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Part 21: Crypto suite SIMON security services for air interface communications

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Partie 21: Services de sécurité par suite cryptographique SIMON pour communications par interface radio

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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 or www.iec.ch/members_experts/refdocs).

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This second edition cancels and replaces the first edition (ISO/IEC 29167-21:2018), which has been technically revised.

The main change is as follows: Annex E has been updated to reflect changes to the over-the-air protocol.

A list of all parts in the ISO/IEC 29167 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

This document provides a common crypto suite for security for radio frequency identification (RFID) devices. The crypto suite is defined in alignment with existing air interfaces and specifies a variety of security services provided by the lightweight block cipher SIMON.

Information technology — Automatic identification and data capture techniques —

Part 21: Crypto suite SIMON security services for air interface communications

1 Scope

This document specifies the crypto suite for SIMON for the ISO/IEC 18000 air interface standards for radio frequency identification (RFID) devices.

SIMON is a symmetric block cipher that is parameterized in both its block length and key length. The block/key length options supported in this crypto suite (in bits) are 64/96, 96/96, 64/128, 128/128 and 128/256.

In this document, a Tag and an Interrogator can support one, a subset or all of the specified options, clearly stating what is supported.

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 18000-63, *Information technology — Radio frequency identification for item management — Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C*

ISO/IEC 19762, *Information technology — Automatic identification and data capture (AIDC) techniques — Vocabulary*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762 and the following apply.

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

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

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

3.1.1
bit string
ordered sequence of 0s and 1s

3.1.2
block cipher
family of permutations that is parameterized by a *cryptographic key* (3.1.4) and, optionally, the *block size* (3.1.3)

3.1.3
block size
number of bits in a *data block* (3.1.6) that is an input (or output) of the *block cipher* (3.1.2)

3.1.4
cryptographic key
string of bits of length given by *key size* (3.1.7) that is used by the *block cipher* (3.1.2) to transform some *data block* (3.1.6)

3.1.5
command
<message> data that the Interrogator sends to the Tag with "Message" as parameter

3.1.6
data block
string of bits whose length is given by the *block size* (3.1.3) of the *block cipher* (3.1.2)

3.1.7
key size
length in bits of the *cryptographic key* (3.1.4) that is used by the *block cipher* (3.1.2)

3.1.8
message
part of the *command* (3.1.5) that is defined by the crypto suite

3.1.9
nonce
data block (3.1.6) that, within the parameters of typical use, can be assumed to be non-repeating

3.1.10
SIMON-b/k-ENC(key, data)
SIMON encryption of a *b*-bit *data block* (3.1.6) using a *k*-bit *cryptographic key* (3.1.4)

3.1.11
SIMON-b/k-DEC(key, data)
SIMON decryption of a *b*-bit *data block* (3.1.6) using a *k*-bit *cryptographic key* (3.1.4)

3.1.12
reply
<response> data that the Tag returns to the Interrogator with *"Response"* (3.1.13) as a parameter

3.1.13
response
part of the *"Reply"* (3.1.12) (stored or sent) that is defined within the crypto suite

3.2 Symbols

$XXXX_2$	Binary notation
$XXXX_h$	Hexadecimal notation
||	Concatenation of syntax elements, transmitted in the order written
Ø	Empty string, typically used to indicate a deliberately empty input or omitted field
|A|	Bit-wise length of the string A expressed as an integer

EXAMPLE 1 $|0000_2| = 4$.

EXAMPLE 2 $|0000_h| = 16$.

EXAMPLE 3 $|\emptyset| = 0$.

fix1(A) String obtained by fixing the first (leftmost) bit to 1_2

EXAMPLE 4 **fix**1(0000_2) = 1000_2.

EXAMPLE 5 **fix**1(0000_h) = 8000_h.

EXAMPLE 6 **fix**1($\emptyset$) = $\emptyset$.

$\mathbf{msb}_n$ (A) *n*-bit binary string obtained by taking the first (leftmost) *n* bits of the binary representation of A

EXAMPLE 7 $\mathbf{msb}_3$ (1010_2) = 101_2.

EXAMPLE 8 $\mathbf{msb}_7$ ($ABCD_h$) = 1010101_2.

EXAMPLE 9 $\mathbf{msb}_7$ ($\emptyset$) = $\emptyset$.

Field [a:b] selection of bits "a" through to, and including, bit "b" from a string of bits denoted Field where Field [0] represents the least significant or rightmost bit

EXAMPLE 10 Field [2:0] represents the selection of the three least significant bits of Field.

EXAMPLE 11 Field, without a specified range, indicates the entirety of Field.

EXAMPLE 12 Field [-1:0] is an alternative representation of the empty string $\emptyset$.

Key.KeyID Cryptographic key identified and indexed by the numerical value KeyID

3.3 Abbreviated terms

CS crypto suite

CSI crypto suite identifier

IA Interrogator authentication

MA Mutual authentication

RFU reserved for future use

TA Tag authentication

4 Conformance

4.1 Air interface protocol specific information

An Interrogator or Tag shall conform with all relevant clauses of this document, except those marked as “optional”.

4.2 Interrogator conformance and obligations

An Interrogator shall implement the mandatory commands described in this document and conform to the relevant part of the ISO/IEC 18000 series.

An Interrogator may implement any subset of the optional commands described in this document.

The Interrogator shall not:

— implement any command that conflicts with this document; or

— require the use of an optional, proprietary or custom command to meet the requirements of this document.

4.3 Tag conformance and obligations

A Tag shall implement the mandatory commands described in this document for the supported types and conform to the relevant part of the ISO/IEC 18000 series.

A Tag may implement any subset of the optional commands described in this document.

A Tag shall not:

— implement any command that conflicts with this document; or

— require the use of an optional, proprietary or custom command to meet the requirements of this document.

5 Overview of the SIMON crypto suite

SIMON is a lightweight Feistel block cipher that is suitable for extremely constrained environments such as RFID Tags. The details of the operation of the SIMON cipher are described in Annex C.

The background for the development of SIMON and its design principles are described in Reference [3].

SIMON is parameterized in terms of the data block size, denoted *b*, and the cryptographic key size, denoted *k*. A particular variant of SIMON is denoted SIMON-*b*/*k* throughout this document. While Reference [3] offers many different choices to the block and key size, this crypto suite only supports the five parameter combinations given in Table 1.

Table 1 — Variants of SIMON-*b*/*k* supported in this document

	SIMON-64/96	SIMON-64/128	SIMON-96/96	SIMON-128/128	SIMON-128/256
Block size (*b* bits)	64	64	96	128	128
Key size (*k* bits)	96	128	96	128	256

It is possible that not all variants of SIMON will be cryptographically suited to all applications. Guidance on the appropriate variant for a given application lies outside the scope of this document and a thorough security and risk assessment is advised before deployment.

Test vectors for parts of this document are provided in Annex D.

Over-the-air protocol commands that use this crypto suite shall be in accordance with Annex E.

6 Parameter and variable descriptions

Table 2 describes all the variables and constants that are used in this document.

Table 2 — SIMON crypto suite variables and constants

Parameter	Description
IChallenge-*b*/*k*	A challenge generated at random by the Interrogator. The length of IChallenge-*b*/*k* depends on the values of *b* and *k*.
TChallenge-*b*/*k*	A challenge generated at random by the Tag. The length of TChallenge-*b*/*k* depends on the values of *b* and *k*.
TRnd-*b*/*k*	A salt value generated at random by the Tag. The length of TRnd-*b*/*k* depends on the values of *b* and *k*.
IRnd-*b*/*k*	A salt value generated at random by the Interrogator. The length of IRnd-*b*/*k* depends on the values of *b* and *k*.
C_TAM-*b*/*k*	A pre-defined constant. The length and value of C_TAM-*b*/*k* depends on the values of *b* and *k*.
C_IAM-*b*/*k*	A pre-defined constant. The length and value of C_IAM-*b*/*k* depends on the values of *b* and *k*.
C_MAM-*b*/*k*	A pre-defined constant. The length and value of C_MAM-*b*/*k* depends on the values of *b* and *k*.
Key.0 … Key.255	A set of up to 256 keys Key.0 through to Key.255. Not all key values need to be specified. However, Key.j shall not be specified when there remain unspecified Key.i with i<j.

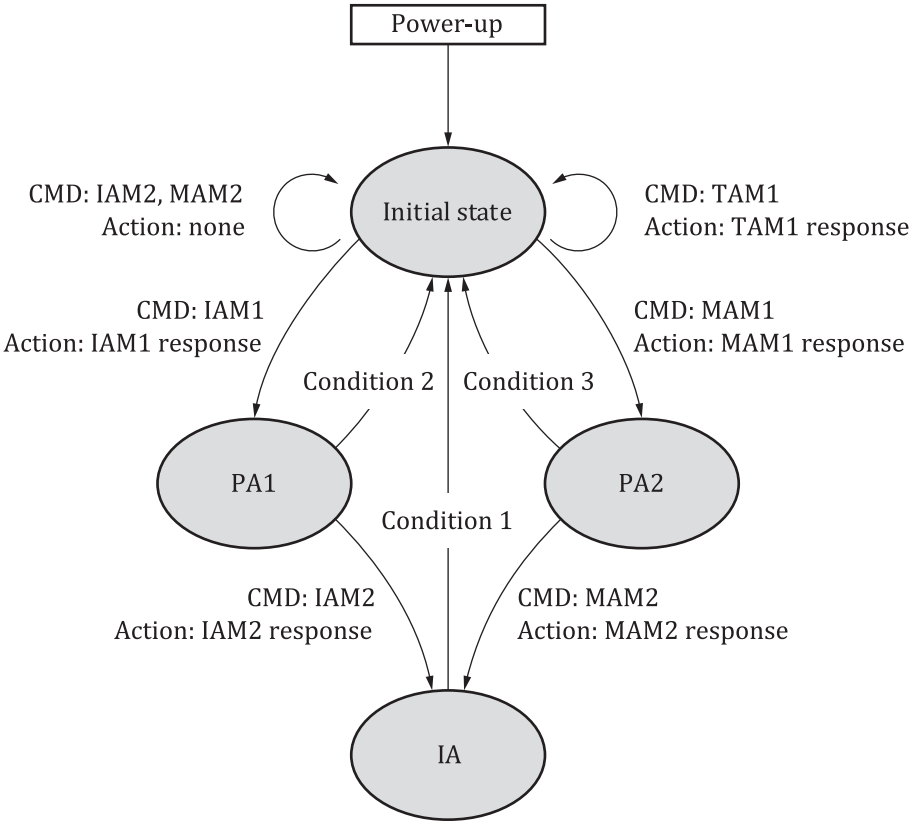
Table 3 gives the values of C_TAM-*b*/*k*, C_IAM-*b*/*k* and C_MAM-*b*/*k* that are used in this document. For a given choice of operational parameters, the length of these constants depends on the block size *b*.

Table 3 — Values of C_TAM-*b*/*k*, C_IAM-*b*/*k* and C_MAM-*b*/*k* for different values of *b* and *k* and different parameter sets PS

b/*k*	64/96	64/128	96/96	128/128	128/256
C_TAM-*b*/*k*	11_2	11_2	FF_h	$FFFF_h$	$FFFF_h$
C_IAM-*b*/*k*	10_2	10_2	FE_h	$FFFE_h$	$FFFE_h$
C_MAM-*b*/*k* for PS =00_2	01_2	01_2	FD_h	$FFFD_h$	$FFFD_h$
C_MAM-*b*/*k* for PS =01_2	1_h	1_h	D_h	FD_h	FD_h

7 Crypto suite state diagram

After power-up and after a reset, the crypto suite shall transition into the **Initial** state, state transitions shall be as described by Annex A and error handling shall be as described by Annex B. The state transition diagram is given in Figure 1.



Condition 1 For all of TAM1, IAM1, MAM1, IAM2, MAM2 and errors, return to Initial state without action.

Condition 2 For all of TAM1, IAM1, MAM1, MAM2 and errors, return to Initial state without action.

Condition 3 For all of TAM1, IAM1, MAM1, IAM2 and errors, return to Initial state without action.

Figure 1 — Crypto suite state diagram

8 Initialization and resetting

After power-up and after a reset, the cryptographic state machine transitions into the **Initial** state.

Implementations of this suite shall ensure that all memory used for any intermediate results is cleared:

— after the completion of each cryptographic protocol,

— if some cryptographic protocol is abandoned or incomplete, and

— after reset.

9 Authentication

9.1 General

This document supports Tag authentication, Interrogator authentication and Mutual authentication.

This clause describes the details of the messages and responses that are exchanged between the Interrogator and Tag for each of the authentication methods.

9.2 Message and response formatting

Messages and responses are part of the security commands described in the air interface specification. Subclauses 9.3, 9.4 and 9.5 describe the formatting of message and response for a Tag authentication method, an Interrogator authentication method and a Tag-Interrogator mutual authentication method.

9.3 Tag authentication (AuthMethod "00")

9.3.1 General

Tag authentication uses a challenge-response protocol as shown in Figure 2.

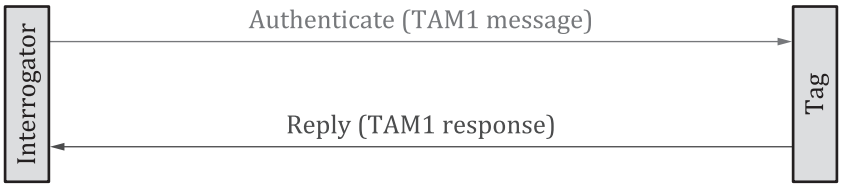


Figure 2 — Tag authentication via a challenge-response scheme

The parameter set PS described in Table 4 gives the lengths of different fields for different block and key sizes.

NOTE The parameter set PS = 00_2 closely matches other parts of the ISO/IEC 29167 series, most notably ISO/IEC 29167-10. This provides some drop-in compatibility between SIMON-128/128 and AES-128.

Table 4 — Parameter set PS = 00_2 for Tag authentication

Parameter set PS = 00_2					
b/k	**64/96**	**64/128**	**96/96**	**128/128**	**128/256**
$t = \lvert$ IChallenge-b/k $\rvert$	42	42	56	80	80
$r = \lvert$ TRnd-b/k $\rvert$	20	20	32	32	32
$c = \lvert$ C_TAM-b/k $\rvert$	2	2	8	16	16

9.3.2 TAM1 message

The Interrogator shall generate a random Interrogator challenge (IChallenge-b/k) that is carried in the TAM1 message shown in Table 5. The Interrogator shall also indicate the variant of SIMON to be used.

NOTE 1 The variant(s) of SIMON deployed on a device is (are) manufacturer dependent.

NOTE 2 Mechanisms to generate the random Interrogator challenge lie outside the scope of this document.

Table 5 — TAM1 message format

Field	**Payload**							
	AuthMethod	**Step**	**RFU**	**BlockSize**	**KeySize**	**KeyID**	**PS**	**Challenge**
Length (bits)	2	2	2	2	2	8	2	t
Value	00_2	00_2	00_2	00_2: b=64 01_2: b=96 10_2: b=128 11_2: RFU	00_2: k=96 01_2: k=128 10_2: k=256 11_2: RFU	variable	00_2	IChallenge-b/k

9.3.3 Intermediate Tag processing

The Tag shall accept the TAM1 message at any time (unless occupied by internal processing and not capable of receiving messages); i.e. upon receipt of the message with valid parameters, the Tag shall abort any cryptographic protocol that has not yet been completed and shall remain in the **Initial** state.

The Tag shall check if the Step is "00_2". If the value of Step is different, the Tag shall return a "Not Supported" error.

The Tag shall check if the RFU is "00_2". If the value of RFU is different, the Tag shall return a "Not Supported" error.

The Tag shall check whether the values of BlockSize and KeySize are supported by the Tag. If at least one of these checks is failed, the Tag shall return a "Not Supported" error.

The Tag shall check whether the values of BlockSize and KeySize are supported by Key.KeyID and that Key.KeyID is authorized for use in Tag authentication. If either or both of these checks is failed, the Tag shall return a "Not Supported" error.

The Tag shall check whether the parameter set PS is supported. If the parameter set PS is not supported, the Tag shall return a "Not Supported" error.

Assuming that the TAM1 message is successfully parsed by the Tag, the Tag shall prepare the TAM1 response.

9.3.4 TAM1 response

The Tag shall generate a random salt TRnd-*b*/*k* of length *r* bits where *r* is given for the parameter set in Table 3.

The Tag shall use Key.KeyID and SIMON encryption to form a *b*-bit string TResponse such that:

TResponse = SIMON-b/k-ENC (Key.KeyID, C_TAM-*b*/*k* || TRnd-*b*/*k* || IChallenge-*b*/*k*).

The Tag shall return TResponse to the Interrogator as shown in Table 6.

NOTE 1 Only one input block of *b* bits is encrypted and so only one invocation of SIMON-*b*/*k* is required.

NOTE 2 Appropriate mechanisms to generate TRnd-*b*/*k* lie outside the scope of this document.

Table 6 — TAM1 response format

Field	Payload Tag Response
Length (bits)	*b*
Value	TResponse

9.3.5 Final Interrogator processing

After receiving TAM1 response, the Interrogator shall use Key.KeyID to compute the *b*-bit string S where:

S = SIMON-*b*/*k*-DEC (Key.KeyID, TResponse).

a) The Interrogator shall check that S[*t*-1:0] = IChallenge-*b*/*k*.

b) The Interrogator may check that S[*b*-1:*b*-*c*] = C_TAM-*b*/*k*.

If these verification steps are successfully completed, the Interrogator may conclude that the Tag and Interrogator possess matching values of Key.KeyID. When combined with an appropriate key management scheme — the definition of which falls outside the scope of this document — the Interrogator may conclude that the Tag is authentic.

NOTE Determining Key.KeyID is a matter of key management and falls outside of the scope of this document.

9.4 Interrogator authentication (AuthMethod “01”)

9.4.1 General

Interrogator authentication uses a challenge-response protocol as shown in Figure 3.

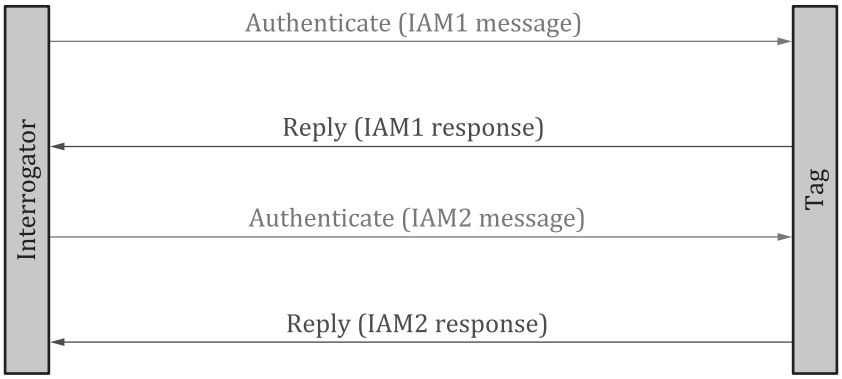


Figure 3 — Interrogator authentication via a challenge-response scheme

The parameter set in Table 7 gives the lengths of specific data fields for different choices of block and key size.

NOTE The parameter set PS = 00_2 closely matches other parts of the ISO/IEC 29167 series, most notably ISO/IEC 29167-10. This provides some drop-in compatibility between SIMON-128/128 and AES-128.

Table 7 — Parameter set PS = 00_2 for Interrogator authentication

Parameter set PS = 00_2					
b*/*k	**64/96**	**64/128**	**96/96**	**128/128**	**128/256**
$t = \lvert$ TChallenge-b/k $\rvert$	42	42	56	80	80
$r = \lvert$ IRnd-b/k $\rvert$	20	20	32	32	32
$c = \lvert$ I_MAM-b/k $\rvert$	2	2	8	16	16

9.4.2 IAM1 message

The Interrogator shall send an initial message IAM1 to the Tag, formatted in accordance with Table 8, prompting the Tag to start a challenge-response exchange.

The Interrogator shall also indicate the variant of SIMON to be used.

NOTE The variant(s) of SIMON deployed on a device is (are) manufacturer dependent.

Table 8 — IAM1 message format

Field	**Payload**						
	AuthMethod	**Step**	**RFU**	**BlockSize**	**KeySize**	**KeyID**	**PS**
Length (bits)	2	2	2	2	2	8	2
Value	01_2	00_2	00_2	00_2: b=64 01_2: b=96 10_2: b=128 11_2: RFU	00_2: k=96 01_2: k=128 10_2: k=256 11_2: RFU	variable	00_2