
**Information technology — MPEG
systems technologies —**

**Part 9:
Common encryption of MPEG-2
transport streams**

*Technologies de l'information — Technologies des systèmes MPEG —
Partie 9: Cryptage commun des flux de transport de contenu MPEG-2*



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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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 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.

The committee responsible for this document is ISO/IEC JTC 1, Information technology, SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

This second edition cancels and replaces the first edition (ISO/IEC 23001-9:2014), which has been technically revised.

ISO/IEC 23001 consists of the following parts, under the general title *Information technology — MPEG systems technologies*:

- *Part 1: Binary MPEG format for XML*
- *Part 2: Fragment request units*
- *Part 3: XML IPMP messages*
- *Part 4: Codec configuration representation*
- *Part 5: Bitstream Syntax Description Language (BSDL)*
- *Part 7: Common encryption in ISO base media file format files*
- *Part 8: Coding-independent code points*
- *Part 9: Common encryption of MPEG-2 transport streams*
- *Part 10: Carriage of timed metadata metrics of media in ISO base media file format*
- *Part 11: Energy-efficient media consumption (green metadata)*
- *Part 12: Sample Variants in the ISO base media file format*

Information technology — MPEG systems technologies —

Part 9:

Common encryption of MPEG-2 transport streams

1 Scope

This part of ISO/IEC 23001 specifies a common media encryption format for use in MPEG-2 transport streams. This encryption format is intended to be used in an interoperable way with media encrypted using the format described by ISO/IEC 23001-7. This part of ISO/IEC 23001 allows conversion between encrypted MPEG-2 transport streams and encrypted ISO base media file format files without re-encryption.

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 13818-7, *Information technology — Generic coding of moving pictures and associated audio information — Part 7: Advanced Audio Coding (AAC)*

ISO/IEC 14496-3, *Information technology — Coding of audio-visual objects — Part 3: Audio*

ISO/IEC 23001-7, *Information technology — MPEG systems technologies — Part 7: Common encryption in ISO base media file format files*

Rec. ITU-T H.222.0 | ISO/IEC 13818-1, *Information technology — Generic coding of moving pictures and associated audio information — Part 1: Systems*

Rec. ITU-T H.264 | ISO/IEC 14496-10, *Information technology — Coding of audio-visual objects — Part 10: Advanced Video Coding*

Rec. ITU-T H.265 | ISO/IEC 23008-2¹⁾, *Information technology — High efficiency coding and media delivery in heterogeneous environments — Part 2: High efficiency video coding*

3 Terms and definitions

No terms and definitions are listed in this document.

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>

4 Abbreviated terms

AES	Advanced Encryption Standard (FIPS-197)
AU	Access Unit
CAT	Conditional Access Table (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
CBC	Cipherblock Chaining (NIST 800-38A)
CENC	Common Encryption (ISO/IEC 23001-7)
CETS	Common Encryption of MPEG-2 Transport Streams
CTR	Counter Mode (NIST SP 800-38A)
DTS	Decoding Time Stamp (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
ECM	Entitlement Control Message (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
ISO-BMFF	ISO Base Media File Format (ISO/IEC 14496-12)
IV	Initialization Vector (NIST SP 800-38A)
KID	Key Identifier (ISO/IEC 23001-7)
MD5	MD5 Message-Digest Algorithm (IETF RFC 1321)
MPEG-2 TS	MPEG-2 Transport Stream (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
NAL	Network Access Layer (Rec. ITU-T H.264 ISO/IEC 14496-10, Rec. ITU-T H.265 ISO/IEC 23008-2)
PAT	Program Association Table (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
PES	Packetized Elementary Stream (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
PID	Packet Identifier (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
PMT	Program Map Table (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
PTS	Presentation Time Stamp (Rec. ITU-T H.222.0 ISO/IEC 13818-1)
RAP	Random Access Point
VCL	Video Coding Layer (Rec. ITU-T H.264 ISO/IEC 14496-10, Rec. ITU-T H.265 ISO/IEC 23008-2)

5 Overview

5.1 General

An interoperable container-independent encryption scheme allows container format changes for encrypted content in the network without the need for the processing node to be able to support for and interoperate with multiple DRM's. Given the need to support clients that use different container formats, such capability allows end-to-end content protection from the content preparation stage till the content consumption by the authorized end user.

If the encrypted parts of elementary streams are the same, and parameters needed to do re-encapsulation are in the clear, it is possible to do re-encapsulation without re-encryption. Partial

bitstream encryption specified in ISO/IEC 23001-7 makes such re-multiplexing of ISO-BMFF files possible. ISO/IEC 23001-7 is specific to ISO-BMFF, while this part of ISO/IEC 23001 provides an MPEG-2 TS framework which provides same functionality for MPEG-2 TS. A combination of ISO/IEC 23001-7 and this part of ISO/IEC 23001 allows re-encapsulation between ISO-BMFF and MPEG-2 TS content without re-encryption.

5.2 Theory of operation

The premise of common encryption is that each access unit is encrypted separately, either completely or partially. Hence each access unit needs two parameters, key and initialization vector. Key resolution is out of scope of this part of ISO/IEC 23001, and depends on the key system in question. The abstraction used in this part of ISO/IEC 23001 is that given a key identifier and a license, a key system will return a key. ECM is used to transport IVs and key identifiers. In order to make it possible to decrypt, it is necessary to be able to identify which access unit is encrypted with which key/IV combination. MPEG-2 TS provides transport-level and PES-level functionality for this using the `transport_scrambling_control` field. Thus the transport stream packet payload is in the clear if the `transport_scrambling_control` value is '00'. Otherwise, the payload is encrypted with key/IV combination identified by the `transport_scrambling_control` value within the nearest ECM.

If the value of `CA_System_ID` equals 'ce', and `transport_scrambling_control` has a value other than '00', the complete transport stream packet payload contains only encrypted bytes. In the same case when the value of `CA_System_ID` value is 'cf', parts of the payload may be non-encrypted, and encrypted and non-encrypted byte ranges are signalled in an adaptation field descriptor `cets_byte_range_descriptor`.

NOTE 1 In the 'ce' CA system, if a packet has `transport_scrambling_control` value other than '00', the encrypting application places only encrypted bytes into its payload; combining non-encrypted and encrypted bytes in the same packet payload is disallowed. The same applies to byte ranges in the 'cf' CA system.

NOTE 2 Given that common encryption is applied separately per each access unit, `transport_scrambling_control` value will most probably change with each access unit, hence ECM's will appear very frequently. For the first encrypted MPEG-2 TS packet of a PES packet, only the immediately preceding ECM is guaranteed to contain the correct key/IV combination for a given access unit, as `transport_scrambling_control` is a 2-bit field and has only 3 available encryption states.

A vendor-specific license is necessary for any practical DRM operation. In ISO/IEC 23001-7, this is carried for each DRM in one or more 'pssh' boxes. In this part of ISO/IEC 23001, same information is carried in a private CETS PSSH PID (one PID per each DRM system). This does not necessarily mean that 'pssh' data has to be carried inband – this is a decision left to the implementer.

Algorithm-related parameters are signalled via the `CA_descriptor` descriptor.

In ISO/IEC 23001-7 each track has its own 'tenc' box and sample-specific IV's. In this part of ISO/IEC 23001, it is implemented as separate ECM PID. If same key/IV combination is used for more than one PID (e.g. same combination for both audio and video), it is possible to use same ECM PID for all PIDs sharing the same key/IV combination. However, this practice may increase the complexity and fragility of the system.

5.3 Notation

This part of ISO/IEC 23001 uses same notation as used in Rec. ITU-T H.222.0 | ISO/IEC 13818-1.

This part of ISO/IEC 23001 makes extensive use of fields with possibly different lengths. An additional short-hand notation is used to improve readability in these cases: length field names are referenced within the "number of bits" column of syntax tables. The alias name for the length field is provided in parenthesis in non-bold font at the same line as the length field, and the number of bits is given as a function of that field.

In the example below, SFL is an alias for the `some_field_length_qwords` field which indicates length in units of 64-bit words. As the latter can have values of 0...3, `some_field` can have lengths of 0, 64, 128 and

192 bits. Note that stating that `some_field` is a 0-bit field implies that `some_field` is not present (in the example below this would result in `some_structure()` being a 1-byte structure).

Syntax	No. bits	Mnemonic
<code>some_structure {</code>		
<code>some_field_length_qwords (SFL)</code>	2	uimsbf
<code>reserved</code>	6	bslbf
<code>some_field</code>	$SFL * 64$	uimsbf
<code>}</code>		

6 Encryption parameter signalling

6.1 CETS ECM

6.1.1 General

CETS ECM provides (a) key ID and initialization vector for each state of `transport_scrambling_control`, and (b) notification of upcoming key rotation. CETS ECM's are expected to be carried very frequently (one ECM per AU) for cases where IV or/and key are changed for each sample.

As it is possible to have a key and/or IV change in the middle of a PES packet (e.g. in case PES carries several access units, which is a common practice for audio), CETS ECM also indicates byte offsets into the beginning of encrypted bytes that are encrypted with different key/IV pair.

CETS ECM shall always be contained in a single MPEG-2 TS packet, therefore the size of `cets_ecm` shall not exceed 184 bytes. Adaptation field stuffing shall be used for smaller `cets_ecm` sizes.

6.1.2 Syntax

Syntax	No. of bits	Format
<pre> cets_ecm() { num_states next_key_id_flag reserved = 0 </pre>	2 1 5	uimsbf bslbf bslbf
<pre> iv_size (IVS) default_key_id </pre>	8 128	uimsbf uimsbf
<pre> for (i = 0; i < num_states; i++) { transport_scrambling_control num_eu for (j = 0; j < num_eu; j++) { key_id_flag encryption_block_start_flag reserved = 0 eu_byte_offset_size (EBOS) </pre>	2 6 1 1 2 4	bslbf uimsbf bslbf bslbf bslbf uimsbf
<pre> if (key_id_flag == 1) { key_id } eu_byte_offset initialization_vector } if (iv_size == 0) { // only cf system key_id_flag constant_initialization_vector_length_qwords (CIVL) reserved = 0 </pre>	128 EBOS*8 IVS*8 1 2 5	bslbf uimsbf bslbf bslbf bslbf bslbf

Syntax	No. of bits	Format
<pre> if (key_id_flag == 1) { key_id } constant_initialization_vector } } if (next_key_id_flag == 1) { countdown_sec reserved = 0 next_key_id } } </pre>	128 CIVL*64 4 4 128	 bslbf bslbf uismbf bslbf bslbf

6.1.3 Semantics

num_states: number of key/IV combinations described in this ECM

next_key_id_flag: if 1, next_key_id is provided in this ECM

iv_size: size of initialization vectors, in bytes. 8-byte and 16-byte initialization vectors shall be supported.

transport_scrambling_control: value of the transport_scrambling_control field that corresponds to this key/IV combination

default_key_id: default key ID used with the access units listed in this CETS ECM.

num_eu: number of encryption units (typically – access units) that share the same transport_scrambling_control state and key ID. If zero (allowed only under `cf` system), the same key and (possibly) same initialization vector will apply to all packets with a given value of the transport_scrambling_control field.

key_id_flag: if 1, explicit key ID will be provided. If 0, default key ID is used.

eu_byte_offset_size: size of eu_byte_offset, in bytes.

encryption_block_start_flag if 1, block mode starts at the beginning of this offset (e.g., in CBC mode IV and not previous cyphertext is used)

key_id: key identifier used for key acquisition for this sample (access unit)

eu_byte_offset: in case of multiple access units packed in one PES packets, indicates the byte offset from the first byte of PES payload till the first byte encrypted using the current key/IV combination. Field length equals eu_byte_offset_size*8.

NOTE Offsets are relative to the first byte of PES packet payload, hence for cases where the first access unit is aligned with the start of the PES payload, this access unit will have a zero offset Non-zero offsets correspond to the additional access units within the same PES packet. The access unit loop is over an integer number of PES packets, and every zero value of eu_byte_offset corresponds to the start of a PES packet.

initialization_vector: initialization vector used in this key/IV combination. Field length equals iv_size*8.

countdown_sec: seconds left till the nearest key rotation

next_key_id: key ID that is expected be used first in countdown_sec seconds in the future

The upcoming key ID's are added in order to allow the client pre-fetch them in time for the key rotation; hence countdown value should be non-zero, i.e. a key rotation notification should be sent at least 1 sec. ahead of time. Countdown is imprecise and non-binding – it only provides an early warning. Moreover, there is no guarantee that the indicated key will be used at the indicated time. A mandatory notification of key use is in `default_key_id` and `key_id` fields of CETS ECM.

constant_initialization_vector_length_qwords: length of constant initialization vector, in 64-bit words. Value of zero (i.e., when length is zero bits) implies that `constant_initialization_vector` field is not present.

constant_initialization_vector: initialization vector used for all key/IV combinations. Field length equals `constant_initialization_vector_length_qwords*64`.

6.2 CETS PSSH

6.2.1 General

A CETS PSSH packet carries the complete payload of a 'pssh' box, as defined in ISO/IEC 23001-7. Each packet uses private syntax and carries a 'pssh' box along with an MD5 hash for integrity.

The first transport stream packet of a CETS PSSH shall have `payload_unit_start_indicator` set to 1.

6.2.2 Syntax

Syntax	No. of bits	Format
<code>cets_pssh_packet() {</code>		
md5_flag	1	bslbf
reserved	31	bslbf
pssh_box()		FullBox
if (md5_flag == 1)		
md5sum	128	bslbf
}		
}		

6.2.3 Semantics

md5_flag: if true, MD5 hash will appear after the 'pssh' box

pssh_box: complete 'pssh' box, as defined in ISO/IEC 23001-7.

NOTE The message length is derived from fields inherited by 'pssh' from the Box class. See ISO/IEC 14496-12 for details on box structure.

md5_sum: MD5 hash of the CETS PSSH packet, starting from `md5_flag` and continuing till the last byte of the 'pssh' box

6.3 CA_descriptor

6.3.1 General

`CA_descriptor` is used to indicate properties of the content protection scheme.

When carried in `TS_program_map_section`, the `CA_descriptor` shall be one of the descriptors following the `ES_info_length` field of the program element for which the ECMs are carried in `CA_PID`

NOTE The above means that `CA_descriptor` will be used in the "inner" ("ES") loop of the PMT, and there will be a descriptor per each encrypted PID.

It is recommended that CA_descriptor size be set such that PMT and CAT sections can fit into a single transport stream packet.

6.3.2 Syntax

Syntax	No. of bits	Format
CA_descriptor(){ descriptor_tag descriptor_length CA_System_ID // 'ce' or 'cf' version_flag reserved = '00' CA_PID scheme_type scheme_version num_systems encryption_algorithm for (i = 0; i < num_systems; i++) { system_id pssh_pid reserved = '000' } if (version_flag == 1) { version if (version_flag > 0) { reserved = '00000000' crypt_byte_block; skip_byte_block; } } for (i=0; i<N; i++) { private_data_byte } }	8 8 16 1 2 13 32 32 8 24 128 13 3	bslbf bslbf bslbf bslbf bslbf uismbf bslbf uismbf bslbf uismbf bslbf uismbf bslbf
} if (version_flag == 1) { version if (version_flag > 0) { reserved = '00000000' crypt_byte_block; skip_byte_block; } } for (i=0; i<N; i++) { private_data_byte } }	8 8 4 4 8	uismbf bslbf uismbf uismbf bslbf

6.3.3 Semantics

CA_System_ID: system identifier of this system, as defined in Rec. ITU-T H.222.0 | ISO/IEC 13818-1 shall be 'ce' or 'cf' in this part of ISO/IEC 23001.

version_flag: true if common encryption version higher than zero is used.

CA_PID: as defined in Rec. ITU-T H.222.0 | ISO/IEC 13818-1

scheme_type: same as 'schm'.scheme_type field in ISO/IEC 23001-7.

scheme_version: same as 'schm'.scheme_version field in ISO/IEC 23001-7.

num_systems: number of 128-bit system ID's is provided below.

encryption_algorithm: specifies the encryption algorithm, same as ``tenc`.IsEncrypted` field in ISO/IEC 23001-7.

system_id: same as `'pssh'.SystemID` field in ISO/IEC 23001-7.

pssh_pid: PID on which `'pssh'` box(es) can be found for this content protection system.

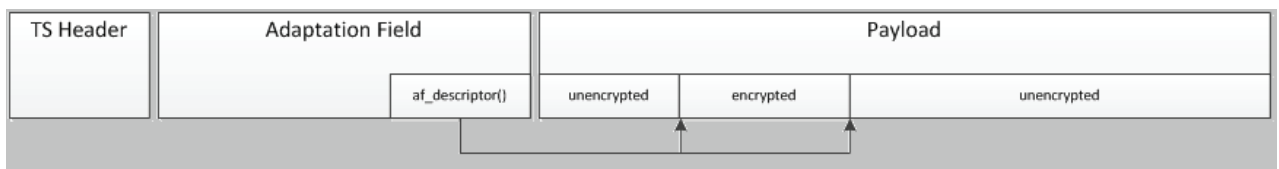
version: specifies the highest version of Common Encryption used. Same as `'tenc'.version` field in ISO/IEC 23001-7.

crypt_byte_block: number of encrypted blocks (in 16-byte blocks) in pattern, same as `'tenc'.default_crypt_byte_block` field in ISO/IEC 23001-7.

skip_byte_block: number of unencrypted blocks (in 16-byte blocks) in pattern, same as `'tenc'.default_skip_byte_block` field in ISO/IEC 23001-7.

6.4 CETS byte range descriptor

6.4.1 General



In case `CA_System_ID` equals `'cf'`, transport stream packets may be partially encrypted. In this case `cets_byte_range_descriptor` shall be used to signal encrypted and non-encrypted messages. `cets_byte_range_descriptor` shall not appear unless `CA_System_ID` equals `'cf'`. It shall not be present if the value of `transport_scrambling_control` is `'00'`.

The descriptor shall appear in `af_descriptor()` structure in the adaptation field of the partially encrypted transport stream packet.

If no `cets_byte_range_descriptor` is present in the `af_descriptor()` of a transport stream packet protected by a `CA_SystemID` equal to `'cf'`, and the value of `transport_scrambling_control` is not `'00'`, then all bytes in the payload are encrypted.

6.4.2 Syntax

Syntax	No. bits	Mnemonic
<code>cets_byte_range_descriptor {</code>		
<code>descriptor_tag //0x07</code>	8	uimsbf
<code>descriptor_length</code>	8	uimsbf
<code>encryption_info_flag</code>	1	bslbf
<code>reserved</code>	7	uimsbf
<code>for (i=0;i< af_desc_length - 1; i++) {</code>		
<code>is_encrypted</code>	1	bslbf
<code>bytes</code>	7	uismbf
<code>if (is_encrypted && encryption_info_flag) {</code>		
<code>encryption_block_start_flag</code>	1	bslbf
<code>initialization_vector_size_qwords (IVS)</code>	2	uismbf
<code>reserved = 0</code>	5	bslbf
<code>initialization_vector</code>	IVS*64	bslbf
<code>}</code>		
<code>}</code>		
<code>}</code>		

6.4.3 Semantics

cets_byte_range is a structure documenting a byte range and its encryption status.

cets_byte_range(0) starts at the first byte of the TS packet payload. For $i > 0$, **cets_byte_range(i)** starts at the end of **cets_byte_range(i-1)**. As an optimization, bytes starting from the end of the last byte range in the descriptor till the end of the payload has encryption state opposite from the one documented in the last range.

encryption_info_flag: if '1', additional encryption related information will be provided for encrypted ranges.

is_encrypted: If '1', all bytes in the range are encrypted. If 0, all bytes in the range are unencrypted.

bytes: number of bytes in this range. Note that the largest offset expressible this way is 127 bytes, so an offset larger than 127 bytes will need to be expressed as two ranges with the same value of the **is_encrypted** field.

encryption_block_start_flag: block mode starts from the start of this byte range

initialization_vector_size_qwords: size of initialization vector (if provided), in 64-bit words. The value shall be 0 if **encryption_block_start_flag** value is 0. If value of **encryption_block_start_flag** is 1, and the value of **initialization_vector_size_qwords** is zero, a default initialization vector is used. This vector is provided in the ECM.

initialization_vector initialization vector.

7 Operation

7.1 Restrictions on encryption

7.1.1 General

Only one key and one initialization vector shall be necessary for decrypting a payload of a TS packet, unless the packet contains start of a new access unit (indicated using ECM or byte range descriptor)

PES headers shall not be encrypted.

NOTE Partial encryption may be applied to the transport stream packet carrying PES header. In the latter case compatibility issues with equipment unaware of the 'cf' conditional access system can be expected.

Payloads and byte ranges that are described as "encrypted" (using non-zero value of `transport_scrambling_control` and, possibly, `cets_byte_range_descriptor`) shall only contain encrypted bytes.

7.1.2 Rec. ITU-T H.264 | ISO/IEC 14496-10 and Rec. ITU-T H.265 | ISO/IEC 23008-2

Start codes and NAL headers shall not be encrypted; moreover VPS, SPS, PPS and AUD shall not be encrypted.

NOTE The above guarantees that an implementation can reliably parse PTS, DTS, AUD and SPS/PPS/VPS regardless of the value of `transport_scrambling_control`.

It is recommended not to encrypt non-VCL units, however it is sometimes necessary to encrypt SEI messages. It is also recommended not to encrypt slice headers.

The input to encryption process is byte stream according to Annex B of Rec. ITU-T H.264 | ISO/IEC 14496-10 and of Rec. ITU-T H.265 | ISO/IEC 23008-2. Start code emulation prevention (as described in Annex B) shall not be applied to encrypted elementary stream.

This implies that start codes may (with a low probability) appear in payloads of transport stream packets with non-zero value of `transport_scrambling_control`

7.1.3 ISO/IEC 13818-7 and ISO/IEC 14496-3

In case of ADTS frames, `raw_data_bytes` may be encrypted, while `adts_fixed_header`, `adts_variable_header`, `adts_error_check`, `adts_header_error_check`, and `adts_raw_data_block_error_check` shall not be encrypted.

When LATM/LOAS in-band configuration is carried in the `AudioSpecificConfig()` structure, hence any byte containing the latter shall not be encrypted. Only `PayloadMux()` element shall be encrypted.

NOTE Rec. ITU-T H.222.0 | ISO/IEC 13818-1:2015, 2.11.2 only allows single audio elementary stream.

7.2 Multiple protected elementary streams

Key/IV information for every encrypted PID should be carried in a separate ECM PID.

It is possible to use same ECM PID for several elementary streams. In this case, `eu_byte_offset_size` shall be 0, and consequently a single PES packet shall carry a single access unit.

Care should be taken to make sure that for every access unit the latest ECM packet will always contain a correct key/IV combination for the value of `transport_scrambling_control` in transport stream packets carrying this access unit.

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- [1] IETF RFC 1321, The MD5 Message-Digest Algorithm, April 1992
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