)

- **table_id** (8 bit) ⇒ Set to 0x02 since it is a TS_program_map_section (see the table in a previous slide)
- **section_syntax_indicator** (1 bit) ⇒ Set to '1'.
- **section_length** ⇒ It specifies the number of bytes of the section starting immediately following the *section_length* field, and including the CRC. The value in this field shall not exceed 1021.
- **program_number** (16 bit) ⇒ It specifies the program number which should be equal to program_number_I (see in PAT). One program definition shall be carried within only one TS_program_map_section. This implies that a program definition is never longer than 1016 bytes.
- **version_number** (5 bit) ⇒ This field is the version number of this TS_program_map_section. The version number shall be incremented by 1 modulo 32 when a change in the information carried within the section occurs.

Program MAP Tables - PID=selected by PAT (encoder)

- **current_next_indicator** \Rightarrow When set to '1' indicates that the TS_program_map_section sent is currently applicable. When the bit is set to '0', it indicates that the TS_program_map_section sent is not yet applicable.
- **section_number** (8 bits) and **last_section_number** (8bits) \Rightarrow Each, set to 0x00.
- **PCR_PID** (13 bit) \Rightarrow It indicates the PID of the Transport Stream packets which shall contain the PCR fields valid for the program specified by program_number.
- **program_info_length** (12 bit) \Rightarrow The first two bits shall be '00'. It specifies the number of bytes of the descriptors immediately following the program_info_length field.

Program MAP Tables - PID=selected by PAT (encoder)

- **stream_type** (8 bit) ⇒ It specifies the type of program element carried within the packets with the PID whose value is specified by the elementary_PID.

stream_type	Description
0x00	Reserved
0x01	MPEG-1 video
0x02	MPEG-2 video
0x03	MPEG-1 audio
0x04	MPEG-2 audio
0x05	Private_sections
0x06	PES packets containing private data
0x07-0x7F
0x80-0xFF	User Private

- **Elementary_PID** (13 bit) ⇒ It specifies the PID of the TS packets which carry the associated program element.
- **ES_info_length** (12 bit) ⇒ It specifies the number of bytes of the descriptors of the associated program element immediately following the *ES_info_length* field

Descriptors

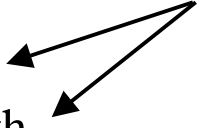
- Descriptors are structures used to carry specific information about the program or program elements (e.g. elementary stream). A particular descriptor is identified by the **descriptor_tag** field. Its followed by the **descriptor_length**. Some **descriptor_tag** values (2-18) have normative meaning,

0-1	Reserved
2	video_stream_descriptor
3	audio_stream_descriptor
....
9	video_window_descriptor
10	CA_descriptor
....
19-63	Reserved
64-255	User_Private

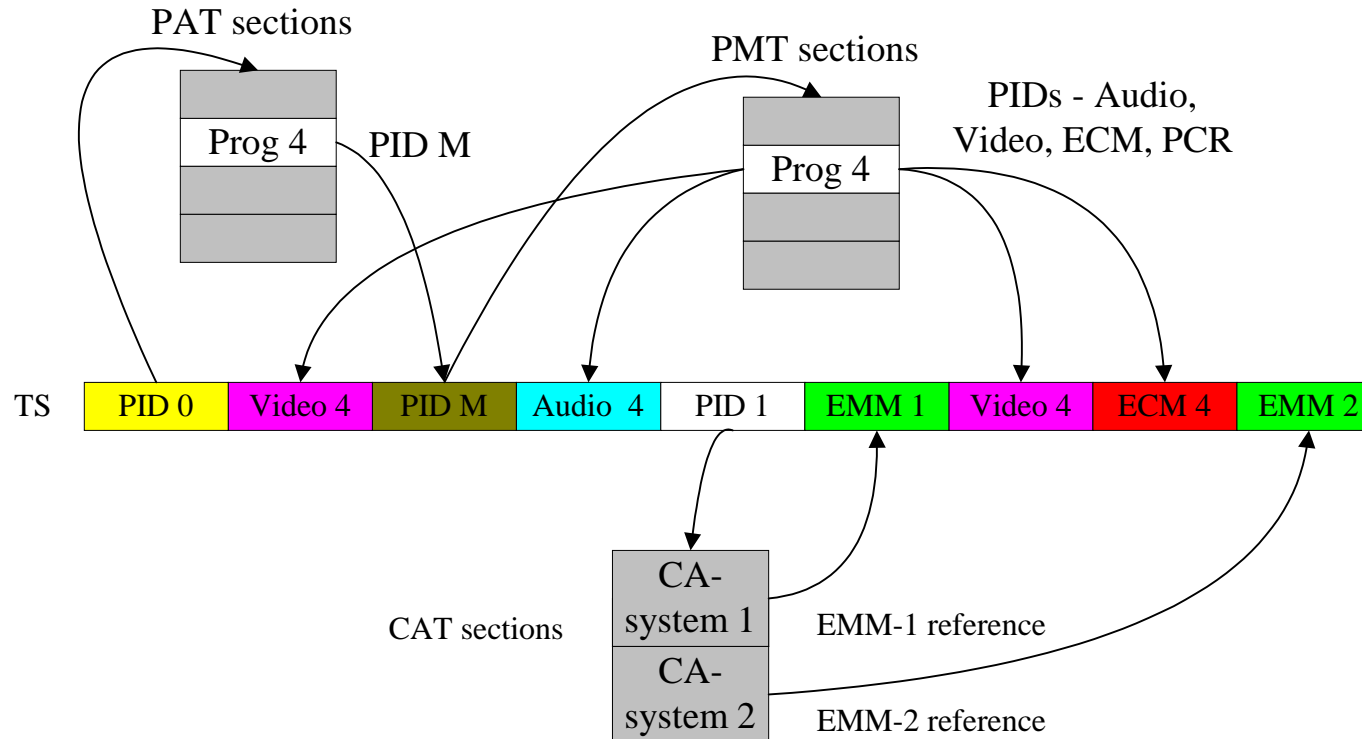
video_stream_descriptor

Fields in any descriptor

```
video_stream_descriptor(){
    descriptor_tag           (8 bits)
    descriptor_length       (8 bits)
    multiple_frame_rate_flag (1 bit)
    frame_rate_code         (4 bits)
    MPEG_1_only_flag        (1 bit)
    constrained_parameter_flag (1 bit)
    still_picture_flag      (1 bit)
    if(MPEG_1_only_flag==1){
        profile_and_level_indication (8 bits)
        chroma_format                 (2 bits)
        frame_rate_extension_flag     (1 bit)
        reserved                       (5 bits)
    }
}
```



Conditional Access Table (CAT) - PID=1



Conditional Access Table (CAT) - PID=1

- This table provides the association between one or more CA systems, their EMM streams (CMT table-ETR 289) and any special parameters associated with them. The table may be segmented into one or more sections, before insertion into TS packets with the following syntax,

table id	section syntax indicator	0'	section length		version number	current next indicator	section number	last section number	N loop descriptors	CRC 32
8	1	1	2	12	18	5	1	8	8	32

- CA fields have the same meaning as those of PAT sections.

Conditional Access Descriptor

- This descriptor is used to indicate the PIDs of TS packets (CA_PID) which shall contain ECM or EMM information (CMT-see ETR 289). If this descriptor appears in a CAT section then a system-wide conditional access management information (EMM) exists.

If this descriptor is present in a PMT section then, the CA_PID points to packets containing program related access control information (ECM). Its presence within loop N indicates applicability to the entire program and within loop N2 indicates applicability to the associated program element (e.g. video stream).

	CA_descriptor() {	
Type of CA system	descriptor_tag	(8 bits)
for ECMs or EMMs.	descriptor_length	(8 bits)
Not specified in MPEG-2,	CA_system_ID	(16 bit)
only specified in DVB (ETR 162)	reserved	(3 bits)
	CA_PID	(13 bits)
	for(i=0;i<N;i++){ private_data_byte}	(8 bits)
	}	

Scrambling and Conditional Access DVB -ETR 289

- The Common Scrambling Algorithm (CSA) is designed to minimize the amount of memory in the de-scrambler circuit at the expense of the complexity in the scrambler.
- The CSA operates on the payload of either a TS packet or a PES packet. Scrambling shall only occur at one level (TS or PES). The scrambling of Sections are at TS level. Clear and scrambled sections cannot be combined in a single TS packet. *Adaptation_Field* stuffing bytes (0xFF) are used to create TS packets with only clear or scrambled Sections.
- ETR 289 specifies the *scrambling_control_field* in TS packets and PES packets,

<i>Bit values</i>	<i>Description</i>
00	No scrambling of TS/PES packet payload
01	Reserved for future DVB use
10	TS/PES packet scrambled with Even Key
11	TS/PES packet scrambled with Odd Key

ETR 289, CA Message Table (CMT) - EMM or ECM

- ETR 289 specifies a Section for the transport of conditional Access (CA) information such as ECMs and EMMs. The structure of this CA information is specific to each CA System Specifier (see a list of *CA_system_id* in ETR 162). The header of *CA_message* section() may be used for filtering. *CA_message* section() is actually a Private section as defined in MPEG-2.

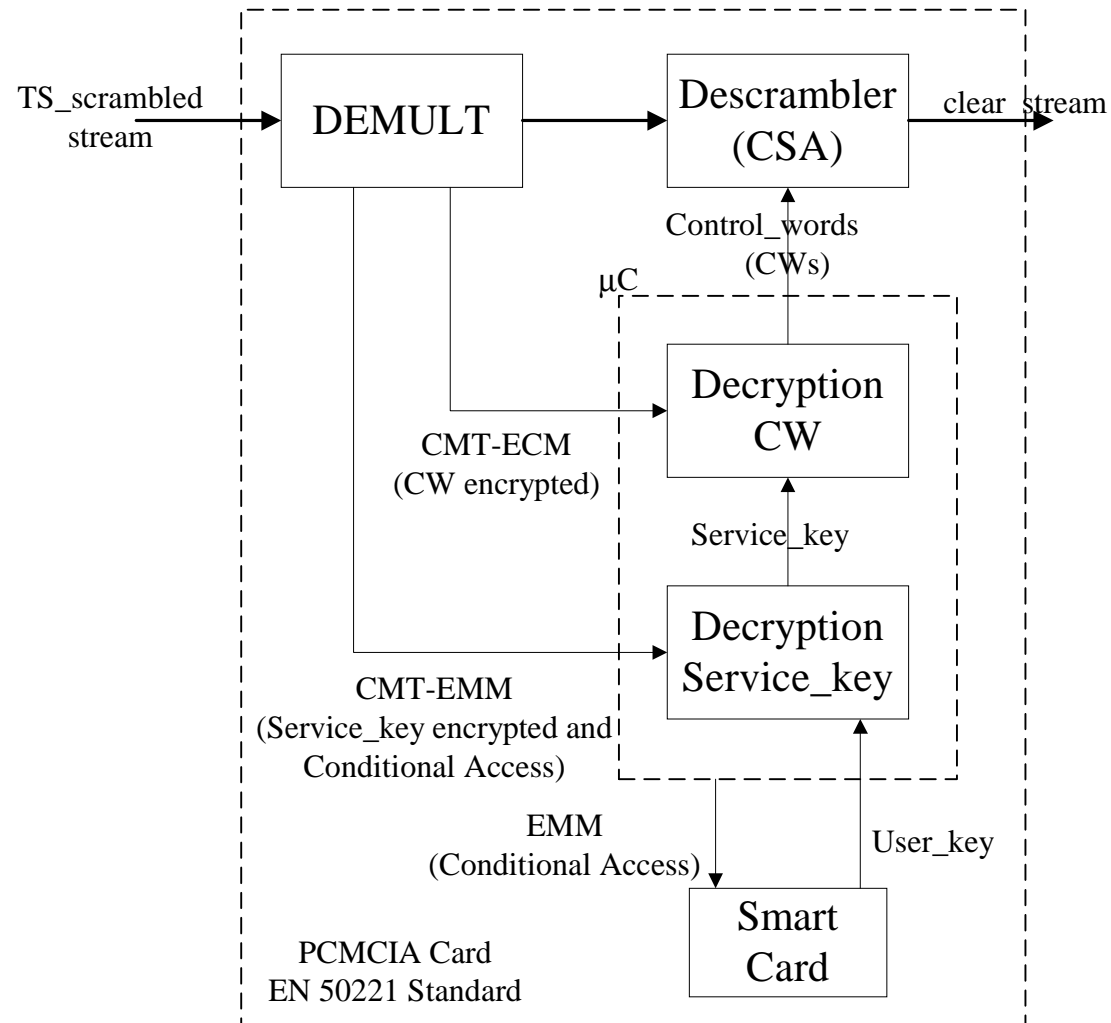
table_id	'0'		CA_section length	N CA_data_bytes
8	1	3	12	

ETR 289, CA Message Table (CMT) - EMM or ECM

- ETR 289 specifies a range of 14 table_id values (0x82-0x8F) for CA_message_sections carrying different types of Conditional Access information (EMM). Two values of the table_id values (0x80 and 0x81) signals that a change of ECM contents has occurred. This change condition can be used for filtering of Conditional Access information.

<i>Table_id value</i>	<i>Description</i>
0x00-0x02	MPEG-2 (PAT, CAT, PMT)
0x03-0x3F	MPEG-2 Reserved
0x40-0x73	DVB-SI – ETS 300 468
0x74-0x7F	DVB reserved for future use
0x80	CA message section (ECM)
0x81	CA message section (ECM)
0x82-0x8F	CA_message_section (CA_system private-EMM)
0x90-0xFE	Private (user defined)

Scrambling and Conditional Access



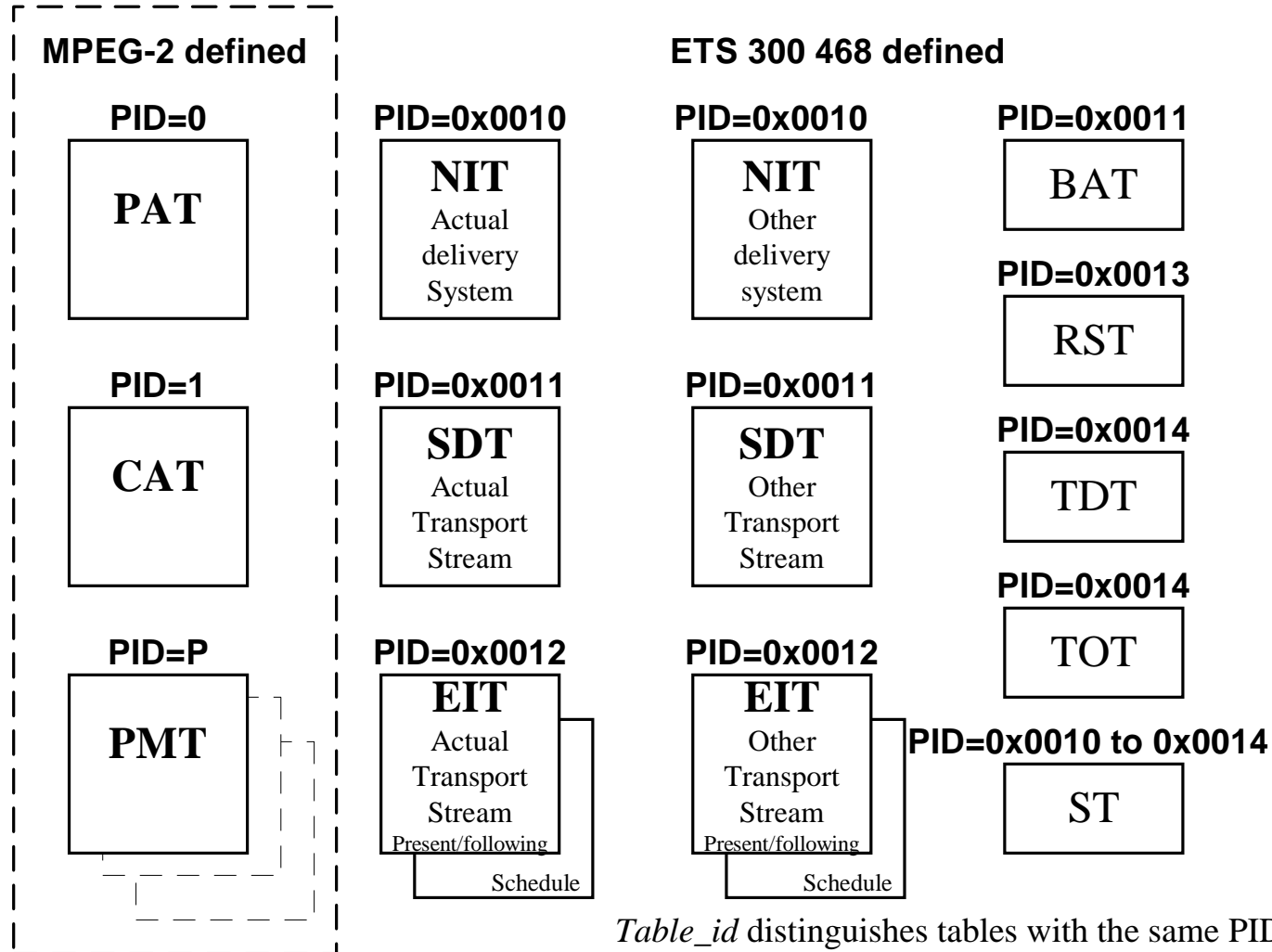
DVB-SI (Specific Information) DVB-ETS 300 468 and ETR 162

- PAT, CAT and PMT of PSI give information only for the multiplex in which they are contained (the actual TS). ETS 300 468 provides additional tables with appropriate descriptors for identification of services, information on services and events carried by different multiplexers and even on other networks. The syntax and semantics of these additional tables and the NIT are defined in this ETS.
- All tables are split into sections before insertion in TS packets.

ETS 300 468

- Network Information Table (**NIT**) - It provides information about the physical network.
- Bouquet (a collection of services marketed as a single entity) Association Table (**BAT**) - It provides a list of services and other information for each bouquet.
- Service Description Table (**SDT**) - It contains data describing the services in the system, e.g. names de services, the service provider, etc.
- Event Information Table (**EIT**) - It contains data concerning events or programmes such as event name, start time, duration, etc.
- Running Status Table (**RST**) - It gives the status of an event (running/not running).
- Stuffing Table (**ST**)- It invalidates existing sections
- Time and Date Tables (**TDT**) - It provides information about the present time and date.
- Time Offset Table (**TOT**) - It provides information about the local time offset.

ETS 300 468



Table_id distinguishes tables with the same PID (e.g. BAT and SDT)

References

- ❑ Recommendation ITU-R BT.601.5, Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios.
- ❑ Recommendation ITU-R BT. 709-3, Parameter values for the HDTV standards for production and international programme exchange.
- ❑ ITU-T Rec. H222.0 | ISO/IEC 13818-1:1994, Information technology-Generic coding of moving pictures and associated audio-Part 1:systems.
- ❑ H. Benoit, 1998, Televisión Digital, Paraninfo, Madrid.
- ❑ ETS 300 421, 1994, Digital broadcasting systems for television, sound and data services; Framing structure, channel coding and modulation for 11/12 GHz satellite services.
- ❑ ETS 300 468, 1997, Specification for Service Information (SI) in DVB systems.
- ❑ ETR 162, 1995, Allocation of services information (SI) codes for DVB systems.
- ❑ ETR 289, 1996, Support for use of scrambling and Conditional Access (CA) within digital broadcasting systems.