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Information technology — High efficiency coding and media delivery in heterogeneous environments —

Part 1: MPEG media transport (MMT)

Technologies de l'information — Codage à haute efficacité et livraison des medias dans des environnements hétérogènes —

Partie 1: Transport des médias MPEG

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

This second edition cancels and replaces the first edition (ISO/IEC 23008-1:2014), which has been technically revised. It also incorporates the Amendment ISO/IEC 23008-1:2014/Amd 1:2015 and the Technical Corrigendum ISO/IEC 23008-1:2014/Cor 1:2015.

The main changes compared to the previous edition are as follows:

— editorial integration of ISO/IEC 23008-1:2014/Amd 1:2015, ISO/IEC 23008-1:2014/FDAmd 2, ISO/IEC 23008-1:2014/Cor 1:2015 and ISO/IEC 23008-1:2014/CD COR 2;

— minor editorial corrections (for example, numbering in Tables and Figures).

A list of all parts in the ISO/IEC 23008 series can be found on the ISO website.

Introduction

This document specifies the MPEG media transport (MMT) technologies for the transport and delivery of coded media data for multimedia services over heterogeneous packet-switched networks including internet protocol (IP) networks and digital broadcasting networks. In this document, “coded media data” includes both timed audiovisual media data and non-timed data.

MMT is designed under the assumption that the coded media data will be delivered over a packet-switched delivery network. Several characteristics of such delivery environment, such as non-constant end-to-end delay of each packet from the sending entity to the receiving entity, have been taken into consideration.

For efficient and effective delivery and consumption of coded media data over packet-switched delivery networks, this document provides the following elements:

— the logical model to construct contents composed of components from various sources, for example, components of mash-up applications;

— the formats to convey information about the coded media data, to enable delivery layer processing, such as packetization;

— the packetization method and the structure of the packet to deliver media content over packet-switched networks supporting media and coding independent hybrid delivery over multiple channels;

— the format of the signalling messages to manage delivery and consumption of media content.

Information technology — High efficiency coding and media delivery in heterogeneous environments —

Part 1: MPEG media transport (MMT)

1 Scope

This document specifies MPEG media transport (MMT) technologies, which include a single encapsulation format, delivery protocols and signalling messages for transport and delivery of multimedia data over heterogeneous packet-switched networks for multimedia services. Types of packet-switched networks supported by this document include bidirectional networks such as Internet Protocol (IP) networks and unidirectional networks such as digital broadcast networks (which may or may not use the IP).

The technologies specified by this document belong to one of three functional areas of MMT: media processing unit (MPU) format, signalling messages and delivery protocol.

The MPU format specifies the "`mpuf`" branded ISO-based media file format (ISOBMFF) encapsulating both timed and non-timed media contents. The MPU format is a self-contained ISOBMFF structure enabling independent consumption of media data, which hides codec-specific details from the delivery function.

The signalling functional area specifies the formats of signalling messages carrying information for managing media content delivery and consumption, e.g. specific media locations and delivery configuration of media contents.

The delivery functional area specifies the payload formats that are independent of media and codec types, which allow fragmentation and aggregation of contents encapsulated as specified by this document for delivery using packet-switched oriented transport protocols. The delivery functional area also provides an application layer transport protocol that allows for advanced delivery of media contents.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 14496-12:2015, *Information technology — Coding of audio-visual objects — Part 12: ISO base media file format*

IETF RFC 3986, *Uniform Resource Identifier (URI): Generic Syntax, January 2005*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
access unit
AU
smallest media data entity to which timing information can be attributed

3.1.2
asset
any multimedia data entity that is associated with a unique identifier and that is used for building a multimedia presentation

3.1.3
dependent asset
asset (3.1.2) for which one or more other assets are necessary for decoding of the contained media content

3.1.4
encoding symbol
unit of data generated by the encoding process

3.1.5
encoding symbol block
set of *encoding symbols* (3.1.4)

3.1.6
FEC code
algorithm for encoding data such that the encoded data flow is resilient to data loss

3.1.7
FEC encoded flow
logical set of flows that consists of an *FEC source flow* (3.1.11) and one or more associated *FEC repair flows* (3.1.9)

3.1.8
FEC payload ID
identifier that identifies the contents of an *MMTP packet* (3.1.20) with respect to the *MMT FEC scheme* (3.1.16)

3.1.9
FEC repair flow
data flow carrying repair symbols to protect an *FEC source flow* (3.1.11)

3.1.10
FEC repair packet
MMTP packet (3.1.20) along with *repair FEC payload identifier* (3.1.27) to deliver one or more *repair symbols* (3.1.29) of a *repair symbol block* (3.1.30)

3.1.11
FEC source flow
flow of *MMTP packets* (3.1.20) protected by an *MMT FEC scheme* (3.1.16)

3.1.12
FEC source packet
MMTP packet (3.1.20) protected by an FEC encoding

3.1.13
media fragment unit
MFU
fragment of a *media processing unit* (3.1.14)

3.1.14
media processing unit
MPU
generic container for independently decodable *timed* (3.1.35) or *non-timed data* (3.1.25) that is media codec agnostic

3.1.15
MMT entity
software and/or hardware implementation that is compliant to a profile of MMT

3.1.16
MMT FEC scheme
forward error correction procedure that defines the additional protocol aspects required to use an FEC scheme in MMT

3.1.17
MMT protocol
MMTP
application layer transport protocol for delivering *MMTP payload* (3.1.22) over IP networks

3.1.18
MMT receiving entity
MMT entity (3.1.15) that receives and consumes media data

3.1.19
MMT sending entity
MMT entity (3.1.15) that sends media data to one or more *MMT receiving entities* (3.1.18)

3.1.20
MMTP packet
formatted unit of the media data to be delivered using the *MMT protocol* (3.1.17)

3.1.21
MMTP packet flow
sequence of *MMTP packets* (3.1.20) with same *MMT sending entity* (3.1.19) and *MMT receiving entity* (3.1.18)

3.1.22
MMTP payload
formatted unit of media data to carry *Packages* (3.1.26) and/or signalling messages using either the *MMT protocol* (3.1.17) or an Internet application layer transport protocols

EXAMPLE RTP.

3.1.23
MMTP session
single *MMTP transport flow* (3.1.24) that is used for certain period of time

3.1.24
MMTP transport flow
series of *MMTP packet flow* (3.1.21) delivered to the same destination

3.1.25
non-timed data
media data that do not have inherent timeline for the decoding and/or presenting of its media content

3.1.26
package
logical collection of media data, delivered using MMT

3.1.27
repair FEC payload ID
FEC payload ID (3.1.8) for repair packets

3.1.28
repair packet block
segmented set of *FEC repair flow* (3.1.9) which can be used to recover lost source packets

3.1.29
repair symbol
encoding symbol that contains redundancy information for error correction

3.1.30
repair symbol block
set of *repair symbols* (3.1.29) which can be used to recover lost *source symbols* (3.1.33)

3.1.31
source FEC payload ID
FEC payload ID (3.1.8) for source packets

3.1.32
source packet block
segmented set of *FEC source flow* (3.1.11) that is to be protected as a single block

3.1.33
source symbol
unit of data to be encoded by an FEC encoding process

3.1.34
source symbol block
set of *source symbols* (3.1.33) generated from a single *source packet block* (3.1.32)

3.1.35
timed data
data that has inherent timeline information for the decoding and/or presentation of its media contents

3.1.36
asset delivery characteristics
ADC
description about required quality of service (QoS) for delivery of *assets* (3.1.2)

Note 1 to entry: ADC is represented by the parameters agnostic to a specific delivery environment.

3.1.37
network abstraction for media
parameter that is used for an interface between media application layer and underlying network layer

3.2 Abbreviated terms

ADC	asset delivery characteristics
AL-FEC	application layer forward error correction
ARQ	automatic repeat request
AU	access unit

AVC	advanced video coding
CLI	cross layer interface
CRI	clock relation information
DCI	device capability information
GFD	generic file delivery
HRBM	hypothetical receiver buffer model
HTTP	hypertext transfer protocol
ISOBMFF	ISO-based media file format
LA-FEC	layer aware forward error correction
LR	license revocation
LS	license signalling
MPI	media presentation information
MC	measurement configuration
MFU	media fragment unit
MMT	MPEG media transport
MMTP	MMT protocol
MP	MMT package
MPU	media processing unit
MTU	maximum transmission unit
MVC	multi-view video coding
NAM	network abstraction for media
NTP	network time protocol
PA	package access
PID	packet identifier
PTP	precision time protocol
RAP	random access point
RTP	real-time protocol
SDP	session description protocol
SI	security information
SSWR	security software request
SVC	scalable video coding

TCP	transmission control protocol
TS	transport stream
UDP	user datagram protocol
URI	uniform resource identifier
URL	uniform resource locator
URN	uniform resource name
UUID	universally unique identifier
UTC	coordinated universal time
XML	extensible mark-up language

4 Conventions

The following convention applies in this document.

— The Big Endian number representation scheme is used.

5 Overview

This document defines a set of tools to enable advanced media transport and delivery services. The tools spread over three different functional areas: media processing unit (MPU) format, delivery and signalling. Even though the tools are designed to be efficiently used together, they may also be used independently regardless of the use of tools from the other functional areas.

The media processing unit (MPU) functional area defines the logical structure of media content, the Package and the format of the data units to be processed by an MMT entity and their instantiation with the ISO-based media file format as specified in ISO/IEC 14496-12. The Package specifies the components comprising the media content and the relationship among them to provide necessary information for advanced delivery. The format of data units in this document is defined to encapsulate the encoded media data for either storage or delivery and to allow for easy conversion between data to be stored and data to be delivered (see Clause 7).

The delivery functional area defines an application layer transport protocol and a payload format. The application layer transport protocol defined in this document provides enhanced features for delivery of multimedia data when compared with conventional application layer transport protocols, e.g. multiplexing and support of mixed use of streaming and download delivery in a single packet flow (see 9.2). The payload format is defined to enable the carriage of encoded media data which is agnostic to media types and encoding methods (see 9.3).

The signalling functional area defines formats of signalling messages to manage delivery and consumption of media data. Signalling messages for consumption management are used to signal the structure of the Package (see 10.3) and signalling messages for delivery management are used to signal the structure of the payload format and protocol configuration (see 10.4).

A multimedia service may use any subset of the tools defined in this document according to its specific needs. Furthermore, interfaces between protocols and standards defined by this specification and those defined in other specifications can also be defined and used. Figure 1 illustrates the different functions and their relationships to existing protocols and standards.

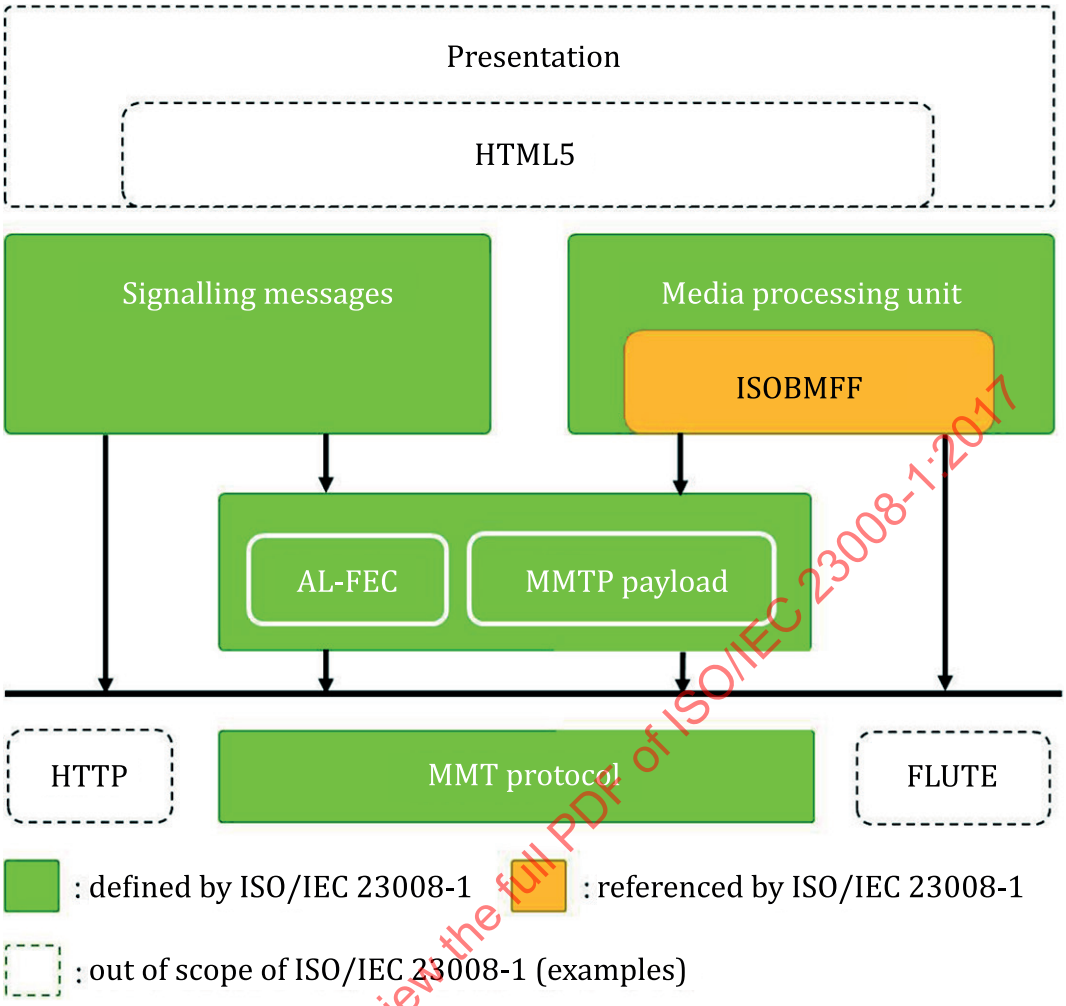


Figure 1 — MMT functional areas, tools and interfaces

Figure 2 depicts the end-to-end architecture for this document. The MMT sending entity is responsible for sending the Packages to the MMT receiving entity as MMTP packet flows. The sending entity may be required to gather contents from content providers based on the presentation information of the Package that is provided by a Package provider.

A Package provider and content providers may be co-located. Media content is provided as an Asset that is segmented into a series of encapsulated MMT processing units that forms a MMTP packet flow.

The MMTP packet flow of such content is generated by using the associated transport characteristics information. Signalling messages may be used to manage the delivery and the consumption of Packages.

This document defines the interfaces between the MMT sending entity and the MMT receiving entity, as well as their operations. The MMT sending entity shall conform to the sender operations as defined in Clause 9.

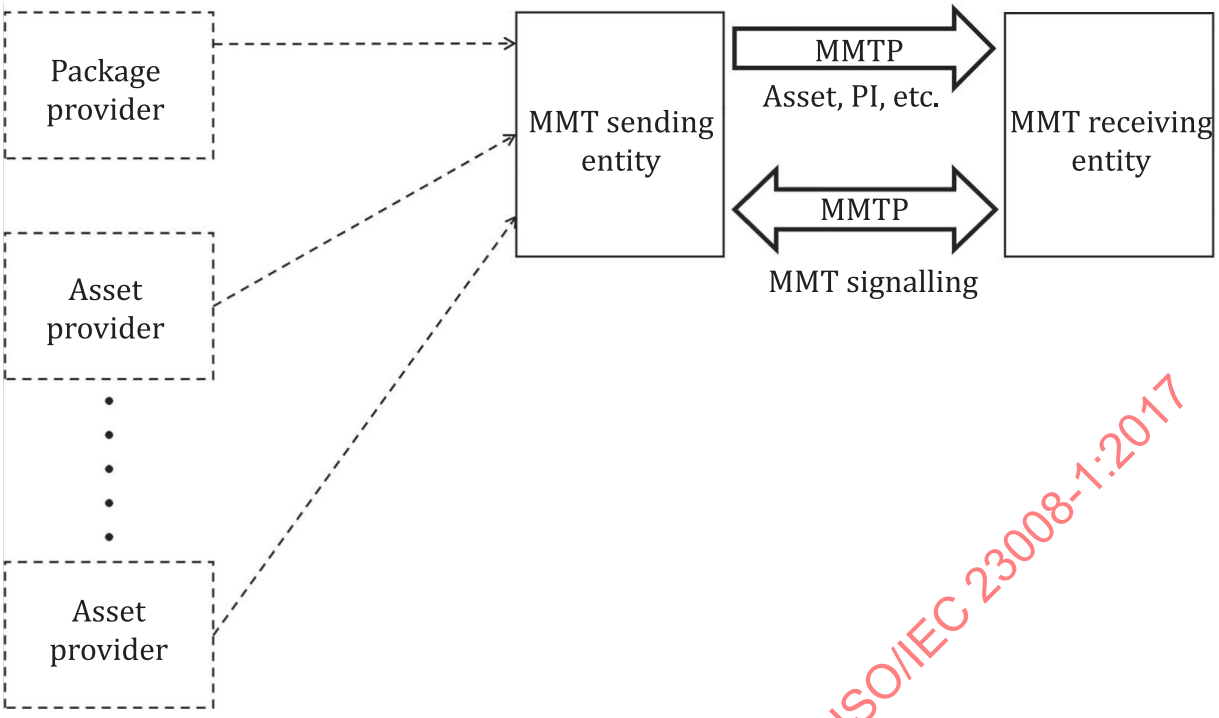


Figure 2 — End-to-end architecture of MMT

An MMT receiving entity operates at one or more MMT functional areas. An exemplary MMT receiving entity architecture is shown in Figure 3.

The MMT protocol (MMTP) is used to receive and de-multiplex the streamed media based on the `packet_id` and the payload type. The de-capsulation procedure depends on the type of payload that is carried and is processed separately and thus, is not shown here.

The presentation engine layer is responsible for setting up the multimedia scene and referencing the content that is received using the MMT protocol.

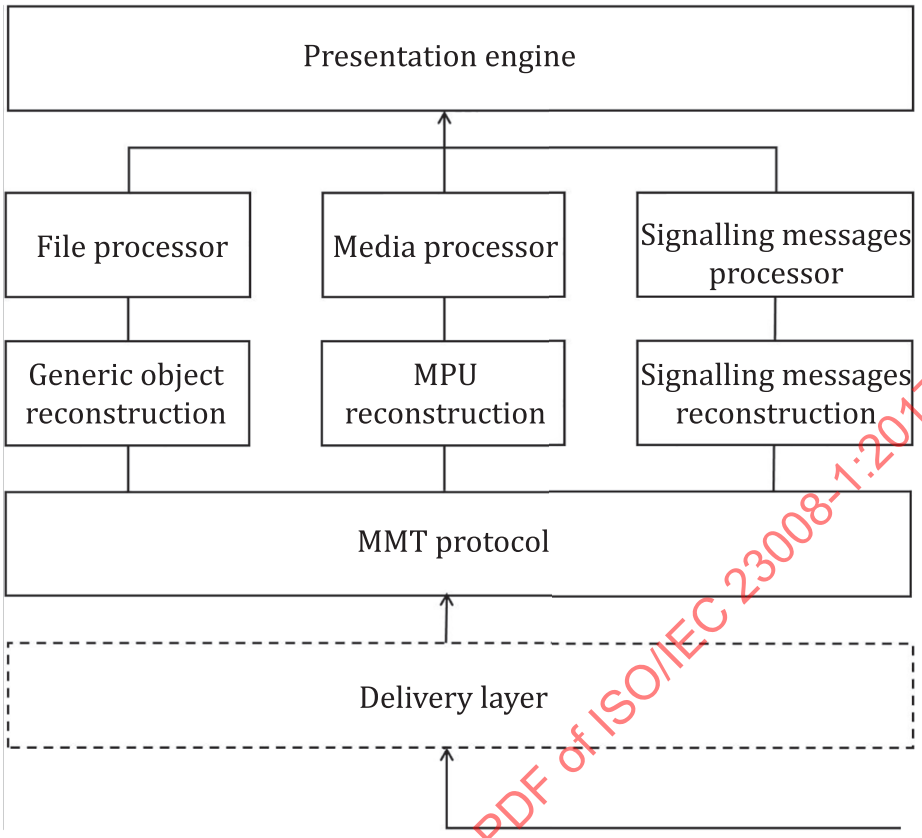


Figure 3 — Example of MMT receiving entity

6 MMT data model

6.1 General

This clause introduces the logical data model assumed for the operation of the MMT protocol. The MMT protocol provides both streaming delivery and download delivery of coded media data. For streaming delivery, MMT protocol assumes the specific data model including MPUs, Assets and Package. The MMT protocol preserves the data model during the delivery by indicating the structural relationships among the MPU, Asset and Package using signalling messages.

The collection of the encoded media data and its related metadata builds a Package. The Package may be delivered from one or more MMT sending entities to the MMT receiving entities. Each piece of encoded media data of a Package, such as a piece of audio or video content, constitutes an Asset.

An Asset is associated with an identifier which may be agnostic to its actual physical location or service provider that is offering it, so that an Asset can be globally and uniquely identified. Assets with different identifiers shall not be interchangeable. For example, two different Assets may carry two different encodings of the same content but they are not interchangeable.

MMT does not specify a particular identification mechanism but allows the usage of URIs or UUIDs for this purpose. Each Asset has its own timeline which may be of different duration than that of the whole presentation created by the Package.

Each MPU constitutes a non-overlapping piece of an Asset, i.e. two consecutive MPUs of the same Asset shall not contain the same media samples. Each MPU may be consumed independently by the presentation engine of the MMT receiving entity.

6.2 Package

As shown in Figure 4, a Package is a logical entity. A Package shall contain one or more presentation information documents such as one specified in ISO/IEC 23008-11, one or more Assets and for each Asset, an associated asset delivery characteristics (ADC). In other words, as processing of a Package is applied per MPU basis and an Asset is a collection of one or more MPUs that share the same Asset ID. It can be also considered that one Package is composed of one presentation information, one or more MPUs and associated ADC for each Asset.

An Asset is a collection of one or more media processing units (MPUs) that share the same Asset ID. An Asset contains encoded media data such as audio or video or a web page. Media data can be either timed or non-timed.

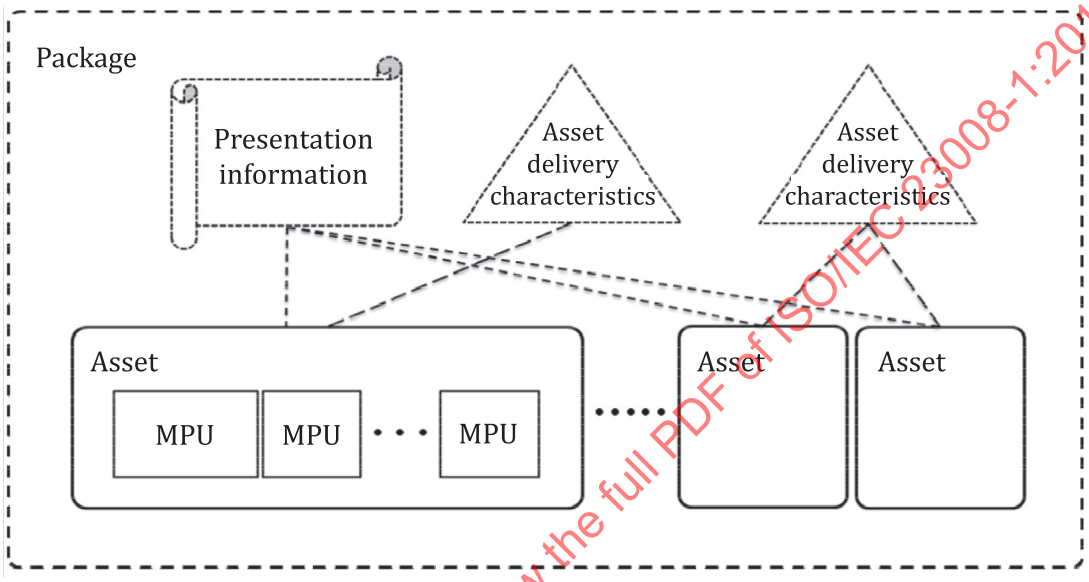


Figure 4 — Overview of Package

Presentation information (PI) documents specify the spatial and temporal relationship among the Assets for consumption. The combination of HTML5 and composition information (CI) documents specified in ISO/IEC 23008-11 is an example of PI documents. In addition, media presentation description (MPD) specified in ISO/IEC 23009-1 can also be used as PI document. A PI document may also be used to determine the delivery order of Assets in a Package. A PI document shall be delivered either as one or more signalling messages defined in this document (see 9.3.3) or as a complete document by some means that is not specified in this document. In the case of broadcast delivery, service providers may decide to carousel PI documents and determine the frequency at which carouseling is to be performed.

Asset delivery characteristics (ADC) shall provide the required QoS information for transmission of Assets. Multiple Assets can be associated with a single ADC. However, a single Asset shall not be associated with multiple ADCs. This information can be used by the entity packetizing the Package to configure the fields of the MMTP payload header and MMTP packet header for efficient delivery of the Assets.

ADC may provide information about an Asset that is relevant for the transport of that Asset.

NOTE Annex D contains a QoS management model for MMT.

6.3 Asset

An Asset is any multimedia data to be used for building a multimedia presentation. An Asset is a logical grouping of MPUs that share the same Asset ID for carrying encoded media data. Encoded media data of an Asset can be either timed data or non-timed data. Timed data are encoded media data that have an inherent timeline and may require synchronized decoding and presentation of the data units at a designated time. Non-timed data are any other type of data that do not have an inherent timeline for

decoding and presenting of its media content. The decoding time and the presentation time of each item of non-timed data are not necessarily related to that of other items of the same non-timed data. For example, it can be determined by user interaction or presentation information.

Two MPUs of the same Asset carrying timed media data shall have no overlaps in their presentation time.

Any type of data which is referenced by the presentation information is an Asset. Examples of media data types which can be considered as an individual Asset are audio, video, or a web page.

6.4 Media processing unit (MPU)

A media processing unit (MPU) is a media data item that may be processed by an MMT entity and consumed by the presentation engine independently from other MPUs.

Processing of an MPU by an MMT entity includes encapsulation/de-capsulation and packetization/de-packetization. An MPU may include the MMT hint track indicating the boundaries of MFUs for media-aware packetization.

Consumption of an MPU includes media processing (e.g. encoding/decoding) and presentation.

For packetization purposes, an MPU may be fragmented into data units that may be smaller than an Access Unit (AU). The syntax and semantics of MPU are not dependent on the type of media data carried in the MPU.

MPUs of a single Asset shall have either timed or non-timed media.

An MPU may contain a portion of data formatted according to other standards, e.g. MPEG-4 AVC or MPEG-2 TS.

For any Asset with `asset_id X` that depends on Asset with `asset_id Y`, the `m-th` MPU of the Asset with `asset_id X` and the `n-th` MPU of the Asset with `asset_id Y` shall be non-overlapping whenever `m` is not equal to `n`, i.e. no sample in the `m-th` MPU of Asset with `asset_id X` is inside the time interval defined by the sample boundaries of the `n-th` MPU of Asset with `asset_id Y`. Additionally, if the "`sidx`" box is present, the media intervals defined by the "`sidx`" box shall be non-overlapping, i.e. no media sample in the `k-th` media interval (defined by the "`sidx`" box) in an MPU is inside the time interval defined by the sample boundaries of the `j-th` media time interval (defined by the "`sidx`" box) for `j` different from `k`. In the absence of an "`sidx`" box, the concatenation of the `j-th` MPU of Asset with `asset_id Y` with the `j-th` MPU of the Asset with `asset_id X` without its MPU metadata results in a valid MPU. When a "`sidx`" box is present, the concatenation of the `k-th` media interval (defined by the "`sidx`" box) of the `j-th` MPU of Asset with `asset_id Y` with the `k-th` media interval (defined by the "`sidx`" box) of the `j-th` MPU of the Asset with `asset_id X` following the metadata of the MPU with `asset_id Y` results in a valid MPU.

A single MPU shall contain an integral number of AUs or non-timed data. In other words, for timed data, a single AU shall not be fragmented into multiple MPUs. For non-timed data, a single MPU contains one or more non-timed data items to be consumed by the presentation engine.

An MPU shall be identified by an associated Asset identification (`asset_id`) and a sequence number.

An MPU that contains timed media shall have at least one stream access point (SAP) as defined in ISO/IEC 14496-12:2015, Annex I. The first access unit of an MPU shall be a SAP (of SAP type 1, 2, or 3) for processing by an MMT entity. For timed media, this implies that the first AU in the MPU payload is always the first in decoding order. For the MPU containing the data formatted according to other standards, the MPU payload starts with the information necessary for the processing of such a format. For example, if an MPU contains video data, the MPU payload contains one or more groups of pictures and the decoder configuration information is required to process them. For timed media data, the presentation duration and the decoding order and the presentation order of each AU are signalled as part of the fragment metadata. The MPU does not have its initial presentation time. The presentation time of the first AU in an MPU is described by the PI document. The PI document specifies the initial presentation time of each MPU. Figure 5 depicts an example of the timing of the presentation of MPUs

from different Assets that are provided by the PI document. In this example, the PI document specifies that the MMT receiving entity shall present MPU #1 of Asset #1 and of Asset #2 simultaneously. At a later point, MPU #1 from Asset #3 is scheduled to be presented. Finally, MPU #2 of Asset #1 and Asset #2 are to be presented in synchronization. The specified presentation time for an MPU defines the presentation time of the first AU in the presentation order of that MPU. If any "`elst`" box is available, the indicated offset shall be applied to the composition time of the first sample in the presentation order of the MPU in addition to the presentation time provided by any presentation information. The presentation time of every MPU shall be provided as part of the presentation information.

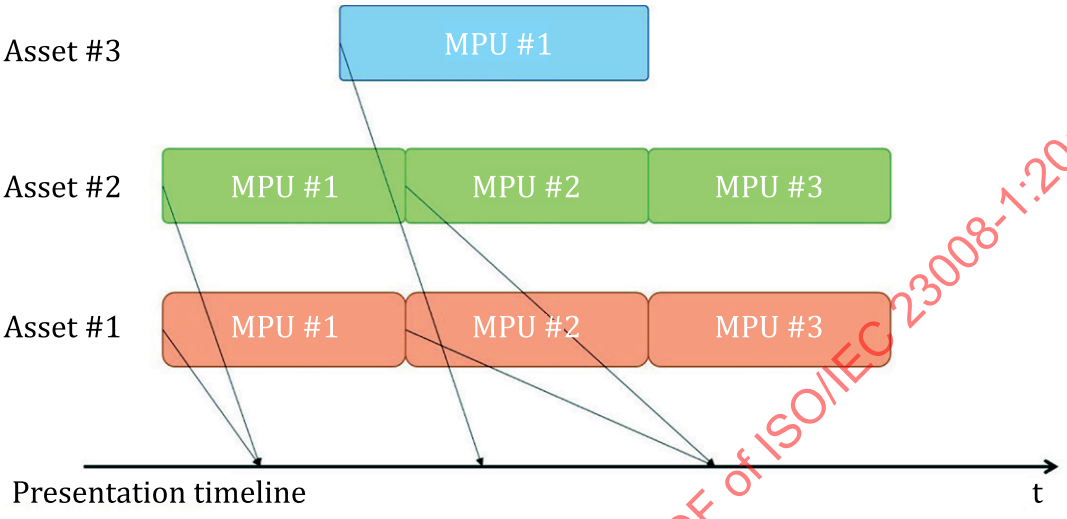


Figure 5 — Example of mapping MPUs to the presentation timeline

An MPU that contains non-timed media data may designate one data item as the primary data item as defined in ISO/IEC 14496-12:2015, 8.11.4.

6.5 Asset delivery characteristics

6.5.1 General

The asset delivery characteristic (ADC) describes the QoS requirements and statistics of Assets for delivery. Each Asset in a Package shall be associated with an ADC. The ADC for each Asset is used by an MMT sending entity to derive the appropriate QoS parameters and the transmission parameters to which a resource reservation and a delivery policy may apply. The ADC is represented in a protocol agnostic format to be generally used by QoS control service entity defined by other standard development organizations, such as IETF, 3GPP, IEEE, etc. It consists of a `QoS_descriptor` element and a `bitstream_descriptor` element. ADC is an XML file that conforms to the schema in 6.5.3. The MIME type of ADC is defined in B.2.

6.5.2 ADC descriptors

6.5.2.1 QoS descriptor

The `QoS_descriptor` element defines required QoS levels on delay and loss for Asset delivery. It consists of `loss_tolerance` attribute, `jitter_sensitivity` attribute, `class_of_service` attribute and `bidirection_indicator` attribute.

6.5.2.2 Bitstream descriptor

The `bitstream_descriptor` element provides the statistics of the Asset. It provides the parameters to implement token bucket traffic shaping such as sustainable rate and buffer size. In addition, peak

rate and maximum MFU size represent burstiness of the Asset as shown in Figure 6, where burstiness is defined as a ratio between a `peak_rate` and `sustainable_rate`.

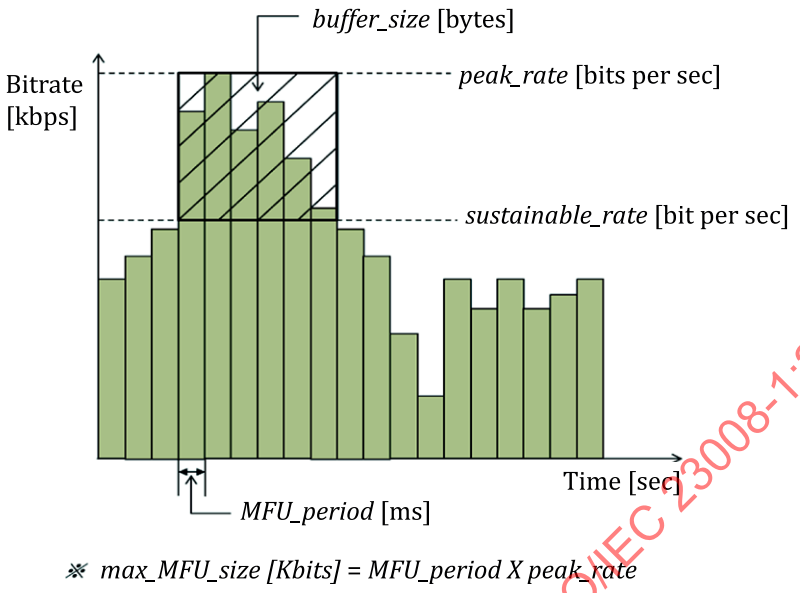


Figure 6 — bitstream_descriptor depicted for a variable bit-rate of Asset

6.5.3 Syntax

```
<complexType name="AssetDeliveryCharacteristic">
    <sequence>
        <element name="QoS_descriptor" type="mmt:QoS_descriptorType" />
        <element name="Bitstream_descriptor" type="mmt:Bitstream_descriptorType”/>
    </sequence>
</complexType>

<complexType name="QoS_descriptorType">
    <attribute name=" loss_tolerance " type="integer"/>
    <attribute name="jitter_sensitivity" type="integer"/>
    <attribute name="class_of_service" type="boolean"/>
    <attribute name="bidirection_indicator" type="boolean"/>
</complexType>

<complexType name="Bitstream_descriptorType">
    <choice>
        <complexType name="Bitstream_descriptorVBRType">
            <attribute name="sustainable_rate" type="float"/>
            <attribute name="buffer_size" type="float"/>
            <attribute name="peak_rate" type="float"/>
            <attribute name="max_MFU_size" type="integer"/>
            <attribute name="mfu_period" type="integer"/>
        </complexType>

        <complexType name="Bitstream_descriptorCBRType">
            <attribute name="peak_rate" type="float"/>
            <attribute name="max_MFU_size" type="integer"/>
            <attribute name="mfu_period" type="integer"/>
        </complexType>
    </choice>
</complexType>
```

6.5.4 Semantics

`loss_tolerance` – indicates the required loss tolerance of the Asset for the delivery. The value of the `loss_tolerance` attribute is listed in Table 1.

Table 1 — Value of loss_tolerance attribute

Value	Description
0	This Asset requires lossless delivery.
1	This Asset allows lossy delivery.

`jitter_sensitivity` – indicates the required jitter level of the underlying delivery network for the Asset delivery between end-to-end. The value of the `jitter_sensitivity` attribute is listed in Table 2.

Table 2 — Value of jitter_sensitivity attribute

Value	Description
0	This Asset requires the preserve time variation between MMTP packets.
1	This Asset does not require the preserve time variation between MMTP packets.

`class_of_service` – classifies the services in different classes and manages each type of bitstream in a particular way. For example, media aware network element (MANE) can manage each type of bitstream in a particular way. This field indicates the type of bitstream attribute as listed in Table 3.

Table 3 — Value of class_of_service attribute

Value	Description
0	The constant bit rate (CBR) service class shall guarantee peak bit rate at any time to be dedicated for transmission of the Asset. This class is appropriate for real-time services which require fixed bit rate such as VoIP without silence suppression.
1	The variable bit rate (VBR) service class shall guarantee sustainable bit rate and allow peak bit rate for the Asset with delay constraints over shared channel. This class is appropriate for most real-time services such as video telephony, video conferencing, streaming service, etc.

`Bidirection_indicator` – If set to "1", bidirectional delivery is required. If set to "0", bidirectional delivery is not required.

`Bitstream_descriptorVBRType` – when `class_of_service` is "1", "`Bitstream_descriptorVBRType`" shall be used for "`Bitstream_descriptorType`".

`Bitstream_descriptorCBRType` – when `class_of_service` is "0" "`Bitstream_descriptorCBRType`" shall be used for "`Bitstream_descriptorType`".

`sustainable_rate` – defines the minimum bit rate that shall be guaranteed for continuous delivery of the Asset. The `sustainable_rate` corresponds to the drain rate in the token bucket model. The `sustainable_rate` is expressed in bits per second.

`buffer_size` – defines the maximum buffer size for delivery of the Asset. The buffer absorbs excess instantaneous bit rate higher than the `sustainable_rate` and the `buffer_size` shall be large enough to avoid overflow. The `buffer_size` corresponds to bucket depth in the token bucket model. The `buffer_size` of a constant bit rate (CBR) Asset shall be zero. The `buffer_size` is expressed in bytes.

`peak_rate` – defines the peak bit rate during continuous delivery of the Asset. The `peak_rate` is the highest bit rate during every `MFU_period`. The `peak_rate` is expressed in bits per second.

MFU_period – defines the period of MFUs during continuous delivery of the Asset. The MFU_period is measured as the time interval of sending time between the first byte of two consecutive MFUs. The MFU_period is expressed in millisecond.

max_MFU_size – indicates the maximum size of MFU, which is MFU_period*peak_rate. The max_MFU_size is expressed in bytes.

6.6 Bundle delivery characteristics

6.6.1 General

The bundle delivery characteristics (BDC) describe the QoS requirements and statistics of the Bundle for delivery. Each Bundle in a Package shall be associated with a BDC. The BDC for each Bundle is used by an MMT sending entity to derive the appropriate QoS parameters and the transmission parameters to which a resource reservation and a delivery policy may apply. The BDC is represented in a protocol agnostic format to be generally used by QoS control service entity defined by other standard development organizations, such as IETF, 3GPP, IEEE, etc. It consists of a QoS_descriptor element and a bitstream_descriptor element as defined in ADC.

6.6.2 BDC descriptors

6.6.2.1 Qos descriptor

The QoS_descriptor element defines required QoS levels on delay and loss for Bundle delivery. It consists of the loss_tolerance attribute, jitter_sensitivity attribute, class_of_service attribute and bidirection_indicator attribute.

6.6.2.2 Bitstream descriptor

The bitstream_descriptor element provides the statistics of the Bundle. It provides the parameters to implement token bucket traffic shaping such as sustainable rate and buffer size. In addition, peak rate and maximum MFU size represent the burstiness of the Bundle where burstiness is defined as a ratio between a peak_rate and sustainable_rate.

6.6.3 Syntax

```
<?xml version="1.0" encoding="UTF-8"?>

<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"targetNamespace="mmt">
    <xs:element name="BundleDeliveryCharacteristic" type="mmt:
BundleDeliveryCharacteristicType">
        <xs:attribute name="MMT_package_id" type="xs:string"/>
    </xs:element>

    <xs:complexType name="mmt:BundleDeliveryCharacteristicType">
        <xs:sequence>
            <xs:element name="Bundle" type="mmt:BundleType"
minOccurs="1" maxOccurs="unbounded"/>
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="mmt:BundleType">
        <xs:sequence>
            <xs:element name="Element_Asset_id" type="asset_id_T" minOccurs="1">
                <xs:attribute name="Intra_Bundle_Priority" type="xs:integer"/>
            </xs:element>
        </xs:sequence>
        <xs:element name="Bundle_QoS_descriptor" type="mmt:QoS_descriptorType"/>
        <xs:element name="Bundle_Bitstream_descriptor" type="mmt:Bitstream
_descriptorType"/>
        <xs:attribute name="Bundle_id" type="xs:integer"/>
        <xs:attribute name="Inter_Bundle_Priority" type="xs:integer"/>
```

```
    </xs:complexType>
    <xs:complexType name="mmt:QoS_descriptorType">
         <xs:attribute name="loss_tolerance" type="xs:integer”/>
         <xs:attribute name="jitter_sensitivity" type="xs:integer”/>
         <xs:attribute name="class_of_service" type="xs:boolean”/>
         <xs:attribute name="distortion_levels" type="xs:integer”/>
         <xs:attribute name="bidirection_indicator" type="xs:boolean”/>
    </xs:complexType>

    <xs:complexType name="Bitstream_descriptorType">
         <xs:choice>
              <xs:complexType name="Bitstream_descriptorVBRType">
                       <xs:attribute name="sustainable_rate" type="xs:float”/>
                       <xs:attribute name="buffer_size" type="xs:float”/>
                       <xs:attribute name="peak_rate" type="xs:float”/>
                       <xs:attribute name="max_MFU_size" type="xs:integer”/>
                       <xs:attribute name="mfu_period" type="xs:integer”/>
              </xs:complexType>
              <xs:complexType name="Bitstream_descriptorCBRType">
                       <xs:attribute name="peak_rate" type="xs:float”/>
                       <xs:attribute name="max_MFU_size" type="xs:integer”/>
                       <xs:attribute name="mfu_period" type="xs:integer”/>
              </xs:complexType>
         </xs:choice>
    </xs:complexType>
</xs:schema>
</xml>
```

6.6.4 Semantics

`loss_tolerance` – indicates the required loss tolerance of the Bundle for the delivery. The value of the `loss_tolerance` attribute is listed in Table 4.

Table 4 — Value of loss_tolerance attribute

Value	Description
0	This Bundle requires lossless delivery.
1	This Bundle allows lossy delivery.

`jitter_sensitivity` – indicates the required jitter level of the underlying delivery network for the Bundle delivery between end-to-end. The value of the `jitter_sensitivity` attribute is listed in Table 5.

Table 5 — Value of jitter_sensitivity attribute

Value	Description
0	This Bundle requires the preserve time variation between MMT protocol packets.
1	This Bundle does not require the preserve time variation between MMT protocol packets.

`class_of_service` – classifies the services in different classes and manages each type of bitstream in a particular way. For example, MANE can manage each type of bitstream in a particular way. This field indicates the type of bitstream attribute as listed in Table 6.

Table 6 — Value of class_of_service attribute

Value	Description
0	The constant bit rate (CBR) service class shall guarantee peak bit rate at any time to be dedicated for transmission of the Bundle. This class is appropriate for real-time services which require fixed bit rate such as VoIP without silence suppression.
1	The variable bit rate (VBR) service class shall guarantee sustainable bit rate and allow peak bit rate for the Bundle with delay constraints over a shared channel. This class is appropriate for most real-time services such as video telephony, video conferencing, streaming service, etc.

`Bidirection_indicator` – If set to "1", bidirectional delivery is required. If set to "0", bidirectional delivery is not required.

`Bitstream_descriptorVBRType` – when `class_of_service` is "1", "`Bitstream_descriptorVBRType`" shall be used for "`Bitstream_descriptorType`".

`Bitstream_descriptorCBRType` – when `class_of_service` is "0", "`Bitstream_descriptorCBRType`" shall be used for "`Bitstream_descriptorType`".

`sustainable_rate` – defines the minimum bit rate that shall be guaranteed for continuous delivery of the Asset. The `sustainable_rate` corresponds to the drain rate in the token bucket model. The `sustainable_rate` is expressed in bytes per second.

`buffer_size` – defines the maximum buffer size for delivery of the Bundle. The buffer absorbs excess instantaneous bit rate higher than the `sustainable_rate` and the `buffer_size` shall be large enough to avoid overflow. The `buffer_size` corresponds to bucket depth in the token bucket model. The `buffer_size` of a constant bit rate (CBR) Bundle shall be zero. The `buffer_size` is expressed in bytes.

`peak_rate` – defines the peak bit rate during continuous delivery of the Bundle. The `peak_rate` is the highest bit rate during every `MFU_period`. The `peak_rate` is expressed in bytes per second.

`MFU_period` – defines the period of MFUs during continuous delivery of the Bundle. The `MFU_period` is measured as the time interval of sending time between the first byte of two consecutive MFUs. The `MFU_period` is expressed in millisecond.

`max_MFU_size` – indicates the maximum size of MFU, which is `MFU_period*peak_rate`. The `max_MFU_size` is expressed in byte.

`MMT_package_id` – this field is a unique identifier of the Package. This BDC describes delivery characteristics of all the possible Bundles within the scope of this package.

`Element_Asset_id` – is an identifier of asset which is an element of current bundle.

`Bundle_id` – is an identifier of the bundle which distinguishes bundles within the package.

`Intra_Bundle_Priority` – defines the relative priority level among assets within a bundle, which ranges from "0" (highest) to "12" (lowest).

`Inter_Bundle_Priority` – defines the relative priority level among bundles, which ranges from "0" (highest) to "12" (lowest).

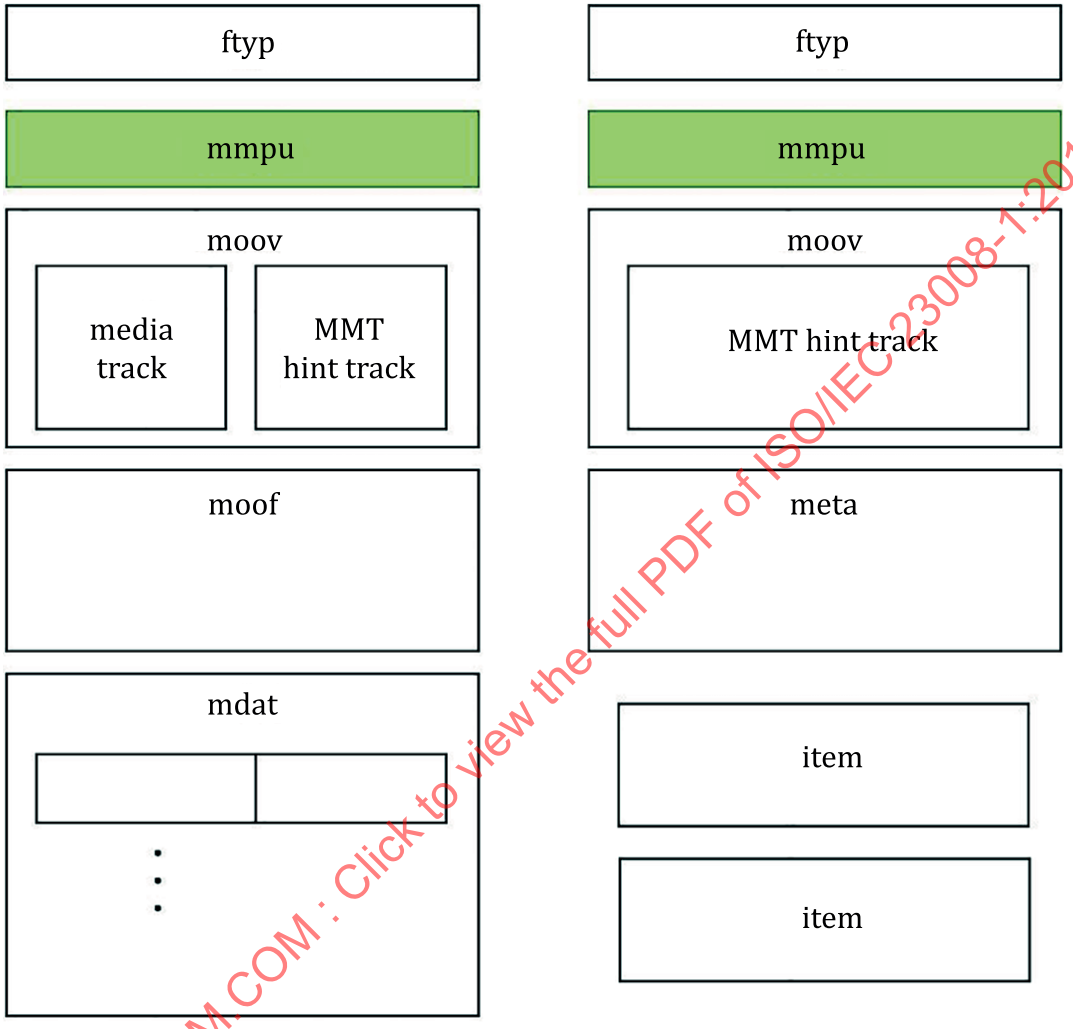
7 ISOBMFF-based MPU

7.1 General

An MPU shall be a conformant ISOBMF file that is generated according to the rules in 7.2. The sequence number and Asset ID of the MPU are provided in the "`mmpu`" box to uniquely identify the MPU encapsulated in the file. Additionally, in case of timed media, a "`sidx`" box may be present to index

movie fragments comprising the MPU. The "moov" box shall contain all codec configuration information for decoding and presentation of media data.

Timed media data are stored as track of the ISOBMFF (a single media track is allowed). Non-timed media are stored as part of metadata in an ISOBMFF. Figure 7 depicts two examples of MMT encapsulation, one for timed and the other for non-timed media. For packetized delivery of MPU, an MMT hint track provides the information to convert encapsulated MPU to MMTP payloads and MMTP packets.



a) MPU with timed media **b) MPU with non-timed media**

Figure 7 — Examples of MPU encapsulation

7.2 MPU brand definition

The brand "mpuf" (MPU file) defined in this document identifies files that conform to the encapsulation rules for MPU. The "mpuf" brand requires the support of the "isom" brand. Support to the other brand, such as the "dash" brand as defined in ISO/IEC 23009-1:2014, 6.3.5.2, may be indicated.

An MPU file is composed of a set of metadata boxes that enables the MPU to be self-contained. An MPU file shall contain "ftyp"and "moov" boxes, should contain an "mmpu" box, and may optionally contain a "sidx" box, all of which are part of the MPU metadata. Other boxes are allowed but will be ignored if the parser does not recognize them.

The "moov" box shall contain at most one media track and may contain MMT hint tracks for MFUs. The tracks in the "moov" box shall contain no samples to ensure small overhead (i.e. the entry_count in the "stts", "stsc" and "stco" boxes shall be set to "0"). The "mvex" box shall be contained in the "moov" box for the file storing an MPU with timed media data to indicate that the movie fragment structure is used. The "mvex" box also sets default values for the tracks and samples of the following movie fragments.

Additionally, an "mmpu" box should occur at the file level and the following rules including orders of boxes shall be applied.

a) If present, the "mmpu" box should be placed right after "ftyp" box.

b) For timed media data, zero or more "sidx" boxes may be present in the file and if present, they shall index the movie fragments that build the current MPU.

In addition to the box orders, the following restrictions shall be applied to the "mpif" brand.

a) The maximum number of independent (e.g. empty "tref" box) media tracks in this file shall be one. Additionally, tracks with non-empty "tref" box (e.g. hint track or SVC/SHVC enhancement layer tracks) may be available.

b) For timed media data, the file shall have at least one movie fragment.

c) For non-timed media data, one "meta" box shall be present at the file level and shall contain the non-timed media items of the MPU.

d) If present, an Edit List Box ("elst") shall only provide an initial offset.

e) Runs of sample data shall be placed in "mdat" box, in decoding order and without any other data in between runs.

f) Any sample auxiliary data, as described by "saio" and "saiz", shall be placed at the beginning of the "mdat" boxes, before any sample data.

g) Any hint data shall be placed after sample data in the "mdat" (or in another mdat placed after sample data) so as not to change sample offsets between before and after transmission.

A "tfdt" box should be present inside the "traf" box of each movie fragment to provide the decode time of the first sample of the movie fragment in decoding order.

If any "elst" box is available, the indicated offset shall be applied to the composition time of the first sample in the presentation order of the MPU in addition to the presentation time provided by any presentation information.

Timed media data are stored as a track of the ISOBMFF and indexed by the "moov" and "moof" boxes in a fully backward-compatible manner. An MMT hint track guides the MMT sending entity in converting the file encapsulating MPU into a packetized media stream to be delivered using a transport protocol such as the MMT protocol.

Non-timed media data are stored as metadata items that are described by a "meta" box. The "meta" box shall appear at the file level. Each file of the non-timed media data shall be stored as a separate floating item of the MPU, i.e. it shall not be contained by any box and shall appear after any boxes of the MPU. The entry point to the non-timed media shall be marked as the primary item of the "meta" box (see ISO/IEC 14496-12:2015, 8.11.4).

7.3 MPU box

7.3.1 Definition

Box type: "mmpu"

Container: File

Mandatory: Yes

Quantity: One or more

The media processing unit ("mmpu") box contains the Asset identifier of the Asset to which the current MPU belongs, as well as other information of the current MPU. The Asset identifier is used to uniquely identify the Asset globally. The MPU information includes the sequence number of the MPU in the corresponding Asset.

When it is required to store the ADC together with MPU, it shall be stored in the "meta" box at the file level and its presence shall be indicated through the "is_adc_present" flag and the MIME type of the item that stores the ADC.

7.3.2 Syntax

```
aligned(8) class MPUBox
   extends FullBox('mmpu', version, 0){


   unsigned int(1) is_complete;
   unsigned int(1) is_adc_present;
   unsigned int(6) reserved;

   unsigned int(32) mpu_sequence_number;


   AssetIdentifier();
}


aligned(8) class AssetIdentifier {
   unsigned int(32) asset_id_scheme;
   unsigned int(32) asset_id_length;
   unsigned int(8)  asset_id_value[asset_id_length];
}
```

7.3.3 Semantics

is_complete – indicates whether this MPU has all the media samples and MFUs or not (e.g. when it is being generated from live content).

mpu_sequence_number – contains the sequence number of the current MPU. For the first MPU in an Asset, the sequence number shall be "0" and it is incremented by "1" for each following MPU. The sequence number is unique within an Asset.

asset_id_scheme – identifies the scheme of Asset ID used in asset_id_value. Valid schemes are listed in Table 7. There are many schemes to express identification of content. It is recommended to use scheme-length-value and not to define a new identification scheme.

Table 7 — Value of asset_id_scheme

Value	Description
0x00000000	UUID (universally unique identifier)
0x00000001	URI (uniform resource identifier)

asset_id_length – the length of asset_id_value.

asset_id_value – contains identifier for the Asset. Format of the value in this field is specific to the value in the asset_id_scheme field.

`is_adc_present` – indicates whether the ADC is present as an XML box in a "`meta`" box. The MIME type of the ADC file as defined in B.2 shall be indicated in an item information box "`iinf`".

8 MMT hint track

8.1 General

An MMT hint track provides an MMT sending entity with hints for the fragmentation of an MPU into MFUs. An MFU enables media-aware fragmentation of an MPU for transportation purposes. One or more MFUs may then be used to build an MMTP payload. Media data in the MPU are extracted and put on an MMTP payload at transport time by the MMT sending entity. This allows an MMT sending entity to perform fragmentation of MPUs with consideration for media-aware delivery.

An MFU is a media sample or subsample as defined in 9.3.1.

An MMT hint track also provides hints for extracting and building of MFUs for encapsulation using the MMTP payload format. An MMTP payload may contain either MPU metadata, fragment metadata, or one or more MFUs. MPU metadata shall include the "`ftyp`" and "`moov`" boxes, should include the "`mmpu`" box, and may include "`sidx`" and other boxes.

Each MFU is composed of a header and the associated media data. The MFU header shall be a copy of the MFU hint sample and the media data is a copy of the media data that is referenced by that MFU hint sample.

If fragmentation is not required, the hint track may be omitted.

An MFU is delivered in an MMTP payload of an MMTP packets.

8.2 Sample description format

8.2.1 Definition

MMT hint tracks are hint tracks with an entry format in the sample description of "`mmth`" box:

8.2.2 Syntax

```
aligned(8) class MMTHintSampleEntry() extends SampleEntry('mmth') {
   unsigned int(16) hinttrackversion = 1;
   unsigned int(16) highestcompatibleversion = 1;
   unsigned int(16) packet_id;
   unsigned int(1) has_mfus_flag;
   unsigned int(1) is_timed;
   unsigned int(6) reserved;

}
```

8.2.3 Semantics

`packet_id` – is a unique identifier for the Asset for which this hint track applies.

`has_mfus_flag` – is a flag indicating whether the MPUs are fragmented into MFUs or not. If this flag is set to FALSE, the hint track applies to the complete MPU, i.e. each track fragment will have a single sample. Otherwise, each hint sample applies to an MFU.

`is_timed` – indicates whether the media data hinted by this track is timed data or non-timed data.

8.3 Sample format

8.3.1 Definition

Each media sample will be assigned to one or more MFUs. Each sample of the MMT hint track will generate one or more MFUs. The hint sample may omit certain bytes of an MFU if deemed redundant, such as the length field of a NAL unit in the case of AVC or HEVC video bitstreams.

8.3.2 Syntax

```
aligned(8) class MMTHSample {

   unsigned int(32) sequence_number;
   if (is_timed) {
      signed int(8) trackrefindex;
      unsigned int(32) movie_fragment_sequence_number
      unsigned int(32) samplenumber;
      unsigned int(8)  priority;
      unsigned int(8)  dependency_counter;
      unsigned int(32) offset;
      unsigned int(32) length;
      multiLayerInfo();
   } else {
      unsigned int(16) item_ID;
   }
}


aligned(8) class multiLayerInfo extends Box("muli") {
   bit(1) multilayer_flag;
   bit(7) reserved0;

   if (multilayer_flag==1) {
      bit(3) dependency_id;
      bit(1) depth_flag;
      bit(4) reserved1;
      bit(3) temporal_id;
      bit(1) reserved2;
      bit(4) quality_id;
      bit(6) priority_id;
      bit(10) view_id;
   }
   else{
      bit(6) layer_id;
      bit(3) temporal_id;
      bit(7) reserved3;
   }
}
```


8.3.3 Semantics

`sequence_number` – an integer number that indicates the sequencing order of this MFU within the MPU. Discontinuity of sequence numbers in an MPU is allowed to indicate that certain MFUs (whose sequence number was not in the sequence) were not processed after packetization of MPU. Examples of MFU processing are delivery and caching by underlying network entity.

`movie_fragment_sequence_number` – is the sequence number of the movie fragment to which the media data of this MFU belongs (see ISO/IEC 14496-12:2015, 8.8.5). The `movie_fragment_sequence_number` in an MPU must start by "1" for the first movie fragment of the MPU and shall be incremented by "1" for every succeeding movie fragment in that MPU.

`trackrefindex` – the ID of the media track from which the MFU data is extracted.

samplenumber – the number of the sample from which this MFU is extracted. Sample number n points to the n-th sample from accumulated samples of the current movie fragment. The sample number of the first sample in the movie fragment is set to "1" (see ISO/IEC 14496-12:2015, 8.8.8).

item_ID – for non-timed media data, this is the ID of the item that is contained in this MFU.

priority – indicates the priority of the MFU relative to other MFUs within an MPU.

dependency_counter – indicates the number of MFUs whose decoding is dependent on this MFU. The value of this field is equal to the number of subsequent MFUs in the order of sequence_number that may not be correctly decoded without this MFU. For example, if the value of this field is equal to n, then n subsequent MFUs may not be correctly decoded without this MFU.

offset – the offset of the media data contained in this MFU. The offset base is the beginning of the containing "mdat" box. MFU shall be placed at the position that offset indicates.

length – the length of the data corresponding to this MFU in bytes.

multilayer_flag – when set to "1", this flag indicates that detailed multi-layer information is present in this box.

dependency_id – dependency identification of this MFU. If the value of this field is a non-zero value, then the data associated with this sample enhance the video by one or more scalability levels in at least one direction (temporal, quality or spatial resolution).

depth_flag – when set to "1", this flag indicates that the given MFU conveys the depth data of video.

quality_id – quality identification of this MFU. If this field contains a non-zero value, then the data associated with this sample enhance the video by one or more scalability levels in at least one direction (temporal, quality or spatial resolution).

priority_id – priority identification of this MFU. If the value of this field is non-zero value, then the data associated with this sample enhance the video by one or more scalability level in at least on direction (temporal, quality or spatial resolution).

temporal_id – temporal identification of this MFU. If the value of this field is a non-zero value, then the data associated with this sample enhance the video by one or more scalability levels in at least one direction (temporal, quality or spatial resolution).

view_id – view identification of this MFU. If the value of this field is a non-zero value, then the data associated with this sample enhance the video by one or more scalability levels in at least one direction (temporal, quality or spatial resolution).

layer_id – indicates the identification of a scalable layer whose information about scalability dimensions is provided in initialization information.

9 Packetized delivery of Package

9.1 General

This clause specifies an application layer transport protocol (the MMT protocol) for packetized delivery of Packages and defines the MMTP payload format.

NOTE For non-packetized delivery of Packages, e.g. using other file delivery protocols, the MMTP payload format and MMT protocol are not required.

The MMT protocol is an application layer transport protocol supporting delivery of Packages over heterogeneous packet-switched delivery networks, including IP-based network environments. The MMT protocol provides enhanced features for delivery of Packages such as protocol level multiplexing, which, for example, enables various Assets to be delivered over a single MMTP packet flow, and

delivery timing model independent of presentation time to adapt to a wide range of network jitters and information to support quality of service (QoS).

MMT provides a generic media streaming solution that supports the transport of different media types and codecs. For this purpose, MMT defines a transport protocol, MMTP, that is designed to support a limited set of payload types agnostic to the media type or coding format but providing information serving the needs of different multimedia delivery services.

The MMTP payload format is defined as a generic payload format for the packetization of media data components of a Package. It is agnostic to media codecs used for encoded media data, so that any type of media data that are encapsulated as an MPU can be packetized into MMTP. The MMTP payload format is also used to packetize signalling messages. The MMTP payload format also supports fragmentation and aggregation of data to be delivered.

MMTP supports both streaming and download modes, where the streaming mode is optimized for packetized streaming of ISO-based media file formatted files (MPU mode) and the download mode allows for flexible delivery of generic files (GFD mode). In addition, MMTP enables delivery of streaming support data such as application layer forward error correction (AL-FEC) (in accordance with Annex C), repair data and signalling messages.

9.2 MMT protocol

9.2.1 General

The MMT protocol is an application layer transport protocol that is designed to efficiently and reliably transport Packages. The MMT protocol can be used for both timed and non-timed media data. It supports several enhanced features, such as media multiplexing, network jitter calculation, and QoS indication. These features are designed to deliver content composed of various types of encoded media data more efficiently. The MMT protocol may run on top of existing network protocols, e.g. UDP and IP. In this document, the carriage of the data formatted in a format other than the MMTP payload format as specified in 9.3 is not defined.

The MMT protocol is designed to support a wide variety of applications and does not specify congestion control. Congestion control is left to implementation.

The MMT protocol supports the multiplexing of different media data such as MPUs from various Assets over a single MMTP packet flow. It delivers multiple types of data in the order of consumption to the receiving entity to help synchronization between different types of media data without introducing a large delay or requiring large buffer. The MMT protocol also supports the multiplexing of media data and signalling messages within a single packet flow.

A single MMTP payload shall be carried in only one MMTP packet. Fragmentation and aggregation are only provided by the payload format and not by MMTP itself. The MMT protocol defines two packetization modes, generic file delivery (GFD) mode as specified in 9.3.3 and MPU mode as specified in 9.3.2. The GFD mode identifies data units using their byte position inside a transport object. The MPU mode identifies data units using their role and media position inside an MPU. The MMT protocol supports mixed use of packets with two different modes in a single delivery session. A single packet flow of MMT packets can be arbitrarily composed of payloads with two types.

The MMT protocol also provides means to calculate and remove jitter introduced by the underlying delivery network, so that constant end-to-end packet delivery delay can be achieved. By using the timestamp field in the packet header, jitter can be precisely calculated without requiring any additional signalling information and protocols.

The MMT protocol provides priority-related information to enable underlying network layers or the intermediate network entities to map the priority information in the MMTP packet header such as `type_of_bitrate`, `delay_sentivity`, `transmission_priority` and `flow_label` to the network protocol according to predetermined priority mapping policy to support the flow control for MMTP packet delivery. For example, when DiffServ (IETF RFC 2474) is used, this priority information

may be used to set the 6-bit DSCP value of the DS field in the IP header. The underlying network entity supporting Diffserv shall then process the IP packets according to the mapping defined by the priority-related information in the MMTP packet header.

9.2.2 Structure of an MMTP packet

The packetization of an MPU that contains timed date is performed in a format aware mode. The type filed of the MMTP packet header is set according to Table 9 (V=0) and Table 10 (V=1) to indicate that the packetization is format aware and that the packet will be delivering using the MPU mode. An MPU can also be delivered in a format agnostic mode using the GFD mode as described in 9.3.3

Figure 8 and Figure 9 illustrate the structure of an MMTP packet of version 0 and version 1, respectively.

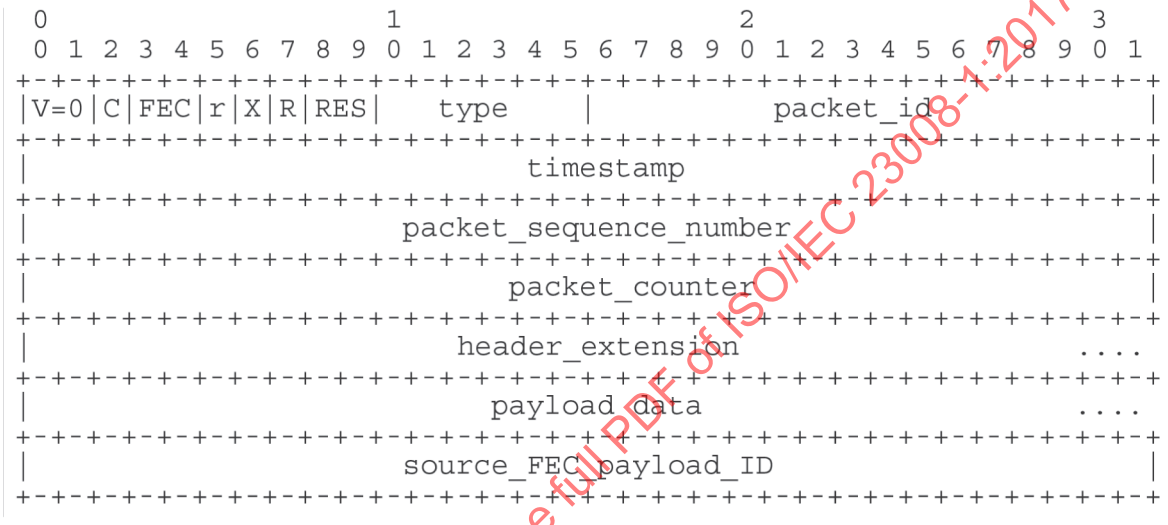


Figure 8 — Structure of MMTP packet (V = 0)

Note that MMTP does not provide an indication of the packet length and relies on lower layer framing protocols to do this. For example, when using MMTP over UDP, the MMTP packet length is provided by the Length field of the UDP datagram.

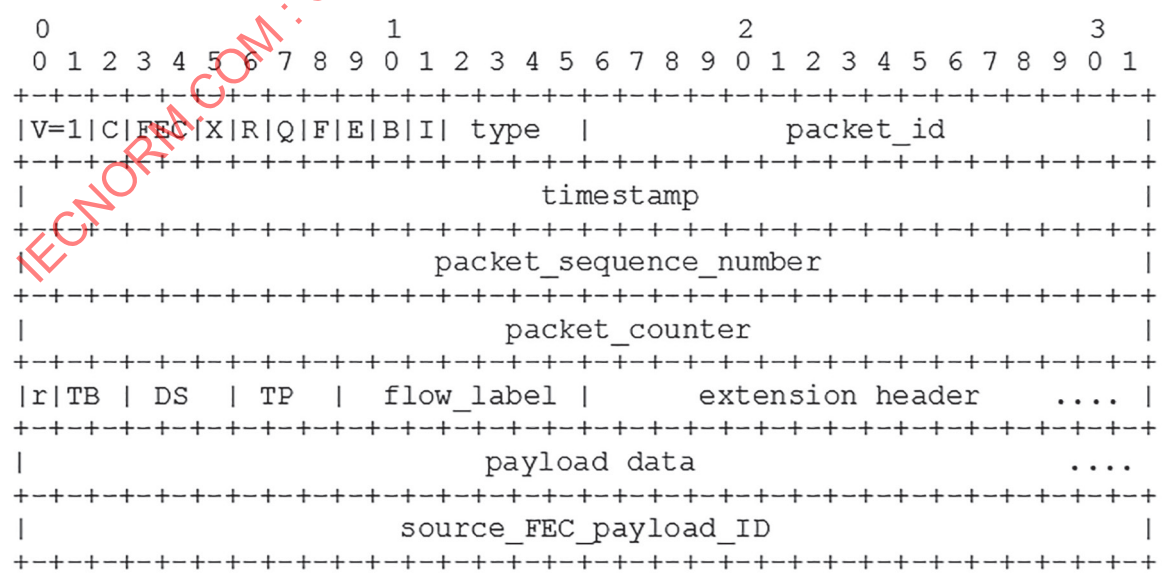


Figure 9 — MMTP packet header, payload and footer (V = 1)

9.2.3 Semantics

`version (V: 2 bits)` – indicates the version number of the MMTP protocol. This field shall be set to "00" to comply with this document and "01" for QoS support.

NOTE If version is set to "01", the length of type is set to 4 bits.

`packet_counter_flag (C: 1 bit)` – "1" in this field indicates that the `packet_counter` field is present.

`FEC_type (FEC: 2 bits)` – indicates the type of the FEC scheme used for error protection of MMTP packets. Valid values of this field are listed in Table 8.

Table 8 — FEC_types

Value	Description
0	MMTP packet without source_FEC_payload_ID field
1	MMTP packet with source_FEC_payload_ID field
2	MMTP packet for repair symbol(s) for FEC Payload Mode 0 (FEC repair packet)
3	MMTP packet for repair symbol(s) for FEC Payload Mode 1 (FEC repair packet)

NOTE If FEC_type is set to 0, it indicates that FEC is not applied to this MMT packet or that FEC is applied to this MMT packet without adding source_FEC_payload_ID.

`reserved (r: 1 bit)` – reserved for future use.

`extension_flag (X: 1 bit)` – when set to "1", this flag indicates that the `header_extension` field is present.

`RAP_flag (R: 1 bit)` – when set to "1", this flag indicates that the payload contains a Random Access Point (RAP) to the data stream of that data type. The exact semantics of this flag are defined by the data type itself.

`reserved (RES: 2 bits)` – reserved for future use.

`Compression_flag (B: 1 bit)` – this field is added at the beginning of the header in order to indicate whether or not header compression is used. When set to "0", the full-size header is used; when set to "1", the reduced-size header is used.

`Indicator_flag (I: 1 bit)` – this field is added to tell the receiver whether or not the current full header will later be used as a reference. This field shall be set to "1" when the full header will be used as a reference. This allows receivers to discover that this header information shall be stored as it will be later used as a reference by packets with reduced headers.

`type(6 / 4 bits)` – this field indicates the type of payload data. Payload type values are defined in Table 9 for version "00" and Table 10 defined value of payload type for version "01".

Table 9 — Data type and definition of data unit (V=0)

Value	Data type	Definition of data unit
0x00	MPU	a media-aware fragment of the MPU
0x01	generic object	a generic object such as a complete MPU or an object of another type
0x02	signalling message	one or more signalling messages or a fragment of a signalling message (see 10.2)
0x03	repair symbol	a single complete repair symbol (see C.4.3)
0x04 ~ 0x1F	reserved for ISO use	for ISO use
0x20 ~ 0x3F	reserved for private use	for private use

Table 10 — Data type and definition of data unit (V=1)

Value	Data type	Definition of data unit
0x0	MPU	a media-aware fragment of the MPU
0x1	generic object	a generic object such as a complete MPU or an object of another type
0x2	signalling message	one or more signalling messages or a fragment of a signalling message (see 10.2)
0x3	repair symbol	a single complete repair symbol (see C.4.3)
0x4 ~ 0x9	reserved for ISO use	for ISO use
0xA ~ 0xF	reserved for private use	for private use

`packet_id (16 bits)` – this field is an integer value that can be used to distinguish one Asset from another. The value of this field is derived from the `asset_id` of the Asset where this packet belongs to. The mapping between the `packet_id` and the `asset_id` is signalled by the MMT Package Table as part of a signalling message (see 10.3.4). Separate value will be assigned to signalling messages and FEC repair flows. The `packet_id` is unique throughout the lifetime of the delivery session and for all MMT flows delivered by the same MMT sending entity. For AL-FEC, the mapping between `packet_id` and the FEC repair flow is provided in the AL-FEC message.

`packet_sequence_number (32 bits)` – an integer value that is used to distinguish packets that have the same `packet_id`. The value of this field starts from arbitrary value and will be incremented by one for each MMTP packet received. It wraps around to "0" after the maximum value is reached. In the FEC repair packet for FEC Payload ID Mode 1, this field shall be replaced with `RS_ID`.

`timestamp (32 bits)` – specifies the time instance of MMTP packet delivery based on UTC. The format is the "short-format" as defined in IETF RFC 5905, NTP version 4, Clause 6. This timestamp specifies the sending time at the first byte of MMTP packet. It is required that an MMT sending entity should provide accurate time information that is synchronized with UTC.

`packet_counter (32 bits)` – an integer value for counting MMTP packets. It is incremented by 1 when an MMTP packet is sent regardless of its `packet_id` value. This field starts from arbitrary value and wraps around to "0" after its maximum value is reached. All packets of an MMTP flow shall have the same setting for *`packet_counter_flag (C)`*, which means that either all packets will have the `packet_counter` field or none of them will have it.

`Source_FEC_payload_ID (32 bits)` – this field shall be used only when the value of FEC type is set to "1" (see C.4.2). The MMTP packet with FEC type = 1 shall be used for AL-FEC protection for FEC Payload ID Mode 0 and this field shall be added to the MMTP packet after AL-FEC protection.

`header_extension` – this field contains user-defined information. The header extension mechanism is provided to allow for proprietary extensions to the payload format to enable applications and media types that require additional information to be carried in the payload format header. The header extension mechanism is designed in such a way that it may be discarded without impacting the correct

processing of the MMTP payload. The header extension shall have the format as shown in Figure 10. This document does not specify any particular header extension.

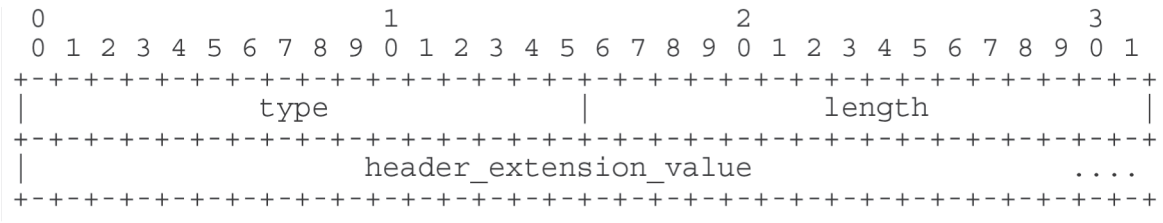


Figure 10 — Structure of extension header

`type (16 bits)` – indicates the unique identification of the following header extension.

`length (16 bits)` – indicates the length of `header_extension_value` field in byte.

`header_extension_value` – provides the extension information. The format of this field is outside the scope of this document.

`QoS_classifier_flag (Q:1bit)` – when set to "1", it indicates that QoS classifier information is used. The QoS classifier contains the `delay_sensitivity` field, `reliability_flag` field, and `transmission_priority` field. It indicates the QoS class property. The application can perform per-class QoS operations according to the particular value of one property. The class values are universal to all independent sessions.

`flow_identifier_flag (F:1 bit)` – when set to "1", it indicates that flow identifier information is used. The flow identifier contains the `flow_label` field and `flow_extension_flag` field. It indicates the flow identifier. The application can perform per-flow QoS operations in which network resources are temporarily reserved during the session. A flow is defined to be a bitsream or a group of bitstreams whose network resources are reserved according to transport characteristics or ADC in Package.

`flow_extension_flag (E: 1 bit)` – if there are more than "127" individual flows, this bit is set to "1" and one more byte can be used in `extension_header`.

`reliability_flag (r: 1 bit)` – when "`reliability_flag`" is set to "0", it shall indicate that the data are loss tolerant (e.g. media data), and that the following "`transmission_priority`" field shall be used to indicate relative priority of loss. When "`reliability_flag`" is set to "1", the "`transmission_priority`" field will be ignored, and shall indicate that the data are not loss tolerant (e.g. signalling data, service data or program data).

`type_of_bitrate (TB: 2 bits)` – indicates the type of bit rate as listed in Table 11.

Table 11 — Value of type_of_bitrate

Value	Description
00	constant bit rate (CBR)
01	non-constant bit rate (nCBR)
10 ~ 11	reserved

`delay_sensitivity (DS: 3 bits)` – indicates the delay sensitivity of the data between end-to-end delivery for the given service as listed in Table 12. This field is derived from the application as the same content may have different delay requirements in different applications.

Table 12 — Value of delay_sensitivity

Value	Description
111	conversational service (~100 ms)
110	live-streaming service (~1 s)
101	delay-sensitive interactive service (~2 s)
100	interactive service (~5 s)
011	streaming service (~10 s)
010	non-real-time service
001	reserved
000	reserved

`transmission_priority (TP: 3 bits)` – provides the transmission_priority for the media packet, when the `reliability_flag` is set to "0". It may be mapped to the NRI of NAL, DSCP of IETF, or other loss priority fields in another network protocol. This field shall take values from "7" ("1112") to "0" ("0002"), where 7 is the highest priority and "0" is the lowest priority.

`flow_label (7 bits)` – indicates the flow identifier. The application can perform per-flow QoS operations in which network resources are temporarily reserved during the session. A flow is defined to be a bitsream or a group of bitstreams whose network resources are reserved according to transport characteristics or ADC in Package. It is an implicit serial number from "0" to "127". An arbitrary number is assigned temporarily during a session and refers to every individual flow for whom a decoder (processor) is assigned and network resource could be reserved.

9.2.4 MMTP session description information

The MMTP session description information may be delivered to receivers in different ways to accommodate different deployment environments. Before a receiver is able to join an MMTP session, the receiver needs to obtain the following information:

— the destination information. In an IP environment, the destination IP address and port number;

— an indication that the session is an MMTP session;

— the version number of the MMT protocol used in the MMTP session;

Additionally, the MMTP session description information should contain the following information:

— the start and end time of the MMTP session.

9.3 MMTP payload

9.3.1 General

The MMTP payload is a generic payload to packetize and carry media data such as MPUs, generic objects, and other information for consumption of a Package using the MMT protocol. The appropriate MMTP payload format shall be used to packetize MPUs, generic objects, and signalling messages described in 10.2.

An MMTP payload may carry complete MPUs or fragments of MPUs, signalling messages, generic objects, repair symbols of AL-FEC schemes, etc. The type of the payload is indicated by the type field in the MMT protocol packet header. For each payload type, a single data unit for delivery as well as a type specific payload header is defined. For example, the fragment of an MPU (e.g. an MFU) is considered as a single data unit when the MMTP payload carries MPU fragments. The MMT protocol may aggregate multiple data units with the same data type into a single MMTP payload. It can also fragment a single data unit into multiple MMTP packets.

An MFU is a sample or subsample of timed data or an item of non-timed data. An MFU shall contain media data that may be smaller than an AU for timed data and the contained media data may be processed by the media decoder. An MFU shall contain an MFU header that contains information on the boundaries of the carried media data. An MFU shall contain an identifier to uniquely distinguish the MFU inside an MPU. It may also provide dependency and priority information relative to other MFUs within the same MPU.

The MMTP payload consists of a payload header and payload data. Some data types may allow for fragmentation and aggregation, in which case a single data unit is split into multiple fragments or a set of data units are delivered in a single MMTP packet.

Each data unit may have its own data unit header depending on the type of the payload. The payload type specific headers are defined in 9.2.2. For types that do not require a payload type, a specific header no payload type header is present and the payload data follows the MMTP header immediately.

Some fields of the MMTP packet header are interpreted differently depending on the payload type. The semantics of these fields will be defined by the payload type in use.

9.3.2 MPU mode

9.3.2.1 General

The delivery of MPUs to MMT receivers using the MMT protocol requires a packetization and depacketization procedure to take place at the MMT sending entity and MMT receiving entity, respectively. The packetization procedure transforms an MPU into a set of MMTP payloads that are then carried in MMTP packets. The MMTP payload format allows for fragmentation of the MMTP payload to enable the delivery of large payloads. It also allows for the aggregation of multiple MMTP payload data units into a single MMTP payload to cater for smaller data units. At the receiving entity, depacketization is performed to recover the original MPU data. Several depacketization modes are defined to address the different requirements of the overlaying applications.

If the payload type is "0x00", the MPU is fragmented in a media-aware way allowing the transport layer to identify the nature and priority of the fragment that is carried. A fragment of an MPU may either be MPU metadata, a Movie Fragment metadata, an MFU, or a non-timed media data item.

9.3.2.2 MMTP payload header for MPU mode

The payload type specific header is provided in Figure 11.

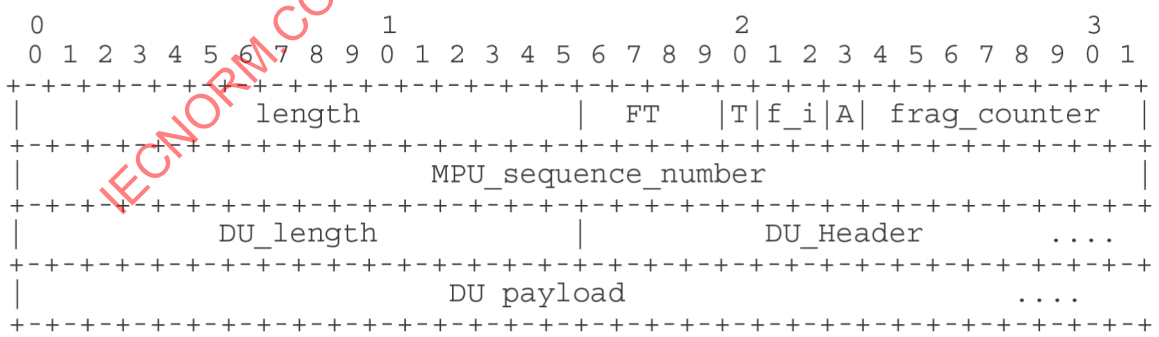


Figure 11 — Structure of the MMTP payload header for MPU mode

For payload that carries an MFU, the DU header is specified depending on the value of the T flag indicating whether the carried data are timed or non-timed media. For timed media (i.e. when the value of T is set to "1"), the DU header fields are shown in Figure 12. For non-timed media (T is set to "0"), the DU header is defined as shown in Figure 13.

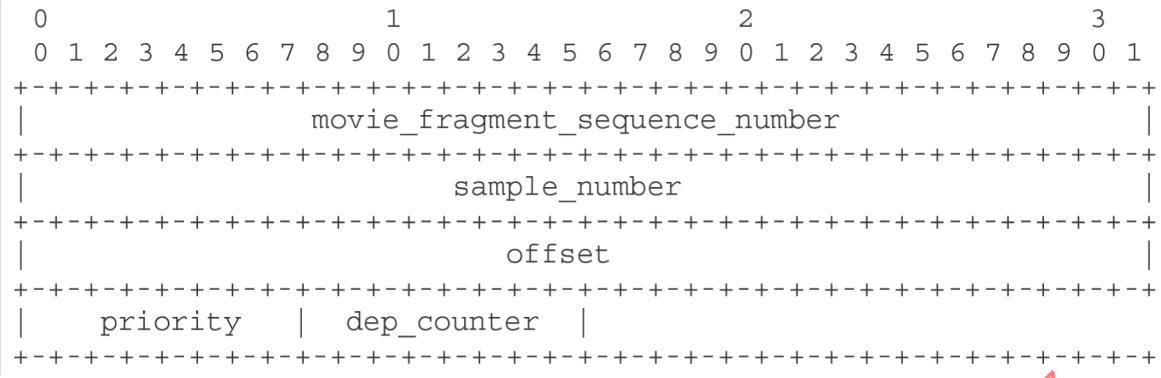


Figure 12 — DU header for timed-media MFU

For non-timed media, the DU header fields are shown in Figure 13.

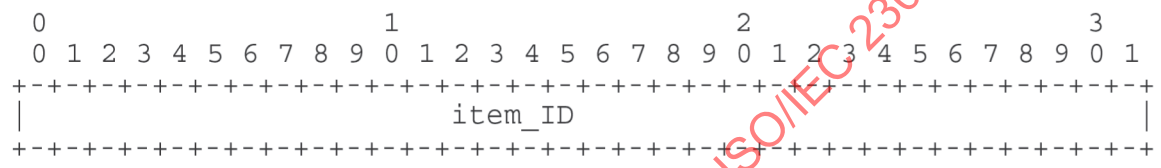


Figure 13 — DU header for non-timed media MFU

9.3.2.3 Semantics

`length (16 bits)` – indicates the length of payload excluding this field in byte.

`MPU Fragment Type (FT: 4 bits)` – this field indicates the fragment type and its valid values are shown in Table 13.

Table 13 — Data type and definition of data unit

FT	Description	Content
0	MPU metadata	contains the ftyp, mmpu, moov, and meta boxes, as well as any other boxes that appear in between.
1	Movie fragment metadata	contains the moof box and the mdat box, excluding all media data inside the mdat box but including any chunks of auxiliary sample information.
2	MFU	contains a sample or subsample of timed media data or an item of non-timed media data.
3 ~ 15	Reserved for private use	reserved

`Timed Flag (T: 1 bit)` – this flag indicates if the fragment is from an MPU that carries timed (value 1) or non-timed media (value 0).

`Fragmentation Indicator (f_i : 2 bits)` – this field indicates that the fragmentation indicator contains information about fragmentation of data unit in the payload. The four values are listed in Table 14. If the value is set to "00", the `aggregation_flag` can be presented.

Table 14 — Values for fragmentation indicator

Value	Description
"00"	Payload contains one or more complete data units.
"01"	Payload contains the first fragment of data unit.
"10"	Payload contains a fragment of data unit that is neither the first nor the last part.
"11"	Payload contains the last fragment of data unit.

The following flags are used to indicate the presence of various information carried in the MMTP payload. Multiple bits can be set simultaneously.

`aggregation_flag (A: 1 bit)` – when set to "1", it indicates that more than 1 data unit is present in the payload, i.e. multiple data units are aggregated.

`fragment_counter` (`frag_count`: 8 bits) – this field specifies the number of payload containing fragments of the same data unit succeeding this MMTP payload. This field shall be "0" if `aggregation_flag` is set to "1".

`MPU_sequence_number (32 bits)` – the sequence number of the MPU to which this MPU fragment belongs.

`DU_length (16 bits)` – this field indicates the length of the data following this field. When `aggregation_flag` is set to "0", this field shall not be present. When `aggregation_flag` is set to "1", this field shall appear as many times as the number of the data units aggregated in the payload and preceding each aggregated data unit.

`DU_Header` – the header of the data unit, which depends on the FT field. A header is only defined for the MFU fragment type, with different semantics for timed and non-timed media as identified by the T flag.

`movie_fragment_sequence_number (32 bits)` – the sequence number of the movie fragment to which the media data of this MFU belongs (see ISO/IEC 14496-12:2015, 8.5.5).

`sample_number (32 bits)` – the sample number of the sample to which the media data of the MFU belongs (see ISO/IEC 14996-12:2015, 8.8.8). The sample number shall be "1" for the first sample of the movie fragment and shall be incremented by "1" for every succeeding sample in order of appearance in the "`mdat`".

`offset (32 bits)` – offset of the media data of this MFU inside the referenced sample.

`subsample_priority (priority: 8 bits)` – provides the priority of the media data carried by this MFU compared with other media data of the same MPU. The value of `subsample_priority` shall be between "0" and "255", with higher values indicating higher priority.

`dependency_counter (dep_counter: 8 bits)` – indicates the number of data units that depend on their media processing upon the media data in this MFU.

`Item_ID (32 bits)` – the identifier of the item that is carried as part of this MFU.

For the FT types "0" and "1", no additional DU header is defined.

9.3.3 Generic file delivery mode

9.3.3.1 General

MMTP also supports the transport of generic files and Assets and uses payload type "`0x01`" as defined in Table 9. An Asset consists of one or more files that are logically grouped and share some commonality for an application, e.g. segments of a dynamic adaptive streaming over HTTP (DASH) Representation, a sequence of MPUs, etc.

In the generic file delivery (GFD) mode, an Asset is transported by using MMTP's GFD payload type.

Each file delivered using the GFD mode requires association of transport delivery information. This includes, but is not limited to, information such as the transfer length.

Each file delivered using the GFD mode may also have associated content-specific parameters such as name, identification, and location of file, media type, size of the file, encoding of the file or message digest of the file. In alignment with HTTP/1.1 protocol as defined in IETF RFC 2616, each file within one generic Asset may have assigned any meta-information about the entity body, i.e. the delivered file. The details are also defined in 9.3.3.2.

9.3.3.2 GFD information

9.3.3.2.1 General

In the GFD mode, each file gets assigned the following parameters.

— `packet_id`: the asset to which each object belongs to. Objects that belong to the same asset are considered as logically connected, e.g. all DASH segments of a Representation and also across Representations that extend over multiple DASH Periods and which carry pieces of the same content.

— `Transport Object Identifier (TOI)`: Each object is associated with a unique identifier within the scope of the `packet_id`.

— `CodePoint`: each object is associated with a CodePoint. A CodePoint associates a specific object and object transport properties. Packets with the same TOI shall have the same CodePoint value. For more details, see Table 16.

NOTE See Annex F for DASH segments over MMTP.

9.3.3.2.2 GFD table

The GFD table provides a list of CodePoints as defined in 9.3.3.2.3. Each CodePoint gets dynamically assigned a CodePoint value. Table 15 shows the structure and semantics of the GFD table.

Table 15 — GFD table

Element or attribute name	Use	Description
GFDTable		the element carries a GFDTable
CodePoint	1...N	defines all CodePoints in the MMTP session
Legend: For attributes: M, mandatory; O, Optional; OD, optional with default value; CM, conditionally mandatory. For elements: <minOccurs>...<maxOccurs> (N=unbounded). Elements are bold; attributes are non-bold and preceded with an @.		

9.3.3.2.3 CodePoints

A CodePoint value can be used to obtain the following information:

— the maximum transfer length of any object delivered with this CodePoint signalling.

In addition, a CodePoint may include the following information:

— the actual transfer length of the objects;

— any information that may be present in the `entity-header` as defined in IETF RFC 2616, 7.1;

— a `Content-Location-Template` as defined in 9.3.3.2.4 using the TOI and `packet_id` parameter, if present. The TOI and `packet_id` may be used to generate the `Content-Location` for each TOI and `packet_id`. If such a template is present, the processing

in 9.3.3.2.4 shall be used to generate the `Content-Location` and the value of the URI shall be treated as the `Content-Location` field in the `entity-header`;

— specific information on the content, for example, how the content is packaged, etc.

Within one session, at most "256" CodePoints may be defined. The definition of CodePoints is dynamically set-up in the MMTP session description.

The CodePoint semantics are described in Table 16.

Table 16 — CodePoint semantics

Element or attribute name	Use	Description
`CodePoint`		Defines the CodePoints in a MMTP session.
`@value`	M	Defines the value of the CodePoint in the MMTP session as provided in the CodePoint value of the MMTP packet header containing the GFD payload. The value shall be between "1" and "255". The value "0" is reserved.
`@fileDeliveryMode`	**M**	Specifies the file delivery mode according to 9.3.3.
`@maximumTransferLength`	M	Specifies the maximum transfer length in bytes of any object delivered with this CodePoint in this MMTP session.
`@constantTransferLength`	OD default: "false"	Specifies if all objects delivered by this CodePoint have constant transfer length. If this attribute is set to TRUE, all objects shall have transfer length as specified in the @maximumTransferLength attribute.
`@contentLocationTemplate`	O	Specifies a template to generate the Content-Location of the entity header.
`EntityHeader`	0 ... 1	Specifies a full entity header in the format as defined in IETF RFC 2616, section 7.1. The entity header applies for all objects that are delivered with the value of this CodePoint.
Legend: For attributes: M, mandatory; O, optional; OD, optional with default value; CM, conditionally mandatory. For elements: <minOccurs>...<maxOccurs> (N=unbounded). Elements are bold; attributes are non-bold and preceded with an @.		

9.3.3.2.4 Content-Location template

A CodePoint may include a `@contentLocationTemplate` attribute. The value of `@contentLocationTemplate` attribute may contain one or more of the identifiers listed in Table 17.

In each URL, the identifiers from Table 17 shall be replaced by the substitution parameter defined in Table 17. Identifier matching is case-sensitive. If the URL contains unescaped $ symbols, which do not enclose a valid identifier, then the result of URL formation is undefined. The format of the identifier is also specified in Table 17.

Each identifier may be suffixed, within the enclosing "$" characters following this prototype:

```
%0[width]d
```

The `width` parameter is an unsigned integer that provides the minimum number of characters to be printed. If the value to be printed is shorter than this number, the result shall be padded with zeros. The value is not truncated even if the result is larger.

The `@contentLocationTemplate` shall be authored such that the application of the substitution process results in valid URIs.

Strings outside identifiers shall only contain characters that are permitted within URLs according to IETF RFC 3986.

Table 17 — Identifiers for URL templates

$<Identifier>$	Substitution parameter	Format
$$	Is an escape sequence, i.e. "$$" is replaced with a single "$".	Not applicable.
$PacketID$	This identifier is substituted with the value of the `packet_id` of the associated MMT flow.	The format tag may be present. If no format tag is present, a default format tag with `width = 1` shall be used.
TOI	This identifier is substituted with the `Object Identifier` of the corresponding MMTP packet containing the GFDpayload.	The format tag may be present. If no format tag is present, a default format tag with `width = 1` shall be used.

9.3.3.3 File metadata

9.3.3.3.1 General

Files can be transported using the GFD mode of the MMT protocol. Furthermore, the GFD mode can also be used to transport entities where an entity is defined according to IETF RFC 2616, section 7. An entity consists of meta-information in the form of entity-header fields and content in the form of an entity-body (the file), as described in IETF RFC 2616, section 7.

This enables that files may get assigned information by in-band delivery in a dynamic fashion. For example, it enables the association of a Content-Location, the Content-Size, etc.

The file delivery mode shall be signalled in the CodePoint. The value is also specified in Table 18.

Table 18 — File delivery modes for GFD

Value	Description	Definition
1	The transport object is a file.	in 9.3.3.2
2	The delivered object is an entity consisting of an entity-header and the file.	in 9.3.3.3

9.3.3.3.2 Regular file

In case of the regular file, the object represents a file.

If the CodePoint defined in the GFD table contains `entity-header` fields or `entity-header` fields can be generated, then all of these `entity-header` fields shall apply to the delivered file.

9.3.3.3.3 Regular entity

In case of the regular entity, the object represents an entity as defined in IETF RFC 2616, section 7. An entity consists of `entity-header` fields and an entity-body.

If the CodePoint defined in the GFD table contains `entity-header` fields or `entity-header` fields can be generated, then all of these `entity-header` fields apply to the delivered file. If the `entity-header` field is present in both locations, then the `entity-header` field in the `entity-header` delivered with the object overwrites the one in the CodePoint.

9.3.3.4 MMTP payload header for GFD mode

The GFD mode of MMTP delivers regular files. When delivering regular files, the object represents a file.

If the CodePoint defined in the MMTP session description contains `entity-header` fields or `entity-header` fields can be generated, then all of these `entity-header` fields shall apply to the delivered file.

The payload packets sent using MMTP shall include a GFD payload header and a GFD payload as shown in Figure 14.

In some special cases, a MMT sending entity may need to produce packets that do not contain any payload. This may be required, for example, to signal the end of a session.

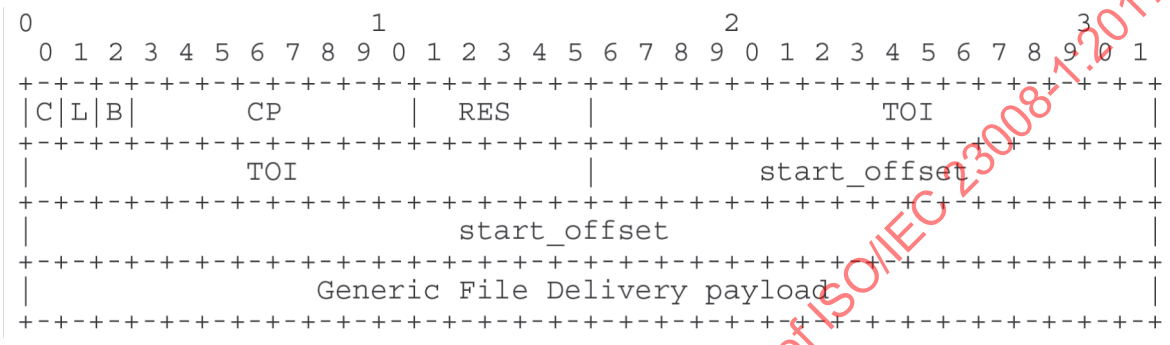


Figure 14 — MMTP payload header for GFD mode

As shown in Figure 14, the GFD payload header has a variable size. Bits designated as "padding" or "reserved" (r) must be set to 0 by the MMT sending entity and ignored by receivers. Unless otherwise noted, numeric constants in this document are in decimal form.

9.3.3.5 Semantics

`C (1 bit)` – indicates that this is the last packet for this session.

`L (1 bit)` – indicates that this is the last delivered packet for this object.

`B (1 bit)` – indicates that this packet contains the last byte of the object.

`CodePoint (CP: 8 bits)` – an opaque identifier that is passed to the packet payload decoder to convey information on the packet payload. The mapping between the CodePoint and the actual codec is defined on a per session basis and communicated out-of-band as part of the session description information.

`RES (5 bits)` – a reserved field that should be set to "0".

`Transport Object Identifier (TOI: 32 bits)` – the object identifier should be set to a unique identifier of the generic object that is being delivered. The mapping between the object identifier and the object information (such as URL and MIME type) may be done explicitly or implicitly. For example, a sequence of DASH segments may use the segment index as the object identifier and a numerical representation identifier as the `packet_id`. This mapping may also be performed using a signalling message.

`start_offset (48 bits)` – the location of the current payload data in the object.

9.3.4 Signalling message mode

9.3.4.1 General

The signalling message mode of MMTP is defined for the delivery of signalling messages. Signalling messages may be encoded in one of different formats, such as binary format or XML format. It is therefore important to enable quick access and filtering of signalling messages at the transport layer and thus, to avoid parsing the signalling message itself for filtering purposes.

Signalling messages may also be large in size, exceeding the MTU size. Other signalling messages may be much smaller than the MTU. The signalling message payload format provides fragmentation and aggregation functionality to support efficient packetization.

9.3.4.2 MMTP payload header for signalling message mode

Figure 15 depicts the signalling message payload format header.

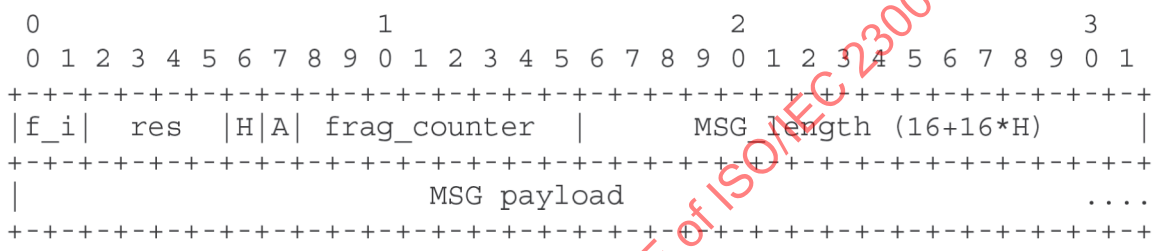


Figure 15 — MMTP payload header for signalling message mode

9.3.4.3 Semantics

The semantic of each field are as follows.

`Fragmentation Indicator (f_i: 2 bits)` – contains information about fragmentation of a signalling message in the MMTP payload. The valid values of this field are shown in Table 19.

Table 19 — Value of fragmentation indicator

Value	Description
00	Payload contains one or more complete signalling messages.
01	Payload contains the first fragment of a signalling message.
10	Payload contains a fragment of a signalling message that is neither the first nor the last fragment.
11	Payload contains the last fragment of a signalling message.

`aggregation_flag (A: 1 bit)` – when set to "1" indicates that more than 1 signalling message is present in the payload, i.e. multiple signalling messages are aggregated.

`fragmentation counter (frag_count: 8 bits)` – this field specifies the number of payload containing fragments of the same signalling message following the current fragment. This field shall be "0" if `aggregation_flag` is set to "1".

`RES (4 bits)` – this field contains bits that are reserved for future use and shall be set to "0".

`H (1 bit)` – this flag indicates if an additional 16 bit is used to indicate the signalling message length.

`MSG_length (16+16*H bits)` – this field indicates the length of the signalling message following this field. When `aggregation_flag` is set to "0", this field shall not be present. When `aggregation_flag` is set to "1", this field shall appear as many times as the number of the signalling messages aggregated in the payload and preceding each aggregated signalling message.

9.4 MMTP operation

9.4.1 General

In this subclause, the behaviour of an MMT receiving entity and of an MMT sending entity when operating the MMTP protocol using different payload types is described.

An MMTP session consists of one MMTP transport flow. An MMTP transport flow is defined as all packet flows that are delivered to the same destination and which may originate from multiple MMT sending entities. In the case of IP, destination is the IP address and port number.

A single Package may be delivered over one or multiple MMTP transport flows.

A single MMTP transport flow may deliver data from multiple Packages.

An MMTP transport flow may carry multiple Assets. Each Asset is associated with a unique `packet_id` within the scope of the MMTP session. MMTP provides a streaming-optimized mode (the MPU mode) and a file download mode (the GFD mode).

The Asset is delivered as a set of related objects denoted as an object flow. The object may either be an MPU, file or signalling message.

Each object flow shall either be carried in MPU mode or GFD mode; however, the delivery of one Package may be performed using a mix of the two modes, i.e. some Assets may be delivered using the MPU mode and others using the GFD mode.

The MMTP packet sub-flow is the subset of the packets of an MMTP packet flow that share the same `packet_id`. The object flow is transported as an MMTP packet sub-flow.

The MPU mode supports the packetized streaming of an MPU. The GFD mode supports flexible file delivery of any type of file or sequence of files.

MMTP is suitable for unicast, as well as multicast media distribution. To ensure scalability in multicast/broadcast environments, MMTP relies mainly on FEC instead of retransmissions for coping with packet error.

Before joining the MMTP session, the MMT receiving entity should obtain sufficient information to enable reception of the delivered data. This minimum required information is specified in 9.2.4.

MMTP requires the MMT receiving entity to be able to uniquely identify and de-multiplex MMTP packets that belong to a specific object flow. In addition, MMT receiving entities are required to be able to identify packets carrying signalling messages and others carrying AL-FEC repair packets by interpreting the type field of the MMTP packet header.

The MMT receiving entity shall be able to simultaneously receive, de-multiplex, and reconstruct the data delivered by MMTP packets of different types and from different object flows.

A single MMTP packet shall carry exactly one MMTP payload.

9.4.2 Delivering MPUs

9.4.2.1 MMT sending entity operation

9.4.2.1.1 Timed media data

The MPU mode is used to transport MPUs sent by a sending entity to a receiving entity.

The packetization of an MPU that contains timed media may be performed in a MPU format aware mode or MPU format agnostic mode. In the media format agnostic mode, the MPU is packetized into data units of equal size (except for the last data unit, of which the size may differ) or predefined size according to the size of MTU of the underlying delivery network by using GFD mode as specified in 9.3.3. It means

that the packetization of the MPU format agnostic mode only considers the size of data to be carried in the packet. The `type` field of the MMTP packet header specified in 9.3.2 is set to "`0x00`" to indicate that the packetization is format agnostic mode.

In the format agnostic mode, the packetization procedure takes into account the boundaries of different types of data in MPU to generate packets by using the MPU mode as specified in 9.3.2. The resulting packets shall carry delivery data units of either MPU metadata, movie fragment metadata, or MFU. The resulting packets shall not carry more than two different types of delivery data units. The delivery data unit of MPU metadata consists of the "`ftyp`" box, the "`mmpu`" box, the "`moov`" box, and any other boxes that are applied to the whole MPU. The FT field of the MMTP payload carrying a delivery data unit of MPU metadata is set to "`0x00`". The delivery data unit of movie fragment metadata consists of the "`moof`" box and the "`mdat`" box header (excluding any media data). The FT field of the MMTP payload carrying a delivery data unit of movie fragment metadata is set to "`0x01`". The media data, MFUs in the "`mdat`" box of the MPU, is then split into multiple delivery data units of MFU in a format aware way. This may, for example, be performed with the help of the MMT hint track. The FT field of the MMTP payload carrying a delivery data unit of MFU is set to "`0x02`".

Each MFU is prepended with an MFU header, which has the syntax and semantics as defined in 8.3. It is followed by the media data of the MFU.

This procedure is described in Figure 16.

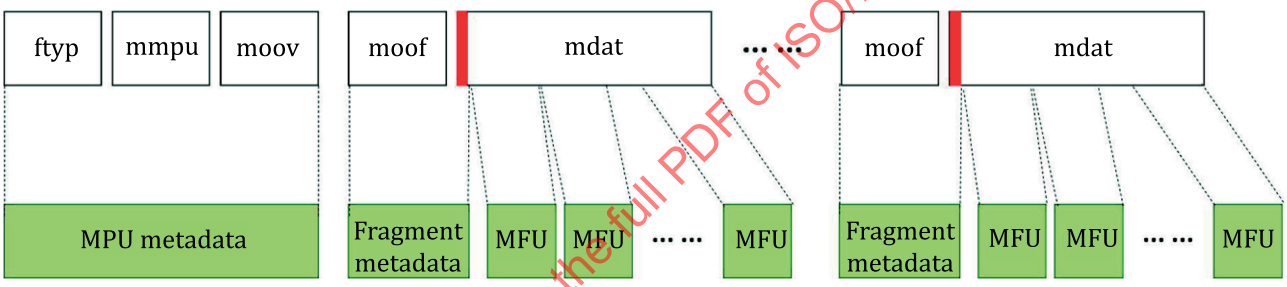


Figure 16 — Payload generation for timed media

9.4.2.1.2 Non-timed media data

The packetization of non-timed media data may also be performed in two different modes. In the MPU format agnostic mode, the MPU is packetized into delivery data units of equal size (except for the last data unit, of which the size may differ) or predefined size according to the size of the MTU of the underlying delivery network by using the GFD mode as specified in 9.3.3. The `type` field of the MMTP packet header specified in 9.2.2 is set to "`0x00`" to indicate that the packetization is format agnostic mode.

In the format agnostic mode, the MPU shall be packetized into the packet containing delivery data units of either MPU metadata or MFU by using MPU mode as defined in 9.3.2. The delivery data unit of MPU metadata contains the "`ftyp`" box, the "`moov`" box, and the "`meta`" box and any other boxes that are applied to the whole MPU. The FT field of the MMTP payload carrying a delivery data unit of MPU metadata is set to "`0x01`". Each delivery data unit of MFU contains a single item of the non-timed media. The `FT` field of the MMTP payload carrying a delivery data unit of MFU is set to "`0x02`".

Each item of the non-timed data is then used to build an MFU. Each MFU consists of an MFU header and the item's data. The MFU header is defined in 8.3. This procedure is described in Figure 17.

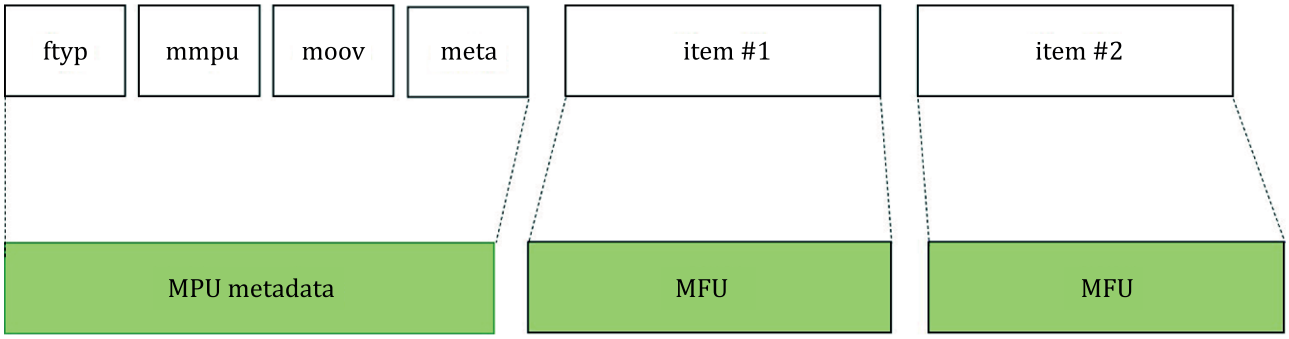


Figure 17 — Payload generation for non-timed media

9.4.2.2 MMT receiving entity operation

The depacketization procedure is performed at the MMT receiving entity to rebuild the transmitted MPU. The depacketization procedure may operate in one of the following modes, depending on the application needs:

— MPU mode: in the MPU mode, the depacketizer reconstructs the full MPU before forwarding it to the application. This mode is appropriate for non-time critical delivery, i.e. the MPU's presentation time as indicated by the presentation information document is sufficiently behind its delivery time.

— Movie Fragment mode: in the Fragment mode, the depacketizer reconstructs a complete fragment including the fragment metadata and the "`mdat`" box with media samples before forwarding it to the application. This mode does not apply to non-timed media. This mode is suitable for delay-sensitive applications where the delivery time budget is limited but is large enough to recover a complete fragment.

— MFU mode: in the media unit mode, the depacketizer extracts and forwards media units as fast as possible to the application. This mode is applicable for very low delay media applications. In this mode, the recovery of the MPU is not required. The processing of the fragment media data is not required but may be performed to resynchronize. This mode tolerates out of order delivery of the fragment metadata MFUs, which may be generated after the media units are generated. This mode applies to both timed and non-timed media.

Using the MFU sequence numbers, it is relatively easy for the receiver to detect missing packets and apply any error correction procedures such as ARQ to recover the missing packets. The payload type may be used by the MMT sending entity to determine the importance of the payload for the application and to apply appropriate error resilience measures.

9.4.3 Delivering generic objects

9.4.3.1 Basic principles for GFD and applications

The files delivered using the GFD mode may have to be provided to an application, for example, presentation information documents or a Media Presentation Description as defined in ISO/IEC 23009-1 may refer to the files delivered using MMTP as GFD objects.

The file shall be referenced through the URI (in accordance with Annex G) provided or derived from `Content-Location`, either provided in-band as part of an entity header or as part of a GFDT.

In certain cases, the files have an availability start time in the application. In this case, the MMTP session shall deliver the files such that the last packet of the object is delivered such that it is available latest at the receiver at the availability start time as announced in the application.

Applications delivered through the GFD mode may impose additional and stricter requirements on the sending of the files within a MMTP session.

9.4.3.2 MMT sending entity operation

9.4.3.2.1 General

If more than one object is to be delivered using the GFD mode, then the MMT sending entity shall use different TOI fields. In this case, each object shall be identified by a unique TOI scoped by the `packet_id` and the MMT sending entity shall use that TOI value for all packets pertaining to the same object.

The mapping between TOIs and files carried in a session is either provided in-band or in a GFDT.

The GFD payload header as defined in 9.3.3.4 shall be used. The GFD payload header contains a CodePoint field that shall be used to communicate to a MMT receiving entity the settings for information that is established for the current MMTP session and may even vary during a MMTP session. The mapping between settings and CodePoint values is communicated in the GFDT as described in 9.3.3.2.2.

Let T > 0 be the Transfer-Length of any object in bytes. The data carried in the payload of a packet consists of a consecutive portion of the object.

Then, for any arbitrary X and any arbitrary Y > 0 as long as X + Y is at most T, an MMTP packet may be generated. In this case, the following shall hold:

a) The data carried in the payload of a packet shall consist of a consecutive portion of the object starting from the beginning of byte X through the beginning of byte X + Y.

b) The `start_offset` field in the GFD payload header shall be set to X and the payload data shall be added into the packet to send.

c) If X + Y is identical to T,

   — the payload header flag B shall be set to "1"

   else

   — the payload header flag B shall be set to "0".

The following procedure is recommended for a MMT sending entity to deliver an object to generate packets containing `start_offset` and corresponding payload data.

a) Set the byte offset counter X to "0".

b) For the next packets to be delivered, set the length in bytes of a payload to a value Y, which is

   1) reasonable for a packet payload (e.g. ensure that the total packet size does not exceed the MTU),

   2) such that the sum of X and Y is at most T, and

   3) such that it is suitable for the payload data included in the packet.

c) Generate a packet according to the rules 1) to 3) above.

d) If X + Y is equal to T,

   — set the payload header flag B to "1"

   else

   — set the payload header flag B to "0"

   — increment X = X + Y

   — go to 2.

The order of packet delivery is arbitrary, but in the absence of other constraints, delivery with increasing `start_offset` number is recommended.

NOTE The transfer length may be unknown prior to sending earlier pieces of the data. In this case, T can be determined later. However, this does not affect the sending process above.

Additional packets may be sent following the rules in a) to c) from above. In this case, the B flag shall only be set for the payload that contains the last portion of the object.

9.4.3.2.2 GFD payload

The bytes of the object are referenced such that byte 0 is the beginning of the object and byte T-1 is the last byte of the object with T as the transfer length (in bytes) of the object.

The data carried in the payload of an MMTP packet shall consist of a consecutive portion of the object starting from the beginning of byte X and ending at the beginning of byte X + Y where

— X is the value of `start_offset` field in the GFD payload header, and

— Y is the length of the payload in bytes.

Note that Y is not carried in the packet, but framing shall be provided by the underlying transport protocol.

9.4.3.2.3 GFD table delivery

When the GFD mode is used, the GFD table (GFDT) shall be provided. A file that is delivered using the GFD mode, but not described in the GFD table is not considered a "file" belonging to the MMTP session. Any object received with an unmapped CodePoint should be ignored by the MMT receiving entity.

The delivery of the GFD table in the MMT signalling message is defined in 10.5.4.

Other ways of delivery of the GFD table may be possible, but are outside the scope of this document.

9.4.3.3 MMT receiving entity operation

The GFDT may contain one or multiple CodePoints identified by different CodePoint values.

Upon receipt of each GFD payload, the receiver proceeds with the following steps in the order listed.

a) The MMT receiving entity shall parse the GFD payload header and verify that it is a valid header. If it is not valid, then the GFD payload shall be discarded without further processing.

b) The MMT receiving entity shall parse the CodePoint value and verify that the GFDT contains a matching CodePoint. If it is not valid, then the GFD payload shall be discarded without further processing.

c) The MMT receiving entity should process the remainder of the payload, including interpreting the other payload header fields appropriately and using the `start_offset` and the payload data to reconstruct the corresponding object as follows.

   1) The MMT receiving entity can determine from which object a received GFD payload was generated by using the GFDT and by the TOI carried in the payload header.

   2) Upon receipt of the first GFD payload for an object, the MMT receiving entity uses the Maximum Transfer Length received as part of the GFDT to determine the maximum length T′ of the object.

   3) The MMT receiving entity allocates space for the T′ bytes that the object may require.

   4) The MMT receiving entity also computes the length of the payload, Y, by subtracting the payload header length from the total length of the received payload.

5) The MMT receiving entity allocates a Boolean array RECEIVED[0..T'-1] with all T entries initialized to false to track received object symbols. The MMT receiving entity keeps receiving payloads for the object block as long as there is at least one entry in RECEIVED still set to false or until the application decides to give up on this object.

6) For each received GFD payload for the object (including the first payload), the steps to be taken to help recover the object are as follows.

   i) Let X be the value of the `start_offset` field in the GFD payload header of the MMTP packet and let Y be the length of the payload, computed by subtracting the MMTP packet and GFD payload header lengths from the total length of the received packet.

   ii) The MMTP receiving entity copies the data into the appropriate place within the space reserved for the object and sets RECEIVED[X ... X+Y-1] = true.

   iii) If all T entries of RECEIVED are true, then the receiver has recovered the entire object.

7) Once the MMT receiving entity receives a GFD payload with the B flag set to "1", it can determine the transfer length T of the object as X+Y of the corresponding GFD payload and adjust the boolean array RECEIVED[0..T'-1] to RECEIVED[0..T-1].

9.4.4 Header compression for MMTP packet

9.4.4.1 General

Header compression provides the method to reduce the size of the header; techniques such as the Robust Header Compression (RoHC defined in IETF RFC 3095) may be used. While such technique can severely reduce the size of headers, it has two major drawbacks.

— It relies on complex computations/coding techniques (described in protocol stacks profiles) that are quite heavy on the receiver's side.

— It is not a transparent technique and headers need to be entirely decoded, even when it is only to do some filtering and most of the decoded packets are rejected.

It provides two types of headers as follows.

— Full-size headers are sent regularly and may be used as a reference for reduced-size headers.

— Reduced-size headers contain differential information with regard to the last full-size header received that is marked as a reference header.

Therefore, by sending only differential information instead of full information, bits savings can be achieved. Additionally, a link to the reference header packet is added in all compressed packets to make sure that the last full header (reference) packets received is indeed the one that shall be used as a reference. Such robustness mechanism is needed as reference packets may actually be lost.

The header compression method applies on the MMTP packet header. For this, a bit (B) is introduced at the beginning of the original header (or at least in the initial fixed part of the header that is common to the full-size header and reduced-size header) to simply inform whether or not the present header is full-size or reduced size.

Then, many fields present in the full-size headers are either removed or replaced by much smaller fields that contain enough information for the receiver to reconstruct the original full-size header field.

In order to let the receiver know that a full-size header will be used as a reference by a further reduced-size header, an extra bit (I) is also added at the beginning of the full-size header in order to mark headers that will be used as a reference later.

Since packet losses may also happen in the network, it is important that even when reduced-size headers are used, it is still possible to detect and identify packet losses. Thus, a smaller sequence number is

introduced for MMTP packets and mandates that the full-size header is used in place of the reduced-size header whenever the reduced sequence number is about to wrap around its initial value.

Similarly, although it is costly in number of bits, the timestamp information associated to packets must be preserved. For this, only the last 19 bits of the full-size 32 bits NTP timestamp are used. This allows keeping the same timestamp precision with a wrap around duration of 8 s. Consequently, a full-size header must be present at least every 8 s. Header compression of the MMTP packet is defined as shown in Figure 18.

9.4.4.2 Syntax

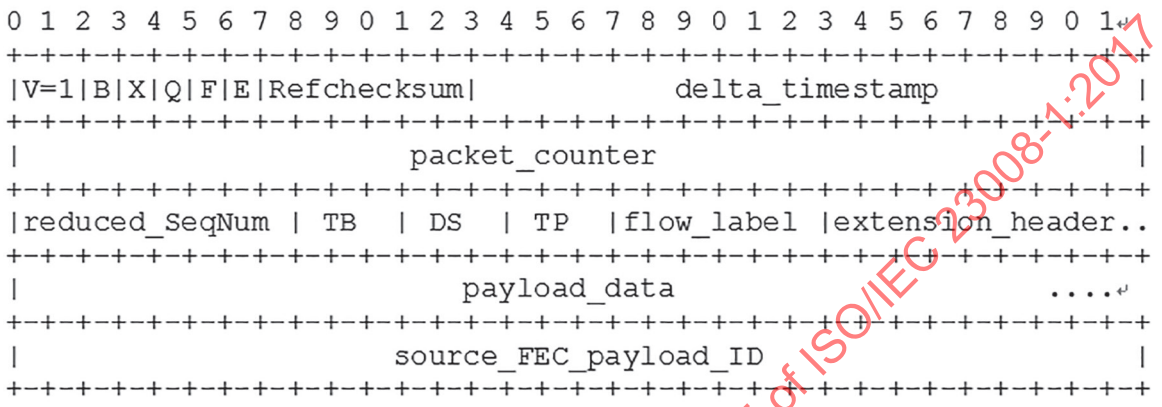


Figure 18 — MMTP with reduced header (B = 1)

9.4.4.3 Semantics

The full-size MMTP packet header introduces new fields with their own semantics.

`Compression_flag (B: 1 bit)` – this field is added at the beginning of the header in order to indicate whether or not header compression is used. When set to "0", the full-size header is used; when set to "1", the reduced-size header is used.

`Indicator_flag (I: 1 bit)` – this field is added to tell the receiver whether or not the current full header will later be used as a reference. This field shall be set to "1" when the full header will be used as a reference. This allows receivers to discover that this header information shall be stored as it will be later used as a reference by packets with reduced headers.

The reduced-size MMTP packet header introduces new additional fields with their own semantics.

`Reference_checksum (RefChecksum: 6 bits)` – contains a 6 bits checksum value that allows the MMT receiving entity to verify that the last reference MMTP packet received is indeed the one that shall be used for decompressing the current MMTP packet header. The checksum value shall be calculated based on the timestamp value and packet sequence number (total 64 bits) value of the MMTP packet with the full header to be used as reference. BSD checksum (8) algorithm is used to compute the checksum but `Reference_checksum` field is set to last 6 bits of the result which is 8 bits.

`delta_timestamp (19 bits)` – contains the difference between the timestamp field of the reference full-size header and the value that would be in the current packet timestamp field if the full-size header was used. This difference is coded in a way similar to the 19 least significant bits of an NTP timestamp. If the difference between these two timestamps is larger than 8 s (and therefore goes beyond the maximum duration that can be coded on 19 bits), then a packet with a full header shall be sent in order to provide a new timestamp reference value for further packets with a reduced-size header.

`reduced_sequence_number (reduced_SeqNum: 8 bits)` – contains the 8 least significant bits of the `packet_sequence_number` field that would be in the header if a full-size header were

used. Since this new field is coded on 8 bits, the reduced decoder shall take into account the number of times this field wrapped around 0 to compute the original `packet_sequence_number` value.

The reduced-size MMTP packet header also suppresses the fields that are present in the full-size header.

— The `version` field is suppressed as reduced-size headers shall have the same version as their referenced header.

— The `I` field is suppressed, as only full-size headers shall be used as a reference.

— The `RAP_flag` is removed as full-size headers shall be sent whenever the payload contains a random access point.

9.4.4.4 MTP packet header compression rules and normative aspects

A packet with a full MMTP header shall at least be sent when one of the following conditions is met:

a) the difference between the timestamps of the current packet and the reference packet is larger than 8 s (and therefore cannot be coded on the 19 bits long `delta_timestamp` field);

b) `packet_id` is not in the range of 0 to 255;

c) the packet contains a random access point (RAP).

Packet header compression is optional on MMTP sending entities and MMTP receiving entities. Consequently, MMT receivers shall ignore packets with the B field set to "1" if they do not support MMTP header compression.

MMTP receiving entities shall not try to decode a reduced-size header for which the full reference header has not been received, whether because the receiver has just joined the stream or the packet with a full reference header has been lost. MMTP receiving entities shall always wait for packets with a reference header (`I` field set to "1") before they can start or restart (in case of packet loss of reference header) the header decoding.

10 Signalling

10.1 General

This clause specifies the signalling function of MMT. It defines a set of message formats to be used to communicate signalling information necessary for the delivery and consumption of Packages. The delivery of signalling messages using the MMT protocol is also specified in this document. This document specifies the message format for carrying signalling tables, descriptors or the delivery-related information. A signalling table has a set of elements and attributes for specific signalling information. A signalling table may also include descriptors that carry more detailed information.

The following eight types of signalling messages are defined for the consumption of Packages.

— Package access (PA) message: This message type contains a PA table that has information on all signalling tables required for Package access, including the MMT Package (MP) table and MPI table (see 10.3.2).

— Media presentation information (MPI) message: This message type contains an MPI table encapsulating a whole or a subset of a presentation information document. It may also include an MP table corresponding to the MPI table for fast Package consumption (see 10.3.3).

— MMT package table (MPT) message: This message type contains an MP table that provides all or a part of information required for a single Package consumption (see 10.3.4).

— Clock relation information (CRI) message: This message type contains a CRI table that provides clock-related information used for the mapping between an NTP timestamp and an MPEG-2 system time clock (see 10.3.5).

— Device capability information (DCI) message: This message type contains a DCI table that provides the required device capability information for Package consumption (see 10.3.6).

— Security software request (SSWR) message: This is used to request security software for consuming a Package or Asset by the MMT receiving entity. It can also include a PA table or an MP table (see 10.3.7).

— License signalling (LS) message: This message carries the license information targeted to a specific MMT receiving entity or group of receivers.

— License revocation (LR) message: This message contains the information to allow the DRM system provided to signal that it has revoked the license for a user or group of users.

The following nine signalling messages are defined that relate to the delivery of the Package.

— Hypothetical receiver buffer model (HRBM) message: This message type is used to provide information to configure an HRBM operation (see 10.4.2); the HRBM is specified in Clause 11.

— Mesurement configuration (MC) message: This message type is used for providing information to configure measurement of delivery quality (see 10.4.3).

— Automatic repeat-request (ARQ) configuration (AC) message: It provides the information required for ARQ configuration (see 10.4.4).

— Automatic repeat-request (ARQ) feedback (AF) message: It provides the information required for ARQ feedback (see 10.4.5).

— Reception quality feedback (RQF) message: This message type is used for measurement reporting by an MMT receiving entity (see 10.4.6).

— NAM feedback (MANF) message: This message type is used for providing information of the NAM parameter by an MMT receiving entity (see 10.4.7).

— Low delay consumption (LDC) message: This message provides information required to decode and present media data by the MMT receiving entity before it receives metadata such as movie fragment headers. (see 10.4.8).

— HRBM removal (HRBMR) message: This message provides information on the management of MMT de-capsulation buffer depending on the operation mode of the client specified in Clause 11. (see 10.4.9).

— Asset delivery characteristic (ADC) message: This message type is used for providing information to configure the network delivery resource (see 10.4.10).

10.2 Signalling message format

10.2.1 General

MMT signalling messages use a general format consisting of three common fields, one specific field (for each signalling message type), and a message payload. A message payload carries signalling information.

The syntax and semantics of a general signalling message format are given in 10.2.2 and 10.2.3, respectively.

XML Syntax for signalling messages is provided in Annex B (see B.1).

10.2.2 Syntax

The syntax of the general format of MMT signalling messages is given in Table 20.

Table 20 — Syntax of the general format of MMT signalling messages

Syntax	Value	No. of bits	Mnemonic
signalling_message () {			
message_id		16	uimsbf
version		8	uimsbf
if(message_id != PA_message && message_id != MPI_message) {			
length		16	uimsbf
} else {			
length		32	uimsbf
}			
extension			
message_payload {			
}			
}			

10.2.3 Semantics

message_id – this field indicates the identifier of the signalling message. Valid message identifier values are listed in Table 61.

version – this field indicates the version of the signalling message. Both the MMT sending entity and MMT receiving entity can verify whether a received message has a new version of not.

length – this field indicates the length of the signalling message. This field for all signalling messages except PA messages and MPI message is 2 bytes long. The length of PA messages and MPI messages is 4 bytes long because it is expected that occasionally an MPI table whose length cannot be expressed by a 2 bytes length fields. Also, note that a PA message includes at least one MPI table.

extension – this field provides extension information for signalling messages that require extension. The content and length of this field are specified for these signalling messages.

message_payload – the payload of the signalling message. The format of this field can be identified by the value of the message_id field.

10.3 Signalling messages for Package consumption

10.3.1 General

This subclause specifies signalling messages that are used to exchange signalling information related to Package consumption. As mentioned above, a signalling message may contain signalling tables. Each signalling table carries information on a specific aspect of the Package, such as a Package structure, presentation information document or clock. Signalling messages can aggregate multiple tables for efficient signalling information exchange. For example, an MPI message delivers an MPI table only or an MPI table and a corresponding MP table. The relationship between a message and a table is shown in Figure 19.

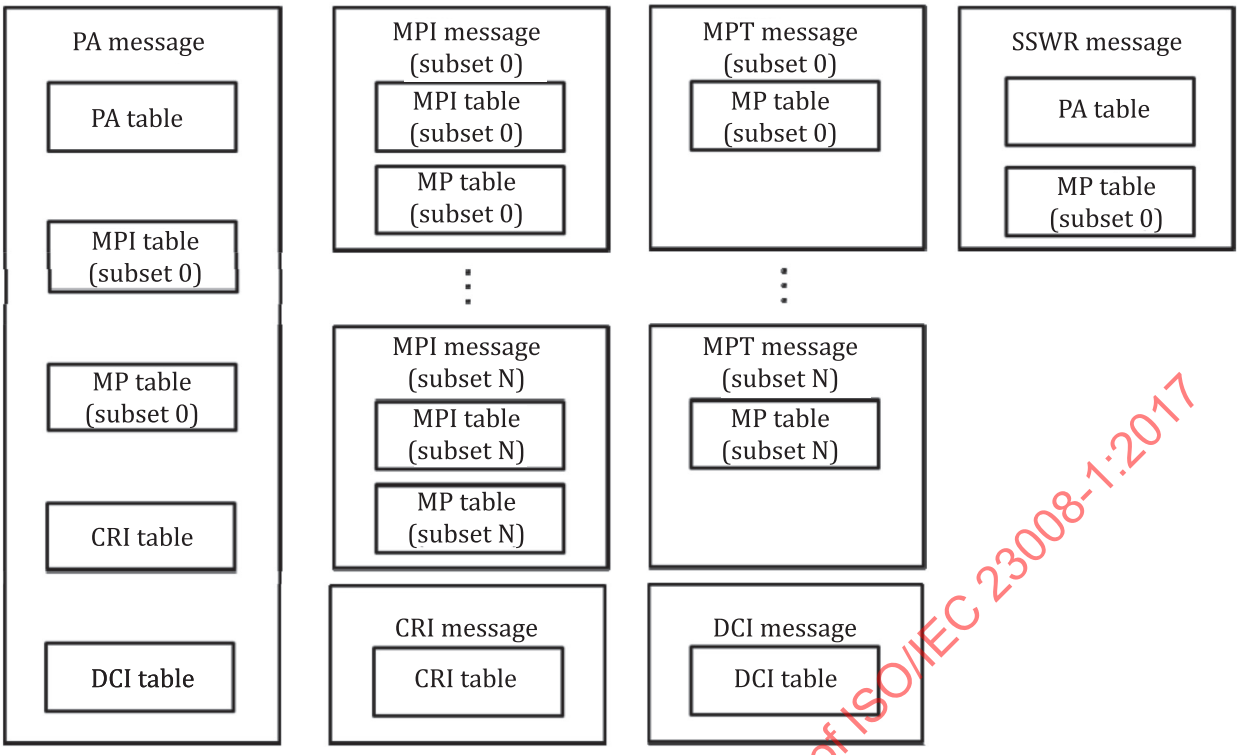


Figure 19 — Structure of the signalling messages and tables for Package consumption

A PA message shall carry a PA table, an MP table (either complete or subset 0), an MPI table (either complete or subset 0) and a DCI table. A PA message may carry a CRI table. An MPI message shall carry an MPI table and may carry an MP table. An MPT message shall carry an MP table. A CRI message shall carry a CRI table. A DCI message shall carry a DCI table. An MPI message and an MPT message can carry several subsets of the complete information needed for efficient delivery and redundancy reduction.

Some signalling tables share the same structure of signalling information. For efficient exchange of those signalling information, a set of descriptors are defined in 10.5.

10.3.2 PA message

10.3.2.1 General

A PA message carries a PA table, which contains information for all other signalling tables for a Package. A PA message also carries an MPI table (either complete or subset 0) and an MP table (either complete or subset 0) for delivery of the minimum information for the processing of the Package.

An MMT receiving entity shall process a PA message before it processes any other signalling messages.

10.3.2.2 Syntax

The syntax of the PA message is defined in Table 21.

Table 21 — PA message syntax

Syntax	Value	No. of bits	Mnemonic
PA_message () {			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**32**	**uimsbf**
extension {			
number_of_tables	N1	**8**	**uimsbf**
for (i=0; i<N1; i++) {			
table_id		**8**	**uimsbf**
table_version		**8**	**uimsbf**
table_length		**16**	**uimsbf**
}			
}			
message_payload {			
for (i=0; i<N1; i++) {			
table()			
}			
}			
}			

10.3.2.3 Semantics

message_id – indicates the identifier of the PA messages.

version – indicates the version of the PA messages.

length – a 32-bit field for conveying the length of the PA message in bytes, counting from the beginning of the next field to the last byte of the PA message. The value "0" is not valid for this field.

number_of_tables – indicates the number of signalling tables included in this PA message.

table_id – indicates the table identifier of a table included in this PA message. It is a copy of the table_id field in the table included in the payload of this PA message.

table_version – indicates the version of a table included in this PA message. It is a copy of the version field in the table included in the payload of this PA message.

table_length – if the table is not an MPI table, it is a copy of the length field in the table included in the message_payload of this PA message. If the table is an MPI table, it is the length derived from the length and the extension length part. In this case, the derived length is a value that equals "the actual length" – 5.

table() – an MMT signalling table instance. The tables in the payload appear in the same order as the table_ids in the extension field. An PA table shall be an instance for table().

10.3.3 MPI message

10.3.3.1 General

An MPI signalling message delivers a whole or a subset of a presentation information document. An MPI message uses an MPI table for encapsulating presentation information documents.

When a subset of a presentation information document is carried by an MPI message, the presentation information document is partitioned into multiple MPI tables. MPI tables for different subsets of a presentation information document shall have different `table_id` values. The `table_id` values are allocated in a contiguous space in increasing order. The MPI table having the lowest `table_id` value provides the base subset among the subsets of a presentation information document and other MPI tables for the remaining subsets of a presentation information document have different `table_id` values. The maximum number of MPI tables for subsets of a PI is 15.

Each MPI message carrying a subset of a presentation information document may have a different transmission period and include the MP table associated with the presentation information document that the MPI message carries.

10.3.3.2 Syntax

The syntax of the MPI message is defined in Table 22.

Table 22 — MPI message syntax

Syntax	Value	No. of bits	Mnemonic
`MPI_message () {`			
`  message_id`		16	uimsbf
`  version`		8	uimsbf
`  length`	N1	32	uimsbf
`  extension {`			
`  reserved`	"111 1111"	7	uimsbf
`  associated_MP_table_flag`		1	bslbf
`  }`			
`  message_payload {`			
`  MPI_table()`			
`  if (associated_MP_table_flag) {`			
`  MP_table ()`			
`  }`			
`  }`			
`}`			

10.3.3.3 Semantics

`message_id` – indicates the identification of the MPI message.

`version` – indicates the version of the MPI message.

`length` – indicates the length of the MPI message in bytes, counting from the beginning of the next field to the last byte of the MPI message. The value "0" is not valid for this field.

`associated_MP_table_flag` – if this flag is set to "1", the MPI message also carries an associated MP table. Whenever an associated MP table exists, the associated MP table shall be delivered by a message together with the MPI table. Value "0" explicitly means that the previously stored MP table in the receiving entity can be continuously used with the newly delivered MPI table. The simultaneous delivery of the MPI table and MP table in a single MPI message helps an MMT receiving entity reduce the signalling acquisition time for Package consumption.

`MPI_table()` – an MPI table defined in 10.3.8.

`MP_table()` – an MP table defined in 10.3.9.

10.3.4 MPT message

10.3.4.1 General

The MPT message carries a whole or a subset of an MP table. Subsets of MP tables can be delivered by different MPT messages.

An MPT provides information for a single Package. A single presentation information document may be split into several subsets of such document. For partial delivery of a presentation information document, Assets referenced by a subset of the presentation information document may be described by a subset of an MP table. MP tables associated with different subsets shall have different `table_ids`. Sixteen (16) contiguous values from 17 are assigned to `table_id` values for MP tables. The value of `table_id` "32" (0x20) is assigned for the complete MP table.

In order to support efficient operation of signaling acquisition, a complete MPT or a subset 0 MPT is also found as part of PA messages.

10.3.4.2 Syntax

The syntax of the MPT message is defined in Table 23.

Table 23 — MPT message syntax

Syntax	Value	No. of bits	Mnemonic
`MPT_message () {`			
`  message_id`		16	uimsbf
`  version`		8	uimsbf
`  length`		16	uimsbf
`  message_payload {`			
`  MP_table ()`			
`  }`			
`}`			

10.3.4.3 Semantics

`message_id` – indicates the identifier of the MPT message.

`version` – indicates the version of the MPT message. The MMT receiving entity can check the version of the received message contained in this field.

`length` – indicates the length of the MPT message. The size of this field is 16 bits. The length of the MPT message is in bytes, counting from the beginning of the next field to the last byte of the MPT message. The value "0" is not valid for this field.

`MP_table()` – MP table defined in 10.3.9.

10.3.5 CRI message

10.3.5.1 General

This message carries clock-related information to be used for mapping between the NTP timestamps and MPEG-2 STC.

To achieve synchronization between Assets that use NTP timestamps and MPEG-2 ES that uses the MPEG-2 presentation time stamp (PTS), it is necessary to inform the relationship between the NTP timestamp and the MPEG-2 STC to an MMT receiving entity by periodically delivering values of the

NTP_timestamp_sample and the STC_sample at the same temporal points. If more than one MPEG-2 ES with different MPEG-2 STCs are used, more than one CRI messages will be used.

10.3.5.2 Syntax

The syntax of the CRI message is defined in Table 24.

Table 24 — CRI message syntax

Syntax	Value	No. of bits	Mnemonic
CRI_message () {			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
message_payload {			
CRI_table()			
}			
}			

10.3.5.3 Semantics

message_id – indicates the identifier of the CRI message.

version – indicates the version of the CRI message. An MMT receiving entity can check the version of a received message using this field.

length – indicates the length of the CRI message, counted in bytes starting from the beginning of the next field to the last byte of the CRI message. The value "0" is not valid for this field.

CRI_table()– a CRI table is defined in 10.3.10.

10.3.6 DCI message

10.3.6.1 General

The DCI message delivers a DCI table that provides required device capabilities for the Package consumption.

10.3.6.2 Syntax

The syntax of the DCI message is defined in Table 25.

Table 25 — DCI message syntax

Syntax	Value	No. of bits	Mnemonic
DCI_message () {			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
message_payload {			
DCI_table()			
}			
}			

10.3.6.3 Semantics

`message_id` – indicates the identifier of the DCI message.

`version` – indicates the version of the DCI message. An MMT receiving entity can check the version of a received message using this field.

`length` – indicates the length of the DCI message, counted in bytes starting from the beginning of the next field to the last byte of the DCI message. The value "0" is not valid for this field.

`DCI_table()` – provides the required device capabilities for the Package consumption. The content of a DCI table is defined in 10.3.11.

10.3.7 PA table

10.3.7.1 General

A PA table provides information on all other signalling tables for the consumption of a Package.

10.3.7.2 Syntax

The syntax of the PA table is defined in Table 26.

Table 26 — PA table syntax

Syntax	Value	No. of bits	Mnemonic
PA_table () {			
table_id		**8**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
information_table_info {			
number_of_tables	N1	**8**	**uimsbf**
for (i=0; i<N1; i++) {			
signalling_information_table_id		**8**	**uimsbf**
signalling_information_table_version		**8**	**uimsbf**
location {			
MMT_general_location_info()			
}			
reserved	"1111 111"	**7**	**bslbf**
alternative_location_flag		**1**	**bslbf**
if (alternative_location_flag == 1) {			
alternative_location {			
MMT_general_location_info()			
}			
}			
}			
}			
reserved	"1111 111"	**7**	**bslbf**
private_extension_flag		**1**	**bslbf**
if (private_extension_flag == 1)			
private_extension {			

Table 26 *(continued)*

Syntax	Value	No. of bits	Mnemonic
} } }			

10.3.7.3 Semantics

`table_id` – indicates the identifier of the PA table.

`version` – indicates the version of the PA table. The newer version obsoletes the information in any older version.

`length` – indicates the length of the PA table in bytes, counting from the beginning of the next field to the last byte of the PA table. The value "0" is not valid for this field.

`number_of_tables` – indicates the number of signalling tables whose information is provided in this PA table.

`signalling_information_table_id` – indicates the ID of a signalling table whose information is provided in this PA table.

`signalling_information_table_version` – indicates the version of a signalling table whose information is provided in this PA table.

`MMT_general_location_info` – provides the location of a signalling table whose information is provided in this PA table. Syntax and semantics of `MMT_general_location_info` are defined in 10.6.1.

`alternative_location_flag` – if this flag is set to "1", an alternative address from where an MMT receiving entity can get the information table is provided.

`MMT_general_location_info_alternative_location` – provides the information of an alternative address from where an MMT receiving entity can get the signalling table. Only `location_type` from "`0x07`" to "`0x0B`" shall be used in `MMT_general_location_info` for a second location.

`private_extension_flag` – if this flag is "1", the private extension is present.

`private_extension` – a syntax element group serving as a container for proprietary or application-specific extensions.

10.3.8 MPI table

10.3.8.1 General

An MPI table carries a complete or a subset of a presentation information document. In case of a subset of a presentation information document, MPI tables for each subset are delivered in separate messages.

10.3.8.2 Syntax

The syntax of the MPI table is defined in Table 27.

Table 27 — MPI table syntax

Syntax	Value	No. of bits	Mnemonic
MPI_table () {			
table_id		**8**	**uimsbf**
version		**8**	**uimsbf**
length	**N1**	**16**	**uimsbf**
reserved	**"1111"**	**4**	**bslbf**
PI_mode		**2**	**uimsbf**
reserved	**"11"**	**2**	**bslbf**
MPIT_descriptors {			
MPIT_descriptors_length	**N2**	**16**	**uimsbf**
for (i=0; i<N2; i++) {			
MPIT_descriptors_byte		**8**	**uimsbf**
}			
}			
PI_content_count	**N3**	**8**	**uimsbf**
for (i =0; i<N3; i++) {			
PI_content_type {			
PI_content_type_length	**N4**	**8**	**uimsbf**
for (j=0; j<N4; j++) {			
PI_content_type_length_byte		**8**	**uimsbf**
}			
}			
PI_content_name_length	**N5**	**8**	**uimsbf**
for (j=0; j<N5; j++) {			
PI_content_name_byte		**8**	**uimsbf**
}			
PI_content_descriptors {			
PI_content_descriptors_length	**N6**	**16**	**uimsbf**
for (i=0; i<N6; i++) {			
PI_contnent_descriptors_byte		**8**	**uimsbf**
}			
}			
PI_content_length	**N7**	**16**	**uimsbf**
for (j=0; j<N7; j++) {			
PI_content_byte		**8**	**uimsbf**
}			
}			
}			

10.3.8.3 Semantics

table_id – indicates the identifier of the MPI table. A complete presentation information document and each subset of a presentation information document shall have distinct table identifiers. The processing order of subsets of a presentation information (PI) document is specified by this information. Since the table_id values are assigned contiguously, the PI subset number can be deduced from this field, i.e. the PI subset number equals this field minus the table_id of the base MPI table. The number

0 indicates base PI and the numbers “1”~“14” indicate the subset of PI. The number “15” has a special meaning since it indicates a complete PI.

`version` – indicates the version of the MPI table. The newer version overrides the older one as soon as it is received if `table_id` indicates a complete MPI, if subset 0 MPI has the same version value as this field (when `PI_mode` is “1”), or if all MPIs with the lower-subset number have the same version value as this field (when `PI_mode` is “0”), or if processing of the MPIs are independent (when `PI_mode` is “2”). If subset 0 MPI table has a newer version, all PIs with higher subset numbers up to 14 previously stored within an MMT receiving entity are treated as outdated except for the independent mode. When the PI subset number is not 0 and `PI_mode` is “1”, the contents of the MPI table with a version different from that of subset 0 PI stored in an MMT receiving entity shall be ignored. Also, when the PI subset number is not 0 and `PI_mode` is “0”, the contents of the MPI table with a version different from that of lower-subset PIs stored in an MMT receiving entity shall be ignored. It shall be modulo-256 incremented per version change.

`length` – indicates the length of the MPI table in bytes, counting from the beginning of the next field to the last byte of the MPI table. The value “0” is not valid for this field.

`PI_mode` – indicates the mode of a PI subset processing. In “`sequential_order_processing_mode`” and with a non-zero subset number of this PI, an MMT receiving entity shall receive all PIs with lower subset numbers that have the same version as this PI before it processes this PI. For example, an MMT receiving entity cannot process subset-3 PI, if it has not received subset-2 PI with the same version. In “`order_irrelevant_processing_mode`” and with the layer number of this MMT-PI set to non-zero, an MMT receiving entity should process a PI right after it receives the PI as long as the subset 0 PI stored in an MMT receiving entity has the same version as this PI. In “`independent_processing_mode`”, versions of each subset of PIs are managed individually. Fragmented PI is adapted in this mode. The value of `PI_mode` is specified in Table 28.

Table 28 — Value of PI_mode

Value	Description
00	“sequential_order_processing_mode”
01	“order_irrelevant_processing_mode”
10	“independent_processing_mode”
11	Reserved

`MPIT_descriptors_length` – indicates the length of the MPIT descriptors syntax loop. The length is counted from the next field to the end of the MPIT descriptors syntax loop. Several descriptors that include information on the whole MPIT can be inserted in this syntax loop.

`MPIT_descriptors_byte` – a byte in the MPIT descriptors syntax loop.

`PI_content_count` – indicates the number of PI contents delivered in this MPI table.

`PI_content_type_length` – indicates the length of the content type of this PI content excluding the terminating null character. The content type shall be one of the MIME media types registered at the IANA website, i.e. http://www.iana.org/assignments/media-types.

`PI_content_type_byte` – a byte in the content type string of this PI content excluding the terminating null character.

`PI_content_name_length` – indicates the length of the name string of this PI content excluding the terminating null character.

`PI_content_name_byte` – a byte in the name string of this PI content excluding the terminating null character.

PI_content_descriptors_length – indicates the length of the PI content descriptors syntax loop. The length is counted from the next field to the end of the PI content descriptors syntax loop. Several descriptors that include information in the PI content can be inserted in this syntax loop.

PI_content_descriptors_byte – a byte in the PI content descriptors syntax loop.

PI_content_length – indicates the length in bytes of this PI content.

PI_content_byte – a byte in this PI content.

10.3.9 MP table

10.3.9.1 General

A complete MP table has the information related to a Package including the list of all Assets. A subset MP table has a portion of information from a complete MP table. In addition, MP table subset 0 has the minimum information required for Package consumption.

10.3.9.2 Syntax

The syntax of the MP table is defined in Table 29.

Table 29 — MP table syntax

Syntax	Value	No. of bits	Mnemonic
MP_table() {			
table_id		8	uimsbf
version		8	uimsbf
length		16	uimsbf
reserved	"11 1111"	6	bslbf
MP_table_mode		2	bslbf
if ((table_id == 0x20)or(table_id == 0x11)){			
MMT_package_id {	N1		
MMT_package_id_length		8	uimsbf
for (i=0; i<N1; i++) {			
MMT_package_id_byte		8	uimsbf
}			
}			
MP_table_descriptors {	N2		
MP_table_descriptors_length		16	uimsbf
for (i=0; i<N2; i++) {			
MP_table_descriptors_byte		8	uimsbf
}			
}			
}			
number_of_assets	N3	8	uimsbf
for (i=0; i<N3; i++) {			
Identifier_mapping()			
asset_type		32	char
reserved	"1111 11"	6	bslbf
default_asset_flag		1	bslbf

Table 29 *(continued)*

Syntax	Value	No. of bits	Mnemonic
asset_clock_relation_flag		**1**	**bslbf**
if (asset_clock_relation_flag == 1) {			
asset_clock_relation_id		**8**	**uimsbf**
reserved	**"1111 111"**	**7**	**bslbf**
asset_timescale_flag		**1**	**bslbf**
if (asset_time_scale_flag == 1) {			
asset_timescale		**32**	**uimsbf**
}			
}			
asset_location {			
location_count	**N4**	**8**	**uimsbf**
for (i=0; i<N4; i++) {			
MMT_general_location_info()			
}			
}			
asset_descriptors {			
asset_descriptors_length	**N5**	**16**	**uimsbf**
for (j=0; j<N5; j++) {			
asset_descriptors_byte		**8**	**uimsbf**
}			
}			
}			
}			

10.3.9.3 Semantics

`table_id` – indicates the identifier of the MP table. A complete MP table and each subset MP tables shall use different table identifiers. The subset number of the MP table is implicitly represented by this field. Since the `table_id` values are assigned contiguously, the MP table subset number can be deduced from this field, i.e. the MP table subset number equals this field minus the `table_id` of the base MP table. The MP table subset number provides the subset number of this MP table. The number "0" indicates the base MP table and the numbers "1"~"14" indicate a subset of MP table. The number "15" has a special meaning since it indicates a complete MP table.

`version` – indicates the version of the MP table. The newer version overrides the older one as soon as it has been received. If the `MP_table_mode` is not set to independent mode and a subset 0 MP table with a newer version number is received, all MP table subsets with a higher subset number (excluding complete MP tables) that were previously stored by the MMT receiving entity shall be treated as outdated. When the MP table subset number is not "0" and `MP_table_mode` is "01", the contents of the MP table subset with a version different from that of the subset 0 MP table stored by an MMT receiving entity shall be ignored. Also, when the MP table subset number is not "0" and `MP_table_mode` is "0", the contents of the MP table subset with a version different from that of lower-subset MP table subsets stored by an MMT receiving entity shall be ignored. The version number wraps around after reaching "255" and shall be incremented by one for every version change.

`length` – contains the length of the MP table in bytes, counting from the beginning of the next field to the last byte of the MP table. The value "0" is not valid for this field.

`MP_table_mode` – indicates the mode of an MP table subset processing when the MP table subset mechanism is used. In "`sequential_order_processing_mode`" and with a non-zero subset number

of this MP table, an MMT receiving entity shall receive all MP table subsets with lower subset numbers that have the same version as this MP table subset before it processes this MP table subset. For example, an MMT receiving entity cannot process a subset-3 MP table if it has not received a subset-2 MP table with the same version. In "order_irrelevant_processing_mode" and with the subset number of this MP table subset set to non-zero, an MMT receiving entity should process an MP table subset right after it receives the MP table subset as long as the subset 0 MP table stored in an MMT receiving entity has the same version as this MP table subset. In "independent_processing_mode", the version of each MP table subset is managed individually. The fragmented MP table, where each MP table subset is delivered by one of multiple MMT sending entities, is adapted in this mode. The independent mode of subsets of the MP table can be used for the multi-channel instantiation, i.e. MP table subsets from subset 0 MP table to subset-N MP table are assigned as logical channels from Ch "0" to Ch "N". When an MPI message carries both an MPI table subset and the associated MP table subset, the PI_mode in the MPI table and the MP_table_mode in the MP table shall have the same value. The value of MP_table_mode is specified in Table 30.

Table 30 — Value of MP_table_mode

Value	Description
00	"sequential_order_processing_mode"
01	"order_irrelevant_processing_mode"
10	"independent_processing_mode"
11	Reserved

MMT_package_id – this field is a unique identifier of the Package.

MMT_package_id_length – the length in bytes of the MMT_package_id string, excluding the terminating null character.

MMT_package_id_byte – a byte in the MMT_package_id. When the MMT_package_id_byte is string, the terminating null character is not included in the string.

asset_type – provides the type of Asset. This is described in a four character code ("4CC") type registered in MP4REG (http://www.mp4ra.org).

MP_table_descriptors – this field provides descriptors for the MP table.

MP_table_descriptors_length – contains the length of the descriptor syntax loop. The length is counted from the next field to the end of the descriptor syntax loop. Several descriptors can be inserted in this syntax loop.

MP_table_descriptors_byte – one byte in the descriptors loop.

number_of_assets – provides the number of Assets whose information is provided by this MP table.

Identifier_mapping – provides information of identifier_mapping as defined in 10.6.3.

asset_clock_relation_flag – indicates whether an Asset uses an NTP clock or other clock systems as the clock reference. If this flag is "1", asset_clock_relation_id field is included. If this field is "0", the NTP clock is used for the Asset.

asset_clock_relation_id – provides a clock relation identifier for the Asset. This field is used to reference the clock relation delivered by a CRI_descriptor() for the Asset. The value of this field is one of the clock_relation_id values provided by the CRI descriptors (see 10.5.1).

asset_timescale_flag – indicates whether "asset_timescale" information is provided or not. If this flag is "1", asset_timescale field is included and if this flag is set to "0", asset_timescale is 90,000 (90 kHz).

location_count – provides the number of location information for an Asset. Set to "1" when an Asset is delivered through one location. When bulk delivery is achieved, in which MPUs contained in an Asset

are delivered through multi-channels, not "1" is set. When one Asset is delivered over multiple locations, an MMT receiving entity shall receive all MPUs of the Asset from all indicated locations.

`asset_timescale` – provides information of time unit for all timestamps used for the Asset; expressed in the number of units in one second.

`MMT_general_location_info_for_asset_location` – provides the location information of the Asset. General location reference information for the Asset defined in 10.6.1 is used. Only the value of `location_type` between "`0x00`" and "`0x06`" shall be used for an Asset location.

`asset_descriptors_length` – the number of bytes counted from the beginning of the next field to the end of the Asset descriptors syntax loop.

`asset_descriptors_byte` – specifies a byte in Asset descriptors.

`default_asset_flag` – indicates whether an Asset is marked as a default asset or not. In case an asset is marked as a default asset, the MPU timestamp descriptor should be present for the corresponding timed asset. If this flag is "0", the asset is marked as a default asset.

10.3.10 CRI table

10.3.10.1 General

The CRI table defined in Table 31 is delivered by the CRI message. Also, it may be delivered by a PA message.

10.3.10.2 Syntax

The syntax of the CRI table is defined in Table 31. A CRI table may include multiple CRI descriptors (see 10.5.1).

Table 31 — CRI table syntax

Syntax	Value	No. of bits	Mnemonic
`CRI_table () {`			
table_id		**8**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
number_of_CRI_descriptor	**N1**	**8**	**uimsbf**
`for (i=0; i<N1; i++) {`			
CRI_descriptor()		**152**	**uimsbf**
`}`			
`}`			

10.3.10.3 Semantics

`table_id` – indicates the table identifier of the CRI table.

`version` – indicates the version of the CRI table. The newer version overrides the older one as soon as it is received.

`length` – indicates the length of the CRI table counted in bytes starting from the beginning of the next field to the last byte of the CRI table. The value "0" is not valid for this field. This value shall be a multiple of 19.

`number_of_CRI_descriptor` - indicates the number of `CRI_descriptor`.

`CRI_descriptor()` – a CRI descriptor as defined in 10.5.1.

10.3.11 DCI table

10.3.11.1 General

The DCI table contains information on required device capabilities for the consumption of the Package. Depending on the MIME type of the Asset, a different set of information may be provided to support the delivery and consumption of the Package. This document differentiates between video, audio and download (applicable to non-timed data) MIME types.

10.3.11.2 Syntax

The syntax of DCI table is defined in Table 32.

Table 32 — DCI table syntax

Syntax	Value	No. of bits	Mnemonic
DCI_table() {			
table_id		**8**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
number_of_assets	**N1**	**8**	**uimsbf**
for (i=0; i<N1; i++) {			
asset_id()			
mime_type()			
reserved	**"111 1111"**	**7**	**bslbf**
codec_complexity_flag		**1**	**bslbf**
if (codec_complexity_flag == 1) {			
if (top_level_mime_type == video) {			
video_codec_complexity {			
video_average_bitrate		**16**	**uimsbf**
video_maximum_bitrate		**16**	**uimsbf**
horizontal_resolution		**16**	**uimsbf**
vertical_resolution		**16**	**uimsbf**
temporal_resolution		**8**	**uimsbf**
video_minimum_buffer_size		**16**	**uimsbf**
}			
} else if (top_level_mime_type == audio) {			
audio_codec_complexity {			
audio_average_bitrate		**16**	**uimsbf**
audio_maximum_bitrate		**16**	**uimsbf**
audio_minimum_buffer_size		**16**	**uimsbf**
}			
}			
}			
else {			
download_capability {			
required_storage		**32**	**uimsbf**

Table 32 *(continued)*

Syntax	Value	No. of bits	Mnemonic
}			
}			
}			
}			

10.3.11.3 Semantics

`table_id` – indicates the identifier of the DCI table.

`version` – indicates the version of the DCI table. The newer version overrides the older one as soon as the DCI table is received.

`length` – indicates the length of the DCI table in bytes, counting from the beginning of the next field to the last byte of the DCI table. The value "0" is not valid for this field.

`number_of_assets` – indicates the number of Assets.

`asset_id` – provides the identifier of the Asset as defined in 10.6.2.

`top_level_mime_type` – indicates the media type part of the MIME type as given in the `mime_type()` syntax element. MIME types are defined in RFC 2046.

`codec_complexity_flag` – if this flag is "1", codec complexity information is provided.

`video_codec_complexity` – indicates the complexity the video decoder has to deal with.

`video_average_bitrate` – indicates the average bitrate of the video in kilo-bit/s for the whole Asset.

`video_maximum_bitrate` – indicates the maximum bitrate of the video in kilo-bit/s for the whole Asset.

`horizontal_resolution` – indicates the horizontal resolution of the video in pixels.

`vertical_resolution` – indicates the vertical resolution of the video in pixels.

`temporal_resolution` – indicates the average temporal resolution of the video in frames per second.

`video_mimimum_buffer_size` – indicates the minimum size of video decoder buffer that needs to be available in kilo-bytes.

`audio_codec_complexity` – indicates the complexity the audio decoder has to deal with.

`audio_average_bitrate` – indicates the average bitrate in kilo-bit/s for the whole Asset.

`audio_maximum_bitrate` – indicates the maximum bitrate in kilo-bit/s for the whole Asset.

`audio_minimum_buffer_size` – indicates the minimum size of audio decoder buffer needs to be processed in kilo-bytes.

`download_capability` – indicates the required capability for download.

`required_storage` – indicates the size of storage in kilobytes required to download.

10.3.12 SSWR message

10.3.12.1 General

The overall operation of downloadable DRM and CAS for MMT is described in Annex E. There are five steps in Annex E. Among them, the message for the security software request is sent from a receiving MMT entity to a downloadable DRM/CAS server. The message for DRM and CAS SW request is defined in this subclause.

10.3.12.2 Syntax

The syntax of SSWR message is defined in Table 33.

Table 33 — SSWR message syntax

Syntax	Value	No. of bits	Mnemonic
SSWR_message () {			
message_id		16	uimsbf
version		8	uimsbf
length		16	uimsbf
message_payload {			
token_ID {			uimsbf
token_ID_URI_length	N1	8	bslbf
for (i=0; i<N1; i++) {			
token_ID_URI_byte		8	
}			uimsbf
Number_of_deviceID	N2	8	uimsbf
for (i=0; i<N2; i++) {			
device_ID {			uimsbf
deviceID_length	N3	8	
for (j=0; j<N3; j++) {			
deviceID_byte		8	
}			uimsbf
}			
}			uimsbf
tokenIssure_ID {			
tokenIssuer_ID_URI_length	N4	8	
for (i=0; i<N4; i++) {			
tokenIssuer_URI_bytes		8	
}			uimsbf
}		64	
tokenIssueTime		64	uimsbf
tokenExpireTime			
information_table_info {			uimsbf
number_of_tables			uimsbf
for (i=0; i<N5; i++) {	N5	8	
MMT_signaling_table_id		8	
MMT_signaling_table_version		8	
}			uimsbf

Table 33 *(continued)*

Syntax	Value	No. of bits	Mnemonic
}			**uimsbf**
}			**umisbf**
}			
}			

10.3.12.3 Semantics

`message_id` – indicates the type of MMT signalling messages.

`version` – indicates the version of MMT signalling messages.

`length` – indicates the length of MMT signalling messages. The value "0" is never used for this field.

`tokenID` – identification of a Token and is provided by the Token Provider. The Token should be provided by a trustable entity. It has sub-elements of Device ID, Token Issuer ID, Issue Time and Expire Time.

`deviceID` – provides the identification of device(s) under the Token. If the MMT client wants to consume Asset/Package of two different devices, then multiple Device IDs should be provided.

`tokenIssureID` – identification of trust entity that issues a Token. This field is to be used by the D-DRM/D-CAS server to verify the validity of the Token.

`tokenIssueTime` – a time at which the Token is issued. The unit of this field is second. The NTC format will be used.

`tokenExpireTime` – a time at which the Token is expired. The unit of this field is second. The NTC format will be used.

`MMT_signaling_table_info` – provides the information of MPT related to Package/Asset to be descripted by downloaded DRM or CAS.

10.3.13 LS message

10.3.13.1 General

The LS message carries the license information targeted to a specific receiver or group of receivers. This information is delivered to receivers that do not have a return channel.

10.3.13.2 Syntax

The syntax of LS message is defined as follows in Table 34:

Table 34 — LS message syntax

Syntax	Value	No. of bits	Mnemonic
LS_message () {			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**32**	**uimsbf**
message_payload {			
system_id		**16*8**	**uimsbf**
number_of_licenses	**N1**	**32**	**uimsbf**
for(i=0;i<N1;i++) {			
license_message_hash_length	**N2**	**8**	**uimsbf**
license_message_hash		**8*N2**	**uimsbf**
encrypted_license_data_length	**N3**	**16**	**uimsbf**
encrypted_license_data		**8*N3**	**uimsbf**
}			
}			
}			

10.3.13.3 Semantics

`message_id` – indicates the identifier of the PA messages.

`version` – indicates the version of the PA messages.

`length` – a 32-bit field for conveying the length of the LS message in bytes, counting from the beginning of the next field to the last byte of the LS message. The value "0" is not valid for this field.

`system_id` – provides the UUID that uniquely identifies the DRM system.

`number_of_licenses` – provides the number of licenses in the LS message.

`license_message_hash_length` – provides the length in bytes of the license message hash.

`license_message_hash` – the license message hash code is used to identify the target receiver or group of receivers for the enclosed license. The license message hash is generated by the content decryption module in the same way as the license server. The hash generation algorithm is DRM system specific.

`encrypted_license_data_length` – provides the length of the encrypted license data.

`encrypted_license_data` – contains an encrypted license that corresponds to the license message of which the hash value is included in this message. The license is encrypted using the certificate of the targeted receiver or group of receivers.

10.3.14 LR message

10.3.14.1 General

The license revocation message is defined to allow the DRM system to provide a signal that it has revoked the license for a user or group of users.

10.3.14.2 Syntax

The syntax of the LR signalling message is defined in Table 35.

Table 35 — LR message syntax

Syntax	Value	No. of bits	Mnemonic
LS_message () {			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**32**	**uimsbf**
message_payload {			
system_id		**16*8**	**uimsbf**
number_of_licenses	**N1**	**32**	**uimsbf**
for(i=0;i<N1;i++) {			
encrypted_license_challenge_length	**N2**	**16**	**uimsbf**
encrypted_license_challenge		**8*N2**	**uimsbf**
}			
}			
}			

10.3.14.3 Semantics

`message_id` – indicates the identifier of the LR messages.

`version` – indicates the version of the LR messages.

`length` – a 32-bit field for conveying the length of the LR message in bytes, counting from the beginning of the next field to the last byte of the LR message. The value "0" is not valid for this field.

`System_id` – provides the UUID that uniquely identifies the DRM system.

`number_of_licenses` – provides the number of licenses in the LS message.

`encrypted_license_challenge_length` – provides the length of the encrypted license challenge.

`encrypted_license_challenge` – contains an encrypted license challenge. The license challenge is encrypted using the certificate of the targeted receiver or group of receivers.

10.3.15 SI table

10.3.15.1 General

The security information table (SIT) provides the required security for the consumption of the Package.

10.3.15.2 Syntax

The syntax of the SIT is defined in Table 36.

Table 36 — SIT syntax

Syntax	Value	No. of bits	Mnemonic
SI_table() {			
table_id		**8**	**uimsbf**
version		**8**	**uimsbf**

Table 36 *(continued)*

Syntax	Value	No. of bits	Mnemonic
length		**16**	**uimsbf**
number_of_Security_System	**N1**		
for (i=0; i<N1; i++) {			
system_id {			
system_id_length	**N2**	**8**	**uimsbf**
for (j=0; j<N2; j++) {			
system_id_byte		**8**	**uimsbf**
}			
}			
systemProvider {			
systemProvider_URL_length	**N3**	**8**	**uimsbf**
for (i=0; i<N3; i++) {			
URL_byte		**8**	**uimsbf**
}			
}			
reserved	**"1111 111"**	**7**	**bslbf**
encryption_flag		**1**	**bslbf**
if (encryption_flag == 1) {			
encAlgorithm {			
encAlgorithm_length	**N4**	**8**	**uimsbf**
for (i=0; i<N4; i++) {			
encAlgorithm _byte		**8**	**uimsbf**
}			
}			
keySize {			
keySize_length	**N5**	**8**	**uimsbf**
for (i=0; i<N5; i++) {			
keySize_byte		**8**	**uimsbf**
}			
}			
keyUrl {			
key_URL_length	**N6**	**8**	**uimsbf**
for (i=0; i<N6; i++) {			
URL_byte		**8**	**uimsbf**
}			
}			
initializationVector {			
initializationVector_length	**N7**	**8**	**uimsbf**
for (i=0; i<N7; i++) {			
length_byte		**8**	**uimsbf**
}			
}			
ivUrl {			
iv_URL_length	**N8**	**8**	**uimsbf**

Table 36 *(continued)*

Syntax	Value	No. of bits	Mnemonic
for (i=0; i<N8; i++) {			
URL_byte		**8**	**uimsbf**
}			
}			
keyUrlTemplate {			
keyUrlTemplate_length	**N9**	**8**	**uimsbf**
for (i=0; i<N9; i++) {			
length_byte		**8**	**uimsbf**
}			
}			
ivUrlTemplate {			
ivUrlTemplate_length	**N10**	**8**	**uimsbf**
for (i=0; i<N10; i++) {			
length_byte		**8**	**uimsbf**
}			
}			
reserved	**"1111 111"**	**7**	**bslbf**
authentication_flag		**1**	**bslbf**
if (authentication_flag == 1) {			
digestUrl {			
digest_URL_length	**N11**	**8**	**uimsbf**
for (i=0; i<N11; i++) {			
URL_byte		**8**	**uimsbf**
}			
}			
digestURLTemplate {			
digestUrlTemplate_length	**N12**	**8**	**uimsbf**
for (i=0; i<N12; i++) {			
length_byte		**8**	**uimsbf**
}			
}			
signatureUrl {			
signature_URL_length	**N13**	**8**	**uimsbf**
for (i=0; i<N13; i++) {			
URL_byte		**8**	**uimsbf**
}			
}			
signatureURLTemplate {			
signatureUrlTemplate_length	**N14**	**8**	**uimsbf**
for (i=0; i<N14; i++) {			
length_byte		**8**	**uimsbf**
}			
}			

Table 36 *(continued)*

Syntax	Value	No. of bits	Mnemonic
signatureLength {			
signature_length	**N15**	**8**	**uimsbf**
for (i=0; i<N15; i++) {			
Length_byte		**8**	**uimsbf**
}			
}			
signatureKeyUrl {			
signatureKey_URL_length	**N16**	**8**	**uimsbf**
for (i=0; i<N16; i++) {			
URL_byte		**8**	**uimsbf**
}			
}			
number_of_License	**N17**		
for (i=0; i<N17; i++) {			
license_Url {			
licenseUrl_length	**N18**	**8**	**uimsbf**
for (j=0; j<N18; j++) {			
URL_byte		**8**	**uimsbf**
}			
}			
licenseURLTemplate {			
lisenceUrlTemplate_length	**N19**	**8**	**uimsbf**
for (i=0; i<N19; i++) {			
length_byte		**8**	**uimsbf**
}			
}			
}			
}			
}			

NOTE How a specific DRM solution or CAS solution works with MMT is out of the scope.

10.3.15.3 Semantics

`table_id` – indicates the ID of SIT.

`version` – indicates a version of SIT. The newer version overrides the older one as soon as it has been received.

`length` – provides the length of SIT counted in bytes starting from the next field to the last byte of the SIT. The value "0" is never used for this field.

`number_of_Security_System` – provides a DRM or CAS system that can process and handle the content protection, access control and rights management.

`systemId` – provides a UUID-formatted opaque string for the system. This can also be used to encode the type of the system.

`systemProvider` – provides a URL location of a provider for the system. This can be used for downloading and installing the system, when needed.

`Encryption` – this optional element provides the information about encryption.

`encAlgorithm` – provides the algorithm used for encryption.

`keySize` – provides the size of initialization vectors in bytes.

`keyUrl` – provides the URL for key derivation.

`IV` – provides the initialization vector.

`ivUrl` – provides the URL for initialization vector derivation.

`keyUrlTemplate` – provides the template for key URL generation.

`ivUrlTemplate` – provides the template for IV URL generation.

`Authentication` – this optional element gives the information required for authentication.

`digestUrl` - provides the URL used for retrieving the digest value.

`digestUrlTemplate` – provides the template for creating the URL used for retrieving the digest value.

`signatureUrl` – provides the URL used for retrieving the signature value.

`signatureUrlTemplate` – provides the template for creating the URL used for retrieving the signature value.

`signatureLength` – provides the length of the signature. It shall appear only if the length is shorter than the normal output size of the signature algorithm.

`signaturekeyUrl` – provides the URL for the key used for the signature.

`License` – this optional element provides the information to get the License.

`licenseUrl` – the license format can be in some standard ones or be dependent on the system that is specified with `systemId` of the System element.

`licenseUrlTemplate` – specifies the template for license URL generation.

10.4 Signalling messages for Package delivery

10.4.1 General

Signalling messages for delivery are HRBM message, ARQ configuration (AC) message, ARQ feedback (AF) message, measurement configuration (MC) message, reception quality feedback (RQF) message, NAM feedback (NAMF) message, low delay consumption (LDC) message, HRBM removal (HRBMR) message and asset delivery characteristic (ADC) message. They are shown in Figure 20.

NOTE AL-FEC message is defined in C.6.

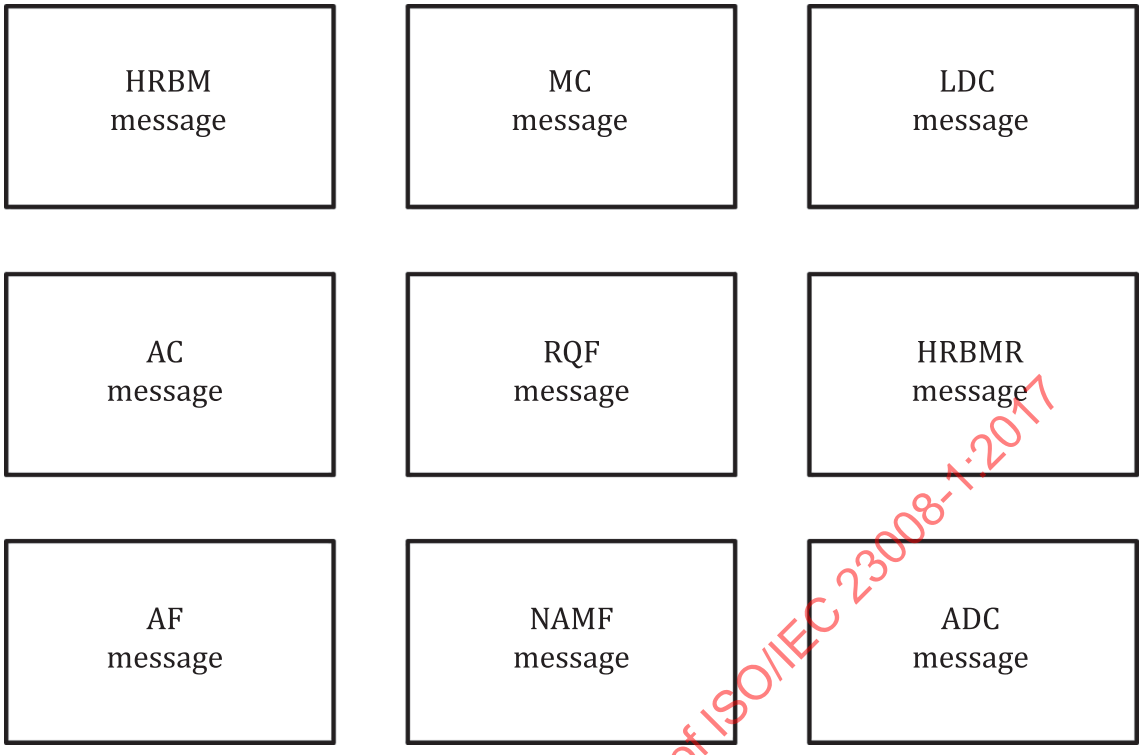


Figure 20 — Structure of the signalling messages for MMT delivery

10.4.2 Hypothetical receiver buffer model (HRBM) message

10.4.2.1 General

The HRBM is described in Clause 11. An HRBM message provides information on end-to-end transmission delay and memory requirement to an MMT receiving entity for efficient operation in a broadcasting environment. As the HRBM is applied per MMTP sub-flow, the MMT receiving entity can recognize the corresponding sub-flow for which it received HRBM information through the `packet_id` of the MMTP packet that carried the HRBM signalling message.

10.4.2.2 Syntax

The syntax of the HRBM message is defined in Table 37.

Table 37 — HRBM message syntax

Syntax	Values	No. of bits	Mnemonic
`HRBM_message ( ){`			
message_id		16	**uimsbf**
version		8	**uimsbf**
length		16	**uimsbf**
`message_payload{`			
max_buffer_size		**32**	**uimsbf**
fixed_end_to_end_delay		**32**	**uimsbf**
max_transmission_delay		**32**	**uimsbf**
`}`			
`}`			

10.4.2.3 Semantics

`message_id` – indicates the identifier of the HRBM message.

`version` – version of the HRBM messages. An MMT receiving entity can use this field to check the version of the received HRBM message.

`length` – length of the HRBM messages in bytes, counting from the first byte of the next field to the last byte of the HRBM message. The value "0" is not valid for this field.

`max_buffer_size` – provides information for the required maximum buffer size in bytes of MMT Assets.

`fixed_end_to_end_delay` – provides information for `fixed_end_to_end_delay` between the sending entity and the receiving entity in millisecond.

`max_transmission_delay` – provides information for the `max_transmission_delay` between the sending entity and receiving entity in millisecond.

NOTE Fixed end-to-end delay is calculated by summing the `max_transmission_delay` and FEC `protection_window_time` (refer to AL-FEC message in C.6).

10.4.3 Measurement configuration (MC) message

10.4.3.1 General

MC messages are used for transport metrics measurement. It provides the information on measurement metrics (e.g. a receiving entity buffer status, round trip delay, NAM parameter), measurement condition such as a measurement starting time and a period and measurement report. The syntax of an MC message is shown in Table 38 and its semantics are described in 10.4.3.2.

10.4.3.2 Syntax

The syntax of the MC message is defined in Table 38.

Table 38 — MC message syntax

Syntax	Values	No. of bits	Mnemonic
MC_message() {			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
message_payload {			
reserved	"1111 11"	**6**	**bslbf**
measurement_mode		**2**	**bslbf**
if(measurement_mode !=11) {			
if(measurement_mode ==01){			
measurement_start_time		**32**	**uimsbf**
}else if(measurement_mode ==10) {			
measurement_start_condition()			
}			
measurement_stop_time		**32**	**uimsbf**
measurement_period		**32**	**uimsbf**
measurement_report{			

Table 38 *(continued)*

Syntax	Values	No. of bits	Mnemonic

server_address{
MMT_general_location_info()
}
report_type
}
}
}
}
		8	**bslbf**

10.4.3.3 Semantics

`message_id` – indicates the message ID. The length of this field is 16 bits.

`version` – indicates the version of the messages. The MMT receiving entity may check whether the version of the received message is new or not. The length of this field is 8 bits.

`length` – indicates the length of the messages in bytes, counting from the beginning of the next field to the last byte of the MC message. The value "0" shall not be used for this field.

`measurement_mode` – indicates when the MMT receiving entity should start measuring the item indicated by `measurement_item_flag`. Valid values for this field are described in Table 39.

Table 39 — Value of measurement_mode

Value	Description
00	Start measurement immediately and stop measurement at the appointed time
01	Start and stop measurement at the appointed time
10	Start measurement at the measurement condition
11	Stop measurement immediately

`measurement_start_time` – indicates a UTC time in NTP format corresponding to the measurement start time. This field is the 32 bits MSB from the full resolution NTP timestamp.

`measurement_start_condition` – indicates a specific condition which the MMT receiving entity starts a measurement. The example of specific condition is the receiver buffer status or the reception channel status. The example of condition is given in Table 39.

`measurement_stop_time` – indicates a UTC time in NTP format corresponding to the measurement stop time. This field is the 32 bits MSB from the full resolution NTP timestamp. The value "`0x0000`" means the MMT receiving entity measures periodically with the `measurement_period` until receiving the "immediately stop measurement" indication.

`measurement_period` – indicates how frequently the MMT receiving entity should measure the item indicated by `measurement_item_flag`. The value "`0x0000`" means the MMT receiving entity is to execute the measurement only once. Other values mean the period for measurement. The unit is seconds.

`measurement_report` – this field provides information for the measurement report. It has a server address where the MMT receiving entity should send measurement results and a template to be used for the measurement report.

`server_address` – indicates the location of the server that receives transport data measurement results. The syntax and semantics are the same of `MMT_general_location_info` that is defined in 10.6.1.

report_type – indicates the type of measurement report request as shown in Table 40.

Table 40 — Value of report_type field

Value	Description
0000 0000	report type is reception_quality_feedback
0000 0001	report type is NAM_feedback
0000 0010	report type is reception_quality_feedback and NAM_feedback
0000 0011 ~ 1111 1111	reserved for future use

10.4.4 ARQ configuration (AC) message

10.4.4.1 General

ARQ configuration information, which includes the policy to be adopted by the MMT sending entity and MMT receiving entity in the event of packet loss, shall be transmitted at the beginning of a session as the ARQ configuration (AC) message from the transmitting MMT sending entity to the MMT receiving entity either in-band or out-of-band. The syntax for AC message is shown in Table 41.

10.4.4.2 Syntax

The syntax of the AC message is defined in Table 41.

Table 41 — AC message syntax

Syntax	Values	No. of bits	Mnemonic
AC_message() {			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
message_payload{			
flow_label_flag		**1**	**bslbf**
if(flow_label_flag == 1) {			
fb_flow_label		**7**	**uimsbf**
} else {			
reserved	**“1111 111”**	**7**	**bslbf**
}			
delay_constrained_ARQ_flag		**1**	**bslbf**
number_of_packet_id	**N1**	**7**	**uimsbf**
for(i=0; i<N1; i++) {			
packet_id		**16**	**uimsbf**
rtx_window_timeout		**32**	**uimsbf**
}			
arq_server_address{			
MMT_general_location_info()			
}			
}			
}			

10.4.4.3 Semantics

`message_id` – indicates AC message ID. The length of this field is 16 bits.

`version` – indicates the version of AC messages. The MMT receiving entity may check whether the received message is new or not. The length of this field is 8 bits.

`length` – indicates the length of AC messages. The length of this field is 16 bits. It indicates the length of the AC message counted in bytes starting from the next field to the last byte of the AC message. The value "0" shall not be used.

`flow_label_flag` – indicates whether `fb_flow_label` exists. If the value is set to 1, the value of `rtx_flow_label` parameter is present.

`fb_flow_label` – indicates the flow label to be used when the MMT receiving entity sends an AF message. The `flow_label` will be allocated to guarantee higher priority for the AF message along the delivery path. This parameter will be presented only if the value of `flow_label_flag` parameter is set to 1.

`delay_constrained_ARQ_flag` – when set to "1", this flag indicates that the server supports delay constrained ARQ.

`number_of_packet_id` – indicates the number of packet id that has lost packets.

`rtx_window_timeout` – indicates the retransmit window timeout. An MMT sending entity will keep an MMTP packet in buffer until the timeout, and thus available for retransmission. The timeout for a certain MMTP packet starts when the MMT sending entity sends the MMTP packet. Thus, the MMT receiving entity can infer whether the MMTP packet is available by referencing the timestamp field in the MMTP packet header. The unit is milliseconds.

`arq_server_address` – indicates address of servers to which the MMT receiving entity can send the AF message to request lost MMTP packets.

NOTE The location_type of `MMT_general_location_info()` will be restricted to 0x01, 0x02 and 0x05 for simplicity.

10.4.5 ARQ feedback (AF) message

10.4.5.1 General

In the event of packet loss, this loss is detected by the MMT receiving entity. An ARQ feedback (AF) message is generated according to the information of the AC message and then transmitted to the MMT sending entity. When the MMT receiving entity detects that one or more packets have been lost, it forms a mask of up to 255 bytes where each bit in a byte corresponds to a sequence number of lost MMTP packets. This allows the AF message to report up to 255x8 lost packets in one AF message. The syntax for the AF message is shown in Table 42.

The method of packet loss detection is outside the scope of this document.

10.4.5.2 Syntax

The syntax of the AF message is defined in Table 42.

Table 42 — AF message syntax

Syntax	Values	No. of bits	Mnemonic
`AF_message() {`			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**

Table 42 *(continued)*

Syntax	Values	No. of bits	Mnemonic
message_payload {			
reserved	**'1111 1'**	**5**	**uimsbf**
argument_type		**1**	**bslbf**
delay_constrained_ARQ_mode		**2**	**uimsbf**
if(argument_type == 0) {			
if (delay_constrained_ARQ_mode == 01){			
ARQ_feedback_timestamp		**32**	**uimsbf**
}			
if (delay_constrained_ARQ_mode == 10){			
propagation_delay		**32**	**uimsbf**
}			
packet_counter		**32**	**uimsbf**
masklength	**N1**	**8**	**uimsbf**
if (delay_constrained_ARQ_mode ==01){			
arrival_deadline		**16**	**uimsbf**
}			
for(i=0; i<N1; i++){			
mask_byte		**8**	**uimsbf**
}			
}			
if(argument_type == 1) {			
reserved	**'1'**	**1**	**bslbf**
number_of_packet_id	**N2**	**7**	**uimsbf**
if (delay_constrained_ARQ_mode == 01){			
ARQ_feedback_timestamp		**32**	**uimsbf**
}			
if (delay_constrained_ARQ_mode == 10){			
propagation_delay		**32**	**uimsbf**
}			
for(i=0; i<N2; i++){			
packet_id		**16**	**uimsbf**
packet_sequence_number		**32**	**uimsbf**
masklength	**N3**	**8**	**uimsbf**
if (delay_constrained_ARQ_mode == 01){			
arrival_deadline		**16**	**uimsbf**
}			
for(j=0; j<N3; j++){			
mask_byte		**8**	**uimsbf**
}			
}			
}			
}			

10.4.5.3 Semantics

message_id – indicates AF message ID. The length of this field is 16 bits.

version – indicates the version of AF messages. The MMT receiving entity may check whether the received message is new or not. The length of this field is 8 bits.

length – indicates the length of AF messages. The length of this field is 16 bits. It indicates the length of the AF message counted in bytes starting from the next field to the last byte of the AF message. The value "0" shall not be used.

argument_type – indicates the type of argument the MMT receiving entity is using when requesting the lost packets to the server. Valid values for this field are described in Table 43.

Table 43 — Value of argument_type

Value	Description
0	Packet counter based ARQ. The MMT receiving entity sends the AF message with *packet_counter*.
1	Packet sequence number based ARQ. The MMT receiving entity sends the AF message with *packet_id* and *packet_sequence_number*.

delay_constrained_ARQ_mode – indicates the type of delay constrained ARQ. Valid values for this field are described in Table 44.

Table 44 — Value of delay_constrained_ARQ_mode

Value	Description
00	No time constrained ARQ. The ARQ server does not need to consider any delay constraints when retransmitting the lost packets for this request.
01	Playout-time constrained ARQ. The MMT receiving entity sends the AF message, with *ARQ_feedback_timestamp* and *arrival_deadline*, to help the server decide whether to retransmit or not.
10	Delivery-time constrained ARQ. The MMT receiving entity sends the AF message, with *propagation_delay* only, to help the server decide whether to retransmit or not.
11	Reserved for future use.

number_of_packet_id – indicates the number of packet id that has lost packets.

delay_constrained_ARQ_flag – indicates the present of arrival_deadline field information.

ARQ_feedback_timestamp – indicates the NTP time at which the ARQ feedback is sent from the MMT receiving entity.

propagation_delay – propagation delay for the MMT packet to arrive at the MMT receiving entity. The MMT receiving entity calculates the propagation_delay by the subtracting the NTP time at the delivery instant of a MMT packet from the NTP time at the arrival instant of the MMT packet. The propagation_delay can be an average result of a propagation delay measured within the measurement_duration.

packet_id – this field is the integer value assigned to each Asset to distinguish packets of one Asset from another. Separate values will be assigned to signalling messages and FEC parity flows.

packet_sequence_number – corresponds to the packet_sequence_number of the first packet indicated by the mask_byte that is identified as having been detected to be lost and hence requiring re-transmission.

masklength – indicates the length of the data behind the mask in bytes.

`arrival_deadline` – indicates the deadline by which the retransmitted packet for the first lost packet should arrive at the MMT receiving entity for timely processing. This parameter represents the time increment from the `ARQ_feedback_timestamp`. The first 8 bits represents integer part and the last 8 bits represents fractional part.

`mask_byte` – mask field, each bit corresponds to a MMTP packet. If the packet behind the packet with `packet_id` is lost, then the corresponding bit will be set to "1".

10.4.6 Reception quality feedback (RQF) message

10.4.6.1 General

An MMT receiving entity can send the reception quality feedback to the MMT sending entity to inform the reception quality of the received MMTP packet flow by using RQF messages. An MMT receiving entity needs to keep track of reception quality per MMT sending entity.

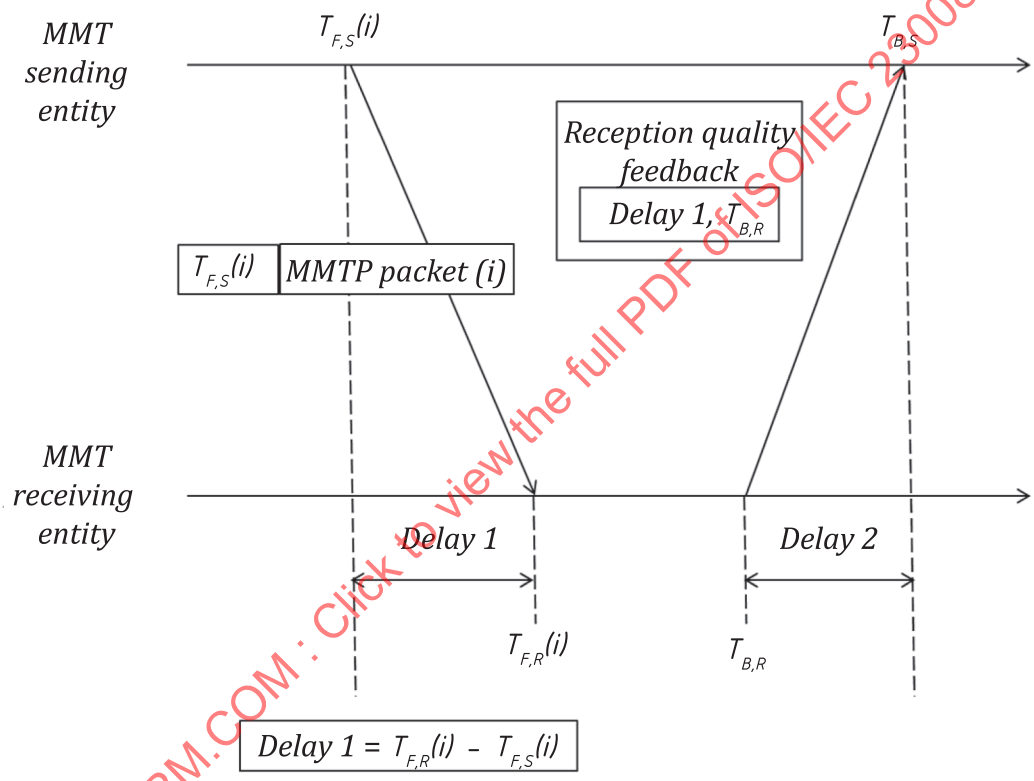


Figure 21 — Round trip time (RTT) calculation

An MMT receiving entity provides information in the feedback to allow the MMT sending entity to calculate the round trip time (RTT) and the process is as shown in Figure 21. In Figure 21, Delay 1 is the delivery time of the MMTP packet from the MMT sending entity to the MMT receiving entity. Delay 1 is calculated by the subtracting $T_{F,S}(i)$ (NTP time at delivery instant of i-th MMTP packet) from $T_{F,R}(i)$ (NTP time at arrival instant of i-th MMTP packet). The Delay 2 is the delivery time for the MMTP packet from the MMT receiving entity to the MMT sending entity. The Delay 2 is calculated by subtracting $T_{B,R}$ (NTP time at delivery instant of the feedback report, i.e. `feedback_timestamp`) from the $T_{B,S}$ (NTP time at arrival instant of the feedback report). Thus, the MMT sending entity can calculate the RTT by adding Delay 1 and Delay 2.

10.4.6.2 Syntax

The syntax of the RQF message is defined in Table 45.

Table 45 — RQF message syntax

Syntax	Values	No. of bits	Mnemonic
RQF_message ( ) {			
message_id		**16**	
version		**8**	
length		**16**	
message_payload {			unsigned short
packet_loss_ratio		**8**	**unsigned char**
inter_arrival_jitter		**32**	**unsigned integer**
max_transmission_delay		**32**	**unsigned integer**
min_transmission_delay		**32**	**unsigned integer**
RTT_parameter( ) {			
propagation_delay		**32**	**unsigned integer**
feedback_timestamp		**32**	**unsigned integer**
}			
}			
}			

10.4.6.3 Semantics

message_id – identifier of the RQF message. The length of this field is 16 bits.

version – version of the RQF message. An MMT receiving entity can use this field to check the version of a received message. The length of this field is 8 bits.

length – length of the RQF in bytes, counting from the first byte of the next field to the last byte of the RQF message. The length of this field is 16 bits and the value "0" is not valid for this field.

packet_loss_ratio – ratio between the number of lost MMTP packets and the total number of transmitted packets. This value is equivalent to taking the integer part after multiplying the loss fraction by 256. The packet_loss_ratio is a result measured within the measurement duration which can be calculated between measurement_start_time and measurement_stop_time or can be provided by average_bitrate_period.

inter_arrival_jitter – deviation of the difference in packet spacing at the MMT receiving entity compared with the MMT sending entity for a pair of packets, measured in timestamp units. It can be estimated based on the time difference between the arrivals of adjacent MMTP packets. The inter_arrival_jitter is an average result measured within the measurement duration which can be calculated between measurement_start_time and measurement_stop_time or can be provided by average_bitrate_period.

RTT_parameter – parameter used for calculating the round trip time (RTT). RTT is the length of time required for the MMTP packet to be sent and the length of time it takes for an acknowledgement to be received. When computing the RTT, the MMT sending entity records the time when the feedback is received. RTT is calculated by subtracting the feedback_timestamp from the recorded time and adding the propagation_delay.

propagation_delay – propagation delay for the MMTP packet to arrive at the MMT receiving entity. The MMT receiving entity calculates the propagation_delay by the subtracting the NTP time at the delivery instant of an MMTP packet from the NTP time at the arrival instant of the MMTP packet. The propagation_delay can be an average result of a propagation delay measured within the measurement_duration.

feedback_timestamp – NTP time at which the feedback is sent from the MMT receiving entity. This parameter is used to measure the propagation delay from the MMT receiving entity to the MMT sending entity.

max_transmission_delay – the maximum transmission delay for the MMTP packet to arrive at the MMT receiving entity. The MMT receiving entity calculates the transmission delay by subtracting the NTP time at the delivery instant of a MMTP packet from the NTP time at the arrival instant of the MMTP packet. The max_transmission_delay is the maximum transmission_delay measured within the measurement_duration.

min_transmission_delay – the minimum transmission delay for the MMTP packet to arrive at the MMT receiving entity. The MMT receiving entity calculates the transmission delay by subtracting the NTP time at the delivery instant of a MMTP packet from the NTP time at the arrival instant of the MMTP packet. The min_transmission_delay is the minimum transmission_delay measured within the measurement_duration.

10.4.7 NAM feedback (NAMF) message

10.4.7.1 Syntax

The syntax of the NAM feedback is defined in Table 46.

Table 46 — NAM_Feedback message syntax

Syntax	Values	No. of bits	Mnemonic
NAMF_message(){			
message_id		16	unsigned short
version		8	unsigned char
length		16	unsigned short
extension {			
NAM_flag		1	unsigned integer
reserved	'111 1111'	7	unsigned integer
}			
message_payload {			
if(NAM_flag == 0) {			
CLI_id		8	unsigned integer
relative_available_bitrate		8	float
relative_buffer_fullness		8	float
relative_peak_bitrate		8	float
average_bitrate_period		16	unsigned integer
current_delay		32	float
generation_time		32	float
BER		32	float
}			
else if(NAM_flag == 1) {			
CLI_id		8	unsigned integer
available_bitrate		32	float
buffer_fullness		32	float
peak_bitrate		32	float
current_delay		32	float
average_bitrate_period		16	unsigned interger

Table 46 *(continued)*

Syntax	Values	No. of bits	Mnemonic
SDU_size		32	unsigned integer
SDU_loss_ratio		8	unsigned integer
generation_time		32	float
BER		32	float
}			
}			
}			

10.4.7.2 Semantics

`message_id` – indicates the NAMF message ID. The length of this field is 16 bits.

`version` – indicates the version of NAMF messages. The MMT receiving entity may check whether the received message is new or not. The length of this field is 8 bits.

`length` – indicates the length of NAMF messages. The length of this field is 16 bits. It indicates the length of the NAM feedback message counted in bytes starting from the next field to the last byte of the NAM Feedback message. The value "0" shall not be used.

`NAM_flag` – indicates whether the NAMF message contains absolute NAM information or relative NAM information. The value "1" should be set, if the NAMF message contains absolute NAM information.

`CLI_id` – is an arbitrary integer number to identify this NAM among the underlying network.

`relative_available_bitrate` – the available bitrate change ratio (%) between the current NAM information and the previous NAM information.

`relative_buffer_fullness` – the remaining buffer fullness change ratio (%) between the current NAM information and the previous NAM information.

`relative_peak_bitrate` – the peak bitrate change ratio (%) between the current NAM information and the previous NAM information.

`available_bitrate` – is the bitrate that the scheduler of the underlying network can guarantee to the MMT stream. The `available_bitrate` is expressed in kilobits per second. Overhead for the protocols of the underlying network is not included.

`buffer_fullness` – the buffer is used to absorb excess bitrate higher than the `available_bitrate`. The `buffer_fullness` is expressed in bytes.

`peak_bitrate` – the `peak_bitrate` is the maximum allowable bitrate that the underlying network can assign to the MMT stream. The `peak_bitrate` is expressed in kilobits per second. Overhead for the protocols of the underlying network is not included.

`current_delay` – this parameter indicates the last hop transport delay. The `current_delay` is expressed in milliseconds.

`average_bitrate_period` – provides the period of time over which the average bitrate of the input of the MMT procotol session that carries the MMTP packet shall be calculated. The `average_bitrate_period` is provided in units of milliseconds.

`SDU_size` – Service data unit (SDU) is data unit in which the underlying network delivers the MMT data. The `SDU_size` specifies the length of the SDU and is expressed in bits. Overhead for the protocols of the underlying network is not included.

SDU_loss_ratio – the SDU_loss_ratio is a fraction of SDUs lost or detected as errorneous. Loss ratio of MMT packets can be calculated as a function of SDU_loss_ratio and SDU_size. The SDU_loss_ratio is expressed in percentile.

generation_time – the time when the parameters are generated. The generation_time is expressed in milliseconds.

BER – bit error rate obtained from the PHY or MAC layer. For BER from PHY layer, this value is presented as a positive value. For BER from the MAC layer, this value is presented as a negative value which can be used as an absolute value.

10.4.8 Low delay consumption (LDC) message

10.4.8.1 General

The LDC Message provides information required to decode and present media data by the MMT receiving entity before it receives metadata such as movie fragment headers. This message indicates that the duration of each sample is fixed as signalled by default_sample_duration in Track Extends Box and the coding dependency structure is fixed across an Asset. When this message is used, the value of decoding time of the first sample of MPU is smaller than the presentation time of the first sample of the MPU by the sum of base_presentation_time_offset and the largest value of sample_composition_time_offset_value paired sample_composition_time_offset_sign is "1."

10.4.8.2 Syntax

The syntax of the low delay consumption message is defined in Table 47.

Table 47 — Low delay consumption message syntax

Syntax	Values	No. of bits	Mnemonic
LDC_message ( ){			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
message_payload {			
base_presentation_time_offset		**31**	**uimsbf**
coding_dependency_structure_flag		**1**	**bslbf**
if (coding_dependency_structure_flag == 1){			
period_of_intra_coded_sample	**N1**	**8**	**uimsbf**
for (i=0 ; i<N1;i++){			
sample_composition_time_offset_sign		**1**	**bslbf**
sample_composition_time_offset_value		**31**	**uimsbf**
}			
}			
}			
}			

10.4.8.3 Semantics

message_id – indicates the identifier of the LDC message.

version – version of the LDC messages. An MMT receiving entity can use this field to check the version of the received LDC message.

length – length of the LDC messages in bytes, counting from the first byte of the next field to the last byte of the LDC message. The value "0" is not valid for this field.

base_presentation_time_offset – provides information about the time difference between decoding time and presentation time in microseconds. The presentation time of each sample shall be greater than the decoding time with this value. This shall not include any difference between the decoding time and presentation time of samples incurred due to reordering of decoded media data.

coding_dependency_structure_flag – provides an indication that the decoding order and presentation order of samples are different from each other. If this flag is set to "0", the decoding order shall be same with the presentation order of samples. If this flag is set to "1", the decoding order shall be different from the presentation order of samples and detailed composition time offset shall be provided in this message for the client to calculate the appropriate decoding time and presentation time of the samples.

period_of_intra_coded_sample – provides the number of samples between two independently coded samples.

sample_composition_time_offset_sign – provides the arithmetic sign of offset added to the difference between decoding time and composition time of sample.

sample_composition_time_offset_value – provides the value of the offset added to the difference between the decoding time and the composition time. If the value of sample_composition_time_offset_sign is "0", then the difference between the value of composition time and the value of decoding time is decreased in microseconds. If the value of sample_composition_time_offset_sign is "1" then the difference between the value of composition time and the value of decoding time is increased in microseconds.

10.4.9 HRBM removal message

10.4.9.1 General

The HRBM removal message provides information on the management of the MMT de-capsulation buffer depending on the operation mode of the client as specified in Clause 11. This message provides information required to calculate both the initial delay before starting the removal of data from the MMTP de-capsulation buffer and the rate of removing data from the MMTP de-capsulation buffer. If this message is signalled, the client shall choose one of operation modes with the maximum required buffer size signalled by this message to prevent overflow or underflow of the MMTP de-capsulation buffer. Depending on the mode chosen by the client, either a complete MPU, a movie fragment or a single MFU is recovered and the reconstructed data is forwarded to the upper layer such as the media engine.

10.4.9.2 Syntax

The syntax for HRBM Removal message is defined in Table 48.

Table 48 — HRBM Removal message syntax

Syntax	Values	No. of bits	Mnemonic
HRBM_Removal_message( ){			
message_id		**16**	**uimsbf**
version		**8**	**uimsbf**
length		**16**	**uimsbf**
message_payload {			
number_of_operation_modes		**8**	**uimsbf**
for(i=0; i<number_of_operation_mode; i++){			
data_removal_type		**8**	**uimsbf**

Table 48 *(continued)*

Syntax	Values	No. of bits	Mnemonic
max_decapsulation_buffer_size		**32**	**uimsbf**
}			
buffer_management_valid		**1**	**bslbf**
reserved		**7**	**uimsbf**
}			
}			

10.4.9.3 Semantics

`message_id` – indicates the identifier of the `HRBM_Data_Removal` message.

`version` – version of the `HRBM_Data_Removal` messages. An MMT receiving entity can use this field to check the version of the received `HRBM_Data_Removal` message.

`length` – length of the `HRBM_Data_Removal` messages in bytes, counting from the first byte of the next field to the last byte of the `HRBM_Data_Removal` message. The value "0" is not valid for this field.

`number_of_operation_modes` – provides the number of operation modes a client can choose to operate.

`data_removal_type` – provides the information for the type of operation mode of client removing data reconstructed at the MMTP de-capsulation buffer defined in HRBM in Clause 11. For each mode, a required buffer size is provided (see values in Table 49).

Table 49 — data_removal_type values

Value	Description
0x00	Reserved
0x01	Client can remove complete MPUs (MPU mode)
0x02	Client can remove complete movie fragments (movie fragment mode)
0x03	Client can remove complete MFUs (MFU mode)
0x04 ~ 0x9F	Reserved for ISO use
0xA0 ~0xFF	Reserved for private use

`max_decapsulation_buffer_size` – provides the information for the required maximum size of the MMTP de-capsulation buffer in bytes of MMT Assets.

`buffer_management_valid` – provides the information whether the buffer management mechanism defined for an Asset is applied. If this flag is set to "0", no restriction to both the initial delay before starting the removal of data from the MMTP de-capsulation buffer and the rate of removing data from the MMTP de-capsulation buffer are applied. Reconstructed data shall be available at the MMTP de-capsulation buffer until the buffer becomes full. Reconstructed data shall be removed from the oldest one according to the operation mode chosen by the client when the buffer is full to add newly-recovered data. If this flag is set to "1", appropriate information to calculate both the initial delay before starting the removal of data from the MMTP de-capsulation buffer and the rate of removing data from the MMTP de-capsulation buffer shall be carried in the media data based on external specification.

10.4.10 ADC message

10.4.10.1 General

An ADC message carries information on ADC which defines QoS requirements and statistics of Asset for delivery, and their associated QoE quality information in alignment with

ISO/IEC 23001-10. Additional operating points can be derived from stream sub-representation via a new `sample_group_index structure`. This is especially useful for low delay streaming applications where quality can be traded for delay reduction. This information can be used by the MMT-aware intermediate network entities for QoS-managed delivery of Assets. To provide more accurate information, the MMT sending entity can update parameter values within ADC message and send it periodically or aperiodically. ADC information delivery can be done both in per-Asset basis and per-MPU basis considering its size.

10.4.10.2 Syntax

The syntax of the ADC message is defined in Table 50.

Table 50 — ADC message syntax

Syntax	Value	No. of bits	Mnemonic
ADC_message () {			
message_id		16	uimsbf
version		8	uimsbf
length		32	uimsbf
message_payload {			
validity_start_time		32	uimsbf
validity_duration		32	uimsbf
ADC_level_flag		1	boolean
flow_label_flag		1	boolean
reserved		6	uimsbf
if (ADC_level_flag == 1){			
MPU_sequence_number		32	uimsbf
}			
packet_id		16	uimsbf
qos_descriptor{			uimsbf
loss_tolerance		8	bslbf
jitter_sensitivity		8	bslbf
class_of_service		1	boolean
bidirection_indicator		1	boolean
reserved		6	bslbf
}			
qoe_descriptor{			
n_samples		16	uimsbf
for (i=0;i<N1; i++) {			
sample_group_index		16	uimsbf
}			
spatial_quality		16	uimsbf
temporal_quality		16	uimsbf
aggregate_rate		32	uimsbf
}			
if (class_of_service == 1)			
bitstream_descriptor_vbr{			
sustainable_rate		16	uimsbf
buffer_size		16	uimsbf

Table 50 *(continued)*

Syntax	Value	No. of bits	Mnemonic
peak_rate		**16**	**uimsbf**
max_MFU_size		**8**	**uimsbf**
mfu_period		**8**	**uimsbf**
}else			
bitstream_descriptor_cbr{			
peak_rate		**16**	**uimsbf**
max_MFU_size		**8**	**uimsbf**
mfu_period		**8**	**uimsbf**
}			
If(flow_label_flag == 1) {			
flow_label		**7**	**uimsbf**
reserved		**1**	**uimsbf**
}			
}			
}			

10.4.10.3 Semantics

`message_id` – indicates the identifier of the ADC messages.

`version` – indicates the version of the ADC messages.

`length` – a 32-bit field for conveying the length of the ADC message in bytes, counting from the beginning of the next field to the last byte of the ADC message. The value "0" is not valid for this field.

`validity_start_time` – indicates the time when the updated ADC message starts to be valid in UTC.

`validity_period_duration` – indicates the validity period duration of the updated ADC message from the `validity_start_time` in milliseconds. The value of this parameter within this ADC message is valid until this duration and the MANE does not need to capture the newer ADC message necessarily.

`ADC_level_flag (1 bit)` – indicates whether included ADC information is for an Asset or for an MPU. If set to "0", the ADC signalling message includes information for an Asset. If set to "1", it includes ADC information for a single MPU.

`flow_label_flag (1 bit)` – indicates whether included `flow_label` is used. If this flag is set to "1", the `flow_label` information is used.

`loss_tolerance` – indicates the required loss tolerance of the Asset for the delivery. The value of `loss_tolerance` attribute is listed in Table 1.

`jitter_sensitivity` – indicates the required jitter level of the underlying delivery network for the Asset delivery between end-to-end. The value of `jitter_sensitivity` attribute is listed in Table 2.

`class_of_service` – classifies the services in different classes and manages each type of bitstream with a particular way. For example, MANE can manage each type of bitstream with a particular way. This field indicates the type of bitstream attribute as listed in Table 3.

`Bidirection_indicator` – if set to "1", the bidirectional delivery is required. If set to "0", the bidirectional delivery is not required.

`bitstream_descriptor_vbr` – when `class_of_service` is "1", "`bitstream_descriptor_vbr`" shall be used for "`Bitstream_descriptorType`".

bitstream_descriptor_cbr – when class_of_service is "0", "bitstream_descriptor_cbr" shall be used for "Bitstream_descriptorType".

n_samples – defines the samples associated with this particular operating point.

spatial_quality – defines the spatial quality associated with samples that are conforming to the ISOBMFF quality format. Examples are PSNR and MSE.

temporal_quality – defines the temporal quality or distortion associated with samples that are computed from the ISOBMFF frame significance values.

aggregate_rate – defines the bitrate associated with the operating point.

sustainable_rate – defines the minimum bitrate that shall be guaranteed for continuous delivery of the Asset. The sustainable_rate corresponds to drain rate in the token bucket model. The sustainable_rate is expressed in bytes per second.

buffer_size – defines the maximum buffer size for delivery of the Asset. The buffer absorbs excess instantaneous bitrate higher than the sustainable_rate and the buffer_size shall be large enough to avoid overflow. The buffer_size corresponds to bucket depth in the token bucket model. Buffer_size of a constant bit rate (CBR) Asset shall be zero. The buffer_size is expressed in bytes.

peak_rate – defines peak bitrate during continuous delivery of the Asset. The peak_rate is the highest bitrate during every MFU_period. The peak_rate is expressed in bytes per second.

MFU_period – defines period of MFUs during continuous delivery of the Asset. The MFU_period measured as the time interval of sending time between the first byte of two consecutive MFUs. The MFU_period is expressed in millisecond.

max_MFU_size – indicates the maximum size of MFU, which is MFU_period*peak_rate. The max_MFU_size is expressed in bytes.

flow_label – indicates the flow identifier. The application can perform per-flow QoS operations in which network resources are temporarily reserved during the session. A flow is defined to be a bitstream or a group of bitstreams whose network resources are reserved according to transport characteristics or ADC in Package. It is an implicit serial number from "0" to "127". An arbitrary number is assigned temporarily during a session and refers to every individual flow for whom a decoder (processor) is assigned and network resource could be reserved.

packet_id (16 bits) – this field is an integer value that can be used to distinguish one Asset from another. The value of this field is derived from the asset_id of the Asset where this packet belongs to. The mapping between the packet_id and the asset_id is signalled by the Package Table as part of a signalling message (see 10.3.4). The packet_id is unique throughout the lifetime of the delivery session and for all MMT flows delivered by the same MMT sending entity. For AL-FEC, the mapping between the packet_id and the FEC repair flow is provided in the AL-FEC message (see C.6).

10.5 Descriptors

10.5.1 CRI descriptor

10.5.1.1 General

This subclause describes the descriptors and information related to signalling tables.

A CRI descriptor can be used to specify the relationship between the NTP timestamp and the MPEG-2 STC for synchronization purpose. The value of clock reference used by the Asset which is derived from the MPEG-2 TS is specified in the clock_relation_id field.

CRI_descriptors are carried in a CRI table.

10.5.1.2 Syntax

The syntax of the `CRI_descriptor()` is defined in Table 51.

Table 51 — CRI_descriptor() syntax

Syntax	Value	No. of bits	Mnemonic
`CRI_descriptor() {`			
descriptor_tag		**16**	**uimsbf**
descriptor_length		**16**	**uimsbf**
clock_relation_id		**8**	**uimsbf**
reserved	"11 1111"	**6**	**uimsbf**
STC_sample		**42**	**uimsbf**
NTP_timestamp_sample		**64**	**uimsbf**
`}`			

10.5.1.3 Semantics

`descriptor_tag` – a tag value indicating the type of a descriptor.

`descriptor_length` – indicates the length in bytes counting from the next byte after this field to the last byte of the descriptor.

`clock_relation_id` – the identifier of a clock relation.

`STC_sample` – contains the MPEG-2 STC value that corresponds to the following `NTP_timestamp_sample`. The sample value of STC is in 42-bit format.

`NTP_timestamp_sample` – the sample value of NTP timestamp that corresponds to the preceding `STC_sample`.

10.5.2 MPU timestamp descriptor

10.5.2.1 General

This descriptor provides presentation time of the first AU of MPU in presentation order after application of any offset such as the one provided by the "`elst`" box. When presentation information (PI) is present, this descriptor shall be ignored.

10.5.2.2 Syntax

The syntax of the `MPU_timestamp_descriptor()` is defined in Table 52.

Table 52 — MPU timestamp descriptor

Syntax	Value	No. of bits	Mnemonic
`MPU_timestamp_descriptor () {`			
descriptor_tag		**16**	**uimsbf**
descriptor_length	**N*12**	**8**	**uimsbf**
`for (i=0; i<N; i++) {`			
mpu_sequence_number		**32**	**uimsbf**
mpu_presentation_time		**64**	**uimsbf**
`}`			
`}`			

10.5.2.3 Semantics

descriptor_tag – a tag value indicating the type of a descriptor.

descriptor_length – indicates the length in bytes counting from the next byte after this field to the last byte of the descriptor.

mpu_sequence_number – indicates the sequence number of the MPU presented at a time given the following mpu_presentation_time.

mpu_presentation_time – indicates the presentation time of the first AU in the designated MPU by the 64-bit NTP time stamp format.

10.5.3 Dependency descriptor

10.5.3.1 General

For each dependent Asset, a dependency descriptor as specified below shall be included in the MPT, within the syntax element asset_descriptors specified in Table 53.

10.5.3.2 Syntax

The syntax of the Dependency_descriptor() is defined in Table 53.

Table 53 — Syntax of dependency descriptor for layered media

Syntax	Value	No. of bits	Mnemonic
Dependency_descriptor() {			
descriptor_tag		**16**	**uimsbf**
descriptor_length		**16**	**uimsbf**
num_dependencies	N1	**8**	**uimsbf**
for (i = 0 ; i < N1 ; i++) {			
asset_id()			
}			
}			

10.5.3.3 Semantics

descriptor_tag – a tag value indicating the type of this descriptor.

descriptor_length – indicates the length in bytes counting from the next byte after this field to the last byte of the descriptor.

num_dependencies – indicates the number of complementary Assets the dependent Asset associated with this descriptor depends on.

asset_id – indicates the asset_id as defined in 10.6.2 of another Asset on which the dependent Asset associated with this descriptor depends. The order of the id-s provided in this descriptor is such that the concatenation of MPUs as defined in 6.4 leads to a valid MPU and follows the media dependency hierarchy.

10.5.4 GFDT descriptor

10.5.4.1 General

A GFDT descriptor contains one or more CodePoints describing association with a specific object and object delivery properties. An MPT may contain a GFD descriptor for each Asset if the MPU(s) consisting the Asset is/are delivered through GFD mode.

10.5.4.2 Syntax

The syntax of GFD descriptor is defined in Table 54 and the semantics of its syntax elements are described in 9.3.3.2.2.

Table 54 — GFDT descriptor syntax

Syntax	Value	No. of bits	Mnemonic
GFD_descriptor () {			
descriptor_tag		16	uimsbf
descriptor_length		32	uimsbf
number_of_CodePoints	N1	8	uimsbf
for(i=0; i<N1; i++) {			
value		8	uimsbf
fileDeliveryMode		2	bslbf
constantTransferLength_flag		1	bslbf
outOfOrderSending_flag		1	bslbf
FileTemplate_flag		1	bslbf
startTOI_flag		1	bslbf
endTOI_flag		1	bslbf
EntityHeader_flag		1	bslbf
maximumTransferLength		48	uimsbf
if(FileTemplate_flag == 1) {			
FileTemplate_length	N2	8	uimsbf
for(j = 0; j < N2; j++)			
FileTemplate_byte		8	uimsbf
} else {			
File_length	N3	16	uimsbf
for(j = 0; j < N3; j++)			
File_byte		8	uimsbf
}			
if(startTOI_flag == 1)			
startTOI			uimsbf
if(endTOI_flag == 1)			
endTOI			uimsbf
if(EntityHeader_flag == 1) {			
EntityHeader_length	N4	16	uimsbf
for(j = 0; j < N4; j++)			
EntityHeader_byte		8	uimsbf

Table 54 *(continued)*

Syntax	Value	No. of bits	Mnemonic
}			
}			
}			

10.5.4.3 Semantics

`descriptor_tag` – a tag value indicating the type of a descriptor.

`descriptor_length` – specifies the length in bytes counting from the next byte after this field to the last byte of the descriptor.

`number_of_CodePoints` – specifies the number of CodePoints contained in this GFD descriptor. This field shall not be set to 0.

`value` – specifies the value of the CodePoint. The value shall be between 1 and 255. The value 0 is reserved.

`fileDeliveryMode` – specifies the file delivery mode according to Table 18. If this field is "1", the delivered object is a regular file and if it is "2", the delivered object is an entity consisting of an entity header and the file.

`constantTransferLength_flag` – specifies if all objects delivered by this CodePoint have constant transfer length. If this flag is set to "1", all objects shall have the transfer length as specified in the maximumTransferLength field. The default value is 0.

`outOfOrderSending_flag` – specifies if an outOfOrderSending attribute is included in this GFD descriptor. If this flag is set to "1", the outOfOrderSending attibute is included in this GFD descriptor. The default value is 0.

`FileTemplate_flag` – specifies if a file template for this CodePoint is included in this GFD descriptor. If this flag is set to "1", `FileTemplate_length` and `FileTemplate_byte` are included in this GFD descriptor.

`startTOI_flag` – specifies if a startTOI is included in this GFD descriptor. If this flag is set to "1", a startTOI is included in this GFD descriptor.

`endTOI_flag` – specifies if an endTOI is included in this GFD descriptor. If this flag is set to "1", an endTOI is included in this GFD descriptor.

`EntityHeader_flag` – specifies if an entity header for this CodePoint is included in this GFD descriptor. If this flag is set to "1", `EntityHeader_length` and `EntityHeader_byte` are included in this GFD descriptor.

`maximumTransferLength` – specifies the maximum transfer length in bytes of any object delivered with the CodePoint set in value field.

`FileTemplate_length` – specifies the length in byte of the file template.

`FileTemplate_byte` – specifies a byte in the file template (e.g. UTF-8, null terminated string).

`startTOI` – specifies the TOI of the first object that is delivered. The length of startTOI is varied according to the length of the TOI field in the MMTP payload for GFD mode with the same CodePoint value set in the value of this GFD descriptor.

`endTOI` – specifies the TOI of the last object that is delivered. The length of endTOI is varied according to the length of the TOI field in the MMTP payload for GFD mode with the same CodePoint value set in the value of this GFD descriptor.

EntityHeader_length – specifies the length in byte of the entity-header.

EntityHeader_byte – specifies a byte in the entity-header. An entity header specifies a full entity header in the format as defined in IETF RFC 2616, 7.1. The entity-header applies for all objects that are delivered with the value of this CodePoint.

10.5.5 SI descriptor

10.5.5.1 General

The SI descriptor is an asset descriptor that can be used by the MMT sender to provide information about the content encryption applied to the asset as part of DRM protection or Conditional Access. For content protection using common encryption, the contents of this descriptor are extracted from the "pssh" box that is located as part of the MPU metadata.

10.5.5.2 Syntax

The syntax of the SI descriptor is defined in Table 55.

Table 55 — SI descriptor syntax

Syntax	Value	No. of bits	Mnemonic
SI_descriptor() {			
descriptor_tag		**16**	**uimsbf**
descriptor_length		**16**	**uimsbf**
security_system_count	**N1**	**8**	**uimsbf**
reserved	**"000 0000"**	**7**	**uimsbf**
system_provider_url_flag		**1**	**bslbf**
if (system_provider_url_flag) {			
system_provider_url_length	**N2**	**8**	**uimsbf**
for (i=0; i<N2; i++) {			
system_provider_url_byte		**8**	**uimsbf**
}			
}			
for (i=0;i<N1;i++) {			
system_id		**16*8**	**uimsbf**
kid_count	**N3**	**16**	**uimsbf**
for(j=0;j<N3;j++) {			
KID		**16*8**	**uimsbf**
}			
data_size	**N4**	**32**	**uimsbf**
for(j=0;j<N4;j++) {			
data		**8**	**uimsbf**
}			
}			
}			

10.5.5.3 Semantics

descriptor_tag – a tag value indicating the type of a descriptor.

descriptor_length – indicates the length in bytes counting from the next byte after this field to the last byte of the descriptor.

security_system_count – provides the number of DRM or CAS system information that can process and handle the content protection, access control and rights management.

system_provider_url_flag – indicates whether a URL location of a provider for the system is provided or not. If this flag is set to "1", a system provider URL is provided. This URL can be used for downloading and installing the system, when needed.

system_provider_url_length – provides the length of a system provider URL.

system_provider_url_byte – specifies a byte in a system provider URL.

system_id – provides the UUID that uniquely identifies the DRM system.

KID_count – specifies the number of KID entries in the descriptor.

KID – identifies a key that the data field applies to.

data_size – specifies the size in bytes of the data field.

data – carries DRM system specific data.

10.6 Syntax element groups

10.6.1 MMT_general_location_info

10.6.1.1 General

An MMT_general_location_info syntax element group is used to provide location information for the payload of the described item.

10.6.1.2 Syntax

The syntax of the MMT_general_location_info is defined in Table 56.

Table 56 — MMT_general_location_info syntax

Syntax	Value	No. of bits	Mnemonic
MMT_general_location_info() {			
location_type		**8**	**uimsbf**
if (location_type == 0x00) {			
packet_ id		**16**	**uimsbf**
} else if (location_type == 0x01) {			
ipv4_src_addr		**32**	**uimsbf**
ipv4_dst_addr		**32**	**uimsbf**
dst_port		**16**	**uimsbf**
packet_ id		**16**	**uimsbf**
} else if (location_type == 0x02) {			
ipv6_src_addr		**128**	**uimsbf**
ipv6_dst_addr		**128**	**uimsbf**
dst_port		**16**	**uimsbf**
packet_ id		**16**	**uimsbf**
} else if (location_type == 0x03) {			

Table 56 *(continued)*

Syntax	Value	No. of bits	Mnemonic
network_id		**16**	**uimsbf**
MPEG_2_transport_stream_id		**16**	**uimsbf**
reserved	"111"	**3**	**bslbf**
MPEG_2_PID		**13**	**uimsbf**
} else if (location_type == 0x04) {			
ipv6_src_addr		**128**	**uimsbf**
ipv6_dst_addr		**128**	**uimsbf**
dst_port		**16**	**uimsbf**
reserved	"111"	**3**	**bslbf**
MPEG_2_PID		**13**	**uimsbf**
} else if (location_type == '0x05') {			
URL_length	N1	**8**	**uimsbf**
for (i=0; i<N1; i++) {			
URL_byte		**8**	**char**
}			
} else if (location_type == '0x06') {			
length	N2	**16**	**uimsbf**
for (i=0;i<N2;i++) {			
byte		**8**	**uimsbf**
}			
} else if (location_type == '0x07') {			
}			
} else if (location_type == '0x08') {			
message_id		**16**	**uimsbf**
} else if (location_type == '0x09') {			
packet_ id		**16**	**uimsbf**
message_id		**16**	**uimsbf**
} else if (location_type == '0x0A') {			
ipv4_src_addr		**32**	**uimsbf**
ipv4_dst_addr		**32**	**uimsbf**
dst_port		**16**	**uimsbf**
packet_ id		**16**	**uimsbf**
message_id		**16**	**uimsbf**
} else if (location_type == '0x0B') {			
ipv6_src_addr		**128**	**uimsbf**
ipv6_dst_addr		**128**	**uimsbf**
dst_port		**16**	**uimsbf**
packet_ id		**16**	**uimsbf**
message_id		**16**	**uimsbf**
} else if(location_type == '0x0C') {			
ipv4_src_addr		**32**	**uimsbf**
ipv4_dst_addr		**32**	**uimsbf**
dst_port		**16**	**uimsbf**
reserved	"111"	**3**	**bslbf**

Table 56 *(continued)*

Syntax	Value	No. of bits	Mnemonic
MPEG_2_PID		**13**	**uimbsf**
}			
}			

10.6.1.3 Semantics

`location_type` – this field indicates the type of the location information as defined in Table 57.

Table 57 — Value of location_type

Value	Description
0x00	An Asset in the same MMTP packet flow as the one that carries the data structure to which this `MMT_general_location_info()` belongs
0x01	MMTP packet flow over UDP/IP (version 4)
0x02	MMTP packet flow over UDP/IP (version 6)
0x03	An elementary stream within an MPEG-2 TS in a broadcast network.
0x04	An elementary stream (ES) in an MPEG-2 TS over the IP broadcast network
0x05	URL
0x06	Reserved for private location information
0x07	The same signalling message as the one that carries the data structure to which this `MMT_general_location_info()` belongs
0x08	A signalling message delivered in the same data path as the one that carries the data structure to which this `MMT_general_location_info()` belongs
0x09	A signalling message delivered in a data path in the same UDP/IP flow as the one that carries the data structure to which this `MMT_general_location_info()` belongs
0x0A	A signalling message delivered in a data path in a UDP/IP (version 4) flow
0x0B	A signalling message delivered in a data path in a UDP/IP (version 6) flow
0x0C	An elementary stream (ES) in an MPEG-2 TS over the IP v4 broadcast network
0x0D~0x9F	Reserved for ISO use
0xA0~0xFF	Reserved for private use

`packet_id` – `packet_id` in the MMTP packet header (see 9.2).

`ipv4_src_addr` – IP version 4 source address of an IP application data flow.

`ipv4_dst_addr` – IP version 4 destination address of an IP application data flow.

`dst_port` – destination port number of an IP application data flow.

`ipv6_src_addr` – IP version 6 source address of an IP application data flow.

`ipv6_dst_addr` – IP version 6 destination address of an IP application data flow.

`network_id` – broadcast network identifier that carries the MPEG-2 TS. This field is specific to the broadcast system in use.

`MPEG_2_transport_stream_id` – MPEG-2 TS identifier.

`MPEG_2_PID` – PID of the MPEG-2 TS packet carrying the ES.

`URL_length` – length in bytes of a URL. The terminating null (“0x00”) shall not be counted.

`URL_byte` – a byte data in a URL. The terminating null (“0x00”) shall not be included.

byte_offset – a byte offset from the first byte of a file.

length – the length of the byte range in bytes.

message_id – MMT signalling message identifier (see Table 62).

10.6.2 asset_id

10.6.2.1 General

An asset_id syntax element group is used to provide an Asset identifier. If the "mmpu" box is present, the values of this syntax element group shall be identical to the Asset identifier of that box. If not present, the assignment of Asset identification is outside the scope of this document.

10.6.2.2 Syntax

The syntax of the asset_id is defined in Table 58.

Table 58 — asset_id syntax

Syntax	Value	No. of bits	Mnemonic
asset_id(){			
asset_id_scheme		**32**	**uimsbf**
asset_id_length	**N1**	**32**	**uimsbf**
for (j=0; j<N1; j++) {			
asset_id_byte		**8**	**uimsbf**
}			
}			

10.6.2.3 Semantics

asset_id_scheme – provides the Asset ID scheme as defined in 7.3.3.

asset_id_length – provides the length in bytes of the asset_id.

asset_id_byte – specifies a byte in the asset_id.

10.6.3 Identifier mapping

10.6.3.1 General

This syntax group element provides a mapping of the content identifier and an MMTP packet sub-flow. The MMTP packet sub-flow is the subset of the packets of an MMTP packet flow that share the same packet_id. The content identifier may be provided in different forms, such as an asset identifier, a URL or a pattern.

10.6.3.2 Syntax

The syntax of the Identifier_mapping() is defined in Table 59.

Table 59 — Identifier_mapping

Syntax	Value	No. of bits	Mnemonic
Identifier_mapping () {			
identifier_type		**8**	**uimsbf**
if (identifier_type == 0x00) {			
asset_id()			
} else if (identifier_type == 0x01) {			
URL_count	N1	16	**uimsbf**
for(i=0;i<N1;i++) {			
URL_length[i]	N2	16	**uimsbf**
for(j=0;j<N2;j++){			
URL_byte[i]		8	**uimsbf**
}			
}			
} else if (identifier_type == 0x02) {			
regex_length	N3	16	**uimsbf**
for(i=0;i<N3;i++){			
regex_byte		8	**uimsbf**
}			
} else if (identifier_type == 0x03) {			
representation_id_length	N4	16	**uimsbf**
for (i=0;i<N4;++) {			
representation_id_byte		8	**uimsbf**
}			
} else {			
private_length	N5	16	**uimsbf**
for(i=0;i<N5;i++){			
private_byte		8	**uimsbf**
}			
}			
}			

10.6.3.3 Semantics

`identifier_type` – provides the type of the identifier that is used for the mapping to the `packet_id`. The list of available identifier types is defined in Table 60.

Table 60 — Identifier types for identifier mapping

Value	Description
0x00	The identifier of the content is provided as an Asset id as defined in 10.6.2.
0x01	The identifier of the content is provided as a list of URLs that are related together and share the same `packet_id` mapping. An example are DASH segments of the same representation.
0x02	The identifier of the content is provided as RegEx string that is used to match one or more URLs that identify files with the same `packet_id` mapping.
0x03	The identifier of the content is provided as a DASH Representation@id as defined in ISO/IEC 23009-1 to identify all DASH segments of the same representation.
0x04 ~ 0xFF	This value range is reserved for private identifiers.

`URL_count` – the URL is a list of URLs and this value indicates the number of URLs provided in this list.

`URL_length` – the length in bytes of the following URL.

`URL_byte` – a byte of the URL that is formatted as an UTF-8 character string.

`regex_length` – the identifier is provided as a regular expression that matches a set of URLs and this field indicates the length of the RegEx string.

`regex_byte` – a byte of the RegEx string that is provided as a UTF-8 string.

`representation_id_length` – the identifier is provided as a DASH Representation@id and this value indicates the length of the Representation@id string.

`representation_id_byte` – a byte of the Representation@id string.

`private_length` – the identifier is provided as private data and this field provides the length of the private identifier in bytes.

`private_byte` – a byte of the private identifier.

10.6.4 mime_type

10.6.4.1 General

This syntax element provides a MIME type as a string.

10.6.4.2 Syntax

The syntax of the `mime_type()` element is defined in Table 61.

Table 61 — mime_type ()

Syntax	Value	No. of bits	Mnemonic
`mime_type () {`			
`  mime_type_length`	N1	8	uimsbf
`  for(i=0;i<N1;i++) {`			
`    mime_type_byte`		8	uimsbf
`  }`			
`}`			

10.6.4.3 Semantics

`mime_type_length` – the length of the MIME type string.

`mime_type_byte` – a byte of the MIME type string, which is provided as a UTF-8 string.

10.7 ID and tags values

The values of the message identifier (`message_id`) are defined in Table 62.

Table 62 — Message identifier (message_id) values

Value	Description
0x0000	PA message
0x0001 ~ 0x0010	MPI messages For a Package, 16 contiguous values are allocated to MPI messages. If the value equals 16 (0x0010), the MPI message carries complete PI. If the value equals N where N = 1 ~ 15, the MPI message carries Subset-(N-1) PI.
0x0011 ~ 0x0020	MPT messages For a package, 16 contiguous values are allocated to MPT messages. If the value equals 32 (0x0020), the MPT message carries complete MPT. If the value equals N where N = 1 ~ 15, the MPT message carries Subset-(N-1) MPT.
0x0021 ~ 0x01FF	Reserved
0x0200	CRI message
0x0201	DCI message
0x0202	SSWR message
0x0203	AL_FEC message
0x0204	HRBM message
0x0205	MC message
0x0206	AC message
0x0207	AF message
0x0208	RQF message
0x0209	ADC message
0x020A	HRBM Removal message
0x020B	LS message
0x020C	LR message
0x020D	NAMF message
0x020E	LDC message
0x020F ~0x6FFF	Reserved for ISO use (16-bit length message)
0x7000 ~0x7FFF	Reserved for ISO use (32-bit length message)
0x8000 ~ 0xFFFF	Reserved for private use

The values of the table identifier (`table_id`) are defined in Table 63.

Table 63 — Table identifier (table_id) values

Value	Description
0x00	PA table
0x01	Main PI (Subset 0 MPI table)
0x02 ~ 0x0F	Subset 1 MPI table ~ Subset 14 MPI table
0x10	Complete MPI table
0x11 ~ 0x1F	Subset 0 MP table (`SUBSET_0_MPT_TABLE_ID`) ~ Subset 14 MP table
0x20	Complete MP table
0x21	CRI table
0x22	DCI table

Table 63 *(continued)*

Value	Description
0x23	SIT table
0x24 ~0x7F	Reserved for ISO use (16-bit length table)
0x80 ~ 0xFF	Reserved for private use

The values of descriptor tag are defined in Table 64.

Table 64 — Descriptor tag values

Value	Description
0x0000	CRI descriptor
0x0001	MPU timestamp descriptor
0x0002	Dependency descriptor
0x0003	GFDT descriptor
0x0004	SI descriptor
0x0005 ~ 0x3FFF	Reserved for ISO use (8-bit length descriptor)
0x4000 ~ 0x6FFF	Reserved for ISO use (16-bit length descriptor)
0x7000 ~ 0x7FFF	Reserved for ISO use (32-bit length descriptor)
0x8000 ~0xFFFF	Reserved for private use

11 Hypothetical receiver buffer model (HRBM)

11.1 General

The HRBM is used to ensure an effective MMT operation under a fixed end-to-end delay and limited memory requirements for buffering of incoming MMTP packets. The hypothetical receiver buffer model shall be used by the MMT sending entity to emulate the behaviour of the receiving entity. It is described in the following subclauses in more detail.

An MMT sending entity shall run the hypothetical receiver buffer model to ensure that any processing it performs on the packet stream is within the reception constraints in the MMT receiving entity. The sending entity shall determine the required buffering delay and the required buffer size and shall signal this information to the receiving entities.

At the receiving entity, several buffers are involved in the reconstruction of an MPU from the MMTP packets received. Some delivery operations, such as FEC coding, interleaving and retransmission, introduce delay and jitter that requires buffering at the receiving entity. The hypothetical receiver buffer model defines operations of the buffers at the receiving entity to ensure that at any time the buffer occupancy is within the buffer size requirement. The buffers, whose operation is defined, are depicted in Figure 22 and are described in detail in 11.2. The MMT HRBM is applied per each MMTP sub-flow, i.e. for all MMTP packets of an MMTP flow that share the same `packet_id`. The actual set of buffers is determined based on the configuration of the delivery session for that particular MMTP sub-flow.

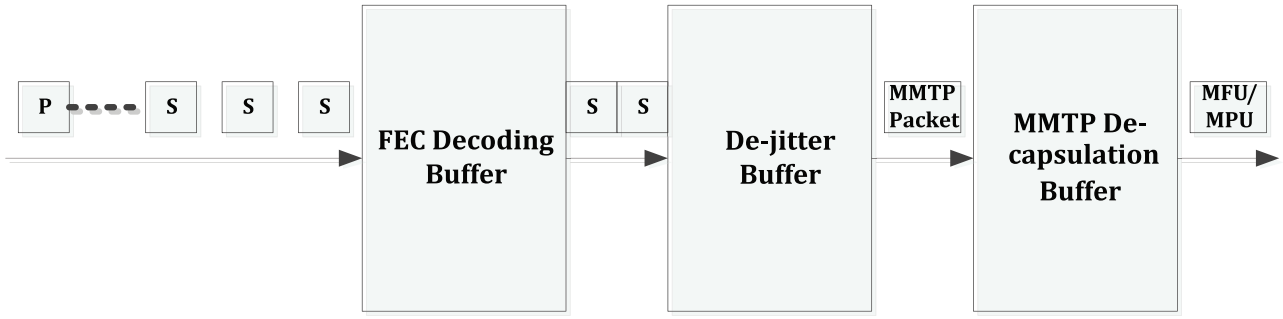


Figure 22 — MMT protocol hypothetical receiver model

11.2 FEC decoding buffer

The FEC decoding buffer is optional and is only required when FEC protection is applied to the MMTP packet sub-flow (e.g. for packets of a particular asset). FEC decoding is typical for many applications, where lower layer transmission may not be sufficient to recover messages from channel errors or when network congestion may cause packet drops or excessive delays. To perform FEC decoding, a buffer is required where incoming packets are stored until sufficient source and repair symbol data are available to perform the FEC decoding.

In this hypothetical receiver buffer model, the FEC decoding buffer is optional and shall operate as follows.

— The FEC decoding buffer is initially empty.

— Incoming packet `i` with transmission timestamp `ts` arrives to the FEC decoding buffer. If `buffer_occupancy + packet_size < max_buffer_size`, accept the packet or otherwise mark the packet as being non-compliant.

— If FEC is applied to packet `i`,

  — determine the source block `j` to which packet `i` belongs;

  — determine the insertion time `ts` of the first packet of source block `j`;

  — at time `ts+protection_window_time`, move all packets of source block `j` to the de-jitter buffer;

  — discard repair packets.

The `protection_window_time` is the required buffering time that must elapse since the reception of the first packet of a source block, until FEC decoding is attempted. This time is typically calculated based on the FEC block size.

11.3 De-jitter buffer

The de-jitter buffer ensures that MMTP packets experience a fixed transmission delay from source to the output of the MMT protocol stack, assuming a maximum transmission delay. Data units that experience a transmission delay larger than the maximum transmission delay might be discarded by the MMT receiving entity.

The de-jitter buffer shall operate as follows.

— The de-jitter buffer is initially empty.

— Accept the MMTP packet as it arrives.

— Remove the MMTP packet at time `ts+Δ`, where `ts` is the timestamp of the MMTP packet and Δ is the signaled fixed end-to-end delay (as described in 10.4.2).

After the de-jittering is applied, all MMTP packets that arrived correctly or were recovered through FEC/retransmissions will have experienced the same end-to-end delay.

NOTE Annex A shows jitter calculation in MMTP.

11.4 MMTP packet decapsulation buffer

The MMTP packet decapsulation buffer is used to perform MMTP packet processing before delivering the payload to the upper layers. The output of the MMTP packet processing may either be the MFU payload (in low-delay operation), a movie fragment or a complete MPU. The decapsulation (removal of the MMTP packet and payload headers) and any required de-fragmentation/de-aggregation of the packets are then performed as part of the MMTP processing. This procedure may require some buffering delay, denoted as decapsulation delay, to reconstruct the data to be passed to the application layer. However, the decapsulation delay is not considered as part of the transmission delay and the availability of the data for consumption by the upper layers will be guaranteed by the entity delivering the MPU, regardless of the decapsulation delay.

The MMTP packet decapsulation buffer shall work as follows.

— The MMTP packet decapsulation buffer is initially empty.

— The MMTP packet is inserted into the MMTP packet decapsulation buffer immediately after the de-jittering is performed.

— For MMTP packets carrying aggregated payload, remove the packet and payload header and extract each single data unit.

— For MMTP packets carrying fragmented payload, the packet is kept in the buffer until all corresponding fragments are received correctly or until a packet is received that does not belong to the same fragmented data unit.

— Depending on the operation mode of the client, if a complete MPU, a movie fragment or a single MFU is recovered, forward the reconstructed data to the upper layer.

11.5 Usage of HRBM

Based on the hypothetical receiver buffer model, an MMT sending entity is able to determine the transmission schedule, the buffer size and the buffering delay Δ, so that no packets are dropped due to buffer overflow, assuming a maximum delivery delay in the target path. The MMT sending entity shall guarantee that packets that experience a transmission delay below a set threshold will be delivered to the upper layer after a constant delay and without causing the MMT receiving entity buffer to underflow or overflow.

11.6 Estimation of end-to-end delay and buffer requirement

An MMT sending entity shall estimate the maximum expected and tolerable transmission delay in the transmission path down to an MMT receiving entity. If FEC is in use, the MMT sending entity shall add the FEC buffering delay that covers for the time needed to assemble a source block since FEC decoding is required to recover lost MMTP packets. Finally, any delays that might be incurred by fragmentation of packets (and other operations) shall be added. The resulting estimation of the MMTP packet delivery delay shall then be signalled to the MMT receiving entities as the fixed end-to-end transmission delay.

fixed end-to-end = maximum transmission delay + FEC buffering time

In order to estimate the resulting buffer requirement, the MMT sending entity shall use the fixed end-to-end delay and subtract the minimum transmission delay for the path down to the MMT receiving

entity and then estimate the buffer size requirement as the product of the maximum bitrate of the MMTP packet stream and the calculated buffered data duration.

$$buffer\ size = (maximum\ delay - minimum\ delay) \times maximum\ bitrate$$

11.7 HRBM signalling

After determining the required buffer size and the fixed end-to-end delay for the system, an MMT sending entity shall communicate this information to the MMT receiving entity. This is done using the HRBM signalling message as specified in 10.4.2. The MMT sending entity continuously runs the hypothetical receiver buffer model to verify that the selected end-to-end delay and buffer size are aligned and do not cause buffer under-runs or overruns. At the MMT receiving entity side, the MMT receiving entity shall perform the buffering as instructed, so that each data unit experiences the signalled fixed end-to-end delay Δ before its payload is delivered to the application layer. Under the assumption that clocks are synchronized, the output time is then calculated based on the transmission timestamp and the signalled fixed end-to-end delay.

12 Cross layer interface (CLI)

12.1 General

Cross layer interface provides the means within the single MMT entity to support QoS by exchanging QoS-related information between the application layer and underlying layers including the MAC/PHY layer. The application layer provides information about media characteristics as top-down QoS information while underlying layers provide bottom-up QoS information such as network channel condition.

CLI provides the unified interface between the application layer and various network layers including IEEE 802.11 WiFi, IEEE 802.16 WiMAX, 3G, 4G LTE, etc. Common network parameters of popular network standards are abstracted as the NAM for static and dynamic QoS control of real-time media application through any network.

12.2 Cross layer information

12.2.1 General

MMT defines an interface for exchanging cross layer information between the application layer and the underlying network layer. The interface allows for top-down as well as bottom-up flow of cross layer information. The cross layer information provides QoS information that may be used by the involved functions to optimize the overall delivery of the media data. MMT entities may support this interface for cross layer information.

12.2.2 Top-down QoS information

The application layer provides top-down QoS information about media characteristics to underlying layers. There are two kinds of top-down information such as Asset level information (e.g. ADC) and packet level information. Asset information is used for capability exchange and/or (re)allocation of resources in underlying layers. Packet level top-down information is written in the appropriate field of every packet for underlying layers to indentify QoS level to support.

12.2.3 Bottom-up QoS information

The underlying layers provide bottom-up QoS information to the application layer about time-varying network condition which enables faster and more accurate QoS control in the application layer. Bottom-up information is represented as an abstracted fashion to support heterogeneous network environments. These parameters are measured in the underlying layers and read by the application layer, periodically or on request of the MMT application.

12.2.4 Network abstraction for media (NAM)

12.2.4.1 General

Network abstraction for media (NAM) is used for an interface between application layers and underlying layers. NAM provides unified representation of network QoS parameters for assuring to communicate with legacy and future standards of underlying layers.

If an MMT receiving entity supports CLI, it shall support the generation of all CLI parameters.

12.2.4.2 Absolute NAM

Absolute NAM is raw QoS value measured in each appropriate unit. For example, bitrate is represented in the unit of bits per second while jitter is in the unit of second.

12.2.4.3 Relative NAM

Relative NAM represents the ratio of the expected NAM value to the current NAM value so that it is unit-less and informs tendency of change.

12.2.5 Syntax

The CLI information is exchanged using a Network Abstraction for Media (NAM) or a relative NAM.

The syntax of the absolute parameters for NAM is defined in Table 65.

Table 65 — Absolute NAM

Syntax	Size (bits)	Mnemonic
NAM {		
CLI_id	8	unsigned integer
available_bitrate	32	float
buffer_fullness	32	float
peak_bitrate	32	float
average_bitrate_period	16	unsigned integer
current_delay	32	float
SDU_size	32	unsigned integer
SDU _loss_ratio	8	unsigned integer
generation_time	32	unsigned integer
BER	32	float
}		

The syntax of the relative parameters for NAM is defined in Table 66.

Table 66 — Relative NAM

Syntax	Size (bits)	Mnemonic
relative_NAM {		
CLI_id	8	unsigned integer
relative_bitrate	8	float
relative_buffer_fullness	8	float
relative_peak_bitrate	8	Float
average_bitrate_period	16	unsigned integer

Table 66 *(continued)*

Syntax	Size (bits)	Mnemonic
current_delay	**32**	**float**
generation_time	**32**	**float**
BER	**32**	**float**
}		

12.2.6 Semantics

CLI_id – is an arbitrary integer number to identify the underlying MMT delivery network for the MMT protocol session.

NOTE Identification of MMT protocol session is outside the scope of this document.

available_bitrate – is the instantaneous bitrate at measured generation_time that the scheduler of the underlying network expects to be available for the MMTP session which carries the MMTP packet. The available_bitrate is expressed in kilobits per second. Overhead for the protocols of the underlying network is not included.

buffer_fullness – signals the buffer level of the generating function. The buffer is used to absorb any excess data caused by the data rates above the available_bitrate. The buffer_fullness is expressed in bytes.

peak_bitrate – is maximum allowable bitrate at measured generation_time that the underlying network is able to handle temporarily as input from to the MMTP session which carries the MMTP packet. The peak_bitrate is expressed in kilobits per second. Overhead for the protocols of the underlying network is not included.

average_bitrate_period – provides the period of time over which the average bitrate of the input of MMT procotol session that carries the MMT packet shall be calculated. The average_bitrate_period is provided in units of milliseconds.

current_delay – is measured transport time for delay between the last hop network entity and receiving entity. The current_delay is expressed in milliseconds.

SDU_size – specifies the length of the service data unit (SDU) in which the underlying network carries the MMTP packet over the MMTP session. It is expressed in bits. Overhead for the protocols of the underlying network is not included.

SDU_loss_ratio – is a fraction of SDUs lost or detected as erroneous. Loss ratio of MMTP packets can be calculated as a function of SDU_loss_ratio and SDU_size. The SDU_loss_ratio is expressed in percentile.

generation_time – is generation time of the current NAM which is based on the NTP timestamp. The generation_time is expressed in milliseconds.

relative_bitrate – the available_bitrate change ratio (%) between the current NAM and the previous NAM parameter.

relative_buffer_fullness – the remaining buffer_fullness change ratio (%) between the current NAM and the previous NAM parameter.

relative_peak_bitrate – the peak_bitrate change ratio (%) between the current NAM and the previous NAM parameter.

BER – bit error rate is the last measured BER at the PHY or MAC layer. For BER from the PHY layer, the value shall be presented as a positive value. For BER from the MAC layer, this value shall be presented as a negative value of which the absolute value is to be used.

Annex A
(informative)

Jitter calculation in MMTP

A.1 General

MMT specifies the timing model to be used for MMTP packets delivery. Delivery of timed media data according to their temporal requirements is an important feature supported by the MMT protocol. Preservation of timing relationships among packets in a single MMTP packet flow or between packets from different MMTP packet flows is another important feature of MMT. The delivery timing model provides also the necessary information to calculate jitter and the amount of delay introduced by the underlying delivery network during the delivery of a Package.

A.2 Network jitter calculation

Network jitter calculation is essential for jitter compensation that may be required by some services using the MMT protocol. Network jitter calculation method used in this document is adopted from IETF RFC 3550. Formula (A.1) is used to calculate the difference in packet spacing, $D_{MMT}(i,j)$, for a pair of MMTP packets i and j at the receiving entity:

$$D_{MMT}(i,j)=(T_{A,j}-T_{A,i})-(T_{D,j}-T_{D,i})=(T_{A,j}-T_{D,j})-(T_{A,i}-T_{D,i}) \quad \text{(A.1)}$$

where $T_{D,i}$ and $T_{D,j}$ denote the delivery time instance of two MMTP packets i and j, respectively, carried in an MMTP packet header. The $T_{A,i}$ and $T_{A,j}$ are the time instances at which MMTP packets i and j have arrived at the MMT receiving entity, respectively.

The inter-arrival jitter, $J_{MMT}(i)$, which is defined to be the mean deviation of the difference in packet spacing is calculated continuously according to Formula (A.2) every time an MMTP packet i is received:

$$J_{MMT}(i)=J_{MMT}(i-1)+[D_{MMT}(i-1,i)-J_{MMT}(i-1)]/16 \quad \text{(A.2)}$$

Annex B
(normative)

XML syntax and MIME type for signalling message

B.1 XML syntax

The following provides the XML syntax for the signalling messages that are defined in this document.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns="urn:mpeg:MMT:schema:
Signalling:2013" targetNamespace="urn:mpeg:MMT:schema:Signalling:2013"
elementFormDefault="qualified" attributeFormDefault="unqualified">
   <xs:annotation>
      <xs:appinfo>MMT Signalling</xs:appinfo>
      <xs:documentation xml:lang="en">This schema defines the syntax for MMT Signalling
messaging that </xs:documentation>
   </xs:annotation>
   <xs:element name="Message">
      <xs:complexType>
         <xs:choice minOccurs="1" maxOccurs="1">
            <xs:element name="PA_message">
               <xs:complexType>
                  <xs:sequence>
                     <xs:element name="table" type="Table" minOccurs="1"
maxOccurs="unbounded"/>
                     <xs:any namespace="##other" processContents="skip"/>
                  </xs:sequence>
               </xs:complexType>
            </xs:element>
            <xs:element name="MPI_message">
               <xs:complexType>
                  <xs:sequence>
                     <xs:element name="MPI_table" type="MPIT"/>
                     <xs:element name="MP_table" type="MPT" minOccurs="0"/>
                     <xs:any namespace="##other" processContents="skip"/>
                  </xs:sequence>
                  <xs:attribute name="associated_MP_table_flag" type="xs:boolean"
use="optional" default="false"/>
                  <xs:anyAttribute namespace="##other" processContents="skip"/>
               </xs:complexType>
            </xs:element>
            <xs:element name="MPT_message">
               <xs:complexType>
                  <xs:sequence>
                     <xs:element name="MP_table" type="MPT"/>
                     <xs:any namespace="##other" processContents="skip"/>
                  </xs:sequence>
               </xs:complexType>
            </xs:element>
            <xs:element name="CRI_message">
               <xs:complexType>
                  <xs:sequence>
                     <xs:element name="CRI_table" type="CRIT"/>
                     <xs:any namespace="##other" processContents="skip"/>
                  </xs:sequence>
               </xs:complexType>
            </xs:element>
            <xs:element name="DCI_message">
               <xs:complexType>
                  <xs:sequence>
                     <xs:element name="DCI_table" type="DCIT"/>
                     <xs:any namespace="##other" processContents="skip"/>
```

```
                  </xs:sequence>
               </xs:complexType>
            </xs:element>
            <xs:element name="AL_FEC_message">
               <xs:complexType>
                  <xs:sequence>
                     <xs:element name="fec_flow">
                        <xs:complexType>
                           <xs:sequence>
                              <xs:element name="FECConfiguration">
                                 <xs:complexType>
                                    <xs:attribute name="repair_flow_id" type="xs:integer”/>
                                    <xs:attribute name="maximum_k_for_repair_flow"
type="xs:integer”/>
                                    <xs:attribute name="maximum_p_for_repair_flow"
type="xs:integer”/>
                                    <xs:attribute name="protection_window_time" type="xs:
integer”/>
                                    <xs:attribute name="protection_window_size" type="xs:
integer”/>
                                    <xs:attribute name="num_of_layer_for_LAFEC" type="xs:
integer”/>
                                    <xs:attribute name="fec_code_id_for_repair_flow"
type="xs:integer”/>
                                    <xs:anyAttribute namespace="##other"
processContents="skip"/>
                                 </xs:complexType>
                              </xs:element>
                              <xs:any namespace="##other" processContents="skip"/>
                           </xs:sequence>
                           <xs:attribute name="fec_flow_id" type="xs:integer”/>
                           <xs:attribute name="source_flow_id" type="xs:integer”/>
                           <xs:attribute name="packet_ids" type="ListT" />
                           <xs:attribute name="fec_coding_structure" type="xs:integer”/>
                           <xs:attribute name="sbbg_mode" type="xs:integer”/>
                           <xs:attribute name="rffsrpts_flag" type="xs:boolean”/>
                           <xs:attribute name="length_of_repair_symbol" type="xs:integer”/
>
                           <xs:anyAttribute namespace="##other" processContents="skip"/>
                        </xs:complexType>
                        </xs:element>
                     </xs:sequence>
                  </xs:complexType>
               </xs:element>
               <xs:element name="HRBM_message">
                  <xs:complexType>
                     <xs:attribute name="max_buffer_size" type="xs:integer”/>
                     <xs:attribute name="fixed_end_to_end_delay" type="xs:integer”/>
                     <xs:attribute name="max_transmission_delay" type="xs:integer”/>
                     <xs:anyAttribute namespace="##other" processContents="skip"/>
                  </xs:complexType>
               </xs:element>

               <xs:element name="ADC_message">
                  <xs:complexType>
                     <xs:attribute name="ADC_level_flag" type="xs:boolean”/>
                     <xs:attribute name="MPU_sequence_number " type="xs:integer"
minOccurs="0"/>
                     <xs:attribute name="packet_id" type="xs:integer”/>

                     <xs:attribute name="loss_tolerance" type="xs:integer”/>
                     <xs:attribute name="jitter_sensitivity" type="xs:integer”/>
                     <xs:attribute name="class_of_service" type="xs:boolean”/>
                     <xs:attribute name="bidirection_indicator" type="xs:boolean”/>

                     <xs:attribute name="flow_label" type="xs:integer”/>
                     <xs:attribute name="sustainable_rate" type="xs:integer" minOccurs="0"/>
                     <xs:attribute name="buffer_size" type="xs:integer" minOccurs="0"/>
                     <xs:attribute name="peak_rate" type="xs:integer”/>
                     <xs:attribute name="max_MFU_size" type="xs:integer”/>
                     <xs:attribute name="mfu_period" type="xs:integer”/>
```

```
<xs:complexType name="mmt:OperationPointCharacteristics">
      <xs:attribute name="sampleGroupIndex" type="xs:integer”/>
      <xs:attribute name="operationPointSpatialQuality" type="xs:integer”/>
      <xs:attribute name="operationPointTemporalQuality" type="xs:integer”/>
      <xs:attribute name="operationPointBitrate" type="xs:integer”/>
      <xs:anyAttribute processContents="lax">
</xs:complexType>

                  <xs:anyAttribute namespace="##other" processContents="skip"/>
               </xs:complexType>
            </xs:element>




         </xs:choice>
         <xs:attribute name="message_id" type="xs:integer”/>
         <xs:attribute name="version" type="xs:integer”/>
         <xs:anyAttribute namespace="##other" processContents="skip"/>
      </xs:complexType>
   </xs:element>

   <xs:complexType name="Table">
      <xs:attribute name="table_id" type="xs:integer”/>
      <xs:attribute name="version" type="xs:integer”/>
      <xs:anyAttribute namespace="##other" processContents="skip"/>
   </xs:complexType>

   <xs:complexType name="PAT">
      <xs:complexContent>
         <xs:extension base="Table">
            <xs:sequence>
               <xs:element name="location" maxOccurs="unbounded">
                  <xs:complexType>
                     <xs:sequence>
                        <xs:element name="MMT_general_location_info" type="MMT_general_
location_info_type" maxOccurs="2"/>
                        <xs:any namespace="##other" processContents="skip"/>
                     </xs:sequence>
                     <xs:attribute name="alternative_location_flag" type="xs:boolean”/>
                     <xs:attribute name="signalling_information_table_id" type="xs:
integer”/>
                     <xs:attribute name="signalling_information_table_version" type="xs:
integer”/>
                     <xs:anyAttribute namespace="##other" processContents="skip"/>
                  </xs:complexType>
               </xs:element>
            </xs:sequence>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>

   <xs:complexType name="MMT_general_location_info_type">
      <xs:choice>
         <xs:element name="asset">
            <xs:complexType>
               <xs:attribute name="packet_id" type="xs:integer”/>
            </xs:complexType>
         </xs:element>
         <xs:element name="flow">
            <xs:complexType>
               <xs:attribute name="ipv4_src_addr" type="xs:string”/>
               <xs:attribute name="ipv4_dst_addr" type="xs:string”/>
               <xs:attribute name="dst_port" type="xs:integer”/>
               <xs:attribute name="packet_id" type="xs:integer”/>
               <xs:anyAttribute namespace="##other" processContents="skip"/>
            </xs:complexType>
         </xs:element>
         <xs:element name="flow_ipv6">
```

```
            <xs:complexType>
               <xs:attribute name="ipv6_src_addr" type="xs:string”/>
               <xs:attribute name="ipv6_dst_addr" type="xs:string”/>
               <xs:attribute name="dst_port" type="xs:integer”/>
               <xs:attribute name="packet_id" type="xs:integer”/>
               <xs:anyAttribute namespace="##other" processContents="skip"/>
            </xs:complexType>
         </xs:element>
         <xs:element name="M2TS">
            <xs:complexType>
               <xs:attribute name="network_id" type="xs:integer”/>
               <xs:attribute name="MPEG_2_transport_stream_id" type="xs:integer”/>
               <xs:attribute name="MPEG_2_PID" type="xs:integer”/>
               <xs:anyAttribute namespace="##other" processContents="skip"/>
            </xs:complexType>
         </xs:element>

         <xs:element name="M2ES">
            <xs:complexType>
               <xs:attribute name="ipv6_src_addr" type="xs:string”/>
               <xs:attribute name="ipv6_dst_addr" type="xs:string”/>
               <xs:attribute name="dst_port" type="xs:integer”/>
               <xs:attribute name="MPEG_2_PID" type="xs:integer”/>
               <xs:anyAttribute namespace="##other" processContents="skip"/>
            </xs:complexType>
         </xs:element>
      </xs:choice>
   </xs:complexType>

   <xs:complexType name="MPIT">
      <xs:complexContent>
         <xs:extension base="Table">
            <xs:sequence>
               <xs:element name="PI_fragment">
                  <xs:complexType>
                     <xs:sequence>
                        <xs:element name="fragment">
                           <xs:complexType>
                              <xs:simpleContent>
                                 <xs:extension base="xs:string">
                                    <xs:attribute name="mime_type" type="xs:string”/>
                                 </xs:extension>
                              </xs:simpleContent>
                           </xs:complexType>
                        </xs:element>
                        <xs:any namespace="##other" processContents="skip"/>
                     </xs:sequence>
                  </xs:complexType>
               </xs:element>
               <xs:any namespace="##other" processContents="skip"/>
            </xs:sequence>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>

   <xs:complexType name="MPT">
      <xs:complexContent>
         <xs:extension base="Table">
            <xs:sequence>
               <xs:element name="asset" type="AssetT"/>
               <xs:element name="descriptor" type="DescriptorT"/>
               <xs:any namespace="##other" processContents="skip"/>
            </xs:sequence>
            <xs:attribute name="MP_table_mode" type="xs:integer”/>
            <xs:attribute name="MMT_package_id" type="xs:string”/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>

   <xs:complexType name="CRIT">
      <xs:complexContent>
```

```
         <xs:extension base="Table">
            <xs:sequence>
               <xs:element name="CRI_descriptor" type="CRIDT"/>
               <xs:any namespace="##other" processContents="skip"/>
            </xs:sequence>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>

   <xs:complexType name="DCIT">
      <xs:complexContent>
         <xs:extension base="Table">
            <xs:sequence>
               <xs:element name="asset">
                  <xs:complexType>
                     <xs:choice>
                        <xs:element name="video">
                           <xs:complexType>
                              <xs:attribute name="video_average_bitrate" type="xs:
integer”/>
                              <xs:attribute name="video_maximum_bitrate" type="xs:
integer”/>
                              <xs:attribute name="horizontal_resolution" type="xs:
integer”/>
                              <xs:attribute name="vertical_resolution" type="xs:integer”/>
                              <xs:attribute name="temporal_resolution" type="xs:integer”/>
                              <xs:attribute name="video_minimum_buffer_size" type="xs:
integer”/>
                              <xs:anyAttribute namespace="##other"
processContents="skip"/>
                           </xs:complexType>
                        </xs:element>
                        <xs:element name="audio">
                           <xs:complexType>
                              <xs:attribute name="audio_average_bitrate" type="xs:
integer”/>
                              <xs:attribute name="audio_maximum_bitrate" type="xs:
integer”/>
                              <xs:attribute name="audio_minimum_buffer_size" type="xs:
integer”/>
                              <xs:anyAttribute namespace="##other"
processContents="skip"/>
                           </xs:complexType>
                        </xs:element>
                        <xs:element name="download">
                           <xs:complexType>
                              <xs:attribute name="required_storage" type="xs:integer”/>
                              <xs:anyAttribute namespace="##other"
processContents="skip"/>
                           </xs:complexType>
                        </xs:element>
                     </xs:choice>
                     <xs:attribute name="mime_type" type="xs:string”/>
                     <xs:anyAttribute namespace="##other" processContents="skip"/>
                  </xs:complexType>
               </xs:element>
               <xs:any namespace="##other" processContents="skip"/>
            </xs:sequence>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>

   <xs:complexType name="AssetT">
                     <xs:sequence>
                        <xs:element name="asset_clock_relation">
                           <xs:complexType>
                              <xs:attribute name="asset_clock_relation_id"/>
                              <xs:attribute name="asset_timescale"/>
                           </xs:complexType>
                        </xs:element>
                        <xs:element name="MMT_general_location_info" type="MMT_general_
```

```
location_info_type"/>
                        <xs:element name="asset_id" type="asset_id_T"/>
                        <xs:any namespace="##other" processContents="skip"/>
                     </xs:sequence>
                     <xs:attribute name="mime_type" type="xs:string”/>
                     <xs:attribute name="default_asset_flag" type="xs:boolean”/>
                     <xs:anyAttribute namespace="##other" processContents="skip"/>
                  </xs:complexType>

   <xs:complexType name="DescriptorT">
      <xs:attribute name="descriptor_tag" type="xs:integer”/>
   </xs:complexType>

   <xs:complexType name="CRIDT">
      <xs:complexContent>
         <xs:extension base="DescriptorT">
            <xs:attribute name="clock_relation_id" type="xs:integer”/>
            <xs:attribute name="STC_sample" type="xs:integer”/>
            <xs:attribute name="NTP_timestamp_sample" type="xs:dateTime”/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>

   <xs:complexType name="MPUTSD">
      <xs:complexContent>
         <xs:extension base="DescriptorT">
            <xs:attribute name="mpu_sequence_number" type="xs:integer”/>
            <xs:attribute name="mpu_presentation_time" type="xs:dateTime”/>
         </xs:extension>
      </xs:complexContent>
   </xs:complexType>


   <xs:simpleType name="ListT">
      <xs:list itemType="xs:integer”/>
   </xs:simpleType>

   <xs:complexType name="asset_id_T">
      <xs:simpleContent>
         <xs:extension base="xs:string">
            <xs:attribute name="asset_id_scheme" type="xs:string”/>
         </xs:extension>
      </xs:simpleContent>
   </xs:complexType>

   <xs:complexType name="Identifier_mapping">
      <xs:choice>
         <xs:element name="asset_id" type="asset_id_T"/>
         <xs:element name="URL" type="xs:anyURI”/>
         <xs:element name="RegEx" type="xs:string”/>
         <xs:element name="RepresentationId" type="xs:string”/>
      </xs:choice>
      <xs:attribute name="identifier_type" type="xs:integer" use="optional" default="0"/>
      <xs:anyAttribute namespace="##other" processContents="skip"/>
   </xs:complexType>
</xs:schema>
```

B.2 MIME type

The type "application/mmt-signalling+xml" may be used for files containing XML formatted MMT messages.

MIME media type name: application

MIME subtype name: mmt-signalling+xml

Required parameters: none

Optional parameters: none

[Ongoing work related to this registration may introduce new optional parameters.]

Encoding considerations: Files are XML formatted with UTF-8 encoding

Security considerations: None

[There is currently no provision for signing or authentication of MMT signalling message.]

Interoperability considerations: The MPEG organization has defined the specification, which defines the XML schema to enable validation of the MMT signalling message files.

Published specification: ISO/IEC 23008-1.

Applications which use this media type: Multimedia

Additional information: None

Magic number(s): None

File extension(s): .xml and .msm may both be used.

Person and e-mail address to contact for further information:

Intended usage: COMMON

Change controller: MPEG

Annex C
(normative)

AL-FEC framework for MMT

C.1 General

MMT provides an AL-FEC mechanism for reliable delivery in IP network environments. The MMT FEC scheme is described as a building block of the delivery function. After packetization, MMTP packets are passed to the MMT FEC scheme for protection. The MMT FEC scheme returns repair symbols with FEC payload IDs. Then, the repair symbols are delivered by MMT protocol with the MMTP packets. The FEC configuration information provides the identification of FEC encoded flow, the information specified FEC coding structure and FEC code. It is delivered to the MMT receiving entity for FEC operation. The outlined architecture is depicted in Figure C.1.

The MMT sending entity determines the Assets within Packages which require protection and the number of FEC source flows. One or more of the Assets are protected as a single FEC source flow, which consists of MMTP packets carrying one or more Assets. The FEC source flow and its FEC configuration information are passed to the MMT FEC scheme for protection. The MMT FEC scheme uses FEC code(s) to generate repair symbols composing one or more FEC repair flows. They are passed to MMT protocol along with FEC payload IDs. Then, the MMT protocol delivers FEC source and repair packets to the MMT receiving entity. At the MMT receiving entity, the MMT protocol passes the FEC source flow and its associated FEC repair flow(s) to MMT FEC scheme. Then, the MMT FEC scheme returns recovered MMTP packets.

The MMT FEC scheme divides the FEC source flow into source packet blocks and generates source symbol blocks. The MMT FEC scheme then passes source symbol blocks to the FEC code for FEC encoding. Here, FEC encoding means the process to generate repairs symbols from the source symbol block. FEC code algorithms, which may be used to generate repairs symbols from source symbol block, are described in ISO/IEC 23008-10.

The MMT FEC scheme can be operated in two different modes. FEC payload ID mode 0, which is adding a source FEC payload ID to the MMTP packet, and FEC payload ID mode 1, which does not modify MMTP packets. C.3 to C.5 describe the details for FEC payload ID mode 0 and C.6 for FEC payload ID mode 1.

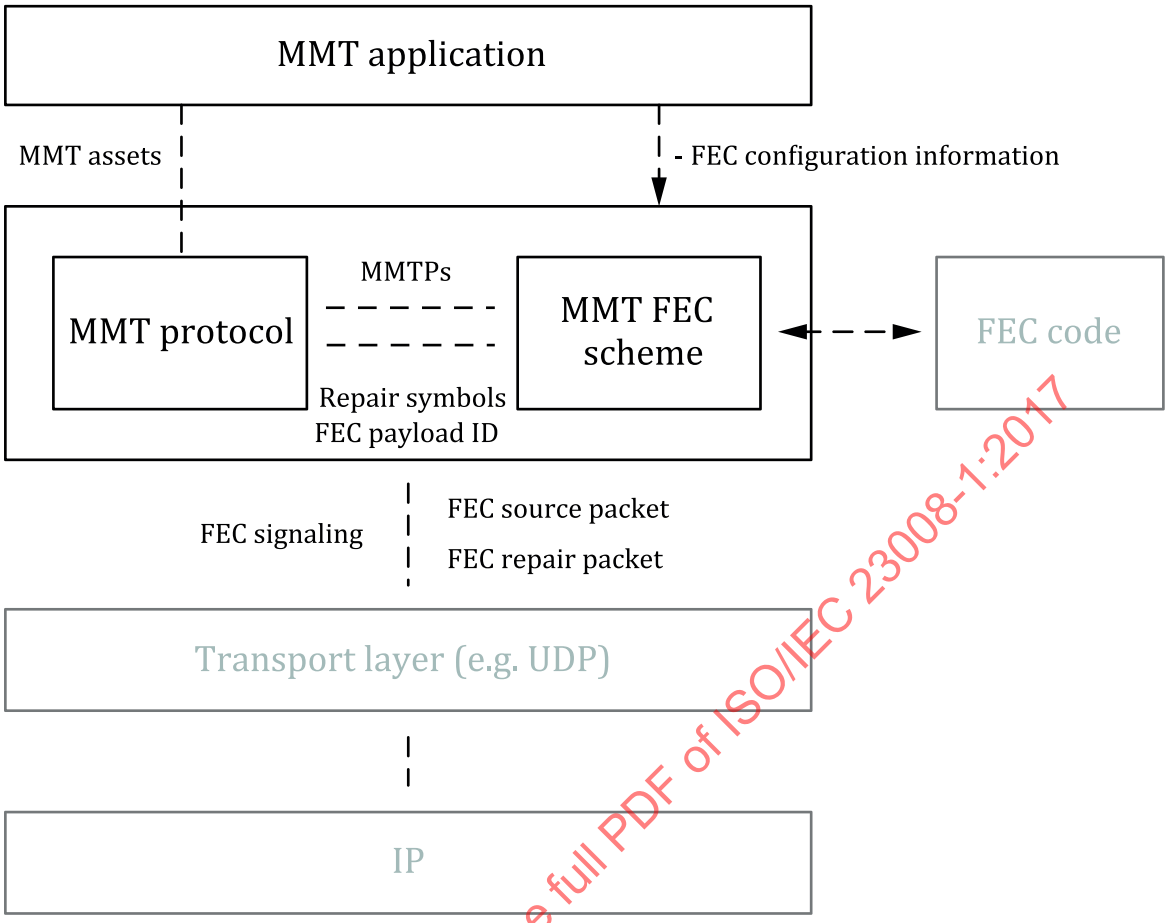


Figure C.1 — Architecture for AL-FEC in MMT

C.2 FEC coding structure

C.2.1 General

The MMT FEC scheme provides multi-level construction of MMTP packets for layered or non-layered media data for an appropriate level of protection of each Asset in an FEC source flow. Note that an FEC source flow may also be an MMTP sub-flow that carries signalling messages. This subclause shows two FEC coding structures. One is a two-stage FEC coding structure and the other is a layer-aware FEC (LA-FEC) coding structure.

C.2.2 Two-stage FEC coding structure

This subclause specifies the two-stage FEC coding structure as an FEC coding structure for AL-FEC to protect a source packet block which consists of a predetermined number of MMTP packets. The two-stage FEC coding structure is depicted as shown in Figure C.2.

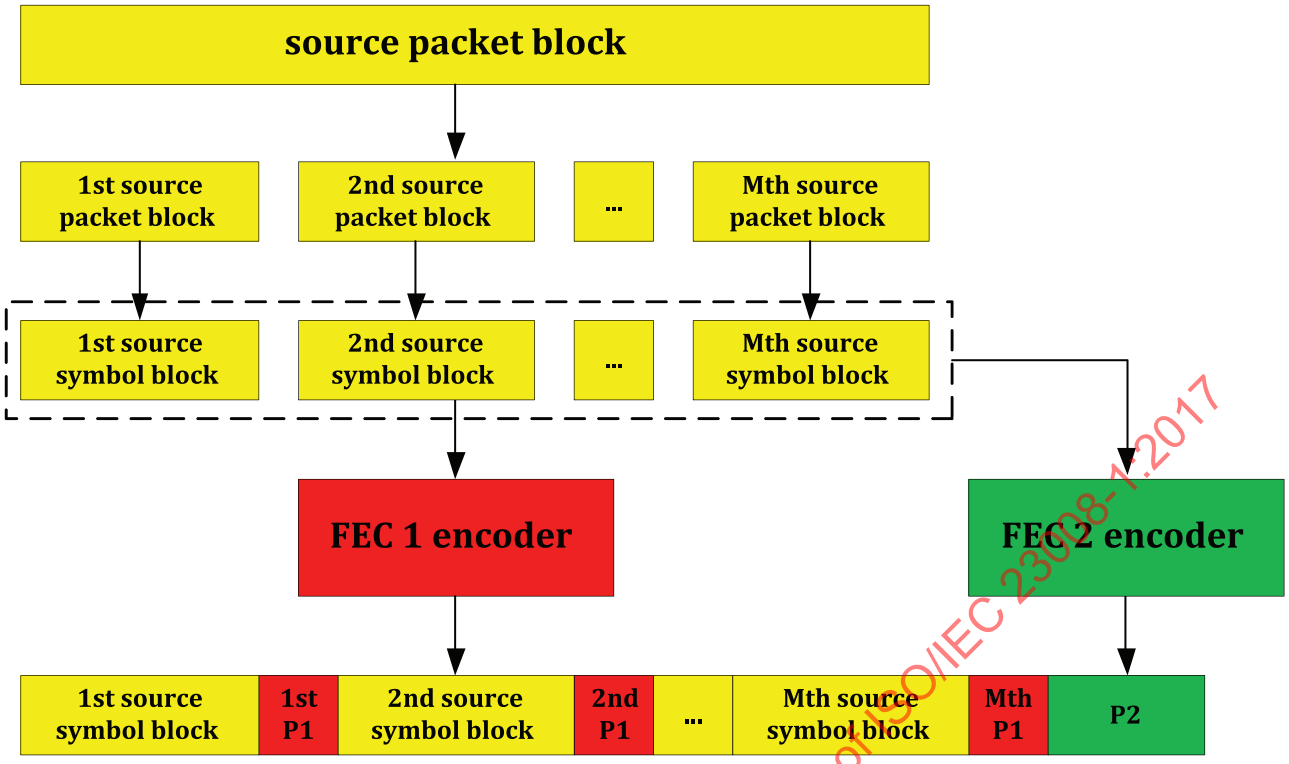


Figure C.2 — Two-stage FEC coding structure

NOTE In Figure C.2, the ith P1 is the repair symbol block for the ith source symbol block and P2 is the repair symbol block for the source symbol block (i=1, 2, ..., M).

The source packet block shall be encoded in one of the following FEC coding structures:

— Case 0: No FEC coding applied;

— Case 1: One-stage FEC coding structure;

— Case 2: Two-stage FEC coding structure.

For the two-stage FEC coding structure, one source packet block is split into M (>1) number of source packet blocks. The split ith source packet block is converted to the ith source symbol block with one of the SSBG modes defined in C.3.3. Then, the ith source symbol block is encoded by FEC 1 code (i = 1, 2, ..., M). Then, M source symbol blocks are concatenated to form a single source symbol block encoded by FEC 2 code. The M number of repair symbol blocks are generated from M source symbol blocks by FEC 1 code, respectively, and one repair symbol block is generated from the concatenated source symbol block by FEC 2 code.

For Case 0, both FEC 1 and FEC 2 encoding shall be skipped, i.e. no repair symbols are generated.

For Case 1, M shall be set to "1" and either FEC 1 encoding or FEC 2 encoding shall be skipped.

C.2.3 Layer-aware FEC (LA-FEC) coding structure

Layer-aware FEC (LA-FEC) is a FEC coding structure that can be applied with any FEC code and is specific for layered media data (e.g. SVC, MVC, or any other). The LA-FEC exploits the dependency across layers of the media for FEC construction and consists in the generation of several repair flows associated to each layer, where each repair flow protects the data of its corresponding layer and the data of all layers, this layer depends on (hereafter referred to as the complementary layer), if any.

First, the MMTP packets from the different layers are grouped into source symbol blocks independently. When the LA-FEC structure is used, the source symbol block generated for FEC encoding of a repair

