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Part 9: Common encryption of MPEG-2 transport streams

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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 23008-2[1)], *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
some_structure {		
some_field_length_qwords (SFL)	2	uimsbf
reserved	6	bslbf
some_field	SFL*64	uismbf
}		

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
cets_ecm(){		
num_states	2	uimsbf
next_key_id_flag	1	bslbf
reserved = 0	5	bslbf
iv_size (IVS)	8	uismbf
default_key_id	128	uismbf
for (i = 0; i < num_states; i++) {		
transport_scrambling_control	2	bslbf
num_eu	6	uismbf
for (j = 0; j < num_eu; j++) {		
key_id_flag	1	bslbf
encryption_block_start_flag	1	bslbf
reserved = 0	2	bslbf
eu_byte_offset_size (EBOS)	4	uismbf
if (key_id_flag == 1) {		bslbf
key_id	128	
}		
eu_byte_offset	EBOS*8	uismbf
initialization_vector	IVS*8	bslbf
}		
if (iv_size == 0) {		
// only cf system		
key_id_flag	1	bslbf
constant_initialization_vector_length_qwords (CIVL)	2	bslbf
reserved = 0	5	bslbf

Syntax	No. of bits	Format
if (key_id_flag == 1) {		
key_id	128	
}		
constant_initialization_vector	CIVL*64	bslbf
}		bslbf
}		
if (next_key_id_flag == 1) {		
countdown_sec	4	uimsbf
reserved = 0	4	bslbf
next_key_id	128	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
`cets_pssh_packet(){`		
`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	8	bslbf
descriptor_length	8	bslbf
CA_System_ID //'ce' or 'cf'	16	bslbf
version_flag	1	bslbf
reserved = '00'	2	bslbf
CA_PID	13	uismbf
scheme_type	32	bslbf
scheme_version	32	uismbf
num_systems	8	bslbf
encryption_algorithm	24	uismbf
for (i = 0; i < num_systems; i++) {		
system_id	128	bslbf
pssh_pid	13	uismbf
reserved = '000'	3	bslbf
}		
if (version_flag == 1) {		
version	8	uismbf
if (version_flag > 0) {		
reserved = '00000000'	8	bslbf
crypt_byte_block;	4	uismbf
skip_byte_block;	4	uismbf
}		
}		
for (i=0; i<N; i++) {		
private_data_byte	8	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.

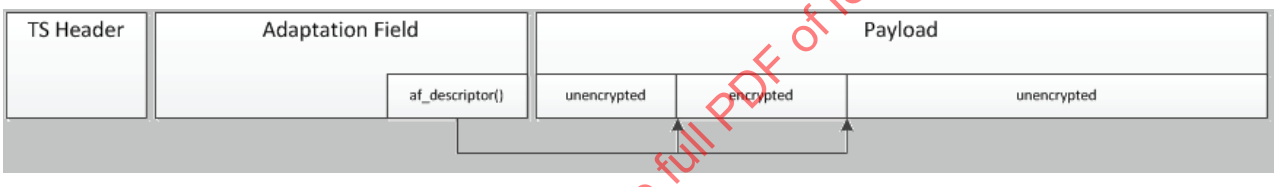
version: specifies the highest version of Common Encryption used. Same as 'tenc'.version field in ISO/IEC 23001-7.

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
cets_byte_range_descriptor {		
descriptor_tag //0x07	8	uimsbf
descriptor_length	8	uimsbf
encryption_info_flag	1	bslbf
reserved	7	uimsbf
for (i=0;i< af_desc_length - 1; i++) {		
is_encrypted	1	bslbf
bytes	7	uismbf
if (is_encrypted && encryption_info_flag) {		
encryption_block_start_flag	1	bslbf
initialization_vector_size_qwords (IVS)	2	uismbf
reserved = 0	5	bslbf
initialization_vector	IVS*64	bslbf
}		
}		
}		

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.

