MPEG-2 ES/PES/TS/PSI

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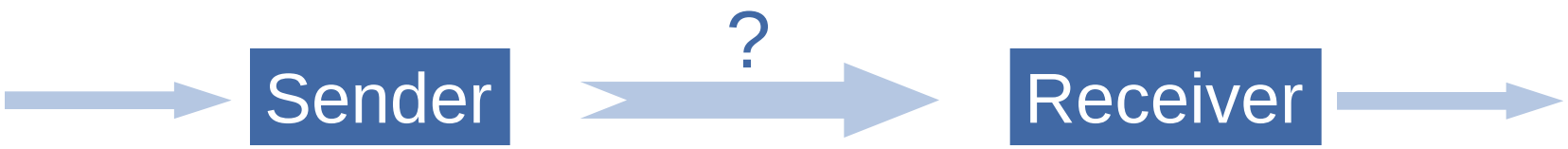
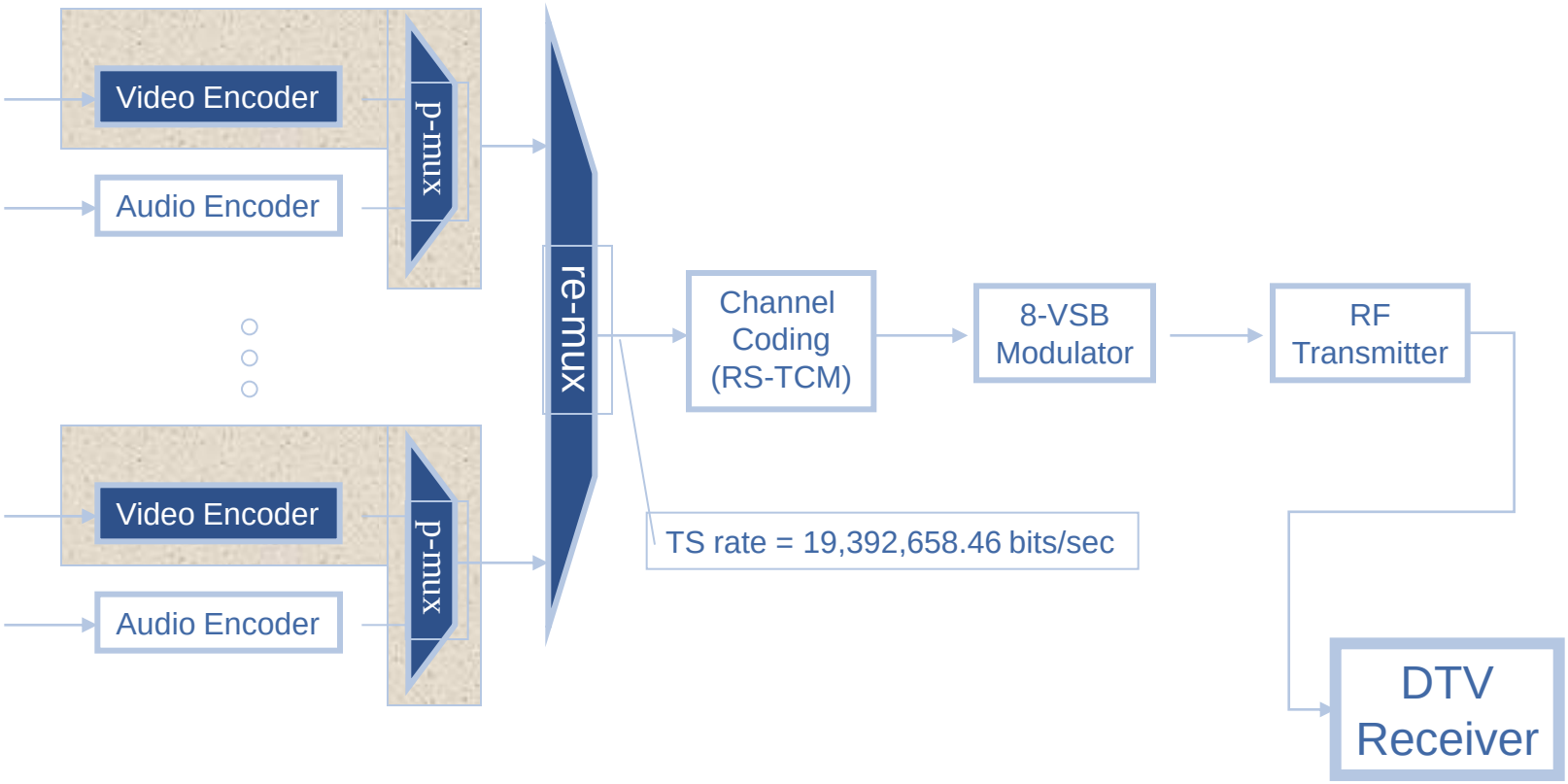
contents

TS as a New DTV Format

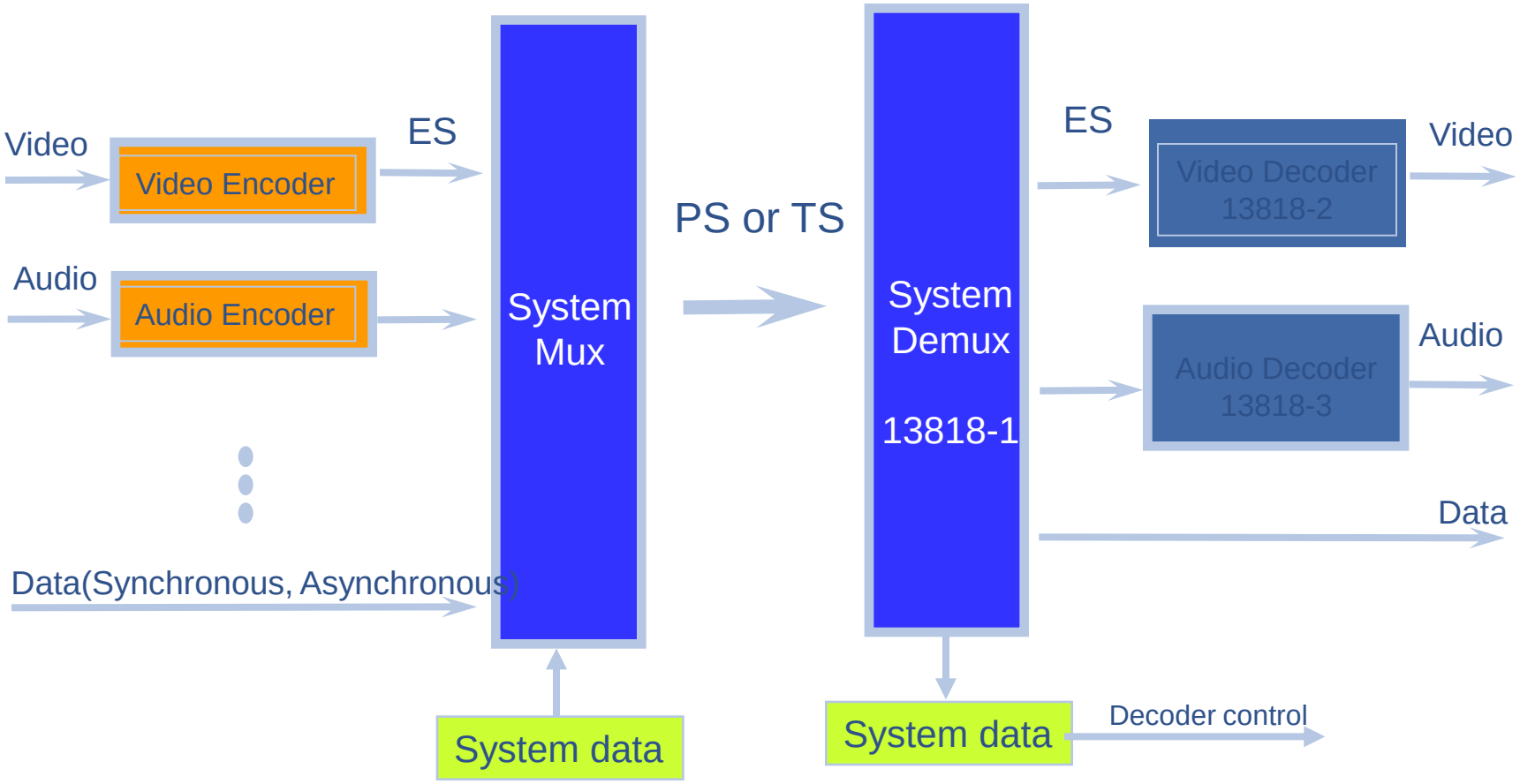


- Analog: NTSC/PAL/SECAM is used in all delivery chain.
- Digital:
  - Production: Multiple standards (component digital, composite digital, 24/30Hz film material)
  - Delivery: MPEG-2 Systems TS (Transport Stream) is considered as *a single world-wide standard* for digital broadcasting.
  - Reception: Multiple standards(PC, TV) (wide spread of non-interlaced display)

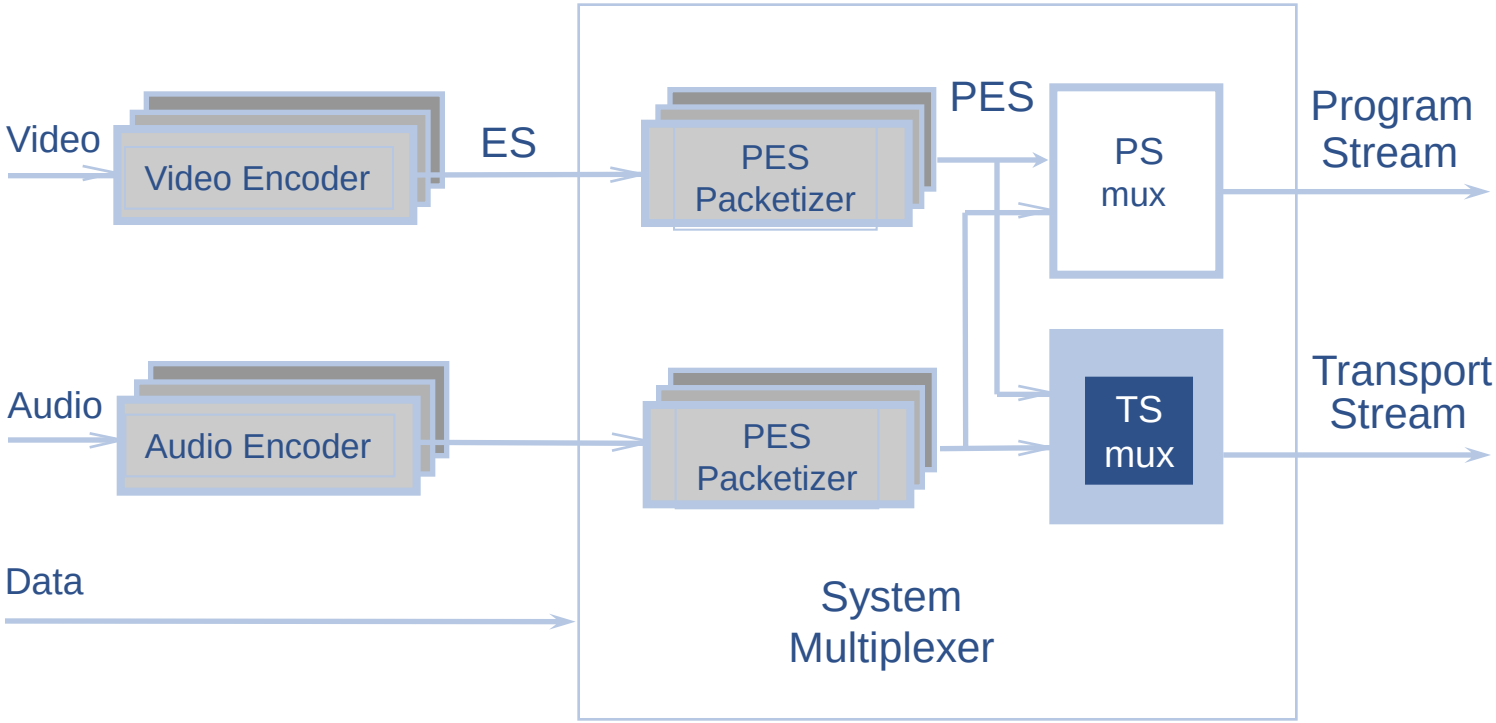
DTV: An Example



MPEG-2 Systems Spec.

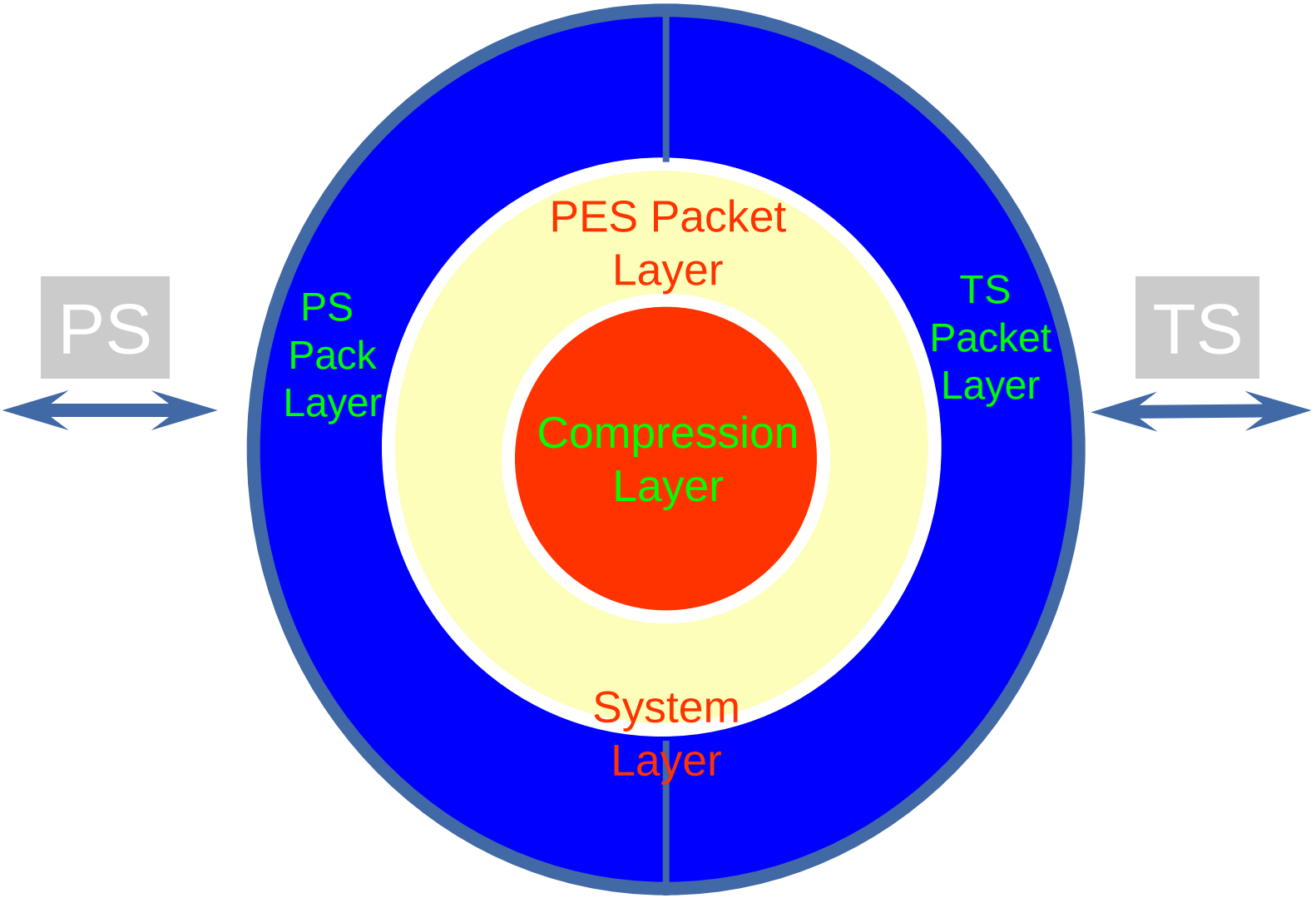


MPEG-2 TS & PS

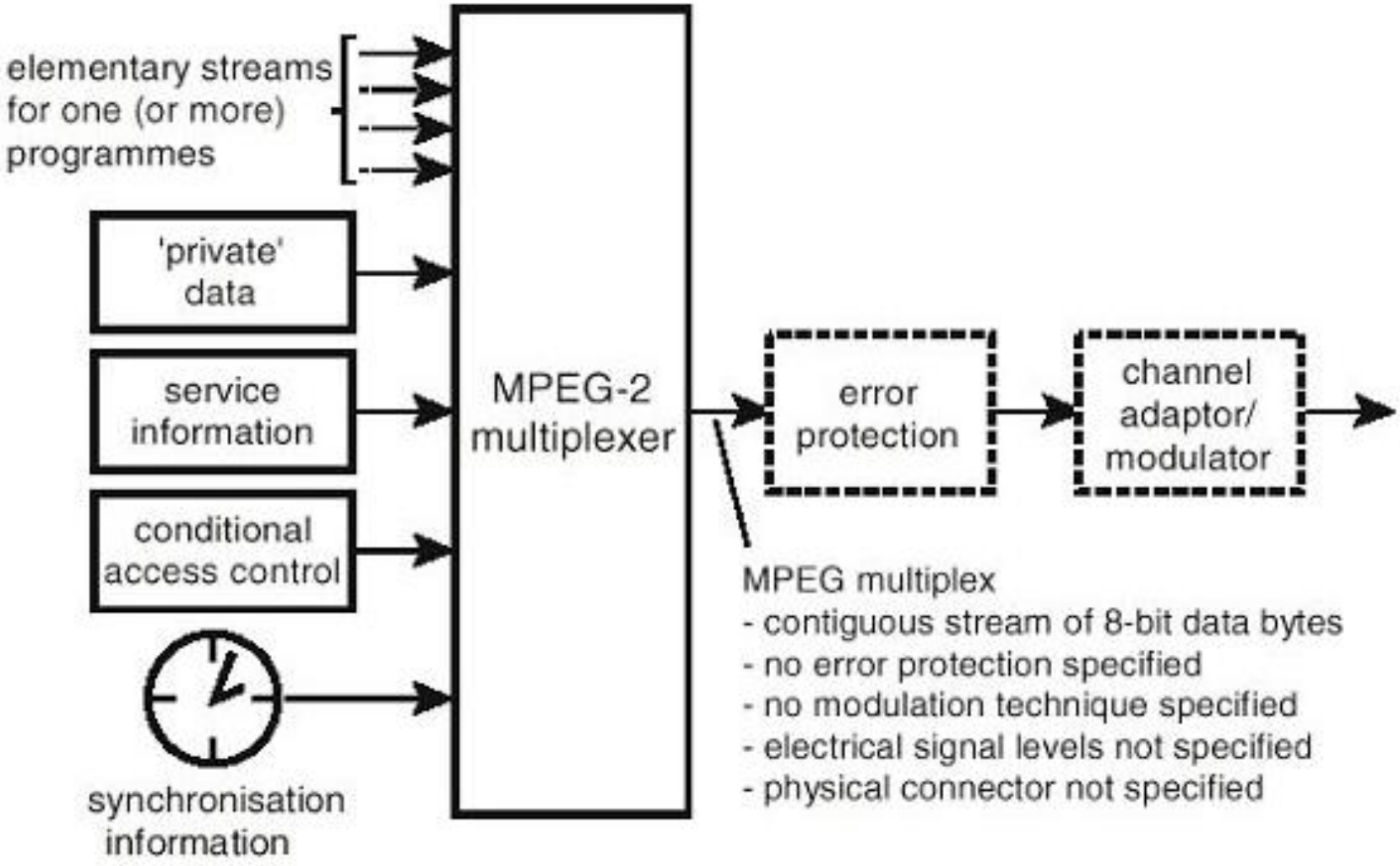


ES : Elementary Stream
PES : Packetized Elementary Stream
PS : Program Stream
TS : Transport Stream

MPEG-2 Systems Layers



Details on the encoder side

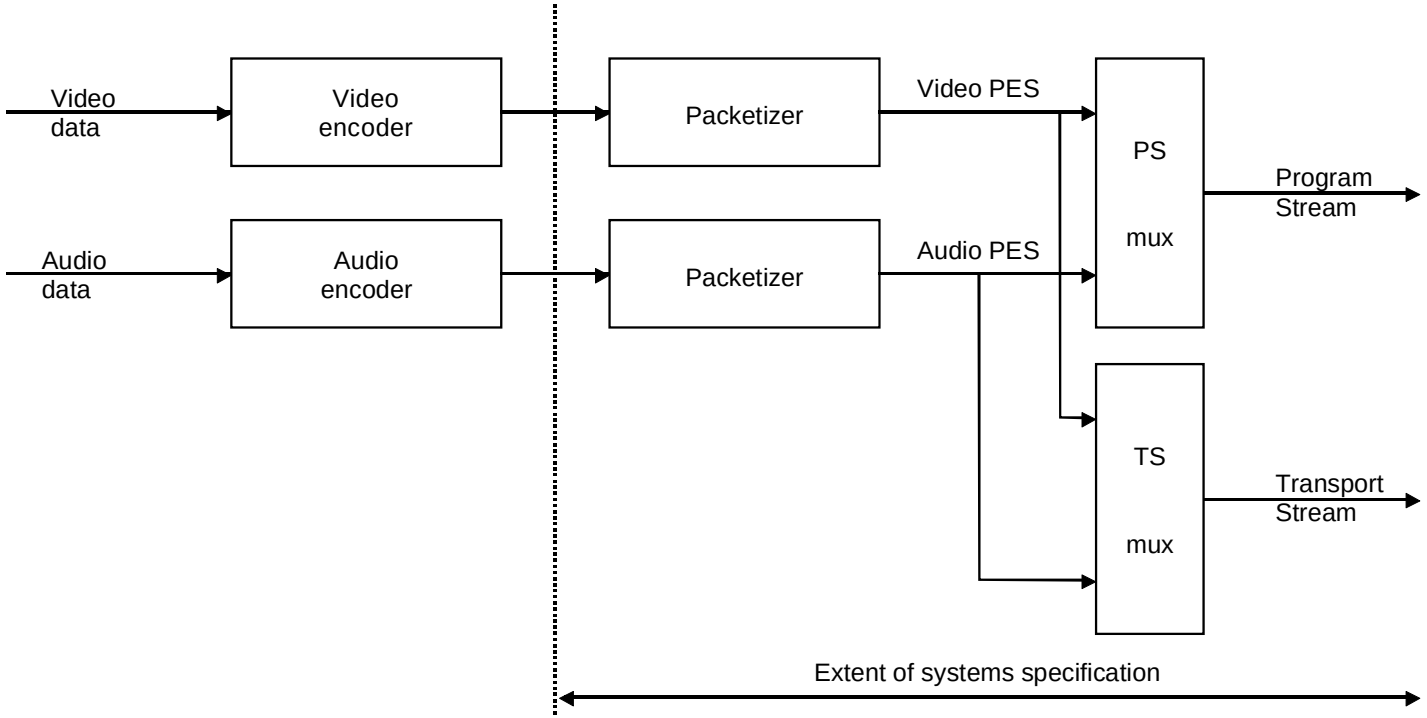


Introduction

- Audio and Video
  - have different CODEC, data size, target application…
  - should be represented simultaneously.
- Synchronization, Multiplexing
  - The system layer support the delivery audio, video, (and other) information to the codec layer.
- Program
  - a set of audio and video data

PS & TS

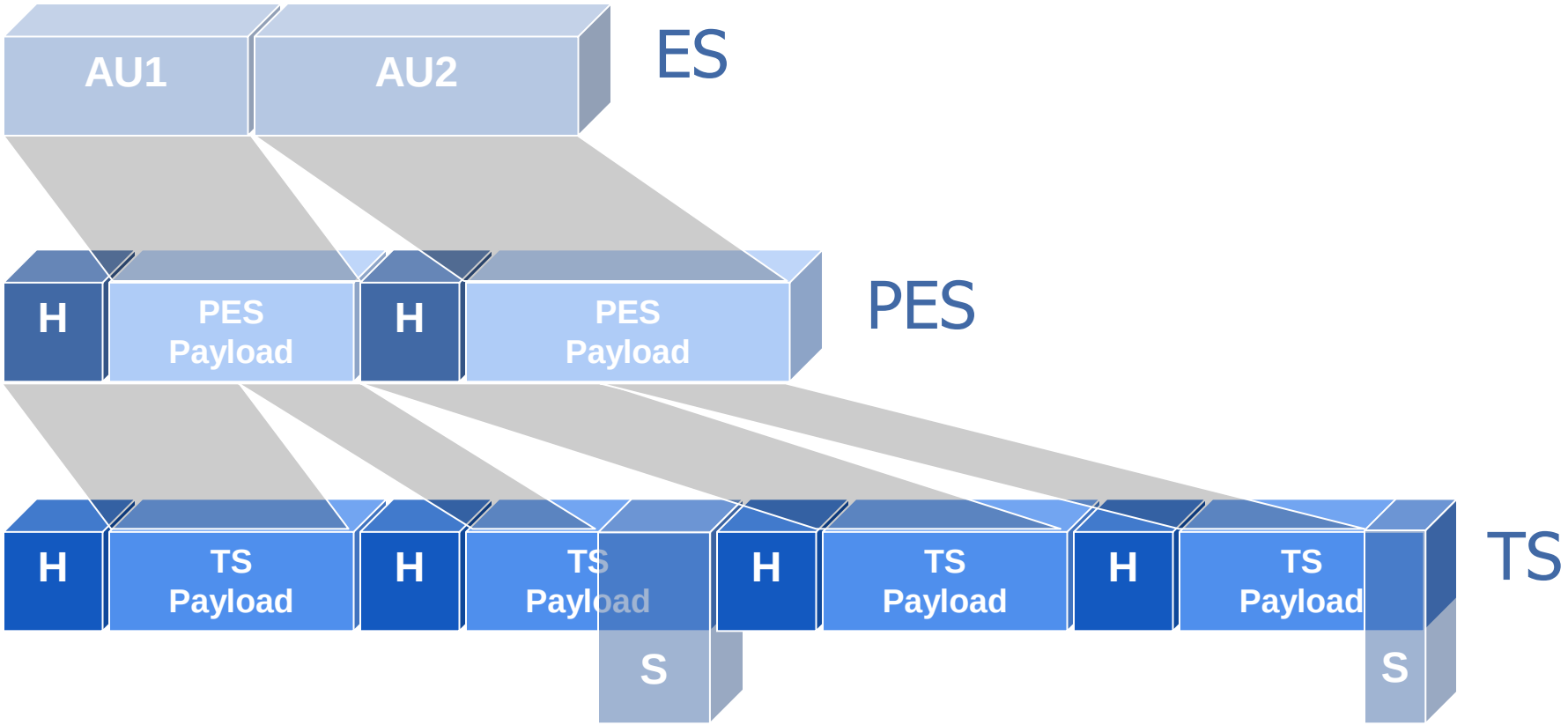
- PS(Program Stream)
  - composed one program
  - error-free environments(e.g. storage)
- TS(Transport Stream)
  - composed one or more programs
  - environments highly prone to error and the loss of packets



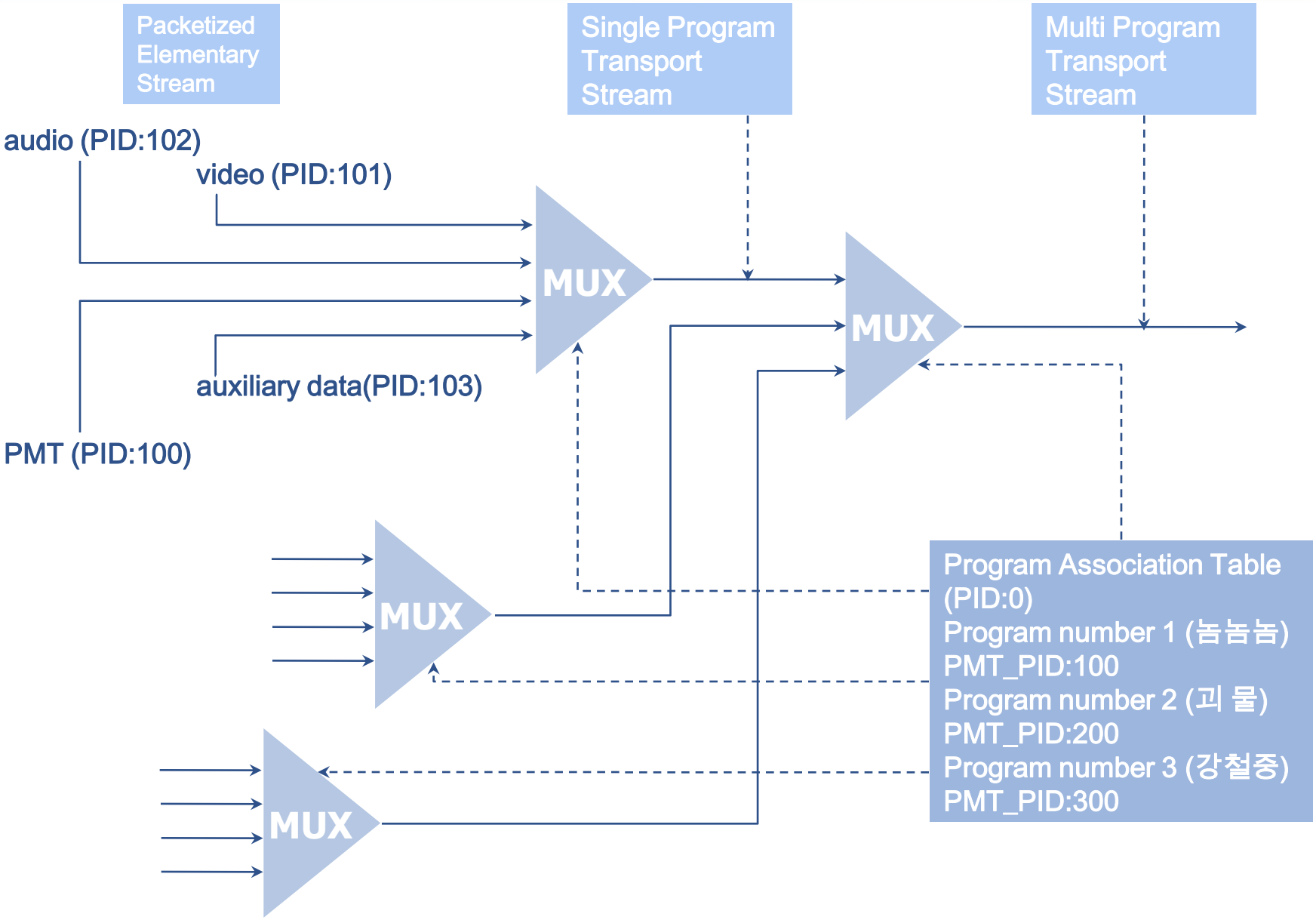
TS & PES Packet

- TS Packet
  - the unit composing TS
  - has 188 bytes fixed length
  - has transport and multiplexing information
- PES(Packetized Elementary Stream) Packet
  - the unit composing PES
  - has variable length
  - has synchronization information

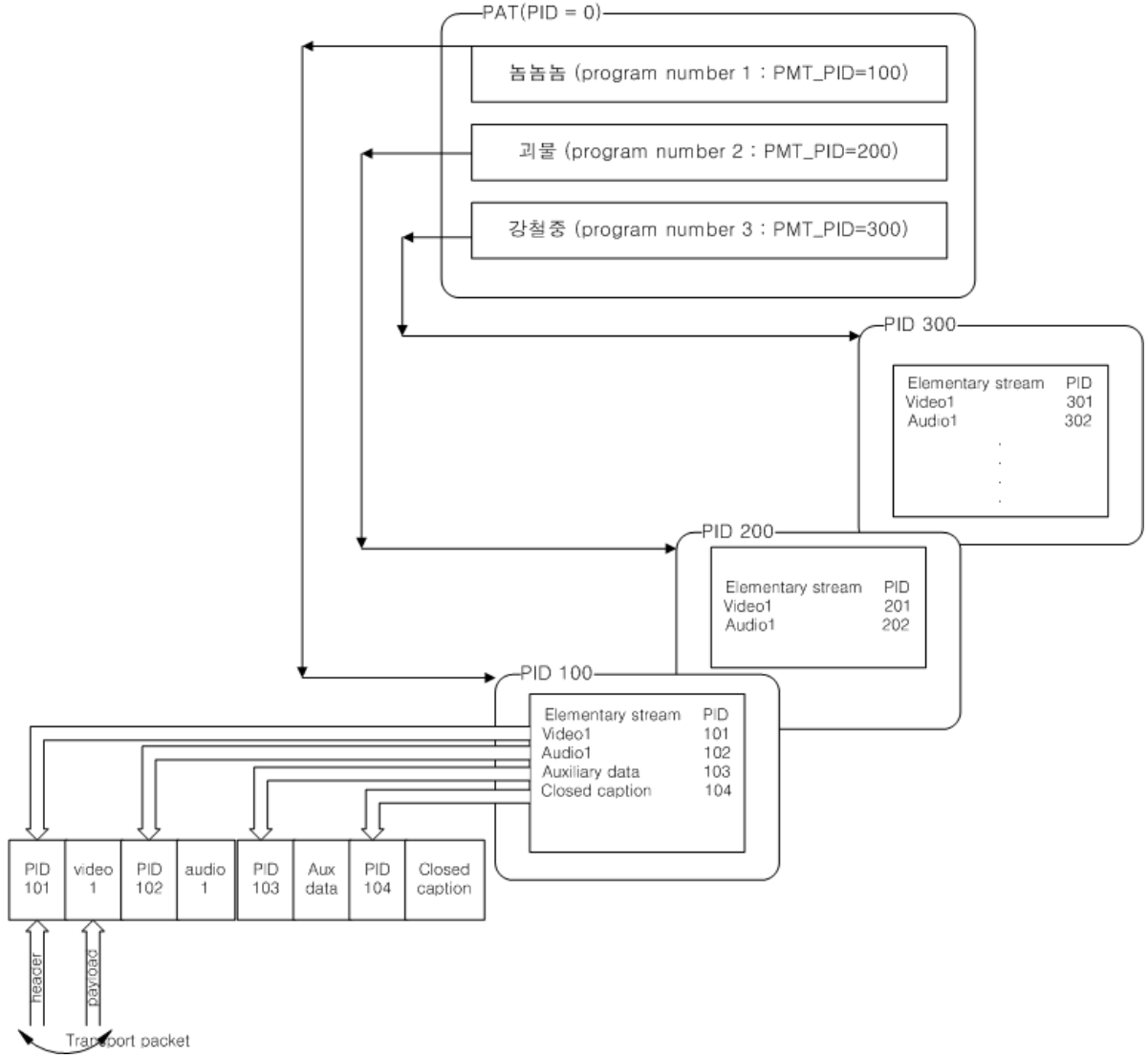
ES -> PES -> TS


AU1
AU2
ES
H
PES Payload
H
PES Payload
PES
H
TS Payload
H
TS Payload
S
H
TS Payload
H
TS Payload
S
TS

TS multiplexing processc



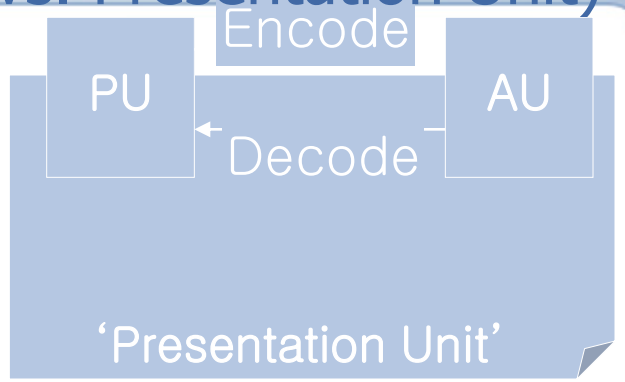
TS multiplexing process



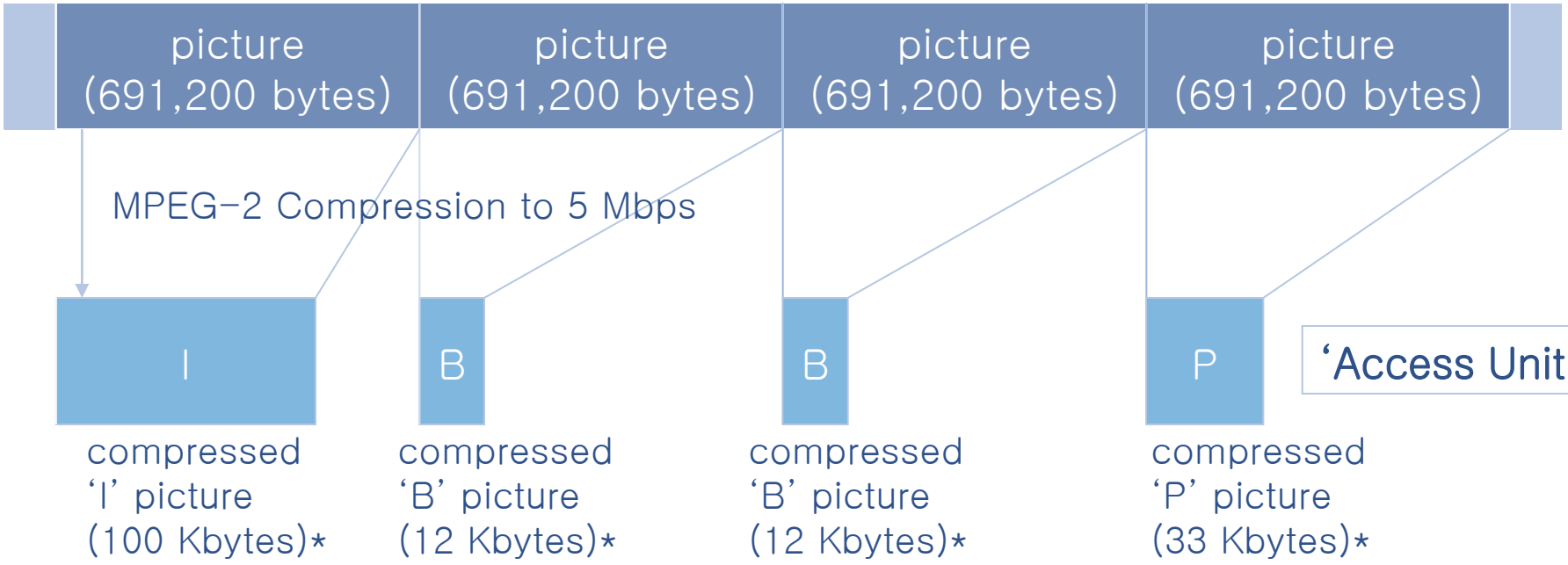
- 각 program의 PMT정보 및 program 1에 대한 transport stream 내용

Elementary Stream

Elementary Stream (ES) (1)
(Access Unit vs. Presentation Unit)



uncompressed digital video stream
(eg. CCIR Rec. 601, 4:2:2)

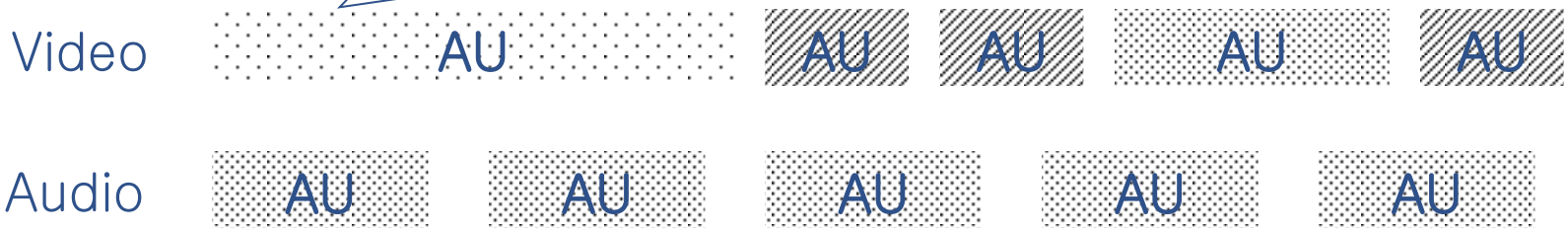


•The actual size depends on target bit-rate and complexity of picture

Elementary Stream (ES) (1)
(AUs can have timing imformations)

PTS or both PTS and DTS

An access unit (AU) is the smallest data entity to which **timing information** can be attributed or A coded representation of a presentation unit. Eg., audio frame, video frame



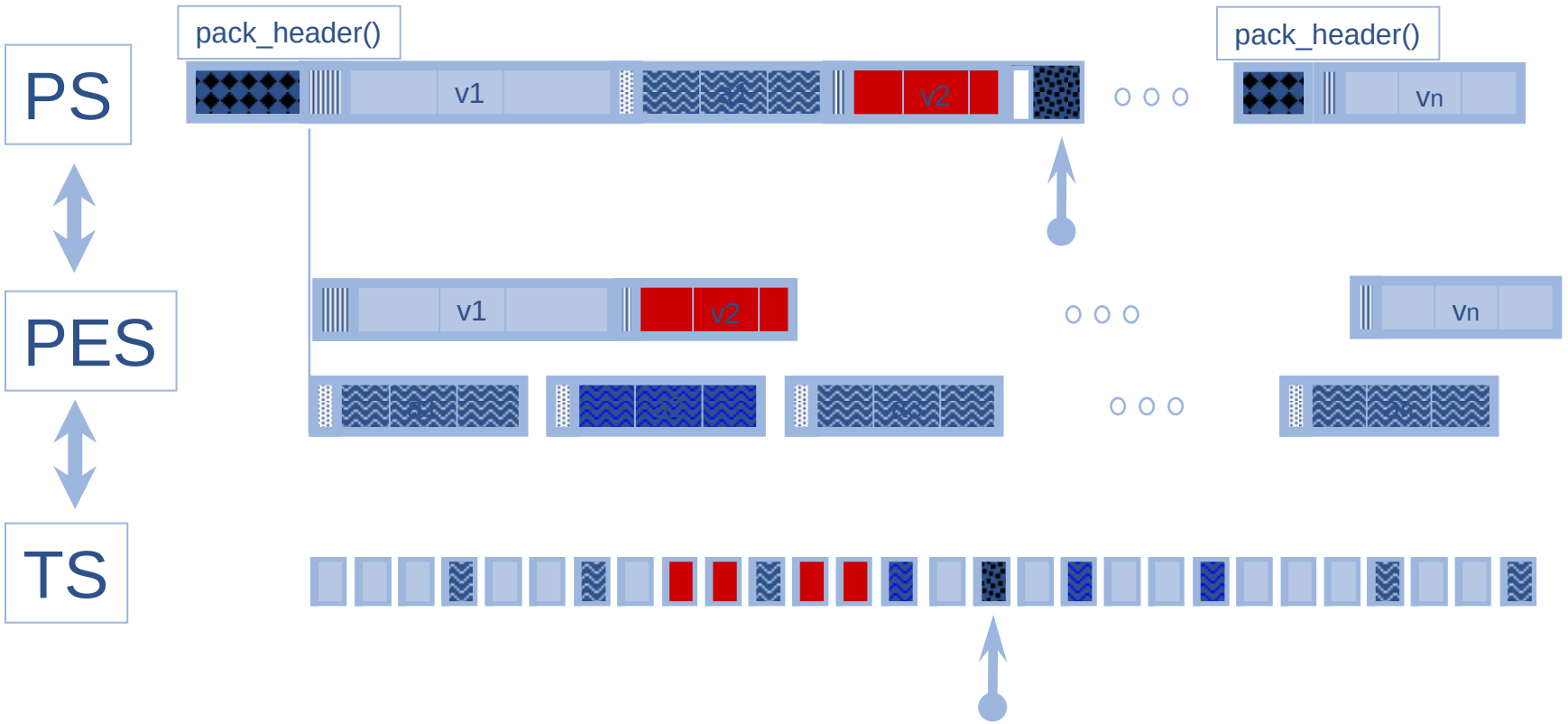
Data from each elementary stream are multiplexed together with information that allows synchronized presentation of the elementary streams within the program

Packetised Elementary Stream

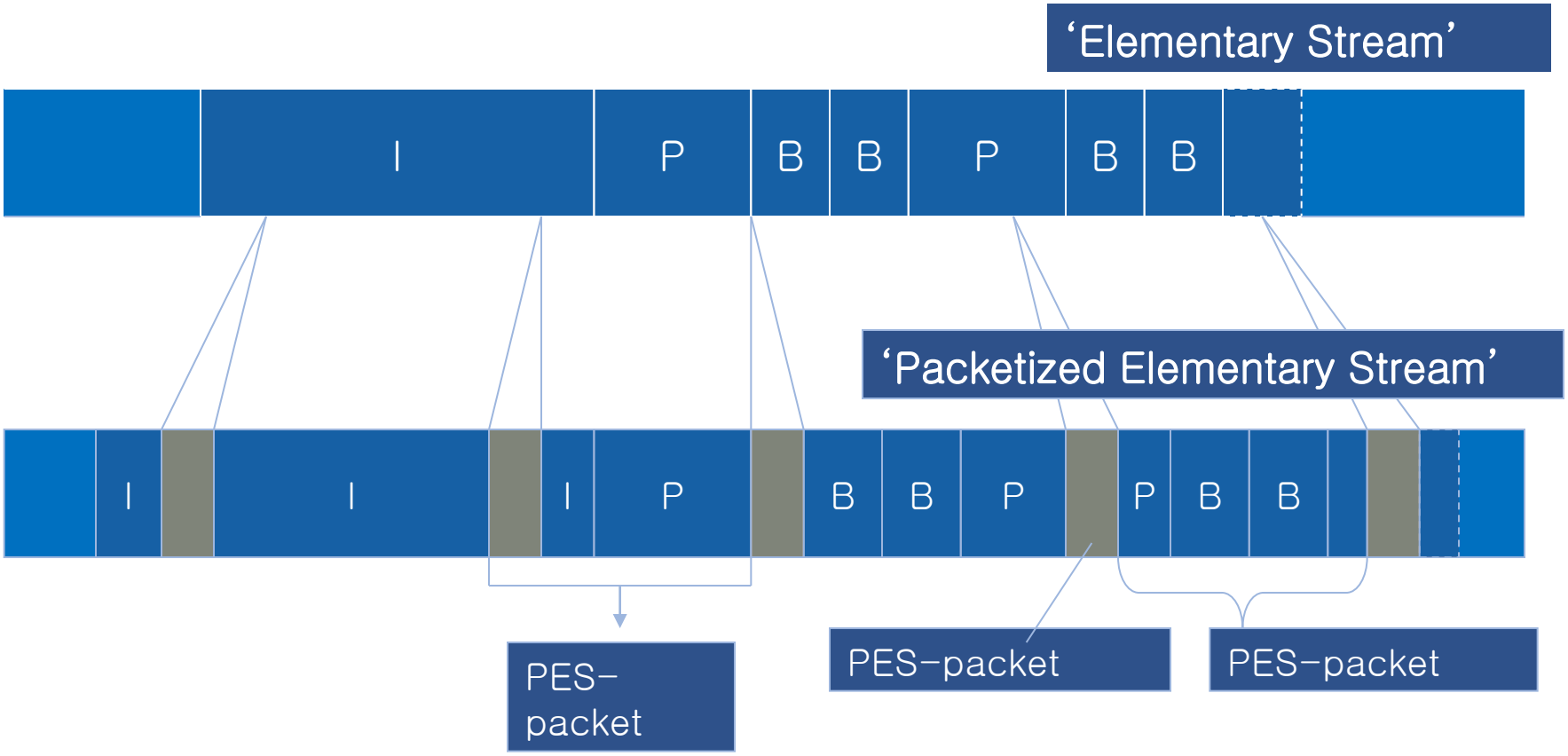
The PES Packets

- The PES packets are used for constructing both of PS and TS.
- The PES packets include a AU(Access Unit) in the most of applications typically, but not mandatory.
- The PES packet delivers PTS or DTS.
- In the video PES packets, trick mode control information can be delivered here.
- The PES packets are identified by *stream_id*.

PES Packets as a Common tools for PS and TS



Packetized Elementary Stream (1)
(Creating a PES from an ES)



* The PES packet header is right where timing information(an PTS or both PTS and DTS) and optionally, either `ESCR` or `ES_Rate` can locate themselves.

Packetized Elementary Stream (4) (PES packet header syntax)

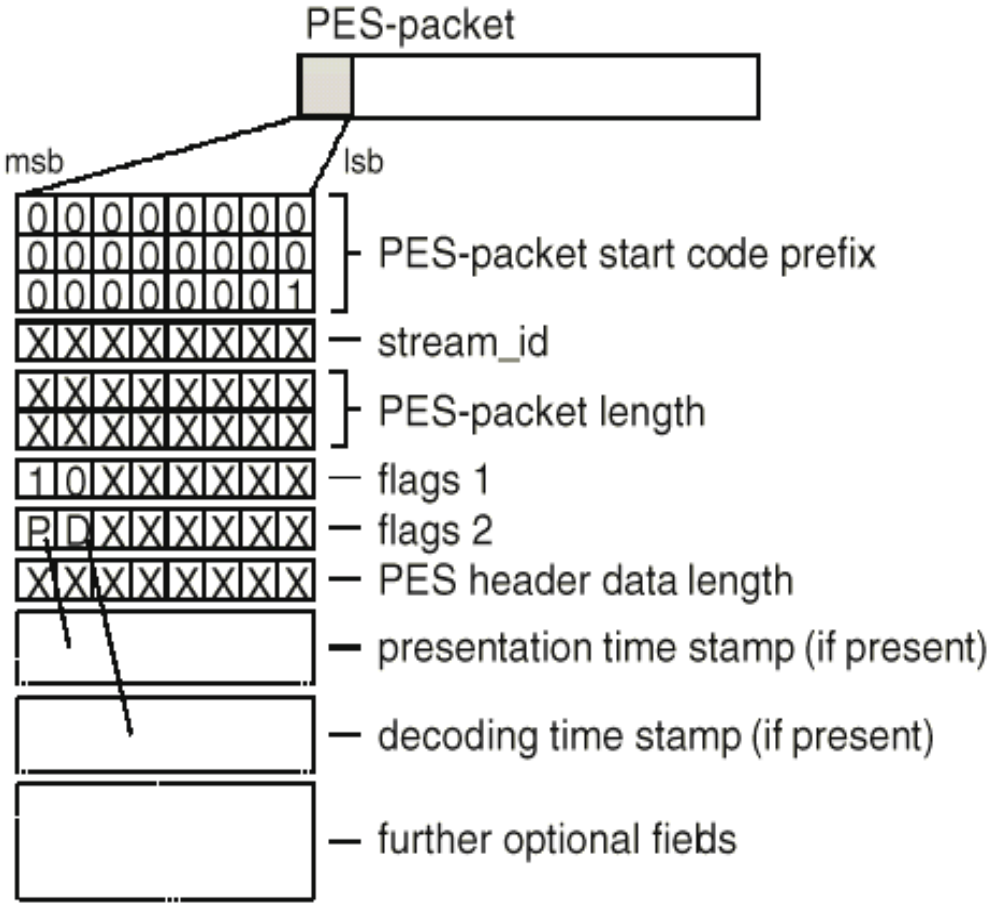
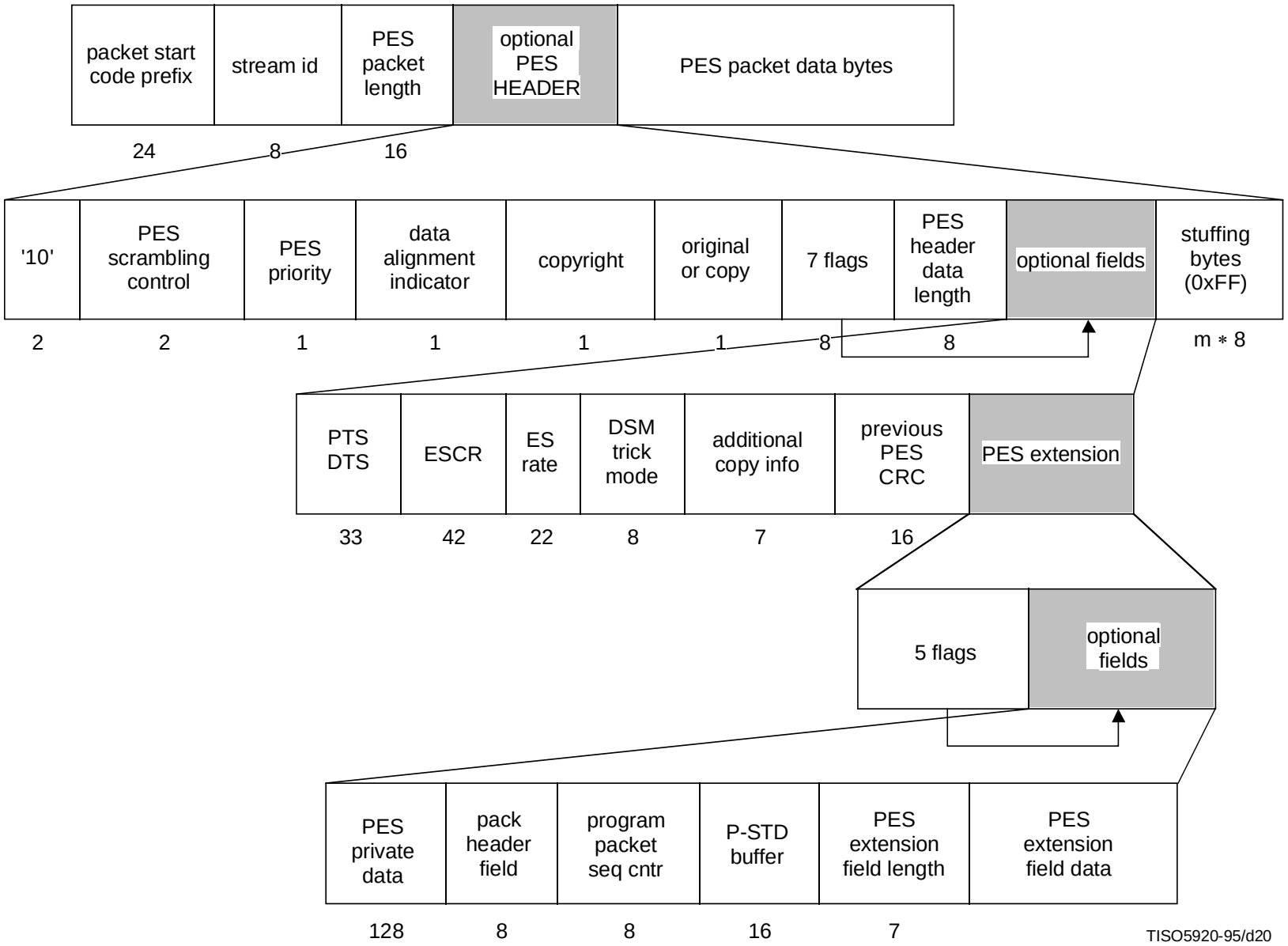


Fig. 4 - A PES-packet header.

PES packet structure



PES packet semantics

- **Packet_start_code_prefix** – (0x000001)
- **Stream_id** – describe the elementary stream type

stream_id	Note	stream coding
1011 1100	1	program_stream_map
1011 1101	2	private_stream_1
1011 1110		padding_stream
1011 1111	3	private_stream_2
110x xxxx		ISO/IEC 13818-3 or ISO/IEC 11172-3 or ISO/IEC 13818-7 or ISO/IEC 14496-3 audio stream number x xxxx
1110 xxxx		ITU-T Rec. H.262 | ISO/IEC 13818-2 or ISO/IEC 11172-2 or ISO/IEC 14496-2 or ITU-T Rec.H.264 | ISO/IEC 14496-10 video stream number xxxx
1111 0000	3	ECM_stream
1111 0001	3	EMM_stream
1111 0010	5	ITU-T Rec. H.222.0 | ISO/IEC 13818-1 Annex A or ISO/IEC 13818-6_DSMCC_stream
1111 0011	2	ISO/IEC_13522_stream
1111 0100	6	ITU-T Rec. H.222.1 type A
1111 0101	6	ITU-T Rec. H.222.1 type B
1111 0110	6	ITU-T Rec. H.222.1 type C
1111 0111	6	ITU-T Rec. H.222.1 type D
1111 1000	6	ITU-T Rec. H.222.1 type E
1111 1001	7	ancillary_stream
1111 1010		ISO/IEC14496-1_SL-packetized_stream
1111 1011		ISO/IEC14496-1_FlexMux_stream
1111.1100		metadata stream
1111.1101	8	extended_stream_id
1111 1110		reserved data stream
1111 1111	4	program_stream_directory

- **Packet start code = packet_start_code_prefix + stream_id**

PES packet semantics

- **PES_scrambling_control** – indicate the scrambling mode of the PES packet payload.

Value	Description
00	Not scrambled
01	User-defined
10	User-defined
11	User-defined

- **Data_alignment_indicator** – When set to a value of '1', it indicates that the PES packet header is immediately followed by the video syntax element or audio sync word indicated in the data_stream_alignment_descriptor

- **Copyright** - When set to '1' it indicates that the material of the associated PES packet payload is protected by copyright.

- **Original_or_copy** - When set to '1' the contents of the associated PES packet payload is an original.

PES packet semantics

- **PTS(presentation time stamp)** - indicates the time of presentation, tpn(k), in the system target decoder of a presentation unit k of elementary stream n.
  - $PTS(k) = ((system\_clock\_frequency \times tpn(k)) \; DIV \; 300) \; \% \; 233$
  - where tpn(k) is the presentation time of presentation unit Pn(k).
- **DTS(decoding time stamp)** - It indicates the decoding time, tdn(j), in the system target decoder of an access unit j of elementary stream n.
  - $DTS(j) = ((system\_clock\_frequency \times tdn(j)) \; DIV \; 300) \; \% \; 233$
  - where tdn(j) is the decoding time of access unit An(j).
- **ES_rate** – specify the rate at which the system target decoder(STD) receives bytes of the PES packet in the case of a PES stream.

PES packet semantics

- **Trick_mode_control** – indicate which trick mode is applied to the associated video stream.

Value	Description
'000'	Fast forward
'001'	Slow motion
'010'	Freeze frame
'011'	Fast reverse
'100'	Slow reverse
'101'-'111'	Reserved

- **Additional_copy_info** – contain private data relating to copyright information.

Packetized Elementary Stream (2) (FAQ)

⌛? : How to define the size of PES packet for a ES?

- The maximum size of PES packet is to be 64 Kbytes, which is defined by `PES_packet_length`.

- The size of PES packet can be chopped as long as satisfying the above definition

⌛? : Does every PES packet have PTS?

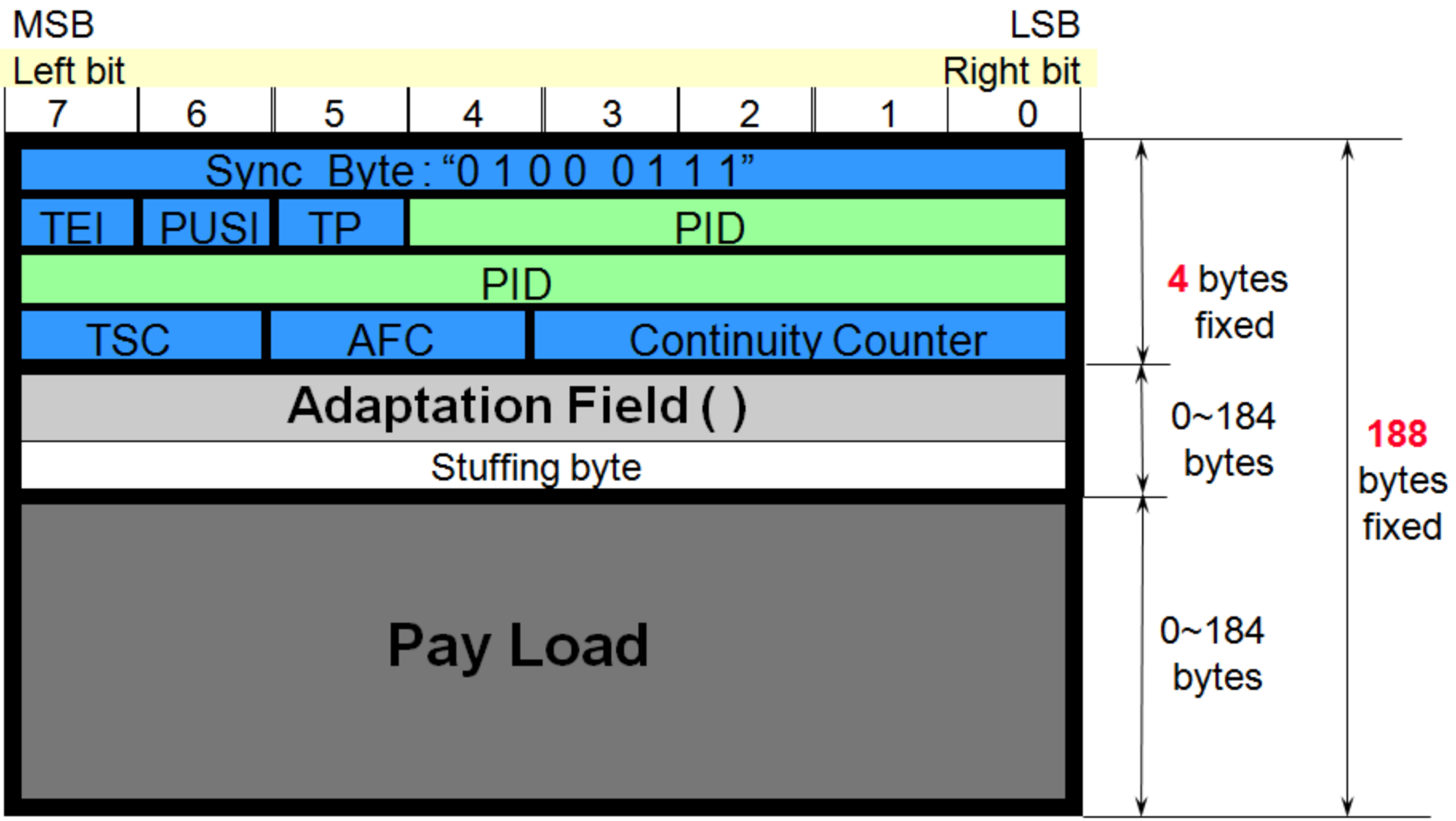
- PES packet with the AU containing start_code shall have PTS. Thus, the rest of PES packets without the AU containing start_code do not have PTS. However, PTS shall be put in PES packets at least every 0.7 second for long-term synchronization.

Transport Stream

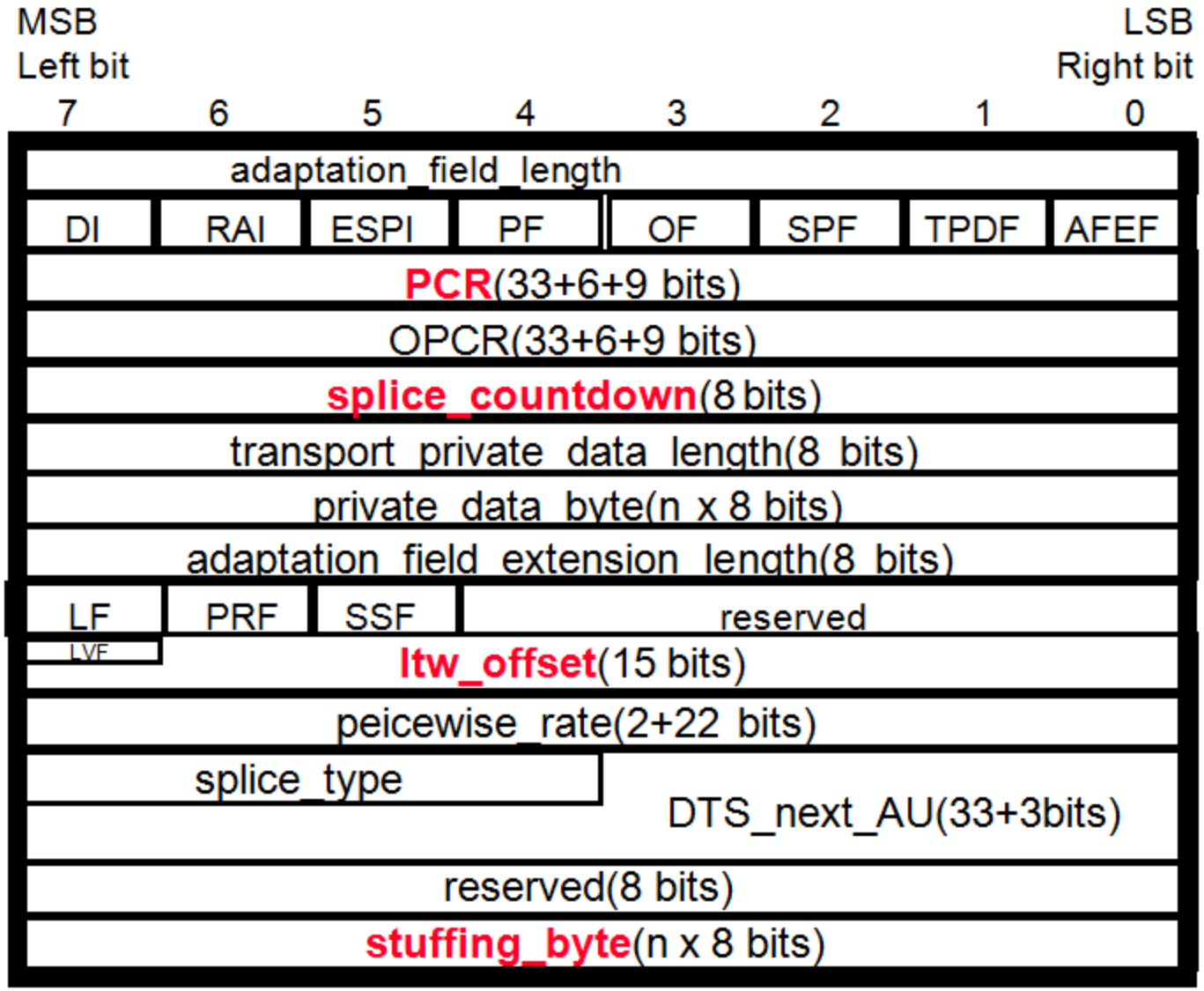
Transport Stream Syntax

Syntax	No. of bits	Mnemonic
transport_packet(){		
sync_byte	8	bslbf
transport_error_indicator	1	bslbf
payload_unit_start_indicator	1	bslbf
transport_priority	1	bslbf
PID	13	uimsbf
transport_scrambling_control	2	bslbf
adaptation_field_control	2	bslbf
continuity_counter	4	uimsbf
if(adaptation_field_control=='10' || adaptation_field_control=='11'){		
adaptation_field()		
}		
if(adaptation_field_control=='01' || adaptation_field_control=='11') {		
for (i=0;i<N;i++){		
data_byte	8	bslbf
}		
}		
}		

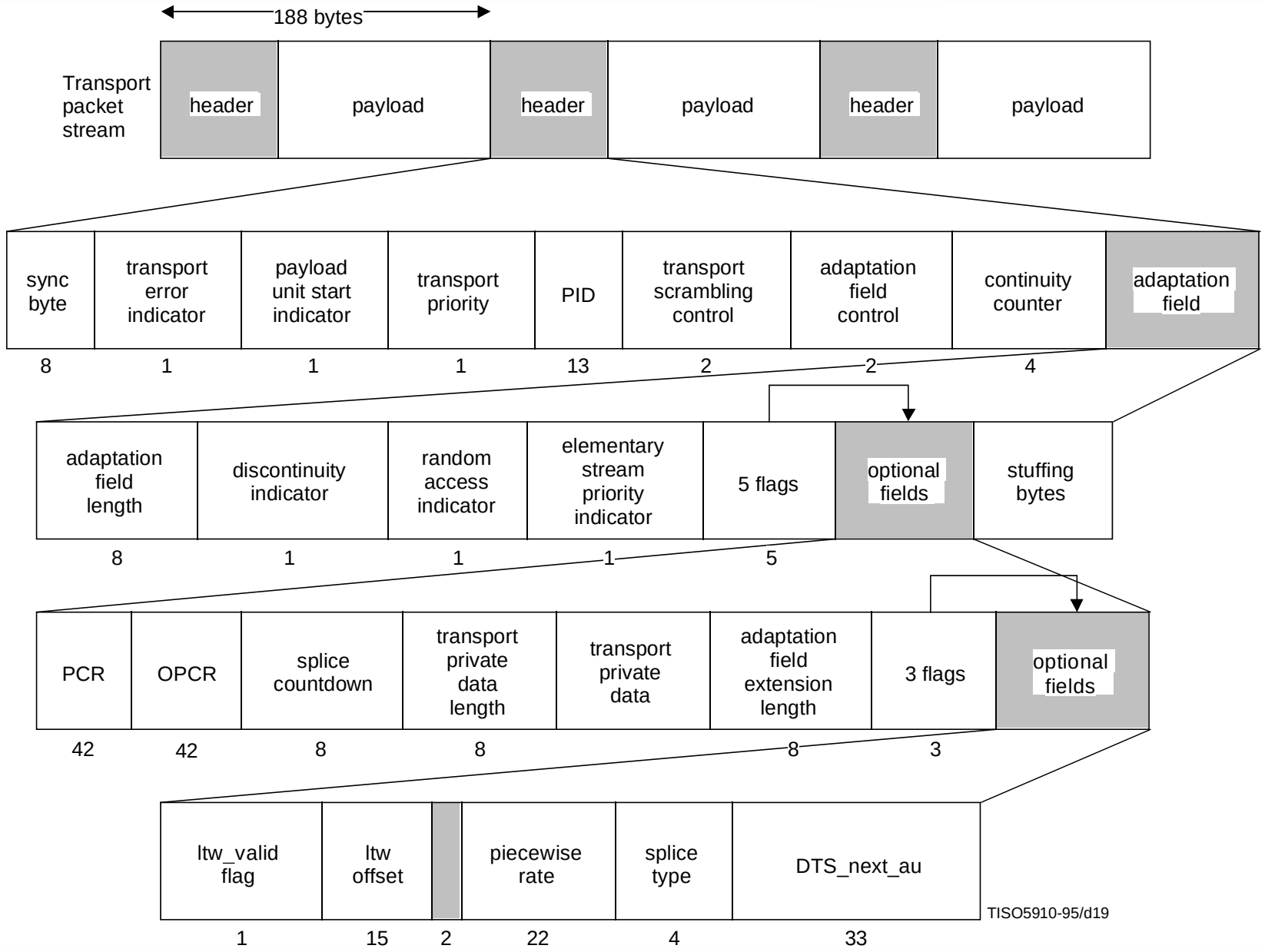
Transport Stream



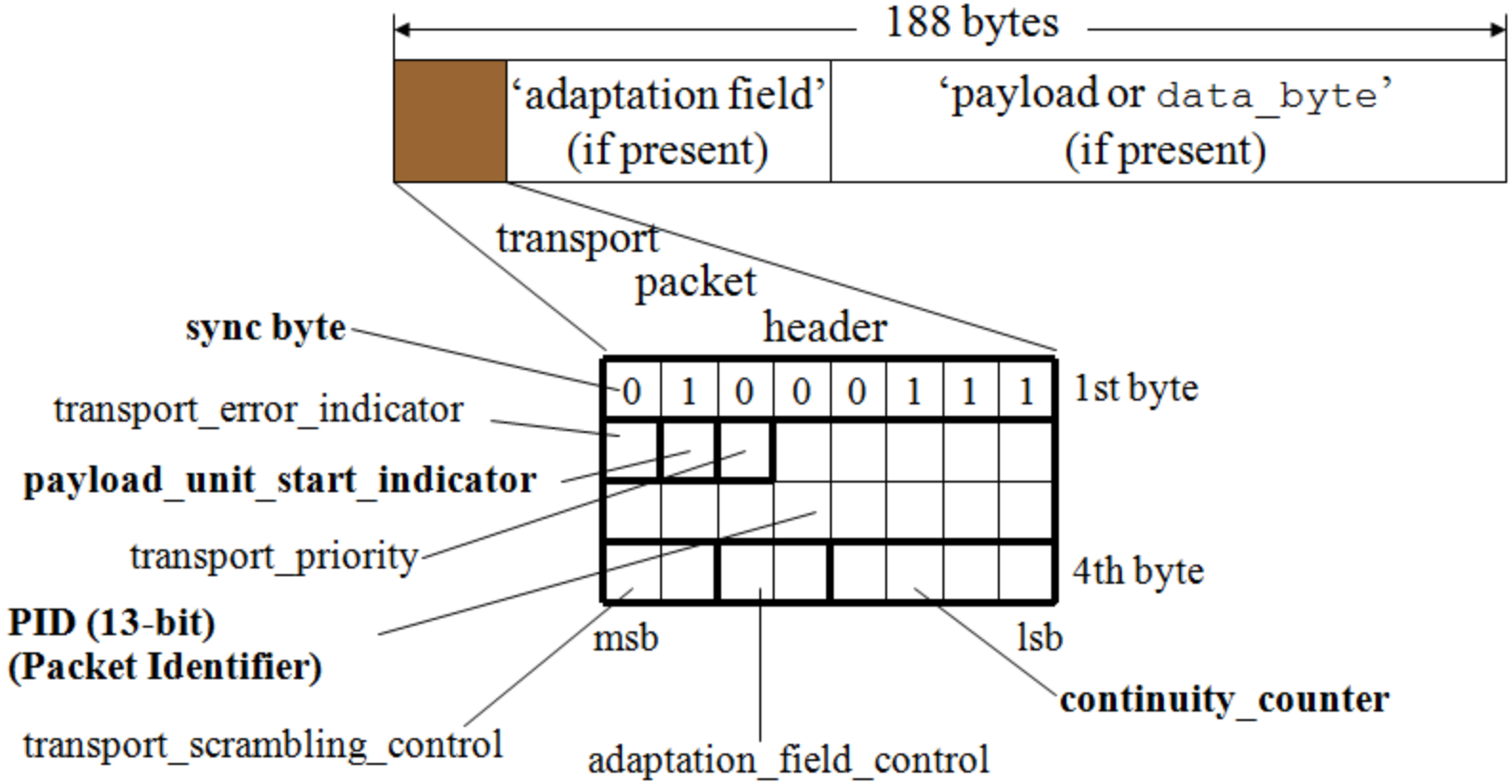
Adaptation Field



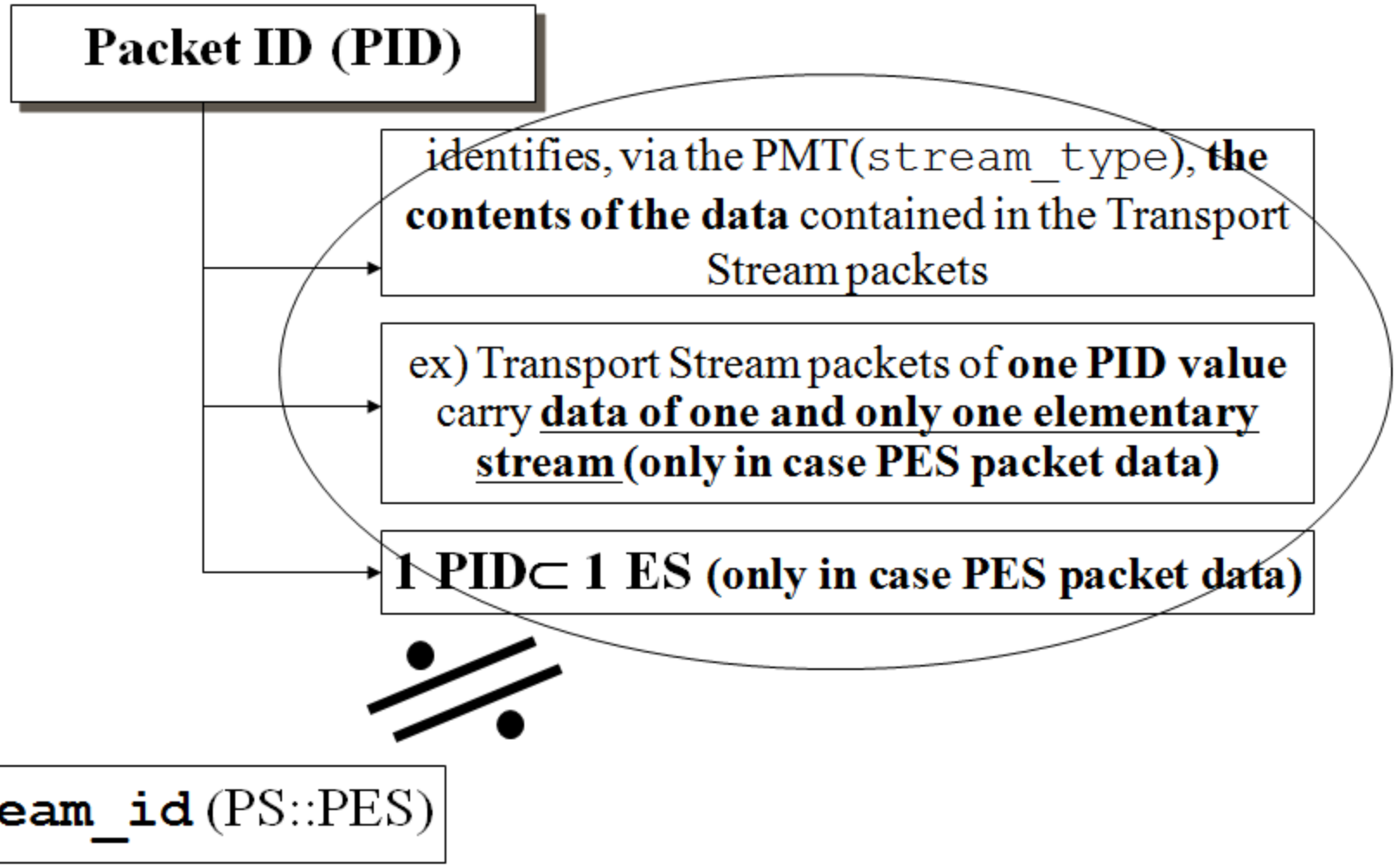
Transport Stream packet structure



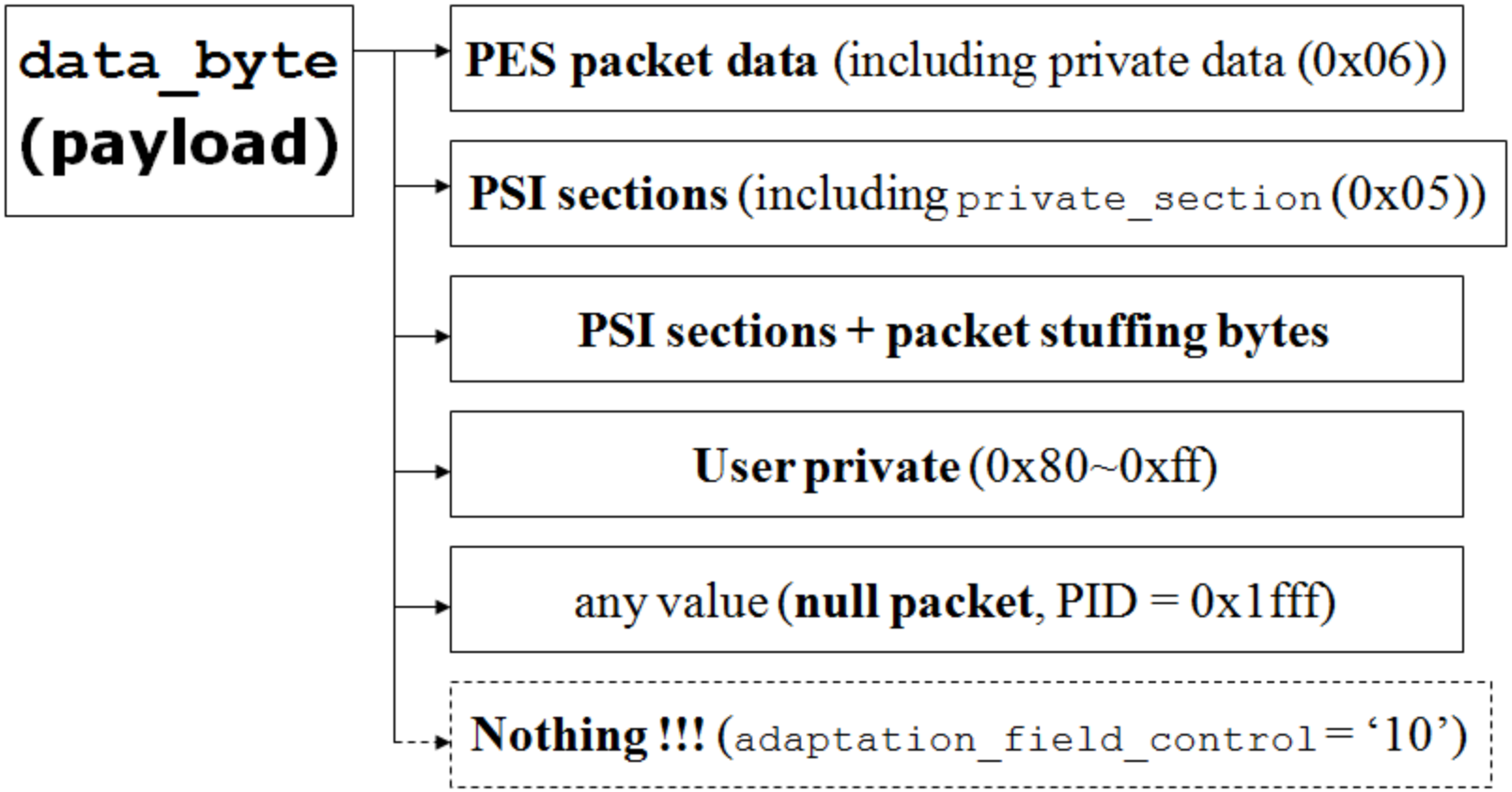
Transport Stream (TS)
(The structure of TS packet header)



Transport Stream (TS) (PID)

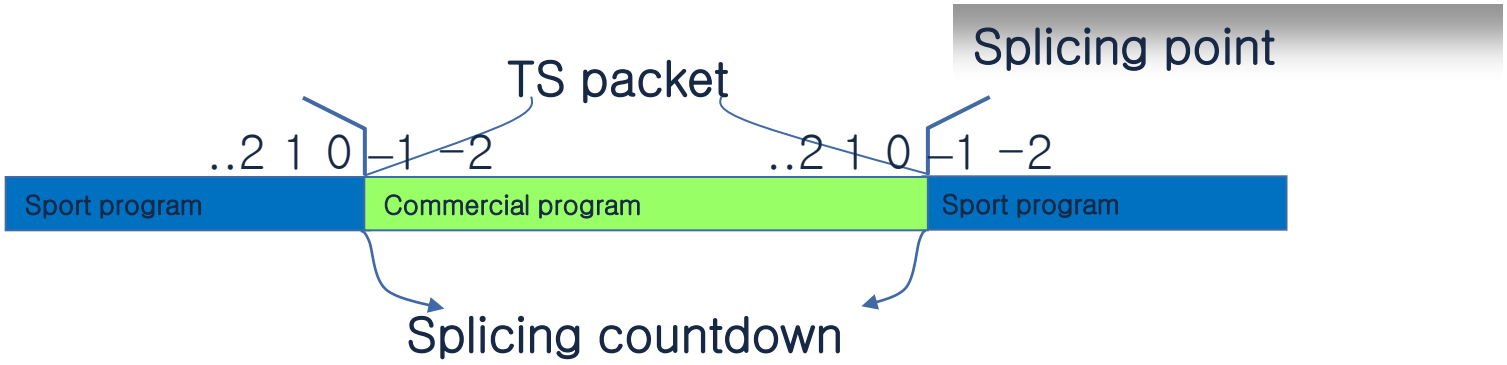


Transport Stream (TS) (The types of data which the payload of a TS packet can have)

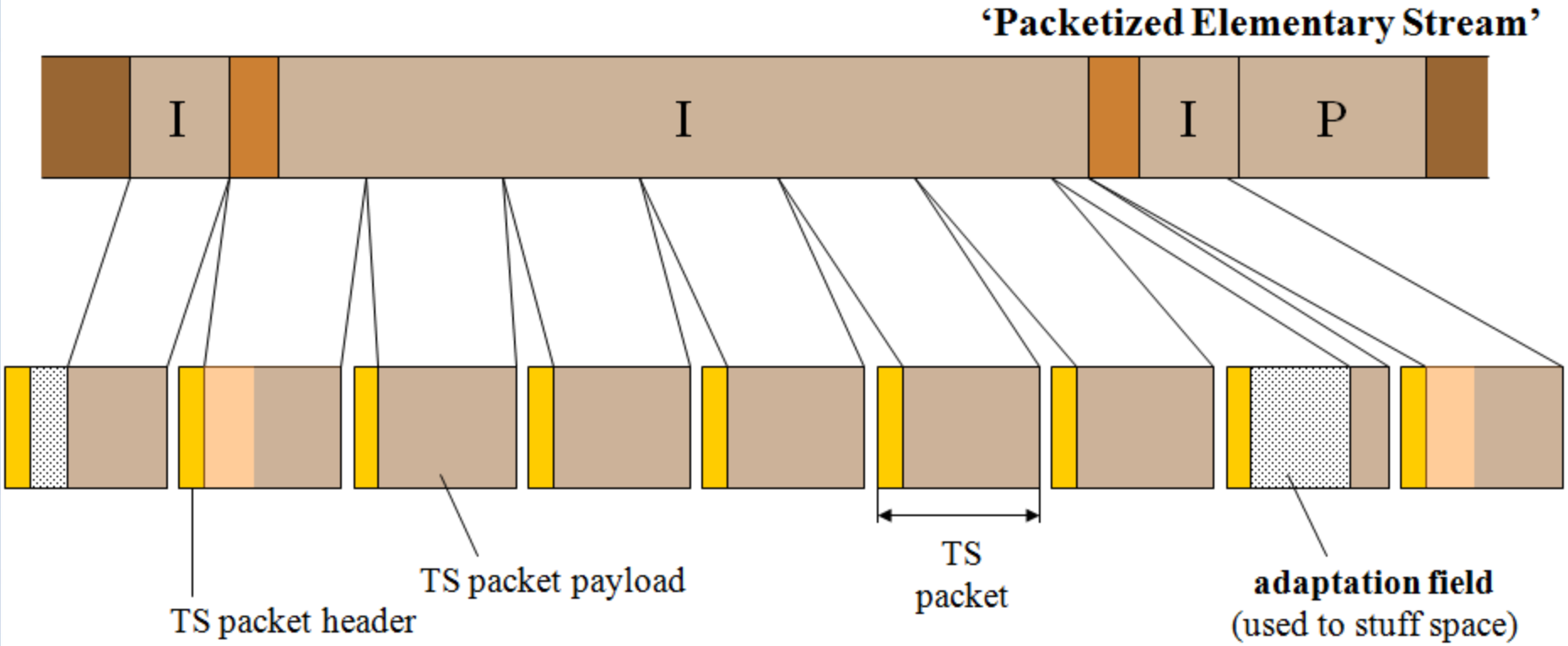


Transport Stream (TS) (Splicing)

Specifying the remaining number of TS packets following associated TS packet until splicing point is reached to zero.



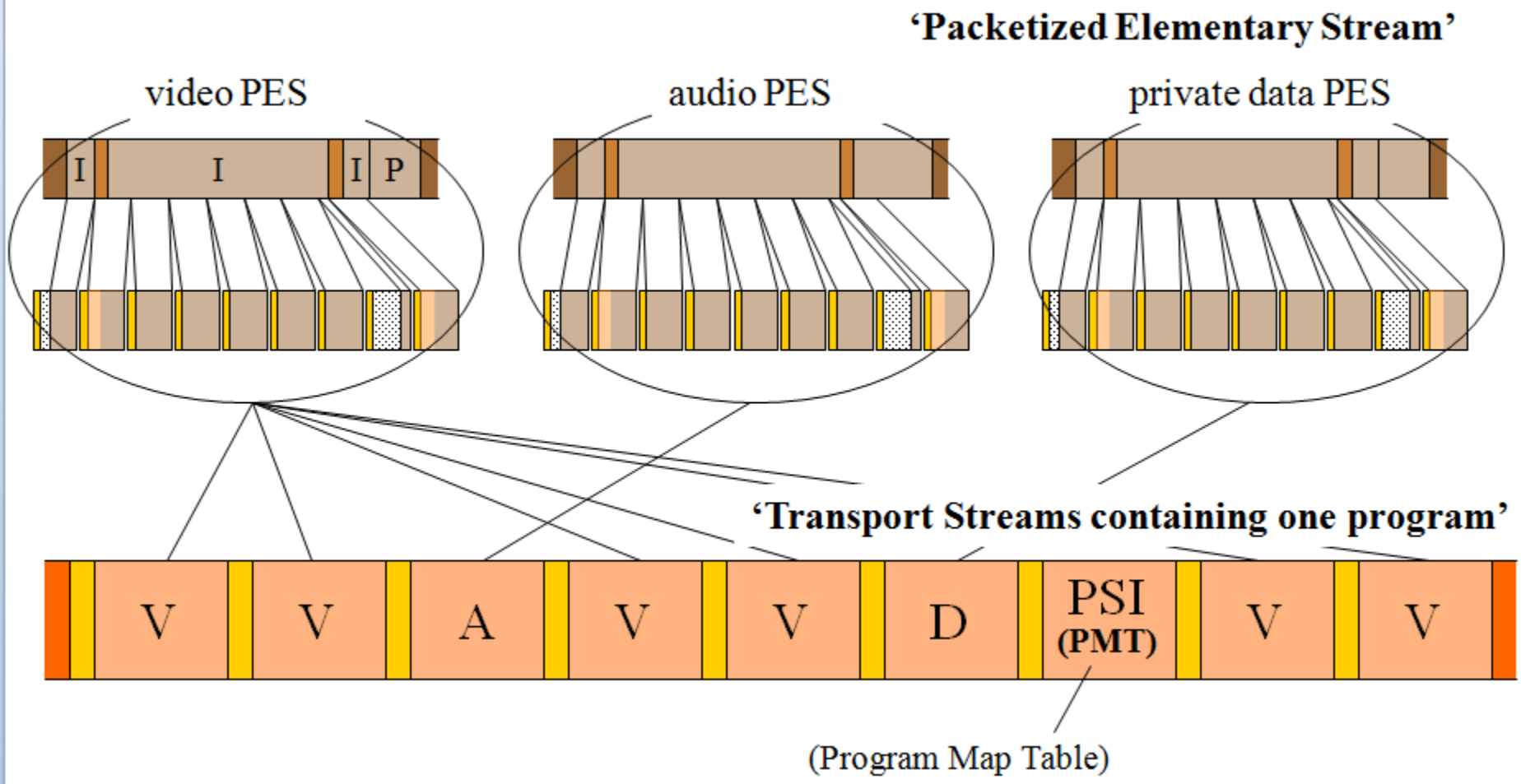
Transport Stream (TS) (Creating an TS packet from an PES')



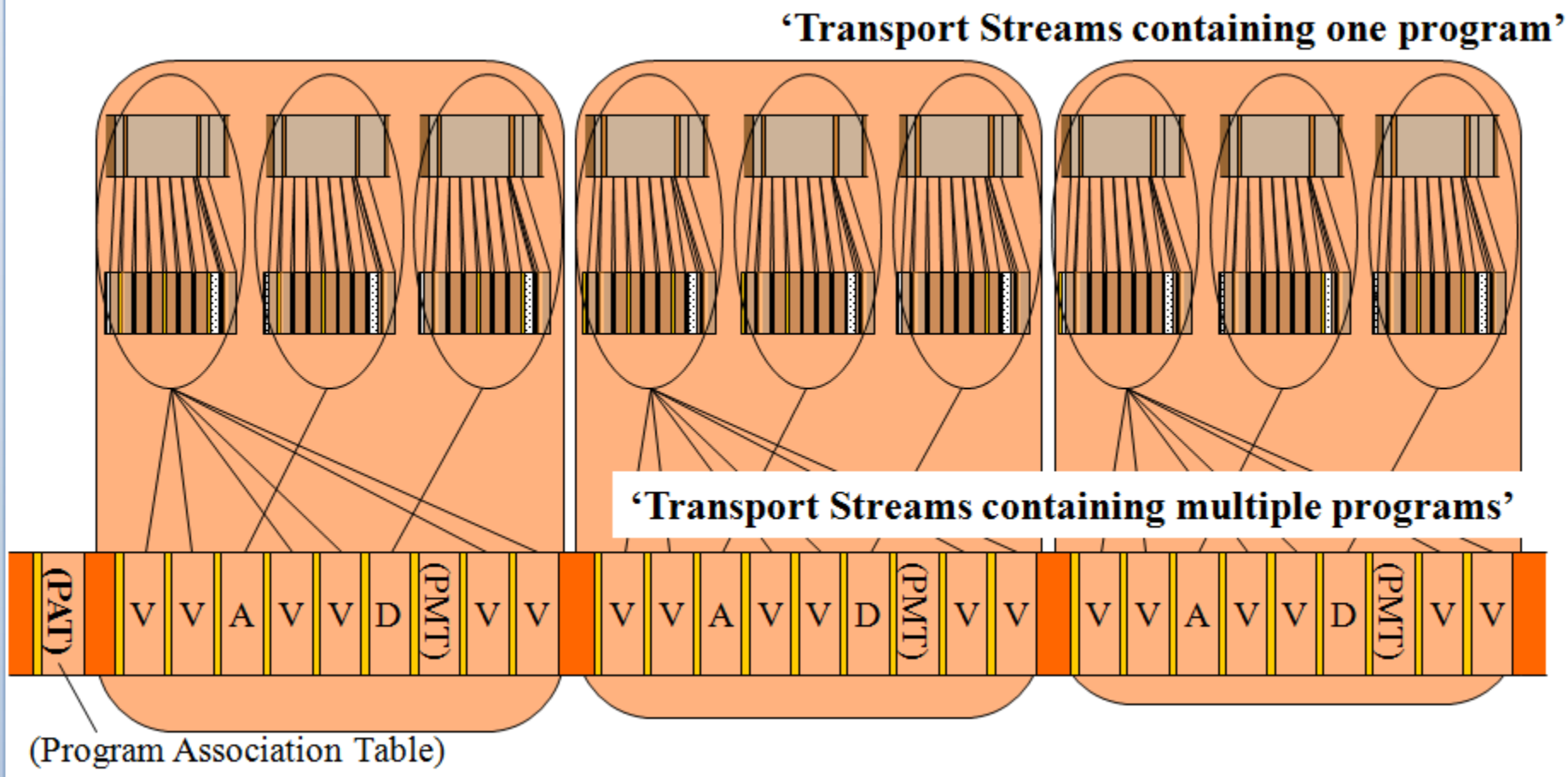
The Unique Rule of cutting or merging in the ISO/IEC 13818-1

The **first byte** of each PES packet headers is located at the **first available payload location** of a Transport Stream packet

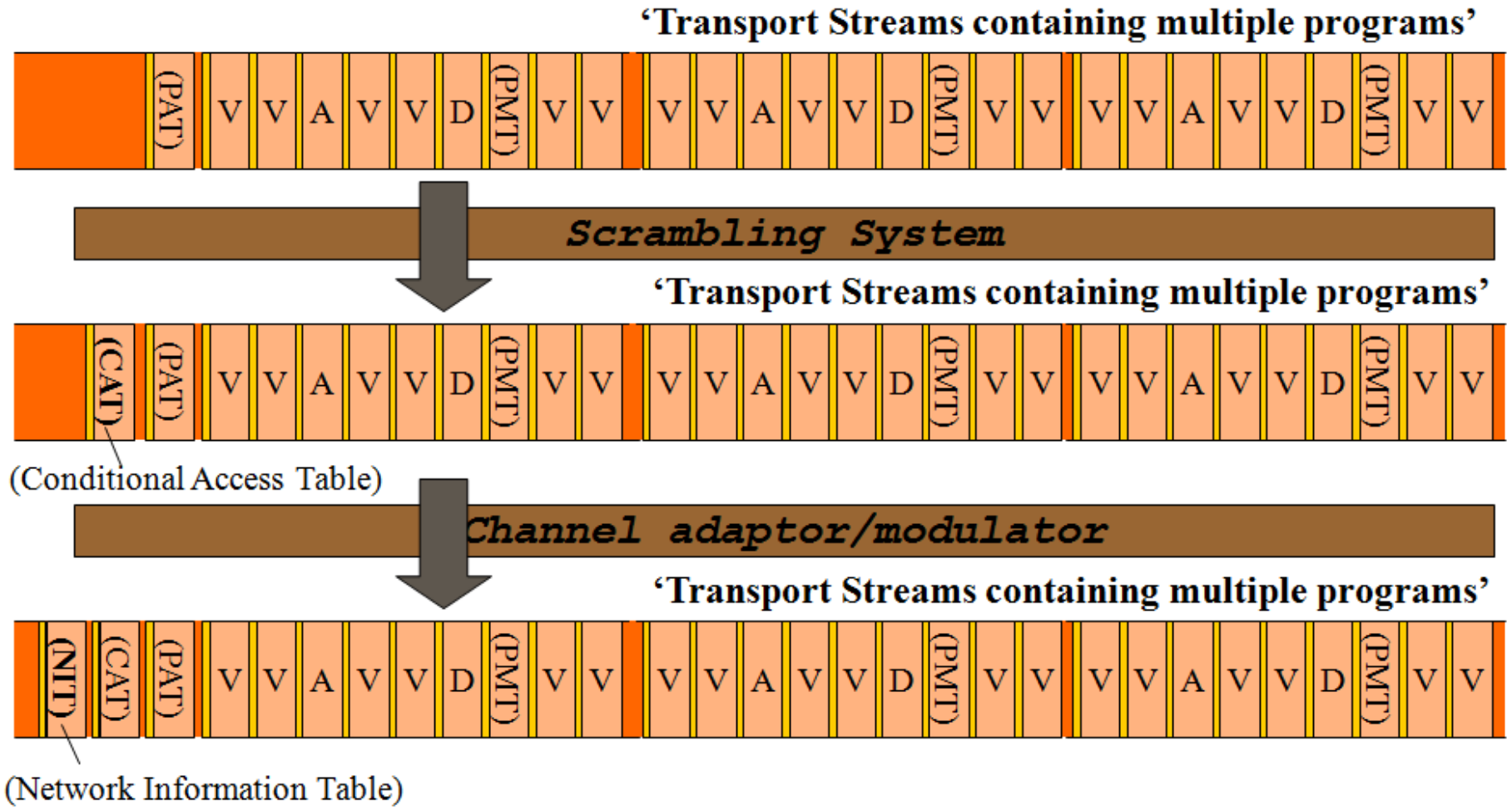
Transport Stream (TS) (Creating an TS containing one program from some TS packets)



Transport Stream (TS) (Creating a TS containing multiple programs)



Transport Stream (TS)
(Adding some PSI tables to TS)



Transport Stream semantics

- **sync_byte** – is a fixed 8-bit field whose value is '0100 0111' (0x47).
- **transport_error_indicator** – When set to '1' it indicates that at least 1 uncorrectable bit error exists in the associated TS packet.
- **payload_unit_start_indicator** – When set to '1' it indicates that this TS packet contains the first PES packet.
- **transport_priority** – When set to '1' it indicates that the associated packet is greater priority than other packets having the same PID which do not have the bit set to '1'.

Transport Stream semantics

- **transport_scrambling_control** – indicates the scrambling mode of the TS packet payload.

Value	Description
00	Not scrambled
01	User-defined
10	User-defined
11	User-defined

- **adaptation_field_control** – 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** – is a 4-bit field incrementing with each TS packet with the same PID.

Transport Stream semantics

- **PID(Packet ID)** – is a 13-bit field, indicating the type of the data stored in the packet payload.

Value	Description
0x0000	Program Association Table
0x0001	Conditional Access Table
0x0002	Transport Stream Description Table
0x0003	IPMP Control Information Table
0x0004-0x000F	Reserved
0x00010 … 0x1FFE	May be assigned as network_PID, Program_map_PID, elementary_PID, or for other purposes
0x1FFF	Null packet
NOTE – The transport packets with PID values 0x0000, 0x0001, and 0x0010-0x1FFE are allowed to carry a PCR.	

Transport Stream semantics

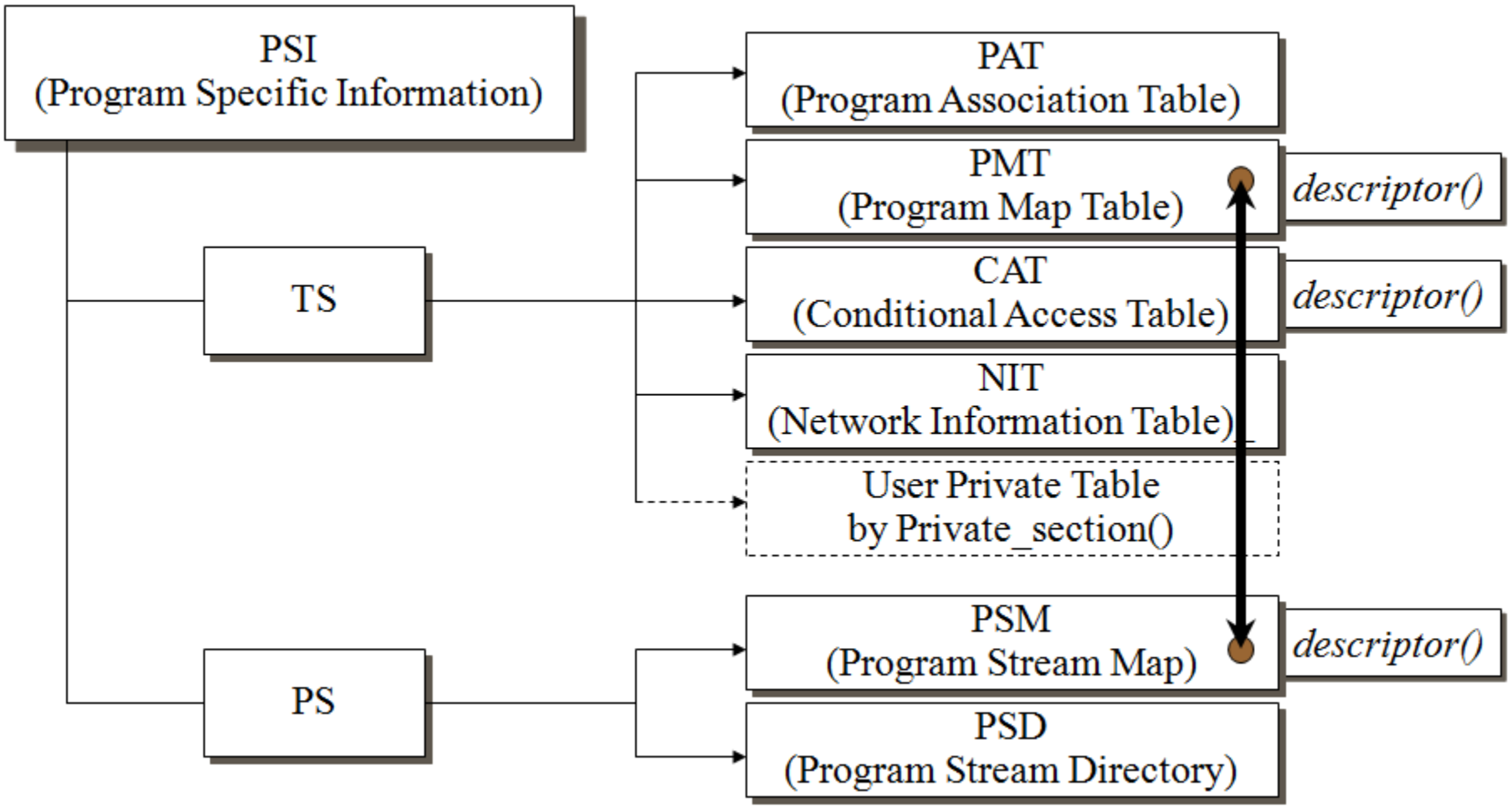
- **Discontinuity_indicator** – set to '1', indicate that the discontinuity state is true for the current TS packet.
- **Random_access_indicator** **-** contain some information to aid random access at this point.
- **PCR(Program Clock Reference) -** A time stamp in the Transport Stream from which decoder timing is derived.

Program Specific Information

PSI(Program specific information) (1/2)

- PSI(Program specific information)
  - A structure stored in TS payload
  - Containes multiplexing information
  - PAT(Program Association Table)
    - Associates program number and program map table pid
    - Reserved PID : 0x00
  - PMT(Program Map Table)
    - Specifies PID values for components of one or more programs

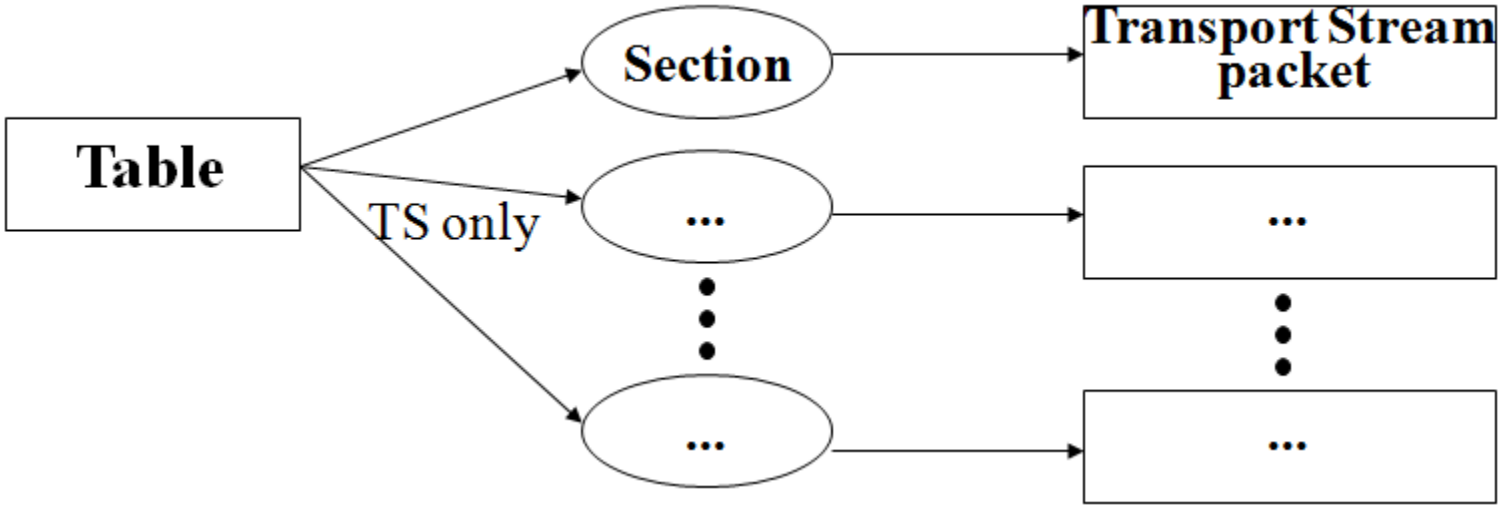
PSI(Program specific information) (2/2)



PSI Table Identifier

Value	Description
0x00	program_association_section
0x01	conditional_access_section(CA_section)
0x02	TS_program_map_section
0x03	TS_description_section
0x04 - 0x37	ITU-T Rec. H.222.0 | ISO/IEC 13818-1 reserved
0x38 - 0x3F	defined in ISO/IEC 13818-6
0x40 - 0xFE	User private
0xFF	Forbidden

- A **table** is split up into **section**s to transport packet data
- PSI shall not be scrambled at all except for `private_data_byte` in `private_section`

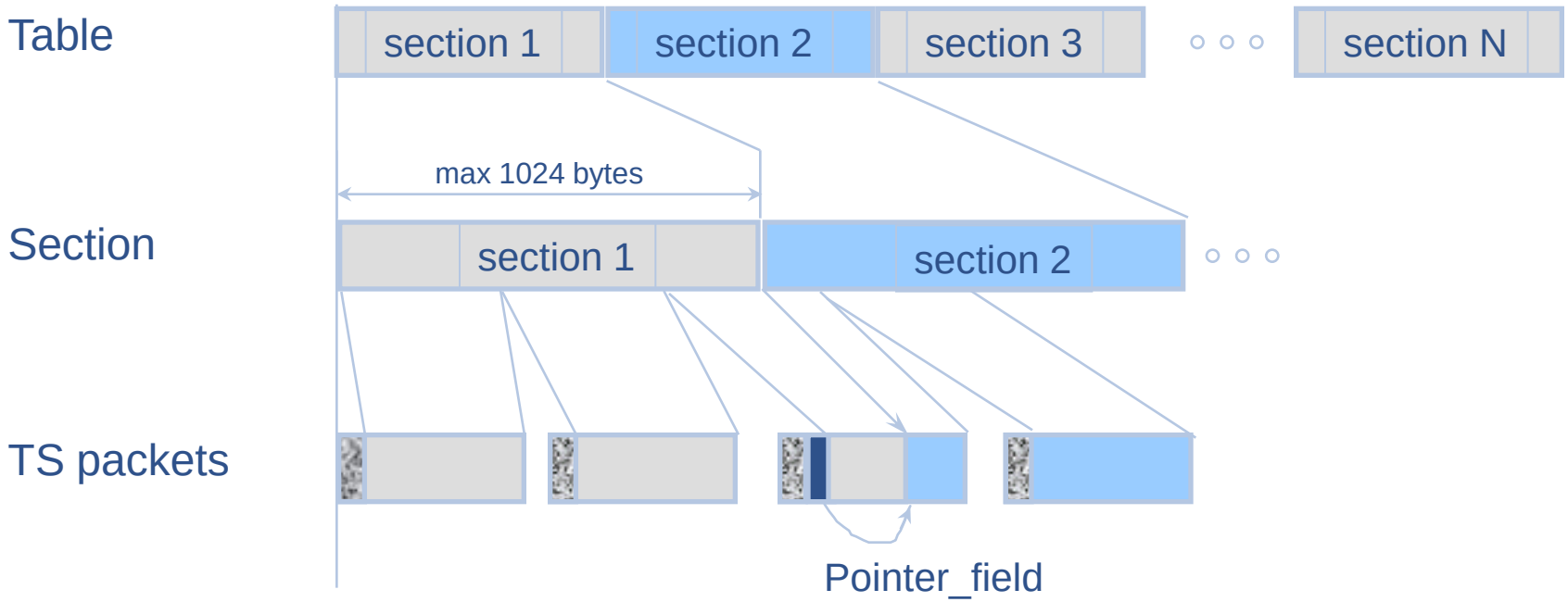


- PSI sections <= 1024 bytes
- private_sections <= 4096 bytes

≫ 188 bytes (TS packet)

`payload_unit_start_indicator` —1→ PSI → **`pointer_field`**

Section and Table Relationships



- If *payload_unit_start_indicator* in the TS header is set to '1', the first byte of payload will start with pointer field.
- If set to '0', there is no pointer field in the payload.

⌛? : What is the rule for splitting a Table into Section?

• When the size of a table is larger than the maximum size such as 1024 byte, the table will bi splitted into a couple of sections. Even the size of the table is smaller than 1024 bytes, the table can be splitted into a couple of sections.

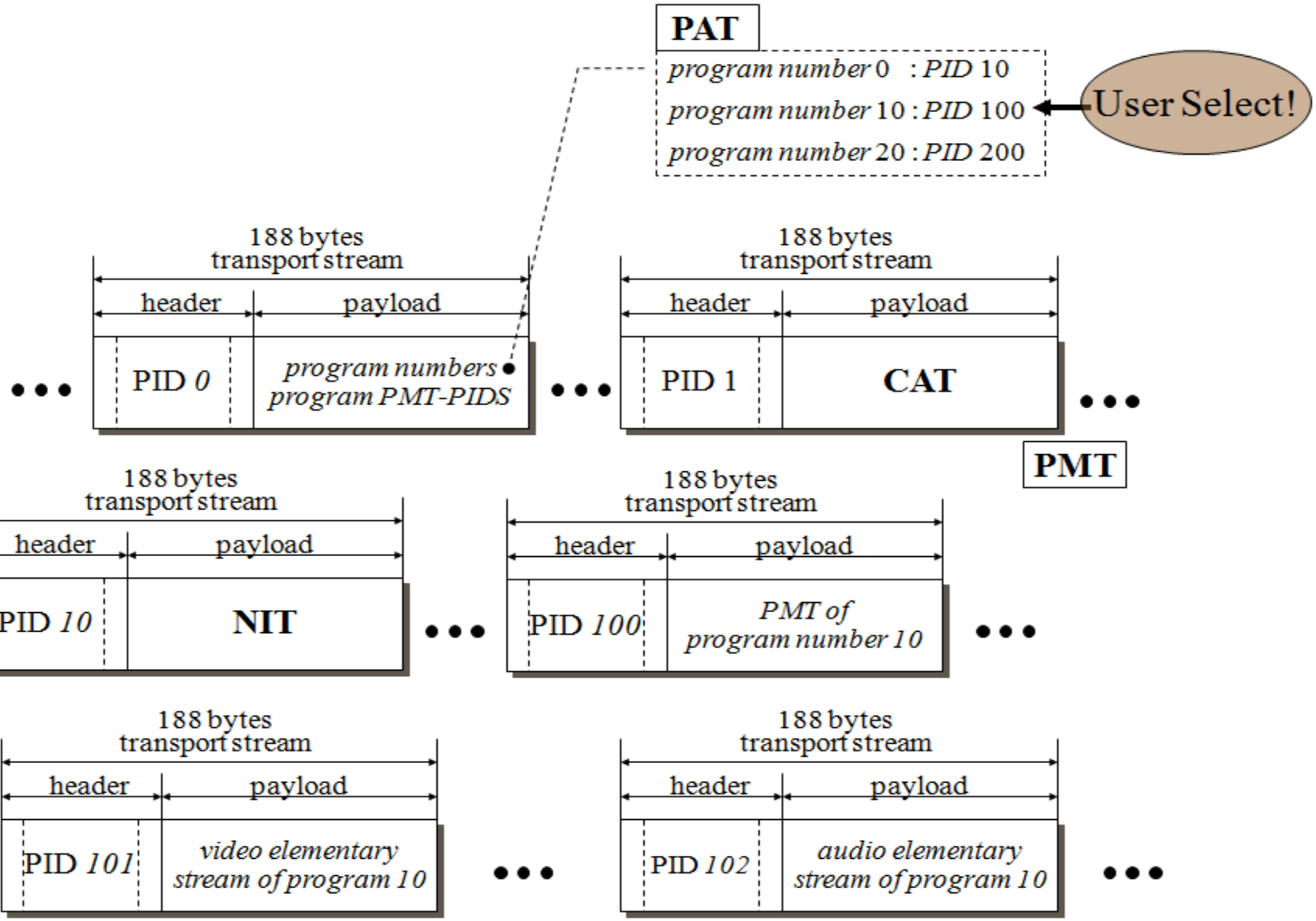
⌛? : Why a point_field is needed?

• There is no regulation for the size of PSI.

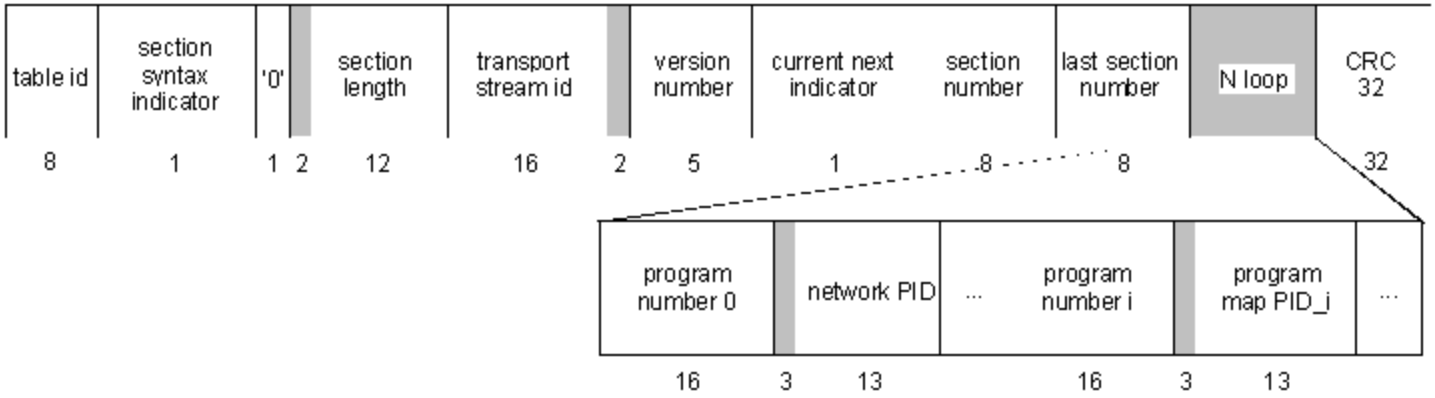
• Thus, a new section can be occurred in the middle of payload in a TS packet.

• recommend to use pointer_field for indication, and put offset for the starting position.

• Or use stuffing byte as PES packet does.


PAT
program number 0 : PID 10
program number 10 : PID 100
program number 20 : PID 200
User Select!
188 bytes transport stream
header
payload
PID 0
program numbers
program PMT-PIDS
188 bytes transport stream
header
payload
PID 1
CAT
PMT
188 bytes transport stream
header
payload
PID 10
NIT
188 bytes transport stream
header
payload
PID 100
PMT of program number 10
188 bytes transport stream
header
payload
PID 101
video elementary stream of program 10
188 bytes transport stream
header
payload
PID 102
audio elementary stream of program 10

PAT structure & semantics



- **Table_id** – shall be set 0x00

Value	description
0x00	program_association_section
0x01	conditional_access_section (CA_section)
0x02	TS_program_map_section
0x03	TS_description_section
0x04	ISO_IEC_14496_scene_description_section
0x05	ISO_IEC_14496_object_descriptor_section
0x06	Metadata_section
0x07	IPMP Control Information Section (defined in ISO/IEC 13818-11)
0x08-0x37	ITU-T Rec. H.222.0 | ISO/IEC 13818-1 reserved
0x38-0x3F	Defined in ISO/IEC 13818-6
0x40-0xFE	User private
0xFF	forbidden

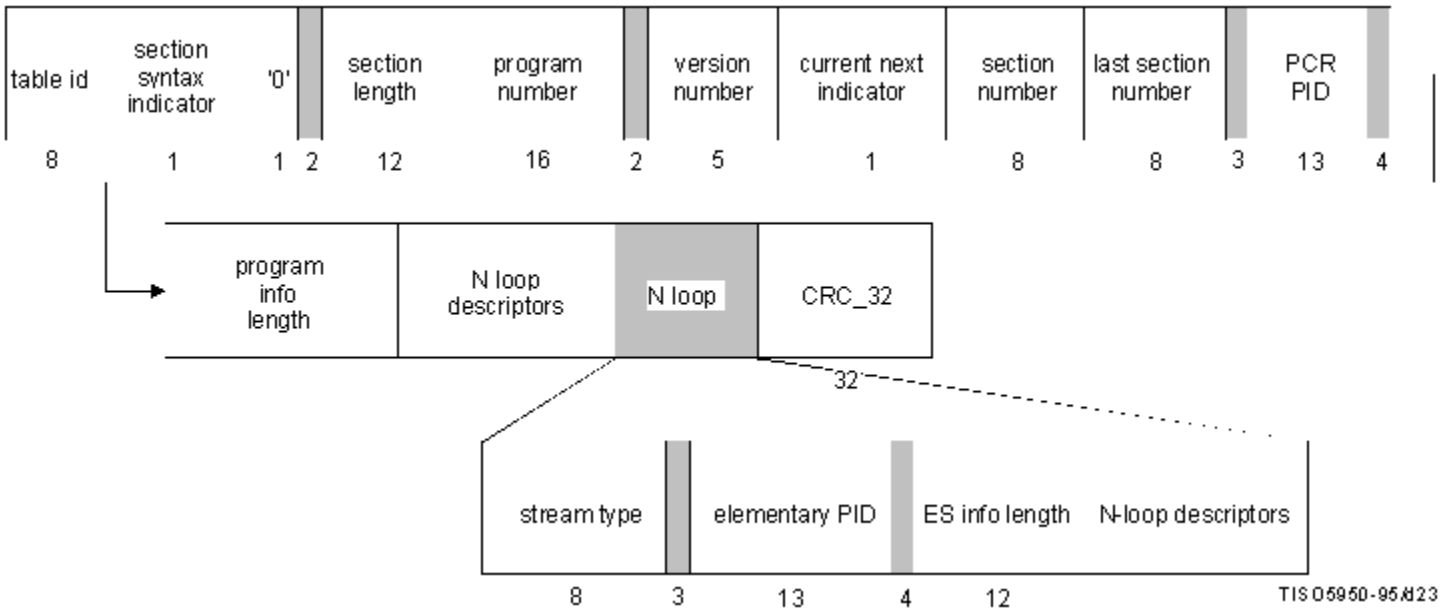
PAT semantics

- **section_length** – the first two bits of which shall be '00'. The remaining 10 bits specify 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 (0x3FD).
- **Transport_stream_id** – identify this Transport Stream from any other multiplex within a network.
- **Current_next_indicator** – when set to '1' indicates that the Program Association Table sent is currently applicable.
- **Section_number** – 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.
- **Program_number** – specifies the program to which the program_map_PID is applicable. When set to 0x0000, then the following PID reference shall be the network PID.

PAT semantics

- **Network_PID** – specifies the PID of the Transport Stream packets which shall contain the Network Information Table.
- **Program_map_PID** – specifying the PID of the Transport Stream packets which shall contain the program_map_section applicable for the program as specified by the program_number.
- **CRC_32** – CRC(circular redundancy check) value that gives a zero output of the registers in the decoder defined in 13818-1 Annex A.

PMT structure & semantics



- **Table_id** – set to '0x02'
- **Program_number** - specifies the program to which the program_map_PID is applicable.
- **PCR_PID** – indicate the PID of the Transport Stream packets which shall contain the PCR fields valid for the program specified by program_number.

PMT structure & semantics

구문	비트수	간략기호
TS_program_map_section() {		
table_id	**8**	**uimsbf**
section_syntax_indicator	**1**	**bslbf**
'0'	**1**	**bslbf**
reserved	**2**	**bslbf**
section_length	**12**	**uimsbf**
program_number	**16**	**uimsbf**
reserved	**2**	**bslbf**
version_number	**5**	**uimsbf**
current_next_indicator	**1**	**bslbf**
section_number	**8**	**uimsbf**
last_section_number	**8**	**uimsbf**
reserved	**3**	**bslbf**
PCR_PID	**13**	**uimsbf**
reserved	**4**	**bslbf**
program_info_length	**12**	**uimsbf**
for(i = 0; i < N; i++) {		
descriptor()		
}		
for(i = 0; i < N1; i++) {		
stream_type	**8**	**uimsbf**
reserved	**3**	**bslbf**
elementary_PID	**13**	**uimsbf**
reserved	**4**	**bslbf**
ES_info_length	**12**	**uimsbf**
for(i = 0; i < N2; i++) {		
descriptor()		
}		
}		
CRC_32	**32**	**rpchof**
}		

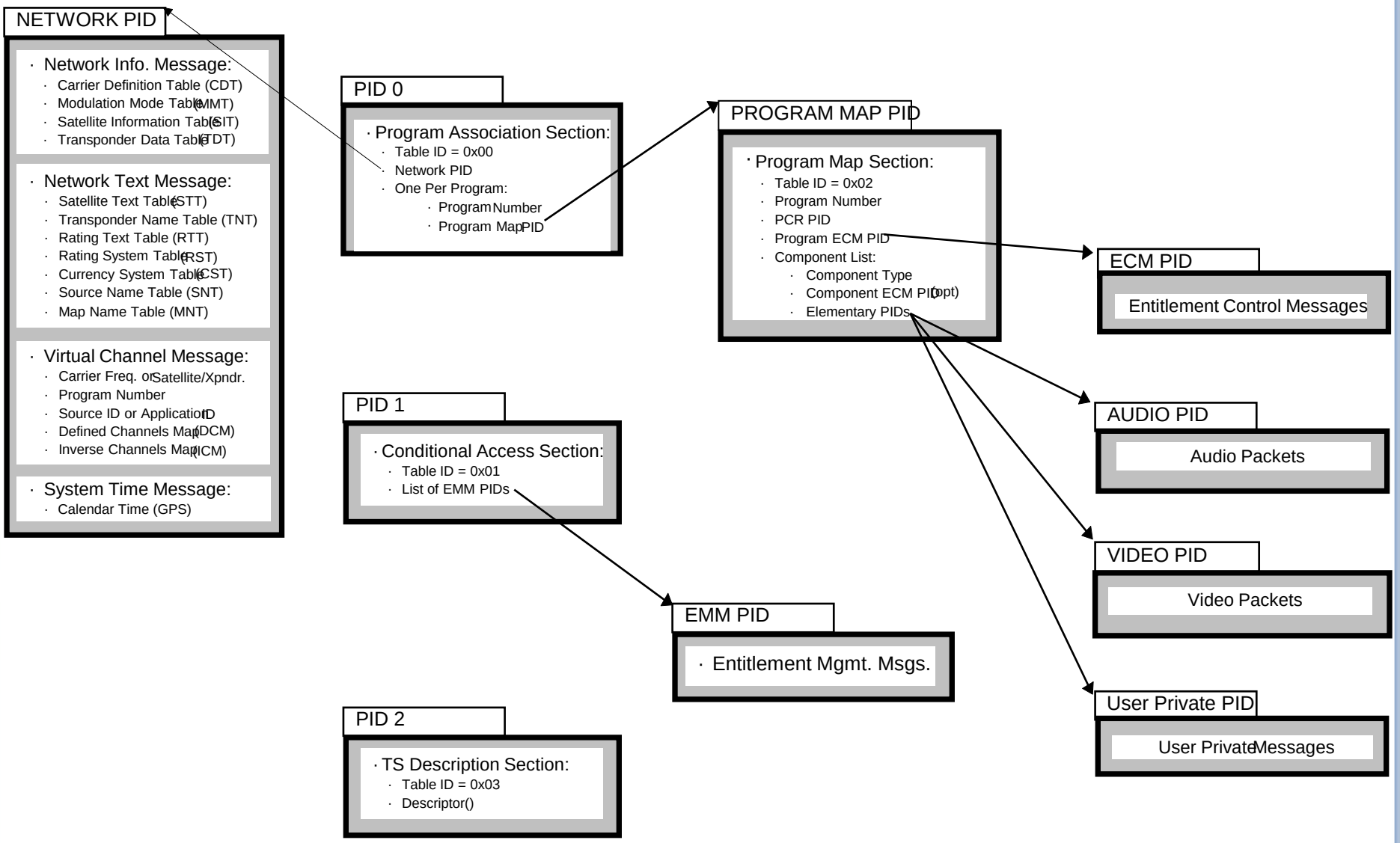
PMT semantics

- **Stream_type** – specify the type of program element carried within the packets with the PID whose value is specified by the elementary_PID.
- **Elementary_PID** – specify the PID of the Transport Stream packets which carry the associated program element.
- **ES_info_length** – the first two bits of which shall be '00'. The remaining 10 bits specify the number of bytes of the descriptors of the associated program element immediately following the ES_info_length field.

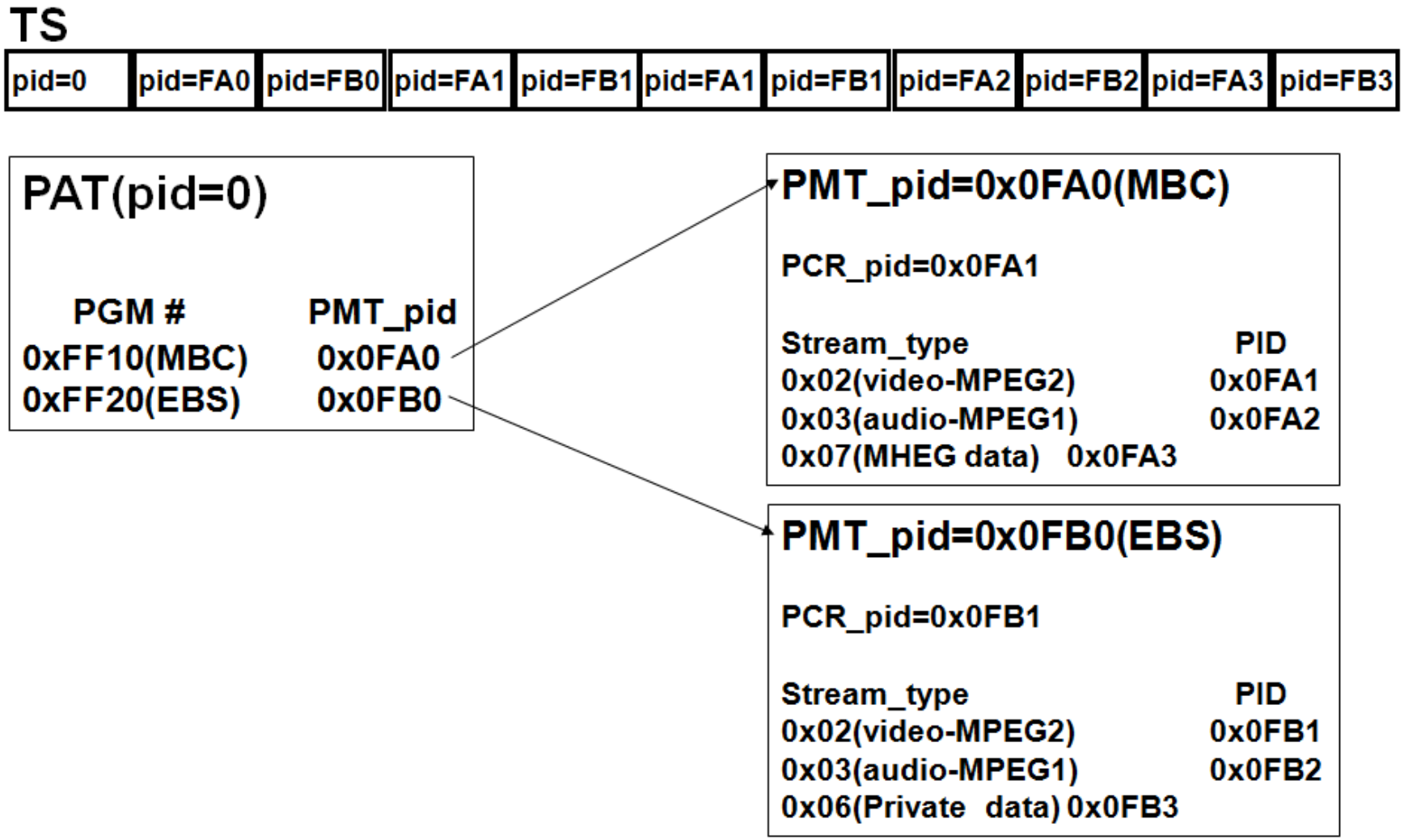
Stream_Type

값	설명
0x00	ITU-T | ISO/IEC reserved
0x01	ISO/IEC 11172-2 Video
0x02	ITU-T Rec. H.262 | ISO/IEC 13818-2 Video or ISO/IEC 11172-2 constrained parameter video stream
0x03	ISO/IEC 11172-3 Audio
0x04	ISO/IEC 13818-3 Audio
0x05	ITU-T Rec. H.222.0 | ISO/IEC 13818-1 private_sections
0x06	ITU-T Rec. H.222.0 | ISO/IEC 13818-1 PES packets containing private data
0x07	ISO/IEC 13522 MHEG
0x08	Annex A – DSM CC
0x09	ITU-T Rec. H.222.1
0x0A	ISO/IEC 13818-6 type A
0x0B	ISO/IEC 13818-6 type B
0x0C	ISO/IEC 13818-6 type C
0x0D	ISO/IEC 13818-6 type D
0x0E	ISO/IEC 13818-1 auxiliary[1]
0x0F	ISO/IEC 13818-7 Audio with ADTS transport syntax
0x10	ISO/IEC 14496-2 Video
0x11	ISO/IEC 14496-3 Audio
0x12	ISO/IEC 14496 SL-packetized stream or FlexMux stream carried in PES
0x13	ISO/IEC 14496 SL-packetized stream or FlexMux stream carried in ISO/IEC 13818-1 sections
0x14	ISO/IEC 13818-6 Synchronized Download Protocol
0x0F - 0x7F	ITU-T Rec. H.222.0 | ISO/IEC 13818-1 reserved
0x80 - 0xFF	User private

Transport Stream Relationships



Demultiplexing Example



Conditional Access Section

- When one or more ES are scrambled, CAT including CA_descriptor with shall be transmitted.

구문	비트수	간략기호
CA_section() {		
table_id	**8**	**uimsbf**
section_syntax_indicator	**1**	**bslbf**
'0'	**1**	**bslbf**
reserved	**2**	**bslbf**
section_length	**12**	**uimsbf**
reserved	**18**	**bslbf**
version_number	**5**	**uimsbf**
current_next_indicator	**1**	**bslbf**
section_number	**8**	**uimsbf**
last_section_number	**8**	**uimsbf**
for(i = 0; i < N; i++) {		
descriptor()		
}		
CRC_32	**32**	**rpchof**
}		

Private Section

구문	비트수	간략기호
private_section() {		
table_id	**8**	**uimsbf**
section_syntax_indicator	**1**	**bslbf**
private_indicator	**1**	**bslbf**
reserved	**2**	**bslbf**
private_section_length	**12**	**uimsbf**
if(section_syntax_indicator== '0') {		
for(i = 0; i < N; i++) {		
private_data_byte	**8**	**bslbf**
}		
}		
else {		
table_id_extension	**16**	**uimsbf**
reserved	**2**	**bslbf**
version_number	**5**	**uimsbf**
current_next_indicator	**1**	**bslbf**
section_number	**8**	**uimsbf**
last_section_number	**8**	**uimsbf**
for (i = 0; i < private_section_length-9; i++) {		
private_data_byte	**8**	**bslbf**
}		
CRC_32	**32**	**rpchof**
}		
}		

TS Description Section

- PID is assigned as 0x0002, and table_id to 0x03.
- TS decrioptor will be applied to all the TS.

구문	비트수	간략기호
TS_description_section() {		
table_id	8	ui
section_syntax_indicator	1	msbf bsl
'0'	1	bf bsl
reserved	2	bf bsl
section_length	12	bf ui
reserved	18	msbf bsl
version_number	5	bf ui
current_next_indicator	1	msbf bsl
section_number	8	bf ui
last_section_number	8	msbf ui
for (i = 0; i < N; I++) {		msbf
descriptor()		
}		
CRC_32	32	rp
		chof
}		

TS Description Section

descriptor_tag	TS	PS	Identification
0	n/a	n/a	Reserved
1	n/a	n/a	Reserved
2	X	X	video_stream_descriptor
3	X	X	audio_stream_descriptor
4	X	X	hierarchy_descriptor
5	X	X	registration_descriptor
6	X	X	data_stream_alignment_descriptor
7	X	X	target_background_grid_descriptor
8	X	X	video_window_descriptor
9	X	X	CA_descriptor
10	X	X	ISO_639_language_descriptor
11	X	X	system_clock_descriptor
12	X	X	multiplex_buffer_utilization_descriptor
13	X	X	copyright_descriptor
14	X		maximum bitrate descriptor
15	X	X	private data indicator descriptor
16	X	X	smoothing buffer descriptor
17	X		STD_descriptor
18	X	X	IBP descriptor
19-26	X		Defined in ISO/IEC 13818-6
27	X	X	MPEG-4_video_descriptor
28	X	X	MPEG-4_audio_descriptor
29	X	X	IOD_descriptor
30	X	X	FMC_descriptor
31	X		SL_descriptor
32	X	X	OCR_ES_ID_descriptor
33	X	X	External_ES_ID_descriptor
34-63	n/a	n/a	ITU-T Rec. H.222.0 | ISO/IEC 13818-1 Reserved
64-255	n/a	n/a	User Private