Preamble Acquisition of MPEG2-TS Multicast Sessions
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Abstract

The ITU-T Rec. H.222.0 | ISO/IEC 13818-1 Transport Stream (MPEG2-TS) addresses the combining of one or more elementary streams of video and audio, as well as other data, into single or multiple streams which are suitable for storage or transmission. The necessary and sufficient information contained in the Program Specific Information (PSI) tables to demultiplex and present programs must be acquired before a RTP receiver can process any data received in MPEG2-TS. In this document, a Retransmission Server is specified to deliver MPEG2-TS preamble prior to unicast burst RTP packets. The Retransmission Server caches raw RTP packets with MPEG2-TS preamble information, and sends them to the RTP receiver which initiates rapid acquisition of MPEG2-TS multicast sessions.

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1. Introduction

Real-time multimedia multicast flows usually carry streams of inter-related data. Certain information must first be acquired by the receivers to start processing multimedia data sent in the multicast session. [I-D.ietf-avt-rapid-acquisition-for-rtp] refers to this information as Reference Information. Part of the Reference Information is conventionally sent periodically in the multicast session and usually consists of items such as a description of the schema for the rest of the data, references to which data to process, encryption information including keys, as well as any other information required to process the data in the primary multicast stream.

The ITU-T Rec. H.222.0 | ISO/IEC 13818-1 Transport Stream[MPEG2-TS] is a stream definition which is tailored for communicating or storing one or more programs of coded data according to ITU-T Rec. H.262 | ISO/IEC 13818-2 and ISO/IEC 13818-3 and other data in environments. The MPEG2-TS is already widespread in the digital broadcasting and IPTV services over both terrestrial and satellite networks, not only in Europe but also in Asia and North America. When the primary multicast stream is using an encapsulation method of MPEG2-TS over RTP that multiplexes video and audio content, together with ancillary metadata, and produces a synchronized multiplexed stream, the receiver must first acquire the necessary and sufficient information before demultiplexing and decoding an incoming MPEG2-TS. However, these necessary and sufficient information of MPEG2 Transport Stream does not reside in MPEG2-TS contiguously and is usually dispersed over a large period of time. When the receivers starts receiving the Reference Information from the random access point as detailed in [I-D.ietf-avt-rapid-acquisition-for-rtp], the Reference Information of MPEG2-TS cannot be completely received particularly the MPEG2-TS Program Specific Information (PSI) tables so that the receivers cannot demultiplex and decode correctly. In order to demultiplex and decode correctly for the receivers, parts of the Reference Information of MPEG2-TS, extracted from MPEG2 transport stream packets prior to the random access point (RAP) over a long period (even several previous Reference Information away), must be acquired before demultiplexing and decoding. In this document, we refers to this information as MPEG2-TS preamble.

This document describes how to convey this preamble information to the receiver before the unicast burst stream defined in RAMS [I-D.ietf-avt-rapid-acquisition-for-rtp].
2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

3. Abbreviation

The following abbreviations are used in this document:

- BAT: Bouquet Association Table
- CAT: Conditional Access Table
- DIT: Discontinuity Information Table
- ECM: Entitlement Control Message
- EIT: Event Information Table
- EMM: Entitlement Management Message
- GoP: Group of Picture
- ICIT: IPMP Control Information Table
- IDR: Instantaneous Decoding Refresh
- IPMP: Intelligent Property Management and Protection
- MP2T: MPEG2 Transport Stream
- MPEG2-TS: MPEG2 Transport Stream
- NIT: Network Information Table
- OPCR: Original Program Clock Reference
- PAT: Program Association Table
- PCR: Program Clock Reference
- PES: Packetized Elementary Stream
- PMT: Program Map Table
- PS: Private Section
4. Overview of MPEG-2 Transport Streams

ITU-T Rec. H.222.0 | ISO/IEC 13818-1 Transport Stream addresses the combining of one or more elementary streams of video and audio, as well as other data, into single or multiple streams which are suitable for storage or transmission. Systems coding follows the syntactical and semantic rules imposed by this Specification and provides information to enable synchronized decoding of decoder buffers over a wide range of retrieval or receipt conditions.

The basic multiplexing approach for single video and audio elementary streams is illustrated in Figure 1. The video and audio data is encoded as described in ITU-T Rec. H.262 | ISO/IEC 13818-2 and ISO/IEC 13818-3. The resulting compressed elementary streams are packetized to produce Packetized Elementary Streams (PES) packets.
The MPEG2 Transport Stream coding layer allows one or more programs to be combined into a single stream. Data from each elementary stream are multiplexed together with information that allows synchronized presentation of the elementary streams within a program.

A Transport Stream consists of one or more programs. Audio and video elementary streams consist of access units (a coded representation of a presentation unit).

Elementary Stream data is carried in PES packets. A PES packet consists of a PES packet header followed by packet data. PES packets are inserted into Transport Stream packets. The first byte of each PES packet header is located at the first available payload location of a Transport Stream packet.

Transport Stream packets begin with a 4-byte prefix, which contains a 13-bit Packet ID (PID). The PID identifies, via the Program Specific Information (PSI) tables, the contents of the data contained in the Transport Stream packet. Transport Stream packets of one PID value carry data of one and only one elementary stream. The PSI tables are carried in the Transport Stream. There are Six PSI tables shown in table 2.28 of h222.0(2006) (There were only the first four PSI tables in the ITU-T Rec. H.222.0(2000 E) | ISO/IEC 13818-1:2000 E):

- Program Association Table;
- Program Map Table;
- Conditional Access Table;
- Network Information Table;
- Transport Stream Description Table;
- IPMP Control Information Table.
These tables contain the necessary and sufficient information to demultiplex and present programs. Program Association Table contains the PIDs of NIT and PMT, what's more, the private section in Transport Stream packets with a PID value is designated as a Program Map Table PID in the Program Association Table. The Program Map Table provides among other information, which PIDs, and therefore which elementary streams are associated to form each program. This table also indicates the PID of the Transport Stream packets which carry the PCR for each program. The Conditional Access Table shall be present if scrambling is employed. The Network Information Table is optional and its contents are not specified by the ITU-T Rec. H.222.0 | ISO/IEC 13818-1. Transport Stream Description Table(TSDT) has 256(an 8-bit field) transport stream description elements shown in Table 2-45-Program and program element descriptors of H.222.0(2006). The IPMP Control Information Table shall be present if IPMP as described in ISO/IEC 13818-11 is used by any of the components in the ITU-T Rec. H.222.0 | ISO/IEC 13818-1 stream.

Except for these PSI tables, ETSI DVB EN 300 468, defines nine PSI tables which are Bouquet Association Table (BAT), Service Description Table (SDT), Event Information Table (EIT), Running Status Table (RST), Time and Date Table (TDT), Time Offset Table (TOT), Stuffing Table (ST), Selection Information Table (SIT), Discontinuity Information Table (DIT).There are other PSI tables defined by organizations and operators.

In this document, terminologies PSI and MPEG2-TS preamble are interchangeable. Media including video, audio and text in an MPEG2-TS is self describing, and the receiver must parse certain control information in the PAT, CAT and PMT tables (i.e., PSI) contained in the transport stream in order to know how to parse the rest of the stream (i.e., to find the audio and video elementary streams, private data and the encryption information for a given program). This document specifies a mechanism to acquire PSI rapidly when a receiver joins in a MPEG2-TS multicast session.

5. Preamble Acquisition of MPEG2-TS Multicast Sessions

5.1. Overview

In video coding, a group of picture (GOP) specifies the order in which intra-frame and inter-frames are arranged. The GOP is a group of successive pictures within a coded video stream. Each coded video stream consists of successive GOPs. A GOP always begins with a Random Access Point (RAP)- an intra-frame(e.g. IDR-frame). Afterwards several inter-frames(e.g. P-frame) follow. The Intra-frame is a reference frame which contains the full image which
represents a fixed image and which is independent of other picture types and do not require any additional information to reconstruct it. The inter-frame is a prediction frame which contains motion-compensated difference information from the preceding Intra-frame or other inter-frames in a video compression stream which is expressed in terms of one or more neighboring frames.

When a receiver joins a primary multicast session, it does not have control over what point in the flow is currently being transmitted, it needs to wait until the next RAP and other necessary and sufficient information for demultiplexing and decoding (which we refer to as the Reference Information in the [I-D.ietf-avt-rapid-acquisition-for-rtp]) shows up in the multicast stream before it can start decoding. In order to reduce the acquisition delay when the RTP receiver joins a multicast session at a random point in time, RAMS in the [I-D.ietf-avt-rapid-acquisition-for-rtp] introduces the method as Unicast- based Rapid Acquisition of Multicast RTP Sessions illustrated in Figure 2 where an auxiliary unicast RTP session carrying the Reference Information to the receiver precedes/ accompanies the primary multicast stream. This unicast RTP flow is transmitted at a faster than natural rate to further accelerate the acquisition.

In MPEG2 transport stream case, the Reference Information is often not contiguous in the flow but dispersed over a large period, it even spans several GOPs. It is often distributed in different RTP packets with other MPEG2-TS packets which are not part of the reference information. Figure 2 illustrates an RTP stream where PAT, PMT and ECM information distribute in the three different RTP packets.
... RTP SN(28255) PAT(TS1)
+---------------------------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+---------------------------------------------------------------+
... RTP SN(28266) PMT(TS6)
+---------------------------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+---------------------------------------------------------------+
... RTP SN(28291) ECM(TS4)
+---------------------------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+---------------------------------------------------------------+
... RTP SN(28301) (Random Access point: IDR-frame(TS6)
+---------------------------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+---------------------------------------------------------------+

Figure 2 Original RTP sequence only with PAT, PMT and ECM

In Figure 2 the TS1 packet of RTP packet with sequence number 28255 is a PAT packet. The TS6 packet of RTP packet with sequence number 28266 is a PMT packet. The TS4 packet of RTP packet with sequence number 28291 is an ECM packet. TS6 of RTP packet with sequence number 28301 is a beginning of a Random Access point of IDR-frame. The Reference Information for this RTP sequence starting at RTP sequence number 28301 needs the PAT information in the RTP SN 28255, the PMT information of in the RTP SN 28266 and the ECM information of in the RTP SN 28291. The process is now to extracts the PSI information and to build a new RTP packet illustrated in Figure 3 where PAT is in TS1, PMT in TS2 and ECM in TS3.

RTP SN(xxx) PAT(TS1),PMT(TS2),ECM(TS3)
+----------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) |
+----------------------------------------+
RTP(RFC4588) SN(28301) (Random Access point: IDR-frame(TS6)
+----------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+----------------------------------------+
...

Figure 3 Preamble MPEG2-TS RTP sequence

In MPEG2-TS PSI information, PAT, PMT, and ECM(ECM shall be present
if scrambling is employed) are always present. Other reference
information enabling automatic configuration of the receiver to
demultiplex and decode the various streams of programs within the
multiplex are optionally provisioned depending on different policies
and demand of demultiplexing and decoding. For example, the
Conditional Access Table shall be present if scrambling is employed.
The IPMP Control Information Table shall be present if IPMP as
described in ISO/IEC 13818-11 is used by any of the components in the
ITU-T Rec. H.222.0 | ISO/IEC 13818-1 stream. The Reference
information (Event Information Table(EIT), Service Description Table
(SDT), etc.) in the ETSI DVB EN 300 468 shall be optionally present to
provide identification of services and events for the user. The
following RTP sequence illustrated in Figure 4 includes more PSI
table elements.

...  
RTP SN(10739) CAT(TS2), EIT(TS7)
+-----------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+-----------------------------------------------+
RTP SN(10758) PAT(TS3)
+-----------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+-----------------------------------------------+
RTP SN(10796) PMT(TS3)
+-----------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+-----------------------------------------------+
RTP SN(10829) ECM(TS2)
+-----------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+-----------------------------------------------+
RTP SN(10834) PAT(TS4)
+-----------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+-----------------------------------------------+
RTP SN(10851) NIT(TS5)
+-----------------------------------------------+
| RTP(H) | TS1(188) | TS2(188) | TS3(188) | TS4(188) | TS5(188) | TS6(188) | TS7(188) |
+-----------------------------------------------+
RTP SN(10872) PMT(TS3)
+-----------------------------------------------+
5.2. MPEG2-TS Preamble Structure

The order of PSI information need to be considered when rebuilding RTP packets. Except for some fixed PIDs (0x0000 for PAT, 0x0001 for CAT, 0x0002 for Transport Stream Description Table, 0x0003 for IPMP Control Information Table), other PIDs are inherited from those fixed PIDs. For example the PID of PMT is inherited from PAT. The PID of ECM is inherited from CAT, or PMT, or Transport Stream Description Table. The PIDs of Private_Section are designated as a Program Map Table PID in the Program Association Table. Figure 6 shows the inheritance of PAT and CAT.
5.3. The Implementation of MPEG2-TS Preamble

There are dozens of PSI tables of MPEG2-TS containing hundreds of the Reference information, which include PAT, PMT, PCR, CAT, NIT, ECM/EMM, Transport Stream Description Elements of the 8-bit field, IPMP Control Information Table, Private Section, other extended reference information, etc. Yet all these MPEG2-TS preambles are not present simultaneously, they simply exist a bit partially except PAT, PMT and ECM (ECM is present if scrambling is employed), and distribute in different RTP packets over a large period.

Most of them have unique PIDs. Yet there are some information elements with the same PID, For example, 256 transport stream description elements (Transport Stream Description Table) which are distributed in different locations have the same PID for 0x0002. SDT, BAT and ST in Table 1: PID allocation for SI of the ETSI DVB EN 300 468 have the same PID for 0x0011. EIT, ST and CIT have the same PID of 0x0012. TDT, TOT and SI have the same PID of 0x0014.

In addition, it is possible having the PSI information with different PIDs. For instance, The Conditional Access Table (CAT) may give the association between one or more CA systems with different ECM/EMM PIDs.

In order to simplify these complicated factors and the receiver’s processing, efficiently transmitting these MPEG2-TS preamble information, the flexible and effective method is to reconstruct new RTP packets which duplicate the raw MPEG2-TS packets of the current Reference information from the original MPEG2-TS packets sequence. For example, as is shown in Figure 7. When duplicating the raw...
MPEG2-TS packets with the Reference information, it is necessary to obey MPEG2-TS Preamble Order described in the above section.

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
...|RTP(H)|...TS2(ECM)...| ...|RTP(H)|...TS5(PAT)...|...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
        +----+
        +-----+
        +-----------------------------+
        |    +-----------------------------+
        |    |   +-+-+-+-+-+-+-+-+-+-+-+    +-+-+-+-+-+-+-+-+-+-+-+
        |    |...|RTP(H)|...TS3(PMT)...| ...|RTP(H)|...TS5(PCR)...|...
        |    |   +-+-+-+-+-+-+-+-+-+-+-+    +-+-+-+-+-+-+-+-+-+-+-+
        |
        |    |                          |
        |    |                          |
        |    +-----------------------------+
        |
SN(xxx) v v v v
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|RTP(H)|TS1-PAT(188)|TS2-PMT(188)|TS3-ECM(188)|TS4-PCR(188)|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7 RTP Reconstruction Process of MPEG2-TS Preamble

Except for the above Reference information, there are two elements of the Reference Information which shall also be considered. One is the information of PES Header, the other is the information of Adaptation Field of TS Header.

Commonly the beginning MPEG2-TS packet of a Random Access Point (RAP)-intra-frame contains a PES Header, followed by a video frame encoding data. Its format is shown in Figure 8.

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TS Header| PES Header | Beginning of video frame encoding data |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 8 The beginning of RAP with PES Header

Yet in some cases, its format is as follows and doesn’t contain PES header shown in Figure 9.

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TS Header| Beginning of video frame encoding data |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 9 The beginning of RAP without PES Header

The PES Header is contained in an early video MPEG2-TS TS packets.
In this case, the PES Header can be an MPEG2-TS preamble information transmitted before RAMS.

Sometimes, the information of Adaptation field of TS header shall be transmitted before RAMS. Adaptation field of TS header in Table 2-6 - Transport Stream adaptation field of H.222.0 contains dozens of information elements which are important to the demultiplex and decode. PCR/OPCR information probably contains in this field. If PCR isn’t present as a PCR TS packet with a PCR PID, the information of Adaptation field of TS header shall be an MPEG2-TS preamble information transmitted before RAMS.

As can be seen there are multiple PSI elements types and they can be part of the preamble information or the RTP_Rx can receive them later from the multicast stream. The important elements are the PAT, PMT and ECM and the application can decide which elements to include in the Preamble stream.

5.4. Message Flow

Figure 10 depicts message flows for PSI acquisition. A RTP receiver sends a rapid acquisition request for a new multicast RTP session to the feedback target address of that session. This RTCP feedback message is defined as the RAMS-Request (RAMS-R) message in [I-D.ietf-avt-rapid-acquisition-for-rtp] and MAY also contain parameters, such as the bandwidth limit, buffering capacity available at the RTP receiver, and so on.

A retransmission server receives the RAMS-R message and sends an RAMS-Information (RAMS-I) message to the RTP receiver. The first RAMS-I message MAY precede the unicast burst or it MAY be sent during the burst. The retransmission server then starts sending unicast PSI RTP packets prior to delivering Unicast RTP Burst.

In this document, a "unicast PSI RTP" delivering process is added for transporting necessary MPEG2-TS preamble information. The unicast PSI RTP stream shall be transmitted before the Unicast RTP burst, as shown in Figure 10. The information is carried as RFC 2250 [RFC2250] MP2T payload type RTP packets.
The SDP[RFC4566] description of the MPEG2-TS Preamble information is conveyed in an RAMS session description as defined in [I-D.ietf-avt-rapid-acquisition-for-rtp]. Figure 11 shows an SDP example which multiplexes the MPEG2-TS Preamble information and an RAMS unicast retransmission session based on Section 8.2 of [I-D.ietf-avt-rapid-acquisition-for-rtp].
v=0
o=S1 1122334455 1122334466 IN IP4 rams.example.com
s=Rapid Acquisition Example with MPEG2-TS Preamble Data
t=0 0
a=group:FID 3 4
a=rtcp-unicast:rsi
m=video 41000 RTP/AVPF 98
i=Primary Multicast Stream
c=IN IP4 233.252.0.2/255
a=source-filter: incl IN IP4 233.252.0.2 192.0.2.2
a=rtpmap:98 MP2T/90000
a=rtcp:41001 IN IP4 192.0.2.1
a=rtcp-fb:98 nack
a=rtcp-fb:98 nack ssli
a=ssrc:123321 cname:iptv-ch32@rams.example.com
a=mid:3
m=video 41002 RTP/AVPF 99 100
i=Unicast Retransmission Stream + Preamble Data
c=IN IP4 192.0.2.1
a=rtpmap:99 rtx/90000
a=rtcp:41003
a=fmtp:99 apt=98; rtx-time=5000
a=rtpmap:100 MP2T/90000
a=mid:4

Figure 11: The SDP description of the MPEG2-TS Preamble information conveying in an RAMS session

6. The Processing of the Receiver

Once received, it is very simple for RTP receivers to process MPEG2-TS Preamble information because it is packetized using raw MPEG2-TS packets. The RTP receiver only removes the RTP header before the demultiplexing and decoding, and does the same as for the RAMS unicast RTP burst retransmission packets.

It is also very flexible for the RTP receiver to support any MPEG2-TS Reference Information without any software Update. The information is received as an MPEG-TS raw data packets using MP2T payload format and therefore is transparent for RTP sessions and RTP receivers who forward it to the demux/decoder.

7. Security Considerations

Comparing to [I-D.ietf-avt-rapid-acquisition-for-rtp], this document specifies delivering PSI information to a RTP receiver prior to
unicast RTP burst packets. PSI is key information for a decoder to parse MPEG2-TS streaming packets, and any tampered PSI results in denial of service of the RTP receiver. Security considerations in [I-D.ietf-avt-rapid-acquisition-for-rtp] also applies.

8. Acknowledgements

TBD.

9. References

9.1. Normative References


[ISO13818-2]

[ISO13818-3]


9.2. Informational References

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