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Part 3: Discrete logarithm based mechanisms

Techniques de sécurité IT — Signatures numériques avec appendice —

Partie 3: Mécanismes basés sur un logarithme discret

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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).

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For an explanation of 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 www. iso .org/iso/foreword. html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 27, *IT Security techniques*.

This fourth edition cancels and replaces the third edition (ISO 14888-3:2016), of which it constitutes a minor revision. The main changes compared to the previous edition are as follows:

— SM2 algorithm has been added to 6.12 and F.14;

— Chinese IBS algorithm has been added to 7.4 and F.15;

— numerical examples of KCDSA, ECDSA and EC-KCDSA have been added to F.3.4, F.6.6, F.6.7, F.6.8, F.7.7, F.7.8 and F.7.9;

— several formulae and symbols have been corrected.

A list of all parts in the ISO/IEC 14888 series can be found on the ISO website.

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.

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Introduction

Digital signature mechanisms can be used to provide services such as entity authentication, data origin authentication, non-repudiation and data integrity. A digital signature mechanism satisfies the following requirements.

— Given either or both of the following two things:

  — the verification key, but not the signature key;

  — a set of signatures on a sequence of messages that an attacker has adaptively chosen,

— it should be computationally infeasible for the attacker to:

  — produce a valid signature on a new message:

  — in some circumstances, produce a new signature on a previously signed message; or

  — recover the signature key;

— it should be computationally infeasible, even for the signer, to find two different messages with the same signature.

NOTE 1 Computational feasibility depends on the specific security requirements and environment.

NOTE 2 In some applications, producing a new signature on a previously signed message without knowing the signature key is allowed. One example of such applications is a membership credential in an anonymous digital signature mechanism as specified in ISO/IEC 20008.

Digital signature mechanisms are based on asymmetric cryptographic techniques and involve the following three basic operations:

— a process for generating pairs of keys, where each pair consists of a private signature key and the corresponding public verification key;

— a process that uses the signature key, called the signature process;

— a process that uses the verification key, called the verification process.

The following are the two types of digital signature mechanisms:

— when, for a given signature key, any two signatures produced for the same message are always identical, the mechanism is said to be deterministic (or non-randomized) (see ISO/IEC 14888-1 for further details);

— when, for a given message and signature key, any two applications of the signature process produce (with high probability) two distinct signatures, the mechanism is said to be randomized (or non-deterministic).

The mechanisms specified in this document are all randomized.

Digital signature mechanisms can also be divided into the following two categories:

— when the whole message has to be stored and/or transmitted along with the signature, the mechanism is termed a "signature mechanism with appendix" (such mechanisms are the subject of the ISO/IEC 14888 series);

— when the whole message, or part of it, can be recovered from the signature, the mechanism is termed a "signature mechanism giving message recovery" (the ISO/IEC 9796 series specifies mechanisms in this category).

The verification of a digital signature requires access to the signing entity’s verification key. It is, thus, essential for a verifier to be able to associate the correct verification key with the signing entity, or more

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precisely, with (parts of) the signing entity's identification data. This association between the signer's identification data and the signer's public verification key can either be guaranteed by an outside entity or mechanism, or the association can be somehow inherent in the verification key itself. In the former case, the scheme is said to be "certificate-based." In the latter case, the scheme is said to be "identity based." Typically, in an identity-based scheme, the verifier can calculate the signer's public verification key from the signer's identification data. The digital signature mechanisms specified in this document are classified into certificate-based and identity-based mechanisms.

NOTE 3 For certificate-based mechanisms, various PKI standards can be used as the basis of key management. For further information, see ISO/IEC 9594-8 (also known as X.509), ISO/IEC 11770-3 and ISO/IEC 15945.

The security of a signature mechanism is based on an intractable computational problem, i.e. a problem for which, given current knowledge, finding a solution is computationally infeasible, such as the factorization problem and the discrete logarithm problem. This document specifies digital signature mechanisms with appendix based on the discrete logarithm problem, and ISO/IEC 14888-2 specifies digital signature mechanisms with appendix based on the factorization problem.

NOTE 4 The first edition of the ISO/IEC 14888 series grouped identity-based mechanisms into ISO/IEC 14888-2 and certificate-based mechanisms into ISO/IEC 14888-3, with both parts covering mechanisms based on both the discrete logarithm and the factorization problems. Since the second edition was published, the mechanisms have been reorganized. ISO/IEC 14888-2 now contains integer factoring-based mechanisms, and this document now contains discrete logarithm based mechanisms.

This document includes 14 mechanisms: two of which (DSA and Pointcheval/Vaudenay algorithm) were in ISO/IEC 14888-3:1998, three of which (EC-DSA, EC-KCDSA, and EC-GDSA) were from ISO/IEC 15946-2:2002 and three of which (KCDSA, IBS-1 and IBS-2) were added in ISO/IEC 14888-3:2006, four of which (SRA, EC-RDSA, EC-SDSA and EC-FSDSA) were added in ISO/IEC 14888-3:2006/Amd 1:2010, and two of which (SM2 and Chinese IBS) are added in this document.

The mechanisms specified in this document use a collision resistant hash-function to hash the message being signed (possibly in more than one part). ISO/IEC 10118 specifies hash-functions.

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NOTE 5 The mechanisms of EC-DSA, EC-GDSA. EC-RDSA and EC-FSDSA may be vulnerable to a key substitution attack[10]. The attack is realized if an adversary can find two distinct public keys and one signature such that the signature is valid for both public keys. There are several approaches of avoiding this attack and its possible impact on the security of a cryptographic system. For example, the public key corresponding to the private signing key can be added into the message to be signed.

Annexes A, B and D are normative elements; Annexes C, E, F, G and H are for information.

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IT Security techniques — Digital signatures with appendix —

Part 3: Discrete logarithm based mechanisms

1 Scope

This document specifies digital signature mechanisms with appendix whose security is based on the discrete logarithm problem.

This document provides

— a general description of a digital signature with appendix mechanism, and

— a variety of mechanisms that provide digital signatures with appendix.

For each mechanism, this document specifies

— the process of generating a pair of keys,

— the process of producing signatures, and

— the process of verifying signatures.

Annex A defines object identifiers assigned to the digital signature mechanisms specified in this document, and defines algorithm parameter structures.

Annex B defines conversion functions of FE2I, I2FE, FE2BS, BS2I, I2BS, I2OS and OS2I used in this document.

Annex D defines how to generate DSA domain parameters.

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 10118-3, *IT Security techniques — Hash-functions — Part 3: Dedicated hash-functions*

ISO/IEC 14888-1, *Information technology — Security techniques — Digital signatures with appendix — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 14888-1 and the following apply.

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

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

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

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3.1
finite commutative group
finite set E with the binary operation **"*"** such that

— for all group elements $a, b \in E$, $a * b \in E$;

— for all group elements $a, b, c \in E$, $(a * b) * c = a * (b * c)$;

— there exists a group element $e \in E$ with $e * a = a$ for all $a \in E$, where e is called the identity element of the group;

— for all group elements $a \in E$, there exists a group element $b \in E$ with $b * a = e$;

— for all group elements $a, b \in E$, $a * b = b * a$

Note 1 to entry: In some cases, such as when E is the set of points on an elliptic curve, arithmetic in the finite set E is described with additive notation.

3.2
cyclic group
finite commutative group (3.1), E, of n elements that contains a group element $a \in E$, called the generator, of order n

3.3
elliptic curve group
cyclic group (3.2) defined on the points of an elliptic curve over a finite field

Note 1 to entry: Let $F = GF(r)$ denote the Galois field with cardinality, r, where either r is an odd prime, p, or r is equal to 2^m, for some positive integer, m.

An elliptic curve defined over F can be determined by an affine curve formula, either of the form $y^2 = x^3 + a_1x + a_2$ (when $r = p$ for some odd prime p) or of the form $y^2 + xy = x^3 + a_1x^2 + a_2$ (when $r = 2^m$ for some positive integer m), where the coefficients a_1 and a_2 are (appropriately chosen) elements of F. The corresponding elliptic curve E consists of a collection of certain affine points from $F \times F$ together with a special (non-affine) point "at infinity".

An affine point P of E is one that can be represented as an ordered pair $(P_x, P_y) \in F \times F$, such that the selection of $x = P_x$ and $y = P_y$ satisfies the given affine curve formula when the indicated arithmetic is performed in the field, F.

Let "+" denote the binary operation known as "elliptic-curve addition", defined for (most) affine points of E by the well-known secant-and-tangent rules. Once the collection of affine points of E is augmented by 0_E, a special point of E "at infinity" that serves as the identity element for "+" (but is not represented as an ordered pair), the set E together with the binary operation "+" forms a finite, commutative, elliptic-curve group, E.

Note 2 to entry: The cardinality of the elliptic-curve group, E, is one more than the number of ordered pairs in $F \times F$ that satisfy the affine curve formula for E.

3.4
order (of a group element *a*)
least positive integer n such that $a^n=e$, where e is the identity element of the group, a^n is defined recursively such that $a^0 = e$ and $a^m = a*a^{m-1}$ ($m > 0$), and * is the group operation

3.5
pairing
function which takes two elements, P and Q, from an *elliptic curve group* (3.3) over a finite field, G_1, as input, and produces an element from another *cyclic group* (3.2) over a finite field, G_2, as output, and which has the following two properties (where it is assumed that the cyclic groups, G_1 and G_2 have order q, for some prime q, and for any two elements P, Q, the output of the pairing function is written as $<P, Q>$)

— Bilinearity: If P, P_1, P_2, Q, Q_1, Q_2 are elements of G_1, and a is an integer satisfying $1 \le a \le q - 1$, then

$<P_1 + P_2, Q> = <P_1, Q> * <P_2, Q>$,

$<P, Q_1 + Q_2> = <P, Q_1> * <P, Q_2>$, and

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$<[a]P, Q> = <P, [a]Q> = <P, Q>^a$

— Non-degeneracy: If P is a non-identity element of G_1, $<P, P> \neq 1$

3.6
trusted key generation centre
KGC
trusted third party, which, in an identity-based signature mechanism, generates a private signature key for each signing entity

4 Symbols and abbreviated terms

$a \oplus b$	bitwise exclusive OR of a and b, where a and b are either bits or strings of bits of the same length, and in the latter case, the XOR operation is performed bit-wise
a_1, a_2	elliptic curve coefficients
a mod n	for an arbitrary integer a and a positive integer n, the unique integer remainder r, $0 \leq r \leq (n - 1)$, satisfying $r = a - bn$, for some integer b.
(A, B, C)	the coefficients of the signature formula, which, for the mechanisms specified in Clause 6, defines how the signature is computed NOTE 1 The signature formula is specified in 5.2.1.
D	a parameter which specifies the relationship between the signature key and the verification key
E	an elliptic curve defined by two elliptic curve coefficients, a_1 and a_2
$\mathcal{E}$	a finite commutative group; for the mechanisms based on a multiplicative group, the elements of $\mathcal{E}$ are in Z_p^*; for the mechanisms based on an additive group of elliptic curve points, the elements of $\mathcal{E}$ are the points on an elliptic curve E over $GF(r)$
$\#\mathcal{E}$	the cardinality of $\mathcal{E}$; for the mechanisms based on a multiplicative group Z_p^*, $\#\mathcal{E}$ is $p - 1$; for the mechanisms based on an additive group of elliptic curve points, $\#\mathcal{E}$ is one more than the number of points on the elliptic curve E over $GF(r)$ [including 0_E (the point at infinity)]
F	a finite field
F_p	a finite field of order p
$gcd(N_1, N_2)$	the greatest common divisor of integers N_1 and N_2
G	an element of order q in $\mathcal{E}$
$GF(r)$	the finite field of cardinality r, where r is a prime power
G_1	a cyclic group of prime order q; elements of G_1 are points on an elliptic curve over $GF(r)$
G_2	a cyclic group of prime order q; elements of G_2 are elements of a finite field $GF(r)$
H_1	a hash-function that converts a data string into an element in G_1 NOTE 2 The input data string is converted to an integer first, then the integer is converted to a point on E over $GF(r)$ by using the I2P function, specified in Annex C.
h, H_2	hash-functions, i.e. one of the mechanisms specified in ISO/IEC 10118

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