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Foreword

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This document was prepared by Technical Committee ISO/TC 68, *Financial services*, Subcommittee SC 2, *Financial Services, security*.

Introduction

The secure management of cryptographic keys requires that their values and usage constraints be protected for both confidentiality and integrity. This is especially true for keys used with the 64-bit block cipher triple data encryption algorithm (TDEA) and the 128-bit block cipher advanced encryption standard (AES) because these block ciphers allow the use of key sizes that are larger than the block size.

This document provides a method of wrapping cryptographic keys in order to provide confidentiality and integrity protection for the keys when being transmitted or stored. The mechanism is designed to use AES as the wrapping cipher.

Banking and related financial services — Key wrap using AES

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1 Scope

This document defines a method for packaging cryptographic keys for transport. This method can also be used for the storage of keys under an AES key. The method uses the block cipher AES as the wrapping cipher algorithm.

Other methods for wrapping keys are outside the scope of this document but can use the authenticated encryption algorithms specified in ISO/IEC 19772.

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 11568-2, *Financial services — Key management (retail) — Part 2: Symmetric ciphers, their key management and life cycle*

ISO/IEC 9797-1, *Information technology — Security techniques — Message Authentication Codes (MACs) — Part 1: Mechanisms using a block cipher*

ISO/IEC 10116, *Information technology — Security techniques — Modes of operation for an n-bit block cipher*

ANS X9 TR-31, *Interoperable Secure Key Exchange Key Block Specification for Symmetric Algorithms*

3 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:

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

Deleted: — IEC Electropedia: available at

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

3.1
advanced encryption standard
AES
algorithm specified in ISO/IEC 18033-3

3.2
bit
binary digit

3.3

byte
sequence of 8 *bits* (3.2)

3.4
ciphertext
encrypted (enciphered) data

3.5
cryptographic key
key
sequence of symbols that controls the operation of a cryptographic transformation (e.g. *encryption* (3.7), *decryption* (3.6), cryptographic check function computation, signature generation, or signature verification)

3.6
decryption
process of transforming *ciphertext* (3.4) into *plaintext* (3.13)

3.7
encryption
process of transforming *plaintext* (3.13) into *ciphertext* (3.4)

3.8
exclusive-OR
bit-by-bit modulo-2 addition of binary vectors of equal length

3.9
initialization vector
binary vector used as the input to initialize the algorithm for the *encryption* (3.7) of a plaintext block sequence to increase security by introducing additional cryptographic variance and to synchronize cryptographic equipment

Note 1 to entry: See ISO/IEC 10116.

3.10
key block
block containing a protected key, its usage constrains and other data, that is wrapped (encrypted) using a key wrapping mechanism

3.11
key wrap
symmetric *encryption* (3.7) algorithm designed to encapsulate (encrypt) cryptographic key material

3.12
nibble
half a *byte* (3.3), which can be represented by a single hexadecimal digit

3.13
plaintext
intelligible data that has meaning and can be read or acted upon without the application of *decryption* (3.6)

Note 1 to entry: Also known as cleartext. In the context of this document, the plaintext is the key being wrapped.

3.14

secure cryptographic device
SCD
device that provides secure storage for secret information, such as keys, and provides security services based on this secret information

3.15
triple data encryption algorithm
TDEA
algorithm specified in ISO/IEC 18033-3

4 Symbols and abbreviated terms

AES	advanced encryption standard
CBC	cipher block chaining (mode of encryption)
CMAC	cipher-based MAC
CTR	counter (mode of encryption)
IV	initialization vector for CBC mode or starting value for CTR mode
K	cryptographic key
MAC	message authentication code
TDEA	triple data encryption algorithm
SCD	secure cryptographic device
$\oplus$	exclusive-OR

5 Key wrap method characteristics

Key management according to ISO 11568-2 requires that symmetric keys be protected by physical protection, by splitting the key into components, or by cryptographic protection. Cryptographic protection can be achieved using an authenticated encryption algorithm such as one standardized in ISO/IEC 19772. However, most of the authenticated encryption algorithms in ISO/IEC 19772 are designed for protecting generic payloads such as long messages or large databases rather than symmetric keys that are short and have high entropy. A clear exception to this is mechanism 2 of ISO/IEC 19772:2009 which is called Key Wrap. As stated in ISO/IEC 19772, “This scheme was originally designed for authenticated-encryption of keys and associated information. This mode is known as AES Key Wrap when the AES block cipher is used”. It is also noted in ISO/IEC 19772 that AES Key Wrap is also specified in NIST, *AES Key Wrap Specification* and Reference [5].

The method defined in this document uses the MAC as IV (compared with Algorithm 5 in ISO/IEC 19772 which is an encrypt-then-MAC authenticated encryption algorithm) and as such it could theoretically support any symmetric encryption algorithm mode (e.g. taken from ISO/IEC 10116) or MAC algorithm (e.g. taken from ISO/IEC 9797-1). However, for the purposes of this document, the key wrap method supports only CBC or CTR mode encryption (as defined in ISO/IEC 10116) and CMAC (Method 5 in ISO/IEC 9797-1 and NIST/SP 800-38B) for MAC generation.

The key usage attributes from ANS/TR 31 shall be included in the wrapping process as defined in Annex A. Other methods include but are not limited to authenticated encryption algorithms in ISO/IEC 19772, RFC 3394[5], ANSI CBC MAC[4] and TDEA Key Wrap[4].

6 Key Block Binding key wrap method

6.1 General

When a key is encrypted with a block cipher that has a block size less than the size of the key, this forces the key to be represented by several blocks resulting in a danger of substitution or misuse of a fragment of the overall key cryptogram. Binding the blocks of the encrypted key may be achieved through various methods.

The Key Block Binding method protects the secrecy of the key blocks and protects the integrity of the association between the key blocks and the key block header (see Annex A for a definition of a key block header). The method uses an AES Key Block Protection Key that was previously exchanged (using secure, possibly manual, methods as described in ISO 11568-2) between the two communicating parties and used for deriving keys used for MACing and encrypting the key blocks. The method can be used for wrapping any cryptographic key (see Table A.4).

The processing components of the Key Block Binding key wrap method are as follows.

- Key derivation as described in 6.3:
  - derivation of the MAC and encryption keys from the protection key.
- Binding and encryption as described in 6.2:
  - binding of the key to be wrapped and its header using the derived MAC key;
  - encryption of the key to be wrapped and its length using the derived encryption key.
- Decryption and validation as described in 6.4:
  - decryption of the wrapped key and its length using the derived encryption key;
  - validation of the associated header data using the derived MAC key.

6.2 Key block binding and encryption

The key block binding and encryption proceeds as follows.

- The confidential portion is constructed using one of the following methods.
  - For CBC mode encryption, the confidential portion (key length and key) is padded on the right with random pad bytes until the resulting string is a multiple of 16 bytes. Additional padding may be used to mask the true length of the key/data as long as the resulting length is a multiple of 16 bytes.
  - For CTR mode encryption, there is no padding. Note that although CTR does not require padding, the confidential portion may be padded in the same way as CBC mode in order to disguise the key length.
- CMAC is applied to the entire payload, that is, the header concatenated with the confidential part, including padding if present, using the derived MAC key (see 6.3) to yield a MAC, m. The MAC is not truncated and is 16 bytes.
- The confidential part (key length, key and random padding if present) is encrypted in either CBC or CTR mode (depending on which mode is chosen) with no additional padding applied and using the

MAC m as IV and the derived encryption key (see 6.3) in accordance with ISO/IEC 10116. This yields a ciphertext, c.

— The ciphertext c is transmitted along with the MAC m and the unencrypted portion (the header).

Figure 1 illustrates the Key Block Binding and encryption described above.

Details of the key block header and key length encoding can be found in Annex A.

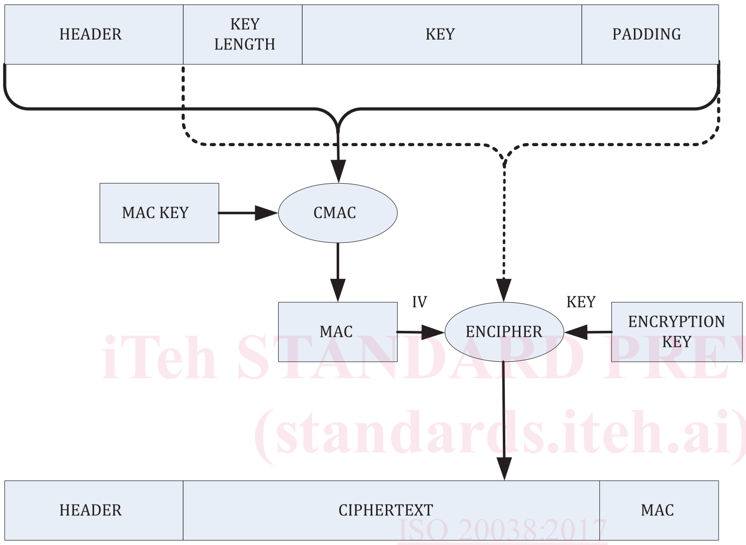


Figure 1 — Key Block Binding

The MAC key and the encryption key are derived keys as described in the next section.

6.3 Key derivation

The encryption key and MAC key are derived from the Key Block Protection Key using CMAC (algorithm 5 in ISO/IEC 9797-1) as detailed in the remainder of this subclause. Table 1 shows the input data to the CMAC function.

Table 1 — Key Derivation Input Data

Nibble #	Field name	Description	Encoding	Range of values
0–1	Counter	A counter that is incremented for each CMAC operation	2H	0x01–0x02
2–5	Key Usage Indicator	Indicates whether the key to be derived is to be used for encryption/decryption or MAC generation/verification	4H	0x0000 = encryption CBC mode 0x0001 = MAC 0x0002 = encryption CTR mode
6–7	Separator	A 1-byte separator, shall be zero	2H	0x00
8–11	Algorithm	Indicates the encryption and MAC	4H	0x0002 = AES 128 bit

	Indicator	block cipher algorithm that is going to use the two derived keys (and is used to derive those keys)		0x0003 = AES 192 bit 0x0004 = AES 256 bit
12–15	Length	Length, in bits, of the keying material being generated for the pair of encryption and MAC keys	4H	0x0080 if AES-128 keys are being generated 0x00C0 if AES-192 keys are being generated 0x0100 if AES-256 keys are being generated

NOTE The counter value in nibbles 0–1 is set to 1 when deriving the first bytes of the encryption key, then is reset to 1 again when deriving the first bytes of the MAC key.

The Counter is incremented for each call to CMAC as part of deriving an encryption or a MAC key from a Key Block Protection Key. The Counter starts at 0x01. The Key Usage Indicator tells if the key generated is a MAC key or an encryption key for CBC mode or CTR mode encryption. The Algorithm Indicator tells which algorithm is used.

Key Block Protection Keys derive keys of the same length. That is, a 128-bit AES key can only be used to derive 128-bit encryption and MAC keys, a 192-bit AES key can only be used to derive 192-bit encryption and MAC keys and a 256-bit AES key can only be used to derive 256-bit encryption and MAC keys.

“Length” indicates how many bits of keying material is to be derived for the encryption and MAC keys. If the derived key is a 128-bit key, then a total of 128 bits (0x0080) are to be derived, if it is a 192-bit key, then a total of 192 bits (0x00C0) are to be derived and if it is a 256-bit key, then a total of 256 bits (0x0100) are to be derived. Note that because wrapping is only allowed using AES, the Length information can be derived from the Algorithm Indicator.

In any sequence of calls to CMAC where the counter is incremented, the Key Usage Indicator and the Algorithm Indicator should remain unchanged. Hence, when deriving an encryption key and a MAC key, that should be done in two distinct sequences of calls to CMAC, each starting with the Counter as 0x01.

Figure 2 illustrates how to derive a 128-bit AES CBC encryption key and MAC key from a 128-bit AES Key Block Protection Key, K.

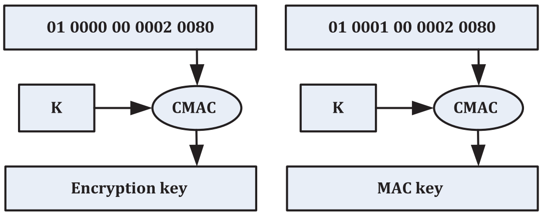
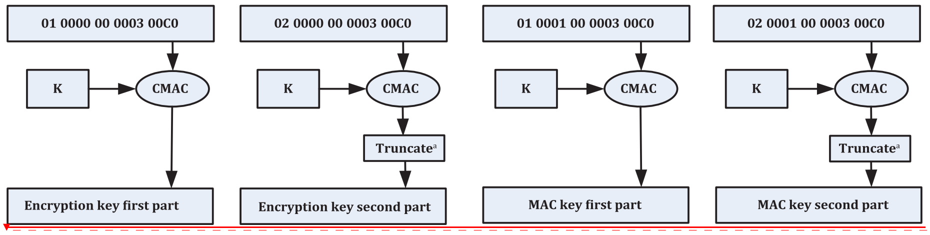


Figure 2 — Deriving AES 128 MAC and CBC encryption keys

Figure 3 illustrates how to derive a 192-bit AES CBC encryption key and MAC key from a 192-bit AES Key Block Protection Key, K.



[a] Select leftmost 64 bits.

Figure 3 — Deriving 192-bit AES MAC and CBC encryption keys

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