

TS

0、名词

缩写	全称	说明
HLS	HTTP Live Streaming	HTTP实时流传输，参阅HLS（draft-pantos-http-live-streaming-20）
TS	Transport Stream	传输流
PES	Packetized Elementary Stream	包式基本流
ES	Elementary Stream	基本流
PSI	Program Specific Information	节目特定信息，PSI 由“对于 传输流的多路分解以及节目成功再现所必要的标准数据”组成，参阅ISO13818-2.4.4
PAT	Program Association Table	节目相关表，是PSI的一种，参阅ISO13818-2.4.1
PMT	Program Map Table	节目映射表，是PSI的一种，参阅ISO13818-2.4.1
PID	packet identifier	包标识符,在传输流中用于标识一个节目的基本流的唯一整数值，如 2.4.3 中所述。
DTS	decoding time-stamp	解码时间戳
PTS	presentation time-stamp	显示时间戳
PCR	Program Clock Reference	节目时钟参考
STC	System Time Clock	系统时钟
T-STD	Transport system target decoder	传输系统目标解码器，用于确定 ITU-T H.222.0 ISO/IEC 13818-1 多路复用比特流语义的解码过程的虚拟参考模型
AUD	Access Unit Delimiter	存取单元分隔符

1、TS

TS文件

TS文件是流式文件，由多个TS包顺序排列组成，播放器从TS文件的任何位置开始下载数据，满足条件后都可以播放 TS文件表示一个节目的组织结构，有节目信息(PAT、PMT)、音视频信息(PES、H.264、AAC等)、时间轴信息(PCR、DTS、PTS等)

TS包（参阅2.4.3）

F.0.1 Transport Stream syntax

See Figure F.1.

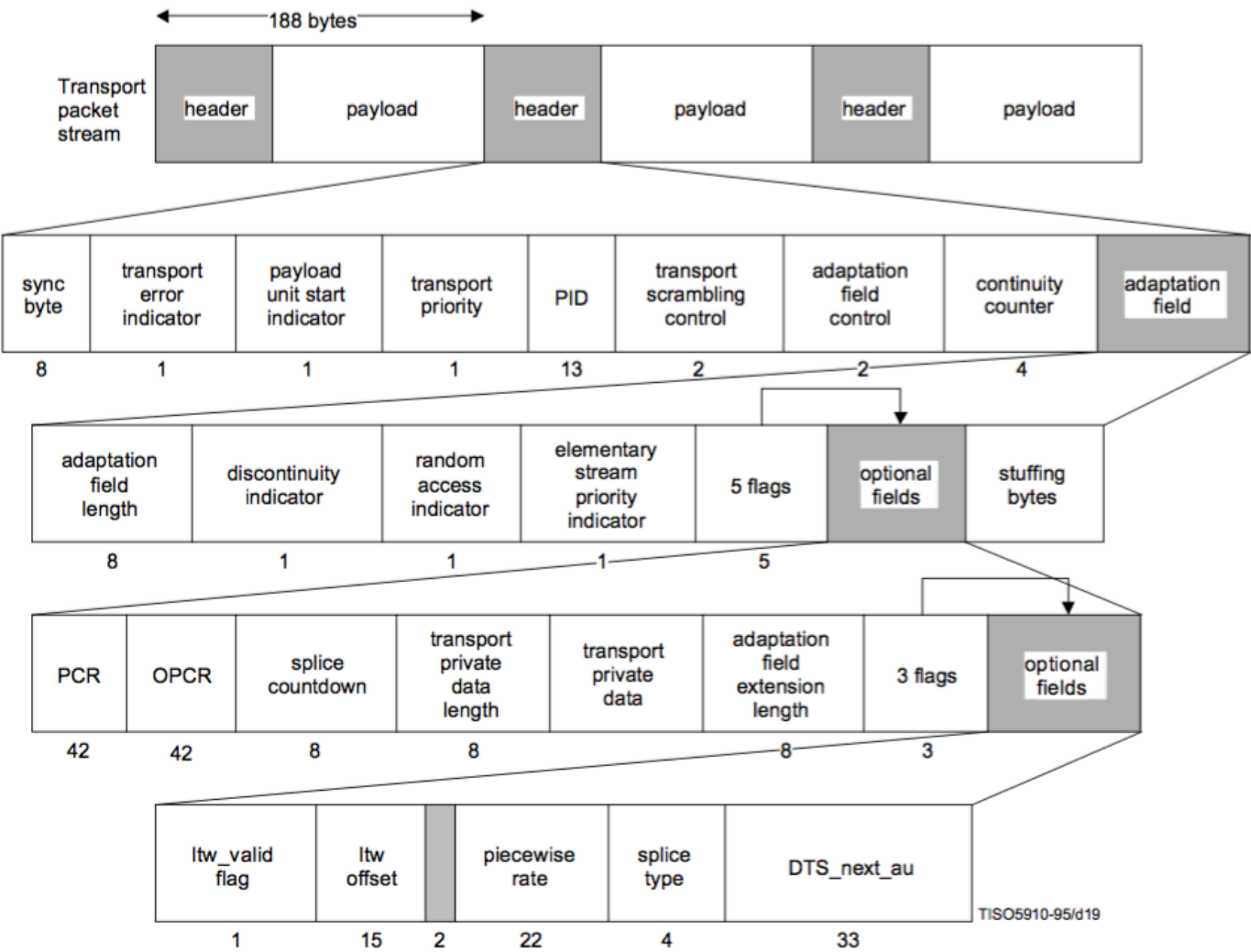


Figure F.1 – Transport Stream syntax diagram

TS包为固定188字节，由header和payload组成，有两种：

- 1、带有一个PES包 (参阅2.4.3.6)
- 2、带有一个PSI (如PAT、PMT) 以及填充字节 (参阅2.4.4)
- 3、空包

这是由payload_unit_start_indicator决定的，1为PES或PSI，0为空包 (参阅2.4.3.3)

PS：通常一个ts文件，第一个TS包带有PAT，第二个带有PMT，后面的带有PES

PES包

See Figure F.2.

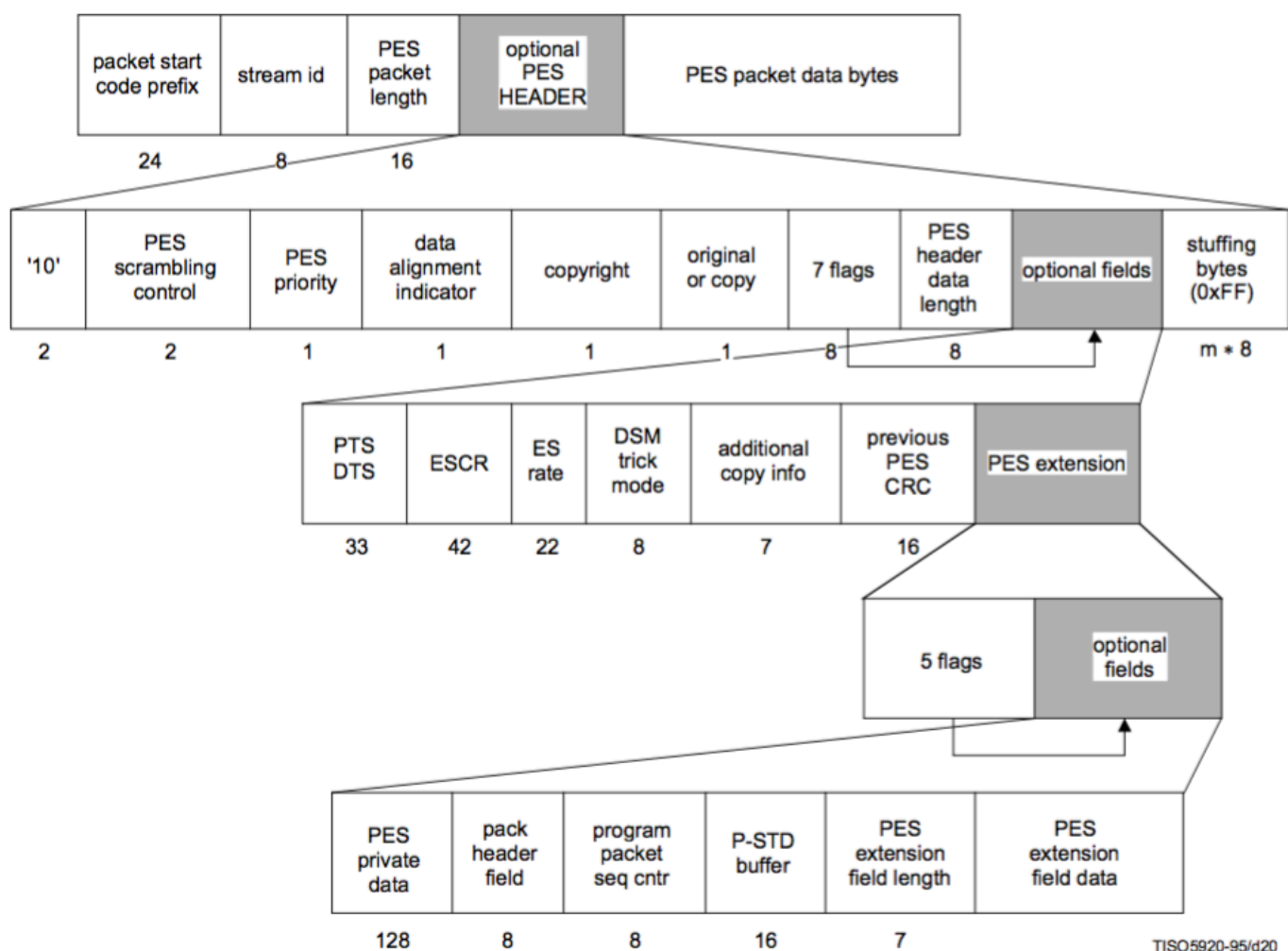


Figure F.2 – PES packet syntax diagram

PES包由header和payload组成，payload为ES包，参阅2.4.3.6

ES包

ES包有两种：音频包和视频包，比如：H.264、aac等，是由PES包的header中的stream_type决定的，参阅Table 2-34，H.264=0x1b aac=0x0f

2、TS文件

接下来拿一个真实的TS文件解包开看一下

使用的工具有EasyICE和Elecard Stream Analyzer

首先来看一下，TS包的排列：

Player	MediaInfo	PSI/SI	PID	Graph	PACKET			
ID	PID	Payload	PCR	PacketType	Frame...	Continuity_Counter	Other	
0	0 (0x0)	1		PAT		0x0	...	
1	4097 (0x1001)	1		PMT		0x0	...	
2	256 (0x100)	1	0:0:0.104	H.264	IDR	0x1	...	
3	256 (0x100)	0		H.264		0x2	...	
4	256 (0x100)	0		H.264		0x3	...	
5	256 (0x100)	0		H.264		0x4	...	
6	256 (0x100)	0		H.264		0x5	...	
7	256 (0x100)	0		H.264		0x6	...	
8	256 (0x100)	0		H.264		0x7	...	
9	256 (0x100)	0		H.264		0x8	...	
10	256 (0x100)	0		H.264		0x9	...	
11	256 (0x100)	0		H.264		0xa	...	
12	256 (0x100)	0		H.264		0xb	...	
13	256 (0x100)	0		H.264		0xc	...	
14	256 (0x100)	0		H.264		0xd	...	
15	256 (0x100)	0		H.264		0xe	...	
16	256 (0x100)	0		H.264		0xf	...	
17	256 (0x100)	0		H.264		0x0	...	
18	256 (0x100)	0		H.264		0x1	...	
19	256 (0x100)	0		H.264		0x2	...	
20	256 (0x100)	0		H.264		0x3	...	
21	256 (0x100)	0		H.264		0x4	...	

可以看到，首先是PAT和PMT的包，接下来才是音视频的包

TS包payload的种类：

PID

包标识, 表示TS包的ID

TS包payload有PAT、PMT、音频包、视频包

音视频包有两种, 一种有PES包, 一种是空包, 音视频数据存储在PES包

PAT包(参阅2.4.4.3-7)

PAT包的PID=0x0

PAT(节目相关表)含有program_number(节目编号)和PMT_PID(PMT的TS包头中的PID)

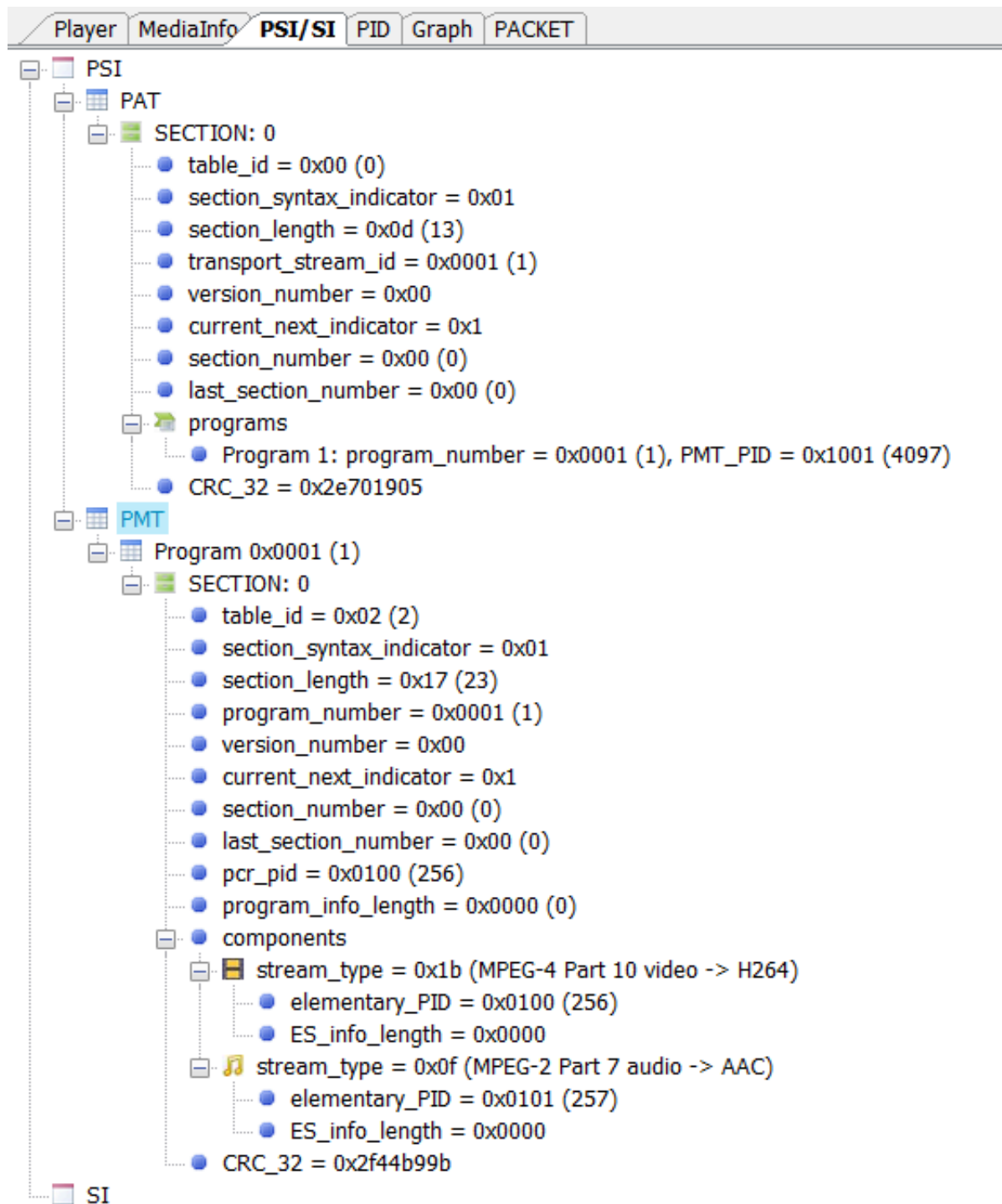
下图中, program_number=0x0001, PMT_PID=0x1001

PMT包(参阅2.4.4.8-9)

PMT(节目映射表)提供节目编号与组成它们的节目元之间的映射

PMT包的PID为上面的PMT_PID

PMT中有很多有用的信息, 比如: pcr_pid、stream_type、elementary_PID



PES包(参阅2.4.3.6)

PAT、PMT后面的TS包有两种，一种带音视频数据的PES包，另一种是空包

后面是一些空包以及P帧的PES包，接下来是AAC的PES包以及AAC的空包，然后是音视频包穿插进行

2、视频包

常用的视频压缩算法是H.264

0x00000000	Transport Packet { PID = 0x0, Payload = Yes (184), Counter =	
0x00000005	PAT Program Association Table	1
0x000000BC	Transport Packet { PID = 0x1001, Payload = Yes (184), Counter =	
0x000000C1	PMT Program Map Table	3
0x00000178	Transport Packet { PID = 0x100, Payload = Yes (176), Counter =	
0x00000184	PES Packet { stream_id = 0xE0 (video stream)}	5
0x00000192	H264 AUD	6
0x00000198	IDR H264 SEI {User data unregistered}	7
0x000001B9	H264 Sequence Parameter Set	8
0x000001C7	H264 Picture Parameter Set	9
0x000001CF	H264 I slice #0 { frame num = 0, pic order cnt lsb = 0 }	
0x00000234	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x000002F0	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x000003AC	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000468	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000524	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x000005E0	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x0000069C	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000758	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000814	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x000008D0	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x0000098C	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000A48	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000B04	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000BC0	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000C7C	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000D38	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x00000DF4	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	

第一个H.264的包是IDR帧，IDR属于I帧，比普通I帧前面多PPS(图像参数集)和SPS(序列参数集)，这两个不能少

Player MediaInfo PSI/SI PID Graph PACKET

ID	PID	Payload	PCR	PacketType	Frame...	Continuity_Counter	Other
0	0 (0x0)	1		PAT		0x0	...
1	4097 (0x1001)	1		PMT		0x0	...
2	256 (0x100)	1	0:0:0.104	H.264	IDR	0x1	...
3	256 (0x100)	0		H.264		0x2	...
4	256 (0x100)	0		H.264		0x3	...
5	256 (0x100)	0		H.264		0x4	...
6	256 (0x100)	0		H.264		0x5	...
7	256 (0x100)	0		H.264		0x6	...
8	256 (0x100)	0		H.264		0x7	...
9	256 (0x100)	0		H.264		0x8	...
10	256 (0x100)	0		H.264		0x9	...
11	256 (0x100)	0		H.264		0xa	...
12	256 (0x100)	0		H.264		0xb	...
13	256 (0x100)	0		H.264		0xc	...
14	256 (0x100)	0		H.264		0xd	...
15	256 (0x100)	0		H.264		0xe	...
16	256 (0x100)	0		H.264		0xf	...
17	256 (0x100)	0		H.264		0x0	...
18	256 (0x100)	0		H.264		0x1	...
19	256 (0x100)	0		H.264		0x2	...
20	256 (0x100)	0		H.264		0x3	...
21	256 (0x100)	0		H.264		0x4	...

Info

PCR:2808000
PTS:9360

Hex View

00000000 47 41 00 31 07 50 00 00 12 48 7E 00 00 01 E0 16 EE 80 80 GA.1.P...H~.....
00000014 05 21 00 01 49 21 00 00 00 01 09 F0 00 00 01 06 05 1A 47 56 .!..I!.....GV
00000028 4A DC 5C 4C 43 3F 94 EF C5 11 3C D1 43 A8 01 FF CC CC FF 02 J.\LC?....<.C.....
0000003C 00 0F 42 40 80 00 00 00 01 27 42 00 1E AB 40 F0 36 FC C8 00 ..B@.....'B...@.6...

Flags

flag	value
transport_packet()	
sync_byte	0x47
transport_error_indicator	0x0
payload_unit_start_indicator	0x1
transport_priority	0x0
PID	0x100
transport_scrambling_control	0x0
adaptation_field_control	0x3
continuity_counter	0x1
adaptation_field()	
adaptation_field_length	0x7
discontinuity_indicator	0x0
random_access_indicator	0x1
elementary_stream_priority_indica...	0x0
PCR_flag	0x1
OPCR_flag	0x0
splicing_point_flag	0x0
transport_private_data_flag	0x0
adaptation_field_extension_flag	0x0
PES_packet()	
stream_id	0xE0
PES_packet_length	0x16EE
PES_scrambling_control	0x0
PES_priority	0x0
data_alignment_indicator	0x0

Nodes

Node View

图中有很多信息：
上面标识IDR，左下角有PCR、PTS，右边有TS包头、PES包头中的一些信息

接下来是P帧

Player MediaInfo PSI/SI PID Graph PACKET

ID	PID	Payload	PCR	PacketType	Frame...	Continuity_Counter	Other
30	256 (0x100)	0		H.264		0xd	...
31	256 (0x100)	0		H.264		0xe	...
32	256 (0x100)	0		H.264		0xf	...
33	256 (0x100)	0		H.264		0x0	...
34	256 (0x100)	1		H.264	P	0x1	...
35	256 (0x100)	0		H.264		0x2	...
36	256 (0x100)	0		H.264		0x3	...
37	256 (0x100)	0		H.264		0x4	...
38	256 (0x100)	0		H.264		0x5	...
39	256 (0x100)	0		H.264		0x6	...
40	256 (0x100)	0		H.264		0x7	...
41	256 (0x100)	0		H.264		0x8	...
42	256 (0x100)	0		H.264		0x9	...
43	256 (0x100)	0		H.264		0xa	...
44	256 (0x100)	0		H.264		0xb	...
45	256 (0x100)	0		H.264		0xc	...
46	256 (0x100)	1		H.264	P	0xd	...
47	256 (0x100)	0		H.264		0xe	...
48	256 (0x100)	0		H.264		0xf	...
49	256 (0x100)	0		H.264		0x0	...
50	256 (0x100)	0		H.264		0x1	...
51	256 (0x100)	0		H.264		0x2	...

Info

PTS:13590

Hex View

00000000 47 41 00 11 00 00 01 E0 07 FA 80 80 05 21 00 01 6A 2D 00 00 GA.....!..j-..
00000014 00 01 09 F0 00 00 01 21 E1 08 1B D3 1E 07 40 98 29 7B 2C 1D!.....@.){..
00000028 F1 AB 6D 7C DC 32 20 71 29 F7 EE FE 18 28 E2 57 46 6F D7 DC ..m|.2 q)....(.Wfo..
0000003C 43 38 E3 31 EF 5F DE B4 7A 88 E9 5F E3 C8 29 49 9B FA 04 A6 C8.1._.z._.)I....

Flags

flag	value
transport_packet()	
sync_byte	0x47
transport_error_indicator	0x0
payload_unit_start_indicator	0x1
transport_priority	0x0
PID	0x100
transport_scrambling_control	0x0
adaptation_field_control	0x1
continuity_counter	0x1
PES_packet()	
stream_id	0xE0
PES_packet_length	0x7FA
PES_scrambling_control	0x0
PES_priority	0x0
data_alignment_indicator	0x0
copyright	0x0
original_or_copy	0x0
PTS_DTS_flags	0x2
ESCR_flag	0x0
ES_rate_flag	0x0
DSM_trick_mode_flag	0x0
additional_copy_info_flag	0x0
PES_CRC_flag	0x0
PES_extension_flag	0x0
PES_header_data_length	0x5

Nodes

Node View

所有的帧都位于PES的payload中，并且都会有AUD作为分割符，少数播放器必须依赖AUD才能播放

3、音频包

常用的视频压缩算法是aac,

PlayerMediaInfoPSI/SIPIDGraphPACKET

ID	PID	Payload	PCR	PacketType	Frame...	Continuity_Counter	Other
72	256	(0x100)	0	H.264		0x7	...
73	256	(0x100)	0	H.264		0x8	...
74	256	(0x100)	0	H.264		0x9	...
75	256	(0x100)	0	H.264		0xa	...
76	256	(0x100)	0	H.264		0xb	...
77	256	(0x100)	0	H.264		0xc	...
78	257	(0x101)	1	AAC		0x1	...
79	257	(0x101)	0	AAC		0x2	...
80	257	(0x101)	0	AAC		0x3	...
81	257	(0x101)	0	AAC		0x4	...
82	257	(0x101)	0	AAC		0x5	...
83	257	(0x101)	0	AAC		0x6	...
84	257	(0x101)	0	AAC		0x7	...
85	256	(0x100)	1	H.264	P	0xd	...
86	256	(0x100)	0	H.264		0xe	...
87	256	(0x100)	0	H.264		0xf	...
88	256	(0x100)	0	H.264		0x0	...
89	256	(0x100)	0	H.264		0x1	...
90	256	(0x100)	0	H.264		0x2	...
91	256	(0x100)	0	H.264		0x3	...
92	256	(0x100)	0	H.264		0x4	...
93	256	(0x100)	0	H.264		0x5	...

Flags

flag	value
transport_packet()	
sync_byte	0x47
transport_error_indicator	0x0
payload_unit_start_indicator	0x1
transport_priority	0x0
PID	0x101
transport_scrambling_control	0x0
adaptation_field_control	0x1
continuity_counter	0x1
PES_packet()	
stream_id	0xC0
PES_packet_length	0x4AB
PES_scrambling_control	0x0
PES_priority	0x0
data_alignment_indicator	0x0
copyright	0x0
original_or_copy	0x0
PTS_DTS_flags	0x2
ESCR_flag	0x0
ES_rate_flag	0x0
DSM_trick_mode_flag	0x0
additional_copy_info_flag	0x0
PES_CRC_flag	0x0
PES_extension_flag	0x0
PES_header_data_length	0x5

info

PTS:9000

Hex View

00000000 47 41 01 11 00 00 01 C0 04 AB 80 80 05 21 00 01 46 51 FF F1 GA.....!..FQ..
00000014 4C 80 01 DF FC 20 66 20 01 98 80 0E FF F1 4C 80 13 9F FC 21 L.... fL....!
00000028 4C E7 42 07 B7 6B 29 B2 C5 3A 32 E3 5D FC 42 A7 87 FC 6A F9 L.B..k)..:2.]..B...j..
0000003C E3 49 97 5F 08 75 BC EA DC 09 E0 A2 60 84 F8 9C C9 A4 39 37 .I...u.....`.....97

4、同步

Mpeg-2规定的STC频率为27MHz，传输流中的PCR，PTS/DTS等均为对该STC的采样值。解码端捕获PCR，恢复出本地的STC，作为音视频同步控制的基准，并依据PTS（DTS）时间标签来安排解码和显示时间表，使音视频分别同步于STC，以实现音视频之间的同步。标准规定在原始音频和视频流中，PTS的间隔不能超过0.7s，而出现在TS包头的PCR间隔不能超过0.1s。

PCR

PMT中的PCR_PID表示该PID值的TS包的adaptation_field(自适应段)中存储PCR

比如，上面PMT那张图中为0x0100(256)，说明在PID为0x0100并且含有adaptation_field的包中才会有PCR，而这个恰好是含有IDR帧的TS包，如下图

0x00000000	Transport Packet { PID = 0x0, Payload = Yes (184), Counter =	
0x00000005	Program Association Table	1
0x000000BC	Transport Packet { PID = 0x1001, Payload = Yes (184), Counter =	
0x000000C1	Program Map Table	3
0x00000178	Transport Packet { PID = 0x100, Payload = Yes (176), Counter =	
<div>Adaptation Field ():</div> <div> adaptation_field_length = 7 discontinuity_indicator = 0 random_access_indicator = 1 elementary_stream_priority_indicator = 0 PCR_flag = 1 OPCR_flag = 0 splicing_point_flag = 0 transport_private_data_flag = 0 adaptation field extension flag = 0 <div>PCR = 0: 0: 0: 104 (2 808 000)</div> program_clock_reference_base = 9 360 program clock reference extension = 0 </div>		
0x00000184	PES Packet { stream_id = 0xE0 (video stream)}	5
0x00000192	H264 AUD	6
0x00000198	H264 SEI {User data unregistered}	7
0x000001B9	H264 Sequence Parameter Set	8
0x000001C7	H264 Picture Parameter Set	9
0x000001CF	H264 I slice #0 { frame_num = 0, pic_order_cnt_lsb = 0 }	
0x00000234	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x000002F0	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	
0x000003AC	Transport Packet { PID = 0x100, Payload = Yes (184), Counter =	

输入到T-STD解码器的第i个字节的PCR值:

$PCR(i) = PCR_base(i) * 300 + PCR_ext(i)$

i: 包含PCR_base域的最后—个比特的字节号。

$PCR_base(i) = ((system_clock_frequency * t(i)) / 300) \% 2^{33} = ((27\ 000\ 000 * t(i)) / 300 \% 2^{33} = 90\ 000 * t(i) \% 8589934592$

$PCR_ext(i) = ((system_clock_frequency * t(i)) / 1) \% 300 = ((27\ 000\ 000 * t(i)) \% 300$

t(i): 字节i的编码时间。

例如:

时间"03:02:29.012"的PCR计算如下:

$03:02:29.012 = ((3 * 60) + 2) * 60 + 29.012 = 10949.012s$

$PCR_base = ((27\ 000\ 000 * 10949.012) / 300) \% 2^{33} = 98\ 541\ 080$

$PCR_ext = ((27\ 000\ 000 * 10949.012) / 1) \% 300 = 0$

$PCR = 98\ 541\ 080 * 300 + 0 = 295\ 623\ 324\ 000$

PTS、DTS

0x00000178	Transport Packet { PID = 0x100, Payload = Yes (176), Counter	5	⌵
0x00000184	PES Packet { stream_id = 0xE0 (video stream)	5	⌴
	packet_length = 5870 PES_scrambling_control = 0 PES_priority = 0 data_alignment_indicator = 0 copyright = 0 original_or_copy = 0 PTS_DTS_flags = 2 ESCR_flag = 0 ES_rate_flag = 0 DSM_trick_mode_flag = 0 additional_copy_info_flag = 0 PES_CRC_flag = 0 PES_extension_flag = 0 PES_header_data_length = 5 PTS = 0: 0: 0: 104 (9 360)		
0x00000192	H264 AUD	6	⌵
0x00000198	H264 SEI {User data unregistered}	7	⌵
0x000001B9	H264 Sequence Parameter Set	8	⌵
0x000001C7	H264 Picture Parameter Set	9	⌵
0x000001CF	H264 I slice #0 { frame_num = 0, pic_order_cnt_lsb = 0 }		⌵
0x00000234	Transport Packet { PID = 0x100, Payload = Yes (184), Counter		
0x000002F0	Transport Packet { PID = 0x100, Payload = Yes (184), Counter		
0x000003AC	Transport Packet { PID = 0x100, Payload = Yes (184), Counter		
0x00000468	Transport Packet { PID = 0x100, Payload = Yes (184), Counter		
0x00000524	Transport Packet { PID = 0x100, Payload = Yes (184), Counter		

PTS和DTS存在于PES包头，由PTS_DTS_flags决定
图中PTS_DTS_flags=0x10(2)表示只有PTS(参阅2.4.3.6)
PTS和DTS都是一个33bit的值

总结

PCR用于构建本地时钟，PTS、DTS相当于时间轴上的增量
PCR存在于包含IDR帧的TS包头
PTS、DTS存在于PES包头
ES包就是音视频数据

播放流程

- 1、获取PAT、PMT，解出PCR_PID(256)、Elementary_PID(H.264=256 AAC=257)
- 2、从每个PID=256并且含有IDR帧的TS包中解出PCR，用于构建本地时钟，从PES包中解出DTS、PTS用于解码和显示的时间值
- 3、从PID=256的TS包解码H.264数据用于显示图像，从PID=257的TS包中解码AAC用于播放声音