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**Information technology — Security  
techniques — Key management —**

Part 4:

**Mechanisms based on weak secrets**

AMENDMENT 1: Unbalanced Password-  
Authenticated Key Agreement with  
Identity-Based Cryptosystems (UPAKA-  
IBC)

[ISO/IEC 11770-4:2017/Amd 1:2019](https://standards.iso.org/iso/iec/11770-4-2017-amd-1-2019)

[Technologies de l'information — Techniques de sécurité — Gestion  
de clés — 11770-4-2017-amd-1-2019](https://standards.iso.org/iso/iec/11770-4-2017-amd-1-2019)

*Partie 4: Mécanismes basés sur des secrets faibles*

*AMENDEMENT 1: Accord dissymétrique de clé authentifié par mot de  
passe utilisant un mécanisme de chiffrement basé sur l'identité*



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# Information technology — Security techniques — Key management —

## Part 4: Mechanisms based on weak secrets

### AMENDMENT 1: Unbalanced Password-Authenticated Key Agreement with Identity-Based Cryptosystems (UPAKA-IBC)

#### Introduction

Insert the following paragraph after Note 2:

- d) **Unbalanced password-authenticated key agreement with identity-based cryptosystems:** Establish one or more secret keys for an entity, *A*, associated with another entity, *B*, where:
- 1) *A* and *B* share a weak secret and *B* has a strong secret; or
  - 2) *A* has a weak secret and *B* has verification data derived from *A*'s weak secret with a one-way function along with a strong secret.

An example of a strong secret could be a long random key. This strong secret is independent of the weak secret and has been generated for an identity-based cryptosystem.

In an unbalanced password-authenticated key agreement mechanism with an identity-based cryptosystem, the shared secret keys are the result of a data exchange between the two entities. The shared secret keys are established if, and only if, *A* has used the weak secret and *B* has a strong secret corresponding to its identity and neither of the two entities can predetermine the values of the shared secret keys.

NOTE 3 This type of key agreement mechanism runs between entities with unbalanced security requirements such as in the client-server model. It is suitable for the case where a client (*A*) conducts authentication based on both a human-memorable password and a server (*B*)'s identity while enhancing server authentication (thus avoiding an attack on a cryptographic protocol in which an unauthorized party masquerades as a legitimate server, which is often called "a server impersonation attack").

#### Clause 3

Insert the following terminological entry at the end of the clause:

#### 3.39

##### **master-secret key**

secret value used by the private key generator to compute private keys for an identity-based encryption (IBE) or identity-based signature (IBS) scheme

Clause 4

Insert the following abbreviated terms:

<i>CT</i>	ciphertext, an octet string
$G_1$	point of order $r$ on $E$ over $F(q)$ , in the same subgroup as $G$
IBE	identity-based encryption
IBS	identity-based signature
<i>ID</i>	distinguished identifier that is uniquely assigned to an identity, which is an octet string
$\kappa$	security parameter
<i>Msg</i>	plaintext, an octet string
<i>msk</i>	master-secret key of IBE or IBS
<i>parms</i>	domain parameters of IBE or IBS
$\sigma$	signature, an octet string
$sk_{ID}$	private key corresponding to an entity with distinguished (octet) identifier <i>ID</i> for an IBE or IBS scheme

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Clause 5

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Replace the definition of  $G$  by the definition of  $G$  and  $G_1$  as follows:

- $G, G_1$  curve points of order  $r$  ( $G$  and  $G_1$  are called the generators of a subgroup of  $r$  points on  $E$ ). It is assumed that the logarithm of  $G_1$  to the base  $G$  is unknown;

Clause 5

Add the following paragraph at the end:

Annex B defines the object identifiers which shall be used to identify the mechanisms specified in this document.

Clause 8

Add new Clause 8 as follows:

## 8 Unbalanced password-authenticated key agreement with identity-based cryptosystems

### 8.1 General

This clause specifies two unbalanced password-authenticated key agreement mechanisms using identity-based cryptosystems. In these mechanisms, one entity has a weak secret derived from a password, and the other entity has the password verification data and a strong secret, i.e., a long random key which is used with an identity-based cryptosystem. An identity-based cryptosystem is an

asymmetric cryptographic technique that allows a public key to be defined as a string, such as an IP address or e-mail address, that represents an entity. The corresponding private key is calculated from an identity, a set of domain parameters, and a domain-wide secret value called a master-secret key. A user public key is calculated by anyone who has the necessary domain parameters, while the master secret key is needed to calculate a user private key, and the calculation can only be performed by a (trusted) private key generator that has this secret.

The two unbalanced password-authenticated key agreement mechanisms with identity-based cryptosystems have the following initialization process and key establishment process.

### Initialization process

The two entities involved agree to use a set of valid domain parameters, a set of key derivation parameters and a set of functions, all of which can be publicly known.

The two entities also agree to use either a shared weak secret derived from a password or shared password-based information, i.e. one entity has a password-based weak secret and the other entity has the corresponding password verification element.

### Key establishment process

- a) *Generate and exchange key tokens.* Each of the two entities involved randomly chooses one or more key token factors associated with the domain parameters, creates the corresponding key tokens, which may be associated with the password or password verification element (a key token associated with the password or password verification element is called a “password-entangled key token”), and then makes the key tokens available to the other entity.
- b) *Check validity of key tokens.* Depending on the operations for producing key tokens in step a), each of the two entities involved chooses an appropriate method to validate the received key tokens based on the domain parameters. If any validation fails, output “invalid” and stop.
- c) *Derive shared secret keys.* Each of the two entities involved applies certain secret value derivation functions to their own key token factor, the other entity’s key tokens and/or shared password or password verification element to produce a shared secret value. Each entity further applies a key derivation function to the shared secret value and the key derivation parameters, to derive one or more shared secret keys.
- d) *Check key confirmation.* The two entities involved use the shared secret keys established using the above steps to confirm their awareness of the keys to each other. This step is optional in Unbalanced Key Agreement Mechanisms with Password and Identity-based Encryption and in Unbalanced Key Agreement Mechanisms with Password and Identity-based Signature.

For convenience, an unbalanced key agreement mechanism with password and identity-based encryption and an unbalanced key agreement mechanism with password and identity-based signature are denoted by UKAM-PiE and UKAM-PiS, respectively.

Because of the use of weak secrets, countermeasures against online guessing attacks shall be taken into account. For example, counters that indicate the number of failed connections can be introduced:

- a counter that tracks the total number of unsuccessful authentication trials in a row;
- a counter that tracks the total number of unsuccessful authentication events during the period of use of a specific password;
- a counter that tracks the total number of authentication events (successful and unsuccessful) during the period of use of the specific password.

**NOTE** In applications using a UKAM-PiE or UKAM-PiS, *A* can play the role of a client and *B* can play the role of a server.

## 8.2 Unbalanced Key Agreement Mechanism with Password and Identity-based Encryption (UKAM-PiE)

### 8.2.1 General

This mechanism is designed to achieve authenticated key agreement using a password and an identity-based encryption scheme, and it establishes one or more shared secret keys between entities *A* and *B*. In the mechanism, *A* and *B* share a password-based octet string  $\pi$ . *B* additionally has a strong secret, i.e., a decryption key which is used for an identity-based encryption scheme. This mechanism provides unilateral explicit key authentication and optionally mutual key authentication.

An identity-based encryption scheme consists of the following four algorithms.

- *IBE.Setup*( $\kappa$ ). Given a security parameter  $\kappa$ , generate a tuple  $\langle \textit{parms}, \textit{msk} \rangle$ , where *parms* denotes IBE domain parameters, *msk* denotes a master-secret key.
- *IBE.Extract*(*parms*, *msk*, *ID*). Given *parms*, *msk*, and *ID*, generate a private key  $sk_{ID}$  for *ID*.
- *IBE.Enc*(*parms*, *ID*, *Msg*). Given *parms*, *ID*, and a plaintext *Msg*, perform the encryption and output the ciphertext of *Msg*, *CT*, for *ID*. Note that *Msg* and *CT* are octet strings.
- *IBE.Dec*(*parms*, *ID*,  $sk_{ID}$ , *CT*). Given *parms*, *ID*, and  $sk_{ID}$ , decrypt a ciphertext *CT* and output a plaintext or "error".

In general, the setup, key extraction and encryption algorithms are probabilistic, while the decryption algorithm is deterministic. It is recommended that applications establish a methodology for authenticating access to private keys by using the string *ID* as an identity in a trusted authentication system (see ISO/IEC 18033-5<sup>[33]</sup> for further guidance on identity-based ciphers).

This mechanism works in both the DL and EC settings.

As noted in ISO/IEC 18033-5, a general purpose IBE scheme should satisfy the appropriate security level, namely semantic security against an adaptive chosen ciphertext attack.

NOTE UKAM-PiE is based on Bibliographic reference [29].

### 8.2.2 Prior shared parameters

Key agreement between two entities *A* and *B* takes place in a shared context consisting of the following parameters:

- a set of valid domain parameters (either DL domain parameters or EC domain parameters) specified in Clause 5;
- a password-based octet string,  $\pi$ , used by *A* and *B*;
- a key token generation function, *D*;
- a private key,  $sk_B$ , used by *B*;
- an encrypted key token generation function, *EK*, used by *A*;
- a key token decryption function, *KD*, used by *B*;
- a password verification function, *S*, used by *B*;
- a key token check function, *T*;
- a secret value derivation function,  $V_S$ ;
- a key derivation function, *K*;



- one or more key derivation parameter octet strings  $\{P_1, P_2, \dots\}$ , where  $A$  and  $B$  shall agree to use the same values;
- the length of a shared secret key,  $L_K$ .

### 8.2.3 Functions

#### 8.2.3.1 Key token generation function, $D$

The key token generation function,  $D$ , is as defined in 6.5.3.2.

#### 8.2.3.2 Encrypted key token generation function, $EK$

The encrypted key token generation function,  $EK$ , takes the IBE domain parameters  $parms$ , an  $ID$ , a password-based octet string  $\pi$ , and an output  $w$  (or  $W$ ) of the function  $D$ , and produces an encrypted key token  $CT$  as output, i.e.  $CT = EK(parms, ID, \pi, w \text{ (or } W))$ . UKAM-PiE is used with the following function  $EK$ :

- Given the IBE domain parameters  $parms$  and three inputs, an octet string  $ID$ , an octet string  $\pi$ , and the output  $w$  (or  $W$ ) of the function  $D$ ,  $EK$  is defined as follows:
  - compute  $d = I2OS(BS2I(H(\pi)))$ ;
  - compute  $e = GE2OS_X(w \text{ (or } W))$ ;
  - compute  $CT = IBE.Enc(parms, ID, d||e)$ ;
  - output  $CT$ .

Functions BS2I (Bit String to Integer conversion), I2OS (Integer to Octet String conversion) and GE2OS<sub>X</sub> (Group Element to Octet String conversion) are described in Annex A.

#### 8.2.3.3 Key token decryption function, $KD$

The key token decryption,  $KD$ , takes the IBE domain parameters  $parms$ , an  $ID$ , a private key  $sk_{ID}$  for  $ID$ , an output  $CT$  of the function  $EK$ , and produces an ordered pair made up of an octet string  $d$  and a group element  $w$  (or  $W$ ) as output. UKAM-PiE is used with either  $KD_{DL}$  or  $KD_{EC}$  as the function  $KD$ :

- $KD_{DL}$  is suitable for use when the mechanism is used with the DL domain parameters, i.e. it operates over the multiplicative group of elements defined over  $F(q)$ . Given the DL domain parameters (including  $g$  and  $q$ ), the IBE domain parameters  $parms$ , an octet string  $ID$ , a group element  $sk_{ID}$ , and the output  $CT$  of the function  $EK$ ,  $KD_{DL}$  is defined as follows:
  - compute  $IBE.Dec(parms, ID, sk_{ID}, CT)$ ;
  - if the output of  $IBE.Dec$  is "error", then output "error";
  - else, the output of  $IBE.Dec$  is  $d||e$  and compute  $w = I2FE(OS2I(e))$ ;
  - output  $(d, w)$ .
- $KD_{EC}$  is suitable for use when the mechanism is used with the EC domain parameters, i.e. it operates over the additive group of elements in an elliptic curve defined over  $F(q)$ . Given the EC domain parameters (including  $G$ ), the IBE domain parameters  $parms$ , an octet string  $ID$ , a group element  $sk_{ID}$ , and the output  $CT$  of the function  $EK$ ,  $KD_{EC}$  is defined as follows:
  - compute  $IBE.Dec(parms, ID, sk_{ID}, CT)$ ;
  - if the output of  $IBE.Dec$  is "error", then output "error";
  - else, the output of  $IBE.Dec$  is  $d||e$  and compute  $W = I2FE(OS2I(e))$ ;

— output  $(d, W)$ .

Functions OS2I (Octet String to Integer conversion) and I2FE (Integer to Field Element conversion) are described in Annex A.

#### 8.2.3.4 Password verification function, $S$

The password verification function,  $S$ , takes an octet string  $d$  output by the function  $KD$ , and a password-based octet string  $\pi$ , and produces a Boolean value written  $S(d, \pi)$  as output. UKAM-PiE is used with the following function  $S$ :

Given an octet string  $d$  output by the function  $KD$  and an octet string  $\pi$ ,  $S$  is defined as follows:

- if  $d = I2OS(BS2I(H(\pi)))$ ,  $S(d, \pi) = 1$ ;
- else,  $S(d, \pi) = 0$ .

Functions BS2I (Bit String to Integer conversion) and I2OS (Integer to Octet String conversion) are described in Annex A.

#### 8.2.3.5 Key token check function, $T$

The key token check function,  $T$ , is as defined in 6.2.3.3.

#### 8.2.3.6 Secret value derivation function, $V_S$

The secret value derivation function,  $V_S$ , takes an integer  $x$  and a selected group element  $y$  (or  $Y$ ) as input and produces another group element written  $V_S(x, y$  (or  $Y))$  as output. UKAM-PiE is used with either  $V_{SDL}$  or  $V_{SEC}$  as the function  $V_S$ :

- $V_{SDL}$  is suitable for use when the mechanism is used with the DL domain parameters, i.e. it operates over the multiplicative group of elements defined over  $F(q)$ . Given the DL domain parameters (including  $r$  and  $q$ ), and two inputs,  $x$  from  $\{1, \dots, r - 1\}$  and  $y$  from  $\{2, \dots, q - 2\}$ ,  $V_{SDL}$  is defined as in [Formula \(35\)](#):

$$V_{SDL}(x, y) = y^x \text{ mod } q \tag{35}$$

- $V_{SEC}$  is suitable for use when the mechanism is used with the EC domain parameters, i.e. it operates over the additive group of elements in an elliptic curve defined over  $F(q)$ . Given the EC domain parameters (including  $r$ ), and two inputs,  $x$  from  $\{1, \dots, r - 1\}$  and a point  $Y (\neq 0_E)$  on  $E$ ,  $V_{SEC}$  is defined as in [Formula \(36\)](#):

$$V_{SEC}(x, Y) = [x] \times Y \tag{36}$$

#### 8.2.3.7 Key derivation function, $K$

The key derivation function,  $K$ , is as defined in 6.2.3.6.

### 8.2.4 Key agreement operation

This mechanism involves both  $A$  and  $B$  performing a sequence of up to four steps, numbered A1-A4 and B1-B4 (for the steps to be followed by  $A$  and  $B$ , respectively). Steps A3, A4, B3, and B4 are optional.

#### Encrypted key token construction (A1)

$A$  performs the following steps:

- choose an integer  $s_A$  randomly from  $\{1, \dots, r - 1\}$  as its key token factor;

- compute  $w_A = D(s_A)$  as its key token;
- compute  $CT = EK(parms, ID_B, \pi, w_A)$  as its encrypted key token;
- make  $CT$  available to  $B$  (by sending  $(ID_A, CT)$  from  $A$  to  $B$ ).

### Key token construction (B1)

$B$  performs the following steps:

- receive  $CT$  from  $A$ ;
- compute  $(d, w_A) = KD(parms, ID_B, sk_B, CT)$ ;
- if the output of  $KD$  is “error”, then output “invalid” and stop; otherwise, continue;
- check validity of  $w_A$  using  $T(w_A)$ : if  $T(w_A) = 0$ , output “invalid” and stop; otherwise, continue;
- check validity of  $d$  using  $S(d, \pi)$ : if  $S(d, \pi) = 0$ , output “invalid” and stop; otherwise, continue;
- choose an integer  $s_B$  randomly from  $\{1, \dots, r - 1\}$  as its key token factor;
- compute  $w_B = D(s_B)$  as its key token;
- make  $w_B$  available to  $A$  (by sending  $(ID_B, w_B)$  from  $B$  to  $A$ ).

### Shared secret key derivation (A2)

$A$  performs the following steps:

- receive  $w_B$  from  $B$ ;
- check validity of  $w_B$  using  $T(w_B)$ : if  $T(w_B) = 0$ , output “invalid” and stop; otherwise, continue;
- compute  $z = V_S(s_A, w_B)$  as a shared secret value;
- compute  $K_i = K(ID_A || ID_B || GE2OS_X(w_A) || GE2OS_X(w_B) || GE2OS_X(z), P_i, L_K)$  as a shared secret key for each key derivation parameter,  $P_i$ .

### Shared secret key derivation (B2)

$B$  performs the following steps:

- compute  $z = V_S(s_B, w_A)$  as a shared secret value;
- compute  $K_i = K(ID_A || ID_B || GE2OS_X(w_A) || GE2OS_X(w_B) || GE2OS_X(z), P_i, L_K)$  as a shared secret key for each key derivation parameter,  $P_i$ .

### Key confirmation (A3 and B3) (optional)

$A$  performs the following steps (A3):

- compute  $o_A = H(120S(4) || ID_A || ID_B || GE2OS_X(w_A) || GE2OS_X(w_B) || GE2OS_X(z))$ ;
- make  $o_A$  available to  $B$ .

$B$  performs the following steps (B3):

- receive  $o_A$  from  $A$ ;
- compute  $o_A' = H(120S(4) || ID_A || ID_B || GE2OS_X(w_A) || GE2OS_X(w_B) || GE2OS_X(z))$ ;
- check if  $o_A \neq o_A'$ , output “invalid” and stop.