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

Part 4:

Mechanisms based on weak secrets

**AMENDMENT 2 — Leakage-resilient
password-authenticated key agreement
with additional stored secrets**

*Technologies de l'information — Techniques de sécurité — Gestion
de clés —*

Partie 4: Mécanismes basés sur des secrets faibles

AMENDEMENT 2



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Information technology — Security techniques — Key management —

Part 4: Mechanisms based on weak secrets

AMENDMENT 2: Leakage-resilient password-authenticated key agreement with additional stored secrets

Introduction

Insert new list item e) as follows:

- e) **Leakage-resilient password-authenticated key agreement with additional stored secrets:** Establish one or more shared secret keys between two entities *A* and *B*, where *A* has a weak secret and a (possibly, insecure) stored secret that might be revealed to or altered by adversaries and *B* has verification data derived from *A*'s weak secret and stored secret. In a leakage-resilient password-authenticated key agreement with additional stored secrets mechanism, 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, the two entities have used the weak secret, the stored secret and the corresponding verification data; and *A*, *B* and an adversary who has obtained and altered the stored secret are all unable to predetermine the values of the shared secret keys.

NOTE 4 Here, "leakage-resilience" means security against either compromise of stored secrets held by client *A* or compromise of verification data held by server *B*, but not both. This type of key agreement mechanism is able to protect *A*'s weak secret from being discovered by *B*, as well as preventing an adversary from getting *A*'s weak secret from *B*. Also, this type of key agreement mechanism prevents an adversary from performing online dictionary attacks unless the adversary obtains *A*'s stored secret. In other words, an adversary who obtains *A*'s stored secret is restricted to performing online dictionary attacks, and the security level in this case is the same as that of the other mechanisms in this document. A typical application scenario would involve use between a client (*A*) and a server (*B*), where a client user employs a portable device such as a smart phone, USB memory or smart card to save the user's stored secret, or where a client terminal shares a network-attached storage device in an office environment.

Clause 2

Replace Clause 2 with the following:

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 (all parts), *Information technology — Security techniques — Hash-functions*

ISO/IEC 29192-5, *Information technology — Security techniques — Lightweight cryptography — Part 5: Hash-functions*

ISO/IEC 9797 (all parts), *Information technology — Security techniques — Message Authentication Codes (MACs)*

ISO/IEC 29192-6, *IT Security techniques — Lightweight cryptography — Part 6: Message Authentication Codes (MACs)*

ISO/IEC 11770-6, *Information technology — Security techniques — Key management — Part 6: Key derivation*

ISO/IEC 18033-2, *Information technology — Security techniques — Encryption algorithms — Part 2: Asymmetric ciphers*

ISO/IEC 19772, *Information technology — Security techniques — Authenticated encryption*

Clause 3

Insert new term 3.40 as follows:

3.40

Hamming weight

number of non-zero elements in a bit string

Clause 4

Replace definitions as follows:

H	a collision-resistant hash-function taking an octet string as input and giving a bit string as output. One of the hash-functions specified in ISO/IEC 10118 (all parts) or ISO/IEC 29192-5 shall be used
$h(x, L_K)$	a collision-resistant hash-function taking an octet string x and an integer L_K as input and giving a bit string of length L_K (in bits) as output. One of the hash-functions specified in ISO/IEC 10118 (all parts) or ISO/IEC 29192-5 shall be used
$mac(k, m)$	a message authentication code (MAC) function taking a key k and a variable-length message m as input and giving a fixed-length output. One of the MAC algorithms specified in ISO/IEC 9797 (all parts) or ISO/IEC 29192-6 shall be used
G, G_a, G_b	points of order r on E over $F(q)$, where the relative discrete logarithms of G, G_a, G_b are unknown
g, g_1, g_a, g_b	elements of multiplicative order r in $F(q)$, where the relative discrete logarithms of g, g_1, g_a, g_b are unknown
K	a function for deriving a key from a secret value and a key derivation parameter. One of the key derivation functions specified in ISO/IEC 11770-6 shall be used

Add the following definitions:

- ⊕ bit-wise exclusive-or operation on bit-strings of equal length
- AE an authenticated encryption, (reversible) transformation of data by a cryptographic algorithm to produce ciphertext that cannot be altered by an unauthorized entity without detection, i.e. that provides data confidentiality, data integrity, and data origin authentication. One of the authenticated encryption methods specified in ISO/IEC 19772 shall be used

Clause 5

Replace the last sentence with the following:

It is also assumed that the entities are aware of a common hash-function H , one of the hash-functions specified in ISO/IEC 10118 (all parts) or ISO/IEC 29192-5.

Clause 9

Add new Clause 9 as follows:

9 Leakage-resilient password-authenticated key agreement with additional stored secrets

9.1 General

This clause specifies two mechanisms (LKAM1 and LKAM2) for leakage-resilient password-authenticated key agreement with additional stored secrets. These mechanisms, specified in 9.2 and 9.3, require one of the two entities to possess verification data for a weak secret and a stored secret known to the other entity.

The two mechanisms share the following initialization and key establishment processes.

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 may be publicly known. The two entities also agree to use shared password-based information, i.e. one entity has a password-based weak secret and a stored secret, and the other entity has the corresponding verification data.

NOTE In the initialization process, the two entities who only share password-based information can establish a secure channel by performing the key establishment process. In the case of LKAM2, the server first sends an RSA parameter n . Through the established secure channel, the two entities can register verification data and stored secrets.

Key establishment process:

- Generate and exchange key tokens.* The two entities involved each randomly choose one or more key token factors associated with the domain parameters, create the corresponding key tokens, which may be associated with the password and the stored secret or verification data (a key token associated with the password and the stored secret or verification data is called an “entangled key token”), and then make the key tokens available to the other entity.
- Check validity of key tokens.* Depending on the operations for producing key tokens in step a), the two entities involved each choose an appropriate method to validate the received key tokens based on the domain parameters. If any validation fails, the entity involved shall output “invalid” and stop.
- Derive shared secret keys.* The two entities involved each apply certain secret value derivation functions to their own key token factor, the other entity’s key tokens and/or shared verification data 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 and update stored secrets.* The two entities involved use the shared secret keys established using the above steps to confirm their awareness of the keys to each other, and to update their stored secrets. This step is mandatory.

9.2 Leakage-resilient key agreement mechanism 1 (LKAM1)

9.2.1 General

This mechanism is designed to achieve leakage-resilient password-authenticated key agreement with additional stored secrets, and establishes one or more shared secret keys between entities A and B . In the mechanism, A has a password-based octet string π and a stored secret s_i , and B has verification data W_i corresponding to π and s_i . This mechanism provides unilateral explicit key authentication and, optionally, mutual key authentication.

This mechanism works in both the DL setting and the EC setting.

NOTE 1 In applications using leakage-resilient password-authenticated key agreement with additional stored secrets, A can play the role of a client and B can play the role of a server.

NOTE 2 This mechanism is based on the work of Shin, Kobara and Imai^[35].

9.2.2 Prior shared parameters

Key agreement between two entities A and B takes place in an environment consisting of the following parameters:

- a set of valid domain parameters (either DL domain parameters or EC domain parameters) as specified in Clause 5;
- a counter which stores the value of i (initially $i = 1$);
- the length L_K of a shared secret key K ;
- a password-based octet string π and a stored secret s_i , which is an integer of L_K bits used by A ;
- a verification element derivation function J , used by A ;
- a verification element $W_i = J(\pi, s_i)$, used by A and B ;
- a key token generation function B , used by A and B ;
- an entangled key token generation function C , used by A ;
- a key token check function T , used by A and B ;
- two secret value derivation functions V_A and V_B , one for each entity;
- a key derivation function K , used by A and B ;
- one or more key derivation parameter octet strings $\{P_1, P_2, \dots\}$, where A and B shall agree to use the same values.

9.2.3 Functions

9.2.3.1 Verification element derivation function J

The verification element derivation function J takes a password-based octet string π and a stored secret s_i as input and produces an element of $F(q)$, written $J(\pi, s_i)$, as output. Leakage-resilient key agreement mechanism 1 can be used with either of the following two functions J_{DL} and J_{EC} :

- J_{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 of $F(q)$. Given the DL domain parameters (including g_b and q), a password-based octet string π and a stored secret s_i , J_{DL} is defined as in [Formula \(40\)](#):

$$J_{DL}(\pi, s_i) = g_b^{BS2I(H(\pi)) + s_i \bmod r} \bmod q \quad (40)$$

- J_{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 of $F(q)$. Given the EC domain parameters (including G_b), a password-based octet string π and a stored secret s_i , J_{EC} is defined as in [Formula \(41\)](#):

$$J_{EC}(\pi, s_i) = [BS2I(H(\pi)) + s_i \bmod r] \times G_b \quad (41)$$

Function BS2I (Bit String to Integer conversion) is described in Annex A.

9.2.3.2 Key token generation function D

The key token generation function D takes an integer x from $\{1, \dots, r-1\}$ as input, and produces an element written $D(x)$ as output. Leakage-resilient key agreement mechanism 1 can be used with either of the following two functions D_{DL} and D_{EC} :

- D_{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 of $F(q)$. Given the DL domain parameters (including g and q) and an input x from $\{1, \dots, r-1\}$, D_{DL} is defined as in [Formula \(42\)](#):

$$D_{DL}(x) = g^x \bmod q \quad (42)$$

- D_{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 of $F(q)$. Given the EC domain parameters (including G) and an input x from $\{1, \dots, r-1\}$, D_{EC} is defined as in [Formula \(43\)](#):

$$D_{EC}(x) = [x] \times G \quad (43)$$

9.2.3.3 Entangled key token generation function C

The entangled key token generation function C takes two inputs, an output W_i of function J and an output X of function D , and produces an element written $C(W_i, X)$ as output. Leakage-resilient key agreement mechanism 1 can be used with either of the following C functions C_{DL} and C_{EC} :

- C_{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 of $F(q)$. Given the DL domain parameters (including q) and two inputs, the output W_i of function J and the output X of function D , C_{DL} is defined as follows:

- compute $C_{DL}(W_i, X) = W_i \times X \bmod q$;
- if $C_{DL}(W_i, X)$ is 0, 1 or $q-1$, output “invalid” and stop; otherwise, output $C_{DL}(W_i, X)$.

- C_{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 of $F(q)$. Given the EC domain parameters and two inputs, the output W_i of function J and the output X of function D , C_{EC} is defined as follows:

- compute $C_{EC}(W_i, X) = W_i + X$;
- if $[2^n] \times C_{EC}(W_i, X) = 0_E$, output “invalid” and stop; otherwise output $C_{EC}(W_i, X)$.

9.2.3.4 Key token check function T

The key token check function T is the same as that defined in 6.2.3.3.

9.2.3.5 Secret value derivation functions V_A and V_B

- The secret value derivation function V_A takes two inputs, an integer x from $\{1, \dots, r-1\}$ and an output Y of function D , and produces an element written $V_A(x, Y)$ as output.

- b) The secret value derivation function V_B takes three inputs, an integer y from $\{1, \dots, r-1\}$, an output X' of function C and an output W_i of function J , and produces an element written $V_B(y, X', W_i)$ as output.
- c) V_A and V_B satisfy the condition $V_A(x, Y) = V_B(y, X', W_i)$.

Leakage-resilient key agreement mechanism 1 can be used with either of the following two functions V_{ADL} and V_{AEC} , and either of the following two functions V_{BDL} and V_{BEC} :

- a) V_{ADL} is suitable for use when the mechanism is used with the DL domain parameters, i.e. it operates over the multiplicative group of $F(q)$. Given the DL domain parameters (including q), an integer x from $\{1, \dots, r-1\}$ and an integer Y from $\{2, \dots, q-2\}$, V_{ADL} is defined in the following steps:
 - compute $V_{ADL}(x, Y) = Y^x \bmod q$;
 - output $V_{ADL}(x, Y)$.
- b) V_{BDL} is suitable for use when the mechanism is used with the DL domain parameters, i.e. it operates over the multiplicative group of $F(q)$. Given the DL domain parameters (including q), an integer y from $\{1, \dots, r-1\}$, an integer X' from $\{2, \dots, q-2\}$ and an integer W_i from $\{2, \dots, q-2\}$, V_{BDL} is defined in the following steps:
 - compute $V_{BDL}(y, X', W_i) = (X' / W_i)^y \bmod q$;
 - output $V_{BDL}(y, X', W_i)$.
- c) V_{AEC} 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 of $F(q)$. Given the EC domain parameters, an integer x from $\{1, \dots, r-1\}$ and a point $Y (\neq 0_E)$ on E , V_{AEC} is defined in the following steps:
 - compute $V_{AEC}(x, Y) = [x] \times Y$;
 - output $V_{AEC}(x, Y)$.
- d) V_{BEC} 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 of $F(q)$. Given the EC domain parameters, an integer y from $\{1, \dots, r-1\}$, a point $X' (\neq 0_E)$ on E and a point $W_i (\neq 0_E)$ on E , V_{BEC} is defined in the following steps:
 - compute $V_{BEC}(y, X', W_i) = [y] \times (X' - W_i)$;
 - output $V_{BEC}(y, X', W_i)$.

9.2.3.6 Key derivation function K

The key derivation function K is the same as that defined in 6.2.3.6.

9.2.4 Initialization operation

In the initialization operation, A chooses an integer s_1 randomly from $\{1, \dots, r-1\}$, computes $W_1 = J(\pi, s_1)$, and then securely transfers W_1 to B . While A has the password-based weak secret π and the stored secret s_1 (along with the counter $i = 1$), B has the corresponding verification data W_1 and the counter $i = 1$.

NOTE Entity A can update the password-based weak secret by performing the initialization operation.

9.2.5 Key agreement operation

In the i -th ($i \geq 1$) key agreement operation, this mechanism involves both A and B performing a sequence of up to three steps, numbered A1 to A3 and B1 to B3 (for the steps to be followed by A and B , respectively).

a) Entangled key token construction (A1)

A performs the following steps:

- 1) compute $W_i = J(\pi, s_i)$ as its verification element;
- 2) choose an integer x randomly from $\{1, \dots, r-1\}$ as its key token factor;
- 3) compute $X = D(x)$ as its key token, and $X' = C(W_i, X)$ as its entangled key token (if the output of function C is "invalid", go back to the above item to choose a different x value at random and try again);
- 4) make i and X' available to B .

b) Key token construction (B1)

B performs the following steps:

- 1) receive i and X' from A ;
- 2) check the validity of i : if the received value of i is not the same as the value B has, output "invalid" and stop; otherwise, continue;
- 3) check the validity of X' using $T(X')$: if $T(X') = 0$, output "invalid" and stop; otherwise, continue;
- 4) choose an integer y uniformly at random from the range $\{1, \dots, r-1\}$ as its key token factor;
- 5) compute $Y = D(y)$ as its key token;
- 6) compute $z = V_B(y, X', W_i)$ as an agreed secret value;
- 7) compute $o_B = H(I2OS(1)||A||B||I2OS(i)||GE2OS_X(X')||GE2OS_X(Y)||GE2OS_X(W_i)||GE2OS_X(z))$;
- 8) make Y and o_B available to A .

c) Key confirmation (mandatory) and shared secret key derivation (A2)

A performs the following steps:

- 1) receive Y and o_B from B ;
- 2) check the validity of Y using $T(Y)$: if $T(Y) = 0$, output "invalid" and stop; otherwise, continue;
- 3) compute $z = V_A(x, Y)$ as an agreed secret value;
- 4) compute $o_B' = H(I2OS(1)||A||B||I2OS(i)||GE2OS_X(X')||GE2OS_X(Y)||GE2OS_X(W_i)||GE2OS_X(z))$;
- 5) if $o_B \neq o_B'$, output "invalid" and stop; otherwise, continue;
- 6) compute $o_A = H(I2OS(2)||A||B||I2OS(i)||GE2OS_X(X')||GE2OS_X(Y)||GE2OS_X(W_i)||GE2OS_X(z))$;
- 7) compute $K_j = K(A||B||I2OS(i)||GE2OS_X(X')||GE2OS_X(Y)||GE2OS_X(W_i)||GE2OS_X(z), P_j, L_K)$ as a shared secret key for each key derivation parameter P_j ($j = 1, 2, \dots$);
- 8) make o_A available to B .

d) Key confirmation and shared secret key derivation (B2)

B performs the following steps:

- 1) receive o_A from A ;
- 2) compute $o_A' = H(I2OS(2)||A||B||I2OS(i)||GE2OS_X(X')||GE2OS_X(Y)||GE2OS_X(W_i)||GE2OS_X(z))$;
- 3) if $o_A \neq o_A'$, output "invalid" and stop; otherwise, continue;
- 4) compute $K_j = K(A||B||I2OS(i)||GE2OS_X(X')||GE2OS_X(Y)||GE2OS_X(W_i)||GE2OS_X(z), P_j, L_K)$ as a shared secret key for each key derivation parameter P_j ($j = 1, 2, \dots$).

e) Update of stored secrets (A3 and B3)

A performs the following step (A3):

- 1) compute $s_{(i+1)} = s_i + \text{BS2I}(H(\text{I2OS}(3)||A||B||\text{I2OS}(i)||\text{GE2OS}_X(X')||\text{GE2OS}_X(Y)||\text{GE2OS}_X(W)||\text{GE2OS}_X(z))) \bmod r$.

B performs the following step (B3):

- 1) compute $u = \text{BS2I}(H(\text{I2OS}(3)||A||B||\text{I2OS}(i)||\text{GE2OS}_X(X')||\text{GE2OS}_X(Y)||\text{GE2OS}_X(W)||\text{GE2OS}_X(z))) \bmod r$;
- 2) compute $W_{(i+1)} = W_i \times (g_b)^u \bmod q$ in the DL setting;
- 3) compute $W_{(i+1)} = W_i + [u] \times G_b$ in the EC setting;
- 4) check the validity of $W_{(i+1)}$ using $T(W_{(i+1)})$: if $T(W_{(i+1)}) = 0$, output "invalid" and stop.

Entity A shall verify the entity B's proof of knowledge of the agreed key before revealing any information derived from the agreed key. Therefore, A2 shall be done before B2 if the latter is performed.

Functions BS2I (Bit String to Integer conversion), I2OS (Integer to Octet String conversion) and GE2OS_X (Group Element to Octet String conversion) are described in Annex A where Annex A shall be referenced for the details of the conversion functions.

Numerical examples can be found in D.1.

NOTE 1 A group element in this mechanism is a point on the curve E in the EC setting, or an integer in the range $\{1, \dots, q-1\}$ in the DL setting.

NOTE 2 In this mechanism, X and Y can be computed before the key agreement operation.

NOTE 3 This mechanism can be extended to provide synchronization, randomized ID and security against server compromise impersonation attacks in the same way as in Section 6 of Reference [36].

9.3 Leakage-resilient key agreement mechanism 2 (LKAM2)

9.3.1 General

This mechanism is designed to achieve leakage-resilient authenticated key agreement with password and untrusted storage using the RSA public key cryptosystem and establishes one or more shared secret keys between entities A and B with joint key control. In the mechanism, A remembers a password (denoted by π when rendered as an octet string), and has, in an untrusted storage device that might be modified or copied by adversaries to impersonate A or B or to reveal the agreed keys, the RSA parameter n , a stored secret u_j where subscript j denotes a counter and a random pseudo identity A' of A . B has password verification data v_j corresponding to both π and u_j , a hash value A'' of A' , and RSA private key parameters d , p , q and so on. These RSA private and public key parameters shall be generated using ISO/IEC 18033-2:2006, 11.1, and the additional requirement and recommendations for e to be used in this mechanism are explained in 9.3.3. This mechanism provides unilateral explicit key authentication, and optionally mutual key authentication.

NOTE 1 In applications using leakage-resilient authenticated key agreement with password and untrusted storage, A can play the role of a client and B can play the role of a server.

NOTE 2 This mechanism is based on the work of Shin, Kobara and Imai^[36].

9.3.2 Prior shared parameters

Key agreement between two entities A and B takes place in an environment consisting of the following parameters, in which L_K , e , H , mac , K , $\{P_1, P_2, \dots\}$ are shared as system parameters among all or a subset of the users of this mechanism:

- the length of a shared secret key L_K which must be a multiple of 8;

- a set of RSA public key parameters, namely a prime integer e and a composite number n generated as specified in ISO/IEC 18033-2:2006, 11.1, where e is specialized for this mechanism as explained in 9.3.3;
- a cryptographic collision-resistant hash-function H giving a $2L_K$ -bit output, that shall be chosen from amongst the functions standardized in ISO/IEC 10118 (all parts) or ISO/IEC 29192-5, being truncated as necessary;
- a message authentication code generation function mac , that shall be chosen from amongst the functions standardized in ISO/IEC 9797 (all parts) or ISO/IEC 29192-6;
- a counter which stores the value of j (initially $j=1$);
- a stored secret u_j and corresponding $v_j = J(\pi, u_j)$ where u_j is an octet string of random L_K bits and J is a password verification element derivation function in 9.3.4.1. Both u_j and v_j are set in the initialization operation in 9.3.5, and then used by A and B , respectively;
- a pseudo identity A'_j and a corresponding hash value $A''_j = H(I2OS(0)||A'_j)$ of the entity A , where A'_j is an octet string of length $L_K/8$ whose constituent bits are generated uniformly at random. Both A'_j and A''_j are set in the initialization operation in 9.3.5 and used by A and B , respectively;
- a key derivation function K , that shall be chosen from amongst the functions standardized in ISO/IEC 11770-6;
- one or more key derivation parameter octet strings $\{P_1, P_2, \dots\}$, where A and B shall agree to use the same values.

9.3.3 Additional requirement and recommendations for RSA public key parameter e

The following requirements on the choice of the parameter e , additional to those specified in ISO/IEC 18033-2:2006, 11.1, apply.

- a) e shall be a prime and $e \geq 2^{L_K}$;
- b) the sum of the Hamming weight of the binary representation of e and the bit-length of e should be as small as possible, subject to requirement a);
- c) e should be as large as possible within b).

NOTE 1 Requirement a) ensures that the e -residue attack^[36], which applies when an adversary can modify the parameter n , is not feasible.

NOTE 2 Recommendation b) is intended to help minimize the computational cost for entity A .

NOTE 3 Recommendation c) is intended to make e -residue attacks as difficult as possible for a given computational cost on A .

NOTE 4 Examples of choices for e satisfying requirement a)-c) are given in C.4.

9.3.4 Functions

9.3.4.1 Password verification element derivation function J

The password verification element derivation function J takes a password-based octet string π and a random L_K -bit stored secret u_j as input, and produces as output an octet string password verification data $v_j = H(I2OS(4)||\pi||A||B) \oplus u_j$.

9.3.4.2 Key token generation function D

The key token generation function D takes password verification data v_j , RSA public parameters n, e and integers x_1, x_2 in $\{1, \dots, n-1\}$ as input, and produces as output $Z = D(e, n, x_1, x_2, v_j)$, an integer in the range $\{0, \dots, n-2\}$. D is calculated as follows:

- compute $y_1 = (x_1)^e \bmod n$;
- compute $W = \text{BS2I}(H(\text{I2OS}(7) || v_j || \text{I2OS}(x_2)))$;
- compute $Z = ((y_1 - 1) + W) \bmod (n - 1)$;
- output Z .

9.3.4.3 Password-entangled key token generation function C

The password-entangled key token generation function C takes, as input, password verification data v_j , an integer Z in $\{1, \dots, n-2\}$, integers y_2, d, p, q in $\{1, \dots, n-1\}$ respectively, and produces an integer x_1 in $\{1, \dots, n-1\}$ as the output of $C(v_j, Z, y_2, d, p, q)$. C is calculated as follows:

- compute $x_2 = (y_2)^d \bmod n$;
- compute $W = \text{BS2I}(H(\text{I2OS}(7) || v_j || \text{I2OS}(x_2)))$;
- compute $y_1 = ((Z - W) \bmod (n - 1)) + 1$;
- compute $x_1 = (y_1)^d \bmod n$;
- output x_1 .

NOTE $y^d \bmod n$ can be calculated efficiently using p and q and Garner's algorithm^[38] with $((((x_p - x_q)/q) \bmod p)q) + x_q$ where $x_p = y^{(d \bmod (p-1))} \bmod p$ and $x_q = y^{(d \bmod (q-1))} \bmod q$.

9.3.4.4 Key derivation function K

The key derivation function K is the same as that defined in 6.2.3.6.

9.3.5 Initialization operation

In the initialization operation, A securely transfers the hash value A''_1 associated with the pseudo identity and the password verification element v_1 to B , and B securely transfers the RSA public key parameters e and n to A . While A has the password π , the pseudo identity A'_1 and the stored secret u_1 , B has the corresponding password verification data v_1 , the hash value A''_1 and the RSA private key parameters d, p, q and so on.

NOTE Entity A can update the password-based weak secret by performing the initialization operation.

9.3.6 Key agreement operation

This mechanism (for $j \geq 1$) involves A and B performing sequences of steps numbered A1 to A6 and B1 to B5 (for the steps to be followed by A and B , respectively). Steps A4 and B3 and later are optional.

a) Key token construction (A1)

A performs the following steps:

- 1) choose two integers x_1 and x_2 randomly from $\{1, \dots, n-1\}$ as its key token factor;
- 2) compute $v_j = J(\pi, u_j)$, $y_2 = (x_2)^e \bmod n$ and $Z = D(e, n, x_1, x_2, v_j)$ as its key token;
- 3) make A'_j, Z and y_2 available to B .

b) Shared secret key derivation (B1)

B performs the following steps:

- 1) receive A'_j, Z and y_2 from A ;

- 2) compute $A''_j = H(I2OS(0) || A'_j)$;
- 3) look for an entry corresponding to A''_j in the server's database; if it does not exist, output "invalid" and stop; otherwise, continue;
- 4) delete other entries for A that do not match with A''_j since they are garbage when communication is cut in the middle of the sequence;
- 5) choose an L_K -bit random string r_1 , and then make r_1 available to A ;
- 6) compute $x_1 = C(v_j, Z, y_2, d, p, q)$;
- 7) compute $K_s = H(I2OS(1) || I2OS(x_1) || A || B || A'_j || r_1 || I2OS(Z) || v_j || I2OS(y_2))$;
- 8) compute $K_i = K(K_s, I2OS(11), L_K)$ as a shared secret key for the following communication;
- 9) compute $K_m = K(K_s, I2OS(10), L_K)$ as the MAC key if the key confirmation below completes successfully.

c) Shared secret key derivation (A2)

A performs the following steps:

- 1) compute $K_s = H(I2OS(1) || I2OS(x_1) || A || B || A'_j || r_1 || I2OS(Z) || v_j || I2OS(y_2))$;
- 2) compute $K_i = K(K_s, I2OS(11), L_K)$ as a shared secret key for the following communication;
- 3) compute $K_m = K(K_s, I2OS(10), L_K)$ as the MAC key if the key confirmation steps in d) below complete successfully.

d) Key confirmation (B2 and A3) (mandatory)

B performs the following steps (B2):

- 1) compute $o_B = \text{mac}(K_m, I2OS(2) || K_s || I2OS(1))$;
- 2) make o_B available to A .

A performs the following steps (A3):

- 1) receive o_B from B ;
- 2) compute $o_B' = \text{mac}(K_m, I2OS(2) || K_s || I2OS(1))$;
- 3) if $o_B \neq o_B'$, output "invalid" and stop.

e) Key confirmation (A4 and B3) (optional)

A performs the following steps (A4):

- 1) compute $o_A = \text{mac}(K_m, I2OS(2) || K_s || I2OS(0))$;
- 2) make o_A available to B .

B performs the following steps (B3):

- 1) receive o_A from A ;
- 2) compute $o_A' = \text{mac}(K_m, I2OS(2) || K_s || I2OS(0))$;
- 3) if $o_A \neq o_A'$, output "invalid" and stop.

f) Storage update (A5, B4, A6 and B5) (optional)

A performs the following steps (A5):

- 1) choose an L_K -bit random string A'_{j+1} , and then compute $A''_{j+1} = H(\text{IOS}(0)||A'_{j+1})$;
- 2) make $AE(K_i, A''_{j+1})$ available to B where $AE(K_i, *)$ is a symmetric authenticated encryption function using K_i as the symmetric key.

B performs the following steps (B4):

- 1) receive $AE(K_i, A''_{j+1})$ from A , and then extract A''_{j+1} from it;
- 2) compute $v_{j+1} = v_j \oplus H(\text{IOS}(2)||K_s)$;
- 3) add $\{A''_{j+1}, v_{j+1}, A\}$ to the server's database;
- 4) make $AE(K_i, \text{reply1})$ available to A where reply1 is a reply message.

A performs the following steps (A6):

- 1) receive $AE(K_i, \text{reply1})$ from B ;
- 2) if the result of decrypting $AE(K_i, \text{reply1})$ is not the same as reply1 , output "invalid" and stop;
- 3) compute $u_{j+1} = u_j \oplus H(\text{IOS}(2)||K_s)$;
- 4) update $\{B, A'_j, u_j\}$ to $\{B, A'_{j+1}, u_{j+1}\}$;
- 5) make $AE(K_i, \text{reply2})$ available to B where reply2 is a reply message.

B performs the following steps (B5):

- 1) receive $AE(K_i, \text{reply2})$ from A ;
- 2) if the result of decrypting $AE(K_i, \text{reply2})$ is not the same as reply2 , output "invalid" and stop;
- 3) delete all A 's records $\{*, *, A\}$ except $\{A''_{j+1}, v_{j+1}, A\}$ from the server's database. The deleted records include old records $\{A''_j, v_j, A\}$ and those that might remain as a result of communication errors between A and B .

Numerical examples can be found in Annex D.2.

NOTE 1 r_1 can be removed if it is acceptable for K_i to be a function only of inputs from A , and joint key control property is not required.

NOTE 2 x_2 can be removed and e can be 3 if n is stored in a location in which adversaries cannot modify it even if they can copy it.

NOTE 3 A' can be replaced with A if anonymity of A against eavesdroppers is not required.

NOTE 4 The octet string of A can be the concatenation of an octet string identifying the user and an octet string identifying the storage or the client terminal.

NOTE 5 After the key agreement, the RSA parameters can be updated by sending a new value of n from B to A encrypted using $AE()$.

NOTE 6 This mechanism can be extended to provide security against server compromise impersonation attacks as in Section 6 of Reference [36].

Annex B

Add the following before -- Balanced Key Agreement Mechanism 1 --:

```
id-km-ws-lKAM-1 OID ::= { id-km-ws leakageResilientKeyAgreementMechanism-1(9) }
id-km-ws-lKAM-2 OID ::= { id-km-ws leakageResilientKeyAgreementMechanism-2(10) }
```

Annex B

Add the following before `END -- KeyManagement-WeakSecrets --`:

```
-- Leakage-Resilient Key Agreement Mechanism 1 --

verificationElementDerivation-9 OID ::= {
  id-km-ws-lKAM-1 verificationElementDerivationFunction(1) }

keyTokenGeneration-9 OID ::= {
  id-km-ws-lKAM-1 keyTokenGenerationFunction(2) }

entangledKeyTokenGeneration-9 OID ::= {
  id-km-ws-lKAM-1 entangledKeyTokenGenerationFunction(3) }

keyTokenCheck-9 OID ::= {
  id-km-ws-lKAM-1 keyTokenCheckFunction(4) }

secretValueDerivation-9 OID ::= {
  id-km-ws-lKAM-1 secretValueDerivationFunction(5) }

keyDerivation-9 OID ::= {
  id-km-ws-lKAM-1 keyDerivationFunction(6) }

-- Leakage-Resilient Key Agreement Mechanism 2 --

passwordVerificationElementDerivation-10 OID ::= {
  id-km-ws-lKAM-2 passwordVerificationElementDerivationFunction(1) }

keyTokenGeneration-10 OID ::= {
  id-km-ws-lKAM-2 keyTokenGenerationFunction(2) }

passwordEntangledKeyTokenGeneration-10 OID ::= {
  id-km-ws-lKAM-2 passwordEntangledKeyTokenGenerationFunction(3) }

keyDerivation-10 OID ::= {
  id-km-ws-lKAM-2 keyDerivationFunction(4) }
```

Annex C

Add new Clause C.4 as follows:

C.4 Parameters in leakage-resilient key agreement mechanism 2 (LKAM2)

Examples of the parameter e chosen to meet requirements a)-c) of 9.3.3 are as follows for $L_K=112$, 128, 192, 224 and 256, respectively:

$e=2^{113}+2^{90}+1=0200000040000000000000000000000001$ for $L_K=112$,
 $e=2^{129}+2^{127}+1=0280000000000000000000000000000001$ for $L_K=128$,
 $e=2^{193}+2^{132}+1=02000000000000000100000000000000000000000000000001$ for $L_K=192$,
 $e=2^{225}+2^{182}+1=020000000000400000000000000000000000000000000000001$ for $L_K=224$,
 $e=2^{257}+2^{132}+1=0200000000000000000000000000000100000000000000000000000000000001$
 for $L_K=256$.

Annex D

Add new Annex D as follows:

Annex D (informative)

Numerical examples

D.1 Numerical examples of LKAM1

This clause lists numerical examples of leakage-resilient key agreement mechanism 1 (LKAM1) with elliptic curve domain parameters.^[37]

secp224r1 (SHA224), $L_K = 112$, HMAC
$A (= \text{lrpakeuser1@aist.go.jp}) = 6C7270616B65757365723140616973742E676F2E6A70$
$B (= \text{lrpakeserver@aist.go.jp}) = 6C7270616B6573657276657240616973742E676F2E6A70$
password (= zokang1) = 7A6F6B616E6731
$H(\pi) (= \text{SHA512}(\text{I2OS}(0) A B \text{password})) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DDB$
$G_b = 038C9C85F629134BEED14A1665662BBFC7F517BDFE070C1E470D2BD921$
$S_1 = 77A29359EA58A369D5F49519334A91C82E2D04A7BA97D56B4B28F9E5$
$W_1 = 033440F4772CD2AA5BB8452DEA433A3308CE6CE8448148135F6E44DD1E$
$X = B7F03B2A8293504BCBE4D10593216B46E0FE3EC3DFA0474E041FE99E$
$X = 020BBDFA70DD45BC4C547E76CE7FF03B4AB32ADA12A52637F82F910D0C$
$X' = 039C4956146DF34530CB82503A0925497761402B7722C71F26C0B0D4FC$
$y = 915186FF1942FCC764FEA417CD728909F5C29419E59273BFC5EBE02A$
$Y = 034E5F87BEE7955E0AFF018DA0D77A12FFFB6C4B130E95602821252304$
$Z = 020A386B68808E33B6DE6A5DF9AF8FA29D4765128CCC2D5E76D6C2FBB7$
$K_1 (= \text{HMAC}(A B \dots, P_1 (= 1), L_K)) = B4989CC5943D6C8A1F8EF04866F43B6B89A70959681DC8A13C0AB494$
$O_B = E26DC0043AA90EBDF33CF4C5B1B1860348D56D2226D0383ED62B56C9$
$O_A = D2F7F179F71D62B9DA5033A5F1096F4EA75E5E24AA6D0A432EE8DD0A$
$S_2 = 05F627B8FA25380326AD512536BA467C8C5B989D4A7B7CE2A163F802$
$W_2 = 02AF9DFB335866BF68D391FBF0F791D195D2EBE6A0FB07AE514E483298$

secp256r1 (SHA256), $L_K = 128$, HMAC
$A (= \text{lrpakeuser1@aist.go.jp}) = 6C7270616B65757365723140616973742E676F2E6A70$
$B (= \text{lrpakeserver@aist.go.jp}) = 6C7270616B6573657276657240616973742E676F2E6A70$
$H(\pi) (= \text{SHA512}(\text{I2OS}(0) A B \text{password})) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DDB$
$G_b = 03836362FFB02357EFF24F4881D96618B2128F55791A445D67E301A5A67B57146B$
$S_1 = 08B637BA75234719211718326BE28CB3C45EF4EA366DEEBAD2A1738D6A77E327$
$W_1 = 03EDA13583FB00976FA641B29F1DA37D95EC4E38328A3E645A522637C635F7AFB7$
$X = 36B80344B46ACC4185A40A740D8008C47BCF6F5C183787DD3E8CFF1CA38A26EC$
$X = 025460E3BA90D478232E64786C016CDC1CA31B67F9C876CBFF5E59CAD80F417896$
$X' = 02CA2646F82997E01610F25B2BA8858557A193FEF31C4360DBE81537C96D4ECA03$

$y = 78574F0E3861B458291DF3D3935624E873FF9AB8FECD7FB731E8E4E28312C53A$
$Y = 02A509BBD2DCA18C790960A7D6A616A29E9361C5B3E8EDCD5474EDDC03F4FF680A$
$Z = 02903FB52457300DC360EE8E29E35C8E2AF029EE2E552F9AC79C7D7414A09BFDFAF$
$K_1 = 642B8E2BAF69CE15311D89111403F530239D324B597998C2E6468F153545BF68$
$O_B = EA9C1114DA052C9946016F3E13E5071F687C0F397FCE48395EB417854F13FA43$
$O_A = 7E44AC7A41F74B739B4119288C00117C4EF697E38E4B4CF9CCA75AF48A220633$
$S_2 = 8674A52EC629B2DB1CA283E9F3C1BAB79A060CA25F8FCB3EFC940EC3A5A6DEF9$
$W_2 = 02ECCBC141C0BD5663378F7F71DD846ADDD11DFEE0160DB8863583680A014A21E7$

secp384r1 (SHA384), $L_K = 192$, HMAC
$A (= \text{lrpakeuser1@aist.go.jp}) = 6C7270616B65757365723140616973742E676F2E6A70$
$B (= \text{lrpakeserver@aist.go.jp}) = 6C7270616B6573657276657240616973742E676F2E6A70$
$H(\pi) (= \text{SHA512}(I2OS(0) A B \text{password})) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DDB$
$G_b = 032795D71E027B79FBD173E29AFEC1FEA012EA8E949261351B1B55A057BA2AEB486DAE7864567E295455102A36E80FFABC$
$S_1 = 172728FF24A8DACA76CB35CD452A5B2965566765284188B170432CB308087F694BA5BE9096646BD841A38CDBF303BA36$
$W_1 = 0387B53DFD61DBCA7B713EEE1CD97F906BDDDB51545605982047180ED861A334816B9280C680B7D006CE16A791E6D34052$
$X = 06E32720C444DB089B0FB133C4B76BCB999AF85BE2F0FEE00828F3D2C8F6F461B6C59DD6C50D221BF62893DAE34D170E$
$X = 024F7E422FAF3CE9B6C41D152810F1219275EF2609C2B773FDDA831042547079A81D6422C333176E4BBEA33B1177A91A29$
$X' = 0245E1A1AEF8670486F0CEB1B64365C6C880EF523B74ADB8FBA8E98E8B7262479342852EACBE59C97A5B443DA391F84DBC$
$y = 04AA9BED6A080FEB1AA1989C879EC789FCE09E0DDF31ACE2AD6AAF9B1B74801E5BF4A47FD5C88FC6D340AA4A510D3C2A$
$Y = 02D07170771E78C29960CD8F2C4BF84C680E0E634D626B4354A29E608746AAF6EF0EE8F6F3916D46AEE0542D0A64945539$
$Z = 02CA358BBFC9048EDEA3F584105E3461F9DE6BE68F8D6FD36A35C206DF9E83AFC9D84D8EEBFC6A9B5AF26166D5324A2B93$
$K_1 = F053027E04824E247DCBD91922C523DB14936475839F0B5D03FE9D93A6D60129E5C77DEB2219BFC8404BE35805487286$
$O_B = 786C709D048E9E9CEAB0C2E032596E5E708ECE7AD3BA38CD998DE574DF65C413494922D50D2D869D572A5CF563EA65DB$
$O_A = 3E9928F723856EA8A9051C1C1AE5B9DBCBF5B71235874C03AFD9FF8A7119B001A87E45310899F4431442604878D50C2A$
$S_2 = 87926DC8F0C6DD5C833A9BAC88CBC7B10540C3FD6ED95522C14DF050BFDDE4A55B551D50747EBB03DDFB231AD11FA8B$
$W_2 = 026B99C3D3216E128D04FCACFBE3BD54BA6D60226406EE9789B6040743302C6A916287178C7E0A9CE3AA1CBCBEF63BF7B7$

secp521r1 (SHA512), $L_K = 256$, HMAC
$A (= \text{lrpakeuser1@aist.go.jp}) = 6C7270616B65757365723140616973742E676F2E6A70$
$B (= \text{lrpakeserver@aist.go.jp}) = 6C7270616B6573657276657240616973742E676F2E6A70$
$H(\pi) (= \text{SHA512}(I2OS(0) A B \text{password})) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DDB$

G_b = 0301FC7EA5FABE261338268E4D869C85792F696FED0C4E8DF2C5CC2E1A058870AD34F2075F6AA9EB345E5C7E389A1F6DACDC69E7F2E23E2E6F4FE634B7AF04B96C0000
S_1 = 0145C5774E00ECF1B110F2830121B25AF54DC20AB69DCAB9EB178A8503F9BB0149584FAAF65643FEB5D3D7ADBAB368DCCD7F516D01B1225016EDCE45DD3D35A222A4
W_1 = 02001641396A47DF8E7904722C402F3CF28D0195A9E9F01C9F8587E21DF000EA8FE9F8F5AC190B8433A678D977802A06F54773D2D703DC7C70A31F86CFDE98456B7B6F
X = 3415721DBA0048D8FFA0B55AE61A5A26FDFED7ED27338B57CCB727821DAEFF7ADE71FF07696940EDE7C6F0ECE64CC528CBFA2B1719AA7EC87A7203701BF28974F2
X = 0201789EDE6B436290240CD0560C417E026CFC40189E01E7D60FA8B34104D841F59528A5FB26A5B5BA08DA8E0731FAA9517D676E8CC6FD18B3423D472CD02417FB32C
X' = 0201E1254B57E3B19B58E5AC4E8C69951695B67B1A6F871ABE1A09F9EF22531624E6676136F8827933C6AFCEB6A9C8C2699FA52A8185A1387F061E51951322F662DAB8
y = 349E027B11682752968B5F81D2A0011AEAC948D879E059DD24FAC570459C431B742D6087ACF370C7EF30D1BAAEC6312A799E8A4408B81BC5CAB320F543DF6B0F96
Y = 0300CCBD31FFF6AD192125F1166FA8315F0862DA0DDFA602A4C16AA285042C1357A91412F88BF94F1AAA23096807205CEC8A88F7E49CCB3FE3E2E99687BC000036A0381
Z = 0201DCCEC1D4104F63ECE5733667130E51994AD9AE3326E90778C4D033F24881C105D129FE7188D2A809ED6A200B2B889A7A10FEB2EA1CB6B66C20A61BAE34D29D5FCF
K_1 = 784C12720D21CF9ABE1863130308C215E77A48F33885DAFD0418C18CA5BAF48DBB77B4D1C6CAD146E84BAA09397C4396375A6203C00E658B99680BDF7483442
O_B = AE16DBDB229E54E861BE925F5FA454348D15DA2268D323FE98F8B5907B35FF938F875130116C41672F4AFF74E93769A1FE092A71BC04C5868F4C2139E798E86
O_A = 3EEE9798B58D8416432B59BFE2718EDE5B928FC2FB2879883D81B5965ACFC470D3DA3620CB9A4B5C74D563779F116651AF7EE10D6EF6E4FA3B006F6D4909CC58
S_2 = 01460B413E44AC230CAD3226FA37EF303AC5F4BBB25374FA4D6164A74410F89E53B4DF5F4AAB621EA58765738FF1D622D06CC8D092BC11549E4F457A799A09B6C50E
W_2 = 02009C79B87EB0FF1AB99F4E58EC7D73181B675021FFEDA0CE34A60F2AEC8FD7346F6156454C88D473120A021C45EC1105487FB4A5FAD01DCF081455E1F05CC3AE6B462

sect233r1 (SHA256), $L_K = 128$, HMAC
A (= lrpakeuser1@aist.go.jp) = 6C7270616B65757365723140616973742E676F2E6A70
B (= lrpakeserver@aist.go.jp) = 6C7270616B6573657276657240616973742E676F2E6A70
$H(\pi)$ (= SHA512(I2OS(0) A B password)) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DDB
G_b = 03001C0CBE86CE485C9A31E30AE144FA26FBA67A84B9430DAABD6EE81608D2
S_1 = 80CD565B13979070999D2B733B7C67F8998C8DFCE1CFC7AA2ADAC34ADF
W_1 = 02017FD21812430AE35D6F95604E7D31DF4B9F1734F8618507CAE552E7AC4C
X = BEFE05840C788DB83D76A374442F9D83E473E87E7583A57D41E3860DA3
X = 030121D46772E77EDE102BE7F0D87FE4554432B72B418DC4640F28C13DCB04
X' = 030038B925C51C0FDB139A3B9C983A182271AE94B03186AB76C92E0D0CD615
y = 8E58498C6E9C433DE2602BDFDEBCB501D67C54A418D53DCA5A2D39F5AF
Y = 0201A7B1C1E33EA306523FBAC0978109606B3801C9EEF25F06EEF79EFC4074
Z = 0200EFD59D2776243486B7F8A6D70C48901A12737CC8524F016FEB89FDB138
K_1 = 0E3BBDCF9C27AAC8157485433D96CEA88F1195645A7C6B86C79D8B2A4DA8AF20
O_B = E7A8215C6C8113E86197130021D1B3510624B2ACAE5168B6833B143163C92D5F
O_A = 9CBF4ADCD3FC4DE526F520DA805520526AE4162562B8D279AC4F8191953C2BCB
S_2 = 5EC18601AEEC38217E68A867C2FC8F66A0FD6E065F246792C2AAA3F07C
W_2 = 0301ED6A3947172912BC8DBB893691DDFAEAA8AA3CE378F6DE825838B09782

sect283r1 (SHA384), $L_K = 192$, HMAC
$A (= \text{lrpakeuser1@aist.go.jp}) = 6C7270616B65757365723140616973742E676F2E6A70$
$B (= \text{lrpakeserver@aist.go.jp}) = 6C7270616B6573657276657240616973742E676F2E6A70$
$H(\pi) (= \text{SHA512(I2OS(0) A B password)}) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DDB$
$G_b = 0300A28B50B8139FE286B2D2E2C0472F226C08A73E5B46410DC3A855A95E51FC5936EE4CBA$
$S_1 = 0189B967F2E0578BFF8FF7A91E86AB06C5B8FEEE98755F650C785858977F4CF1EACB3566$
$W_1 = 020134C6F0D6432C45E17344F56AC1BD32E4773EE5E7FC154B615F70E9232884A6ED89AFCG$
$X = 6D6EA2F06155FB6EF0A501F700E2D5564168A42A04D0982313155CA99F0DE873858272$
$X' = 020797C2BD11D4B68D95C9339B844137C7271121124DE28EFB74591E8E960DF00CBD0DDCD8$
$X' = 0304A03C7473B46D6BD7F317BFDE936D12840118C33CF87CFD42EA5D6C05929C6E4C58846F$
$y = 031C8259C15815B83B5821D6769DE7D1A5749B8F336914EDBB073EB67F26CA36B4F6BED4$
$Y = 0200D87675C56855A645233E8732CBCD2D0AEFEFB7F432887517A10186A69F6D750B0D3A13$
$Z = 02077C8D10FB2EC7E26F5A25DB4875D9C31B89C90D5609BD0EEDDE9562059AA5DA42371E4E$
$K_1 = B54951F161350F5DB64CC5C9BA5D8B504C8D11F53622779AA75BFE705582C647D288FADEE074199A038EE88976EA8093$
$O_B = 8A410DE35B583BD661518CF98D953684E97CC0FAB6149452417277F842D25606C5485C20A27662EBC06F297C37329BC2$
$O_A = BD7CD009CEE8185B7C6D22513F2BE610A69C9AFEADA6BE24936EEE61073CFE6B5D6E5FB22A865F1F6280886745AD24AC$
$S_2 = 02805D7E24ACBC7677DA4489A68EABDD7649FEF32C9369BF2CAAA17A7619BBE65135DFD9$
$W_2 = 0200B77B97EE94A9D75530C47059A6B3BC88D871F86ECC2B7DD4611E7C0B02619CB6501$

sect409r1 (SHA512), $L_K = 256$, HMAC
$A (= \text{lrpakeuser1@aist.go.jp}) = 6C7270616B65757365723140616973742E676F2E6A70$
$B (= \text{lrpakeserver@aist.go.jp}) = 6C7270616B6573657276657240616973742E676F2E6A70$
$H(\pi) (= \text{SHA512(I2OS(0) A B password)}) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DDB$
$G_b = 0200708C13AFA264704D56E9E96049E700352D76249BB30AC28EFAC3046B62A03D909FBA4D0B0416A1A75EFB48EC1DFEC46A480C99$
$S_1 = E22E2D8868A7331EE6C9DDF3A5BC71D5833D48ECB2AD63E30C0B3F3242F4AD712AE3AB5325D5A3E22474A536E0A7522AB1EF22$
$W_1 = 0300E2AB649F26205F689C2C8C860CA3B95A2DAFED5867C306D3540A9ADF1BDA229BCFBA6BAA46A0BDC10FD3E506393B472639538F$
$X = 88B91481A83B9C19CD4C3DF3B029419A2DBCFA934AB26594981206629F3C6EE9B6110EE91B547A5C85E0BB501D8A12A65548FF$
$X' = 03010D5C610DD654DD3A39ED05CAA6CBA5B75E720F06AFEA0D54CC31C93414230E7673FFD945C755873B55CDA040530460013313C3$
$X' = 02017330B65524EB502E5C818954320AFE000C39DB6E9CFDDC57E73E20ED5BA0E6CD3F8B8E4EF8F3EA0DB15D62025FD16E52ADFBD$
$y = 6E67CB1AE43571006FD3005657B8409926F40BBA28E1E3FA171B31D125C9AEA35F6374D95821526482EE57B81CDDCC4DD2CFA2$
$Y = 0300879FA3A9295CA8581F878B7A8945868C223F00E007B2C587A0ED727BD06CB845D2D76F9F0B3113E0D840A94B685851C8F944DF$
$Z = 03005B1A6089322D7754BE58303F775967263E113DBA277A12F485FA067FF93139F78F526B58AFB5E54B4E81E4D85CB85BA6C306E3$

$K_1 = \text{E30D0863036B3EBF9E271AB0F8A32219368E5D946054F57E97DE368F8CFB3D23519BCBB16B3CA09FC757B}$ $\text{EC803877FCD44703F2346327F319128F6A7F923CF95}$
$O_B = \text{0CA98948D9D7F2A9A05EB156AD51B4CA6389D78AB2FBE3069389C3BBBDD6D290C275EE504E50C4D4B2FDB}$ $\text{709954B9BECCBFB65F84FD34036CD0CB294AEE513F4}$
$O_A = \text{14E97AC5FD6F0C4A43E107E70F505E6CBD70C1F7ADE5E8B4E1EBC6CE8CEE883E14E65AD49A154E2641652}$ $\text{35D9E15BF0E9E5BF34024ED3124D10D80141D6BD863}$
$S_2 = \text{D95C91FCA449ED36273C6708A132DB34C7F93DF3DDFCBEC1D21C99313397FB308E8D4CAC53D9F8CEF4BD3}$ 85E91BD2DA8BE7766
$W_2 = \text{0200986D96C4D23EB65C8915EC257C29A0F35A2EC5B4D07B6EC0F80175636421BC023AD2FAA3F6CAA297}$ $\text{868D5F5D6E09500A71191F}$

sect571r1 (SHA512), $L_K = 256$, HMAC
$A (= \text{lrpakeuser1@aist.go.jp}) = 6C7270616B65757365723140616973742E676F2E6A70$
$B (= \text{lrpakeserver@aist.go.jp}) = 6C7270616B6573657276657240616973742E676F2E6A70$
$H(\pi) (= \text{SHA512(I2OS(0) A B password)}) = 64C0F6239CCA16866612D8E1115B5ADA038D88B2A1376CC24E3B54F308DCBF18256A008ED70342EB5F32BAB141717BEB59B46EAE36D8E50EBA514287CFA66DD$
$G_b = 0207BBB9AB624978D634EAB74C381AE69EDE5377095CDB8F68E111FBCB4DCE7898C37E32A8E50B3CC1AF5177E6876EC5A56C953C493DB21603EC8DCBFB210F0354824B6173D2550FDD$
$S_1 = 0260AC86F64047E56070B76A0345DFB594AB33BFD7233554AA8B0B9413FF6620A2D4E50639DD0886FDD177DA5E7DC7353E5AB8A0B3B31699F0A0697742DCD2C60CEE20C331219780$
$W_1 = 020349A54418ADAE8F71EB4F5339023FEF1922C2FB5AFF86AE7C01AFBDC9FAC2AC82ACDDCEB259BB740C6EEE530B189777215CD4AEA995C7060A15D795042266DAAC4B03608FFDFDFBC8$
$X = 017E33C05B015B4A1E7ADD458C08BCCBECA494525987BF81008BB2F570E28AC50C9DC1A6E1A688F9D7E4CB21DE6177C8EC4B88DC293FD6E36684B0FFF91163133E4935400A75761E$
$X = 0204E4685B756105248DB2D31870E8162C3488B620BE9CCFA9A484EB15677582036132B21C1099A20BE927221F6BD070CB26C53584A5BF9CEC2C6FA7AEAF0B48497F266FA3E99EBAF9$
$X' = 03013417D0989691E426E081AF15E177518ACE9B37A57496B6342616BD5968CB7DBC47F40A24451E018A61F3F73A56C4E816C784D6F3712018CCFD1F8C8AE6A75618E36B81FEB6B7F$
$y = 025A9F76667645F39A4B2EBDDEBF55249E9135D7EDABECB69C8E2089E5BC2B17E16FBCDF1F61F4C07F310AAE6FAE4236FF2FB5B01870777ABAEB0FF8E6C6FF65CCDFE9FDFF05E3E9$
$Y = 03004A4DF3A5337772EAC17E0B4DB1D4AF5293C74868C8EA0859FB1867FA9C567A8B49EF877646420A823039E446D2EE4EC461A577FEBEFD43E74016A37A258356FC95AD746D56786$
$Z = 020252EE40059B7DF364A605776EFADD349495D85DAADBAF82C3340E369AD6A520053C2BB1E0973228D521698F83CE83E6856C90D8B05ABAC6CD9877299226769CB1BB807D6DC7A01F$
$K_1 = \text{BA7D494A386089990A39C5C2064AFDD263AFB4038B5A2E2AEB9875F0409A5606C8B18064C1F288C4FACD6436FCC449FCACE685626B8DA5C3C635DB50FC79AEF4}$
$O_B = \text{F3BFC7CD8CA2EDF01EABE89BDE570D524808473DE20C6A679FF4C142D959BF47EC76F06E83A9E5854F05405966FAE07FCADDFD23DE3A1887C42A70A4D8D5C4F}$
$O_A = \text{C715CE1E8CA379F71AFCE59198128184A51FA2EB31F621317CAF0B248F9BAD30D0C65DA73814F2BEA54583DF970C5F8D988195CF97440EFA9E06C5ED84ABAB8D}$
$S_2 = 0260AC86F64047E5C18A0497B18FDF47BD60F821B7BA96A7F6D18E26D1FF09CEAE8CDC1756BDCA316DAEB2E018855625BD9AF5DE7140F4944872604FA1DCB1E556369203B20C3834$
$W_2 = 0206390807781A7BC0C8BEE076C88B321DEDCAD6BCAEDD76BFFA6EB67011ED4E77B950B3C040A615C4821A2257C4CF304FD0D606859ACABA891BD4A2810C2292B4C261F1447F99CADE$

D.2 Numerical examples of LKAM2

This clause lists numerical examples of leakage-resilient key agreement mechanism 2 (LKAM2) with the parameters in C.4.

$e = 020000040000000000000000000001$ for $L_K = 112$ (RSA-2 048, SHA224), HMAC

$A (= \text{lkam2user1@aist.go.jp}) = 6\text{C}6\text{B}616\text{D}32757365723140616973742\text{E}676\text{F}2\text{E}6\text{A}70$
$B (= \text{lkam2server@aist.go.jp}) = 6\text{C}6\text{B}616\text{D}3273657276657240616973742\text{E}676\text{F}2\text{E}6\text{A}70$
$\text{password} (= \text{zokang1}) = 7\text{A}6\text{F}6\text{B}616\text{E}6731$
$H(\text{I2OS}(4) \text{password} A B) = 45\text{AEDB}90\text{B}740\text{E}9\text{DE}9\text{CA}7526\text{A}7\text{EFDADDBD}6\text{E}40\text{F}6628\text{BF}15\text{DE}14288687$
$A'_1 = 87\text{E}73\text{FDEF}41\text{F}684342\text{D}1\text{A}1\text{B}898\text{AEFB}7\text{E}7\text{D}5\text{CBA}39\text{AC}5\text{AB}757\text{EA}194\text{B}36$
$A''_1 = \text{DE}1\text{AD}38862\text{B}96\text{C}40\text{FB}702\text{F}3539644\text{EAFDD}5116\text{DB}4\text{D}32\text{C}60\text{A}81\text{F}6110\text{E}$
$n = \text{BB}0\text{DDDD}835\text{E}966\text{C}0\text{F}03\text{A}215\text{ABFA}7998\text{AAC}98\text{B}9\text{C}2\text{C}72245\text{C}6\text{FEE}4\text{C}1\text{B}71\text{C}0\text{BA}39\text{BBF}6\text{D}20\text{D}3\text{CA}39\text{CD}62\text{B}0\text{DB} \text{EE}89\text{A}490\text{D}0\text{ECE}2\text{D}87\text{CC}6\text{FF}6\text{F}9\text{DCA}313543\text{DB}3\text{A}61\text{E}14\text{FBF}4\text{C}10187\text{A}15\text{A}4\text{C}6\text{A}69\text{E}7\text{B}35\text{B}3211\text{C}1\text{A}3741234\text{F}94\text{BC} \text{26C}82\text{F}665\text{B}27\text{F}70122\text{F}40\text{CA}0\text{EDB}13\text{CE}1\text{D}04809\text{FB}2\text{DA}53\text{D}4\text{BFC}11065696\text{DC}36\text{A}2\text{F}8466\text{E}7\text{DC}7\text{C}741\text{D}3\text{F}061474\text{F}3 \text{66BE}172757350\text{A}3\text{C}15\text{D}41\text{FF}78\text{EB}163101414\text{DDC}BD3001\text{BE}93\text{B}0\text{B}348\text{D}4\text{FCBCF}59\text{C}902\text{CC}76893\text{FFC}1\text{BED}277\text{F}6\text{C}5 \text{FE}86\text{BE}9\text{FF}69\text{CEB}0\text{C}05648977\text{ACEB}60\text{F}169741\text{F}08\text{B}64\text{F}7983\text{B}2331364\text{C}0\text{EE}274\text{FB}521\text{BB}6\text{AD}4\text{E}1\text{D}0\text{B}3\text{B}9\text{F}6\text{EC}65 \text{82B}61\text{B}6636\text{EBAD}9\text{EA}8\text{A}77247\text{E}16\text{E}80\text{C}4\text{BB}228\text{D}4\text{A}5\text{B}62\text{BACAD}716\text{EB}249343\text{E}683\text{CA}3\text{E}81$
$d = 900\text{BC}7\text{F}2\text{D}740\text{FC}02\text{BB}42204\text{DB}6\text{DA}1465\text{BB}8782\text{C}28\text{EB}66\text{F}070\text{D}8\text{EF}151\text{B}9\text{A}3\text{BDDAE}77\text{D}8\text{EE}832\text{C}5\text{DE}693118\text{E} \text{A}4\text{C}66\text{F}3\text{F}4\text{D}252\text{E}6\text{FB}47\text{F}6997\text{E}7\text{C}0\text{E}0232251\text{FD}6\text{AD}0\text{F}363\text{CD}53\text{AA}4\text{BE}2\text{BE}7\text{C}60\text{ADD}8\text{F}8\text{B}83\text{D}76\text{B}9964\text{F}7999\text{E}586 \text{EE}7\text{D}5\text{B}49\text{B}43\text{F}72887\text{A}4\text{D}917\text{EBE}5\text{C}96\text{DA}5\text{D}22\text{D}7\text{B}7\text{BBA}6\text{D}26\text{EBA}A687\text{FD}7\text{AD}7\text{B}24\text{A}563\text{C}8\text{EC}403\text{D}29\text{F}475\text{C}3705\text{AAC} \text{F}39331\text{E}39\text{A}6876\text{F}85\text{D}621\text{F}5853\text{D}4\text{BEC}23198100\text{CBEE}39417\text{A}4593\text{CEFB}97\text{A}64\text{DBBC}244\text{F}4\text{FD}237\text{CBEEFC}8\text{DCC}649 \text{4BE}22952\text{DAF}68\text{F}64543\text{C}347\text{D}090\text{A}8327\text{A}5\text{A}66183\text{CD}1\text{E}8\text{E}5\text{DE}86\text{C}7\text{F}59\text{A}67\text{C}5\text{F}0\text{FE}092310094856369315534\text{F}94 \text{025AD}3\text{E}731467\text{D}241\text{B}301\text{D}56\text{DCD}2\text{A}3\text{CAB}0\text{F}12379\text{E}1\text{E}72\text{E}82821247\text{A}4\text{F}570\text{C}4\text{E}526\text{CD}99$
$u_1 = \text{DEFF}10\text{A}3\text{DCEA}53\text{B}9\text{CDA}7\text{C}210\text{C}1\text{E}9\text{AA}0\text{DF}590\text{FF}8\text{F}96\text{A}4\text{E}280772\text{D}29\text{A}5$
$v_1 = 9\text{B}51\text{CB}336\text{BAABA}675100907\text{ABF}1407\text{D}62374\text{F}0\text{E}9\text{BE}1\text{BF}75\text{E}6305\text{AF}22$
$x_1 = 90\text{A}25\text{DFA}4\text{B}7011\text{F}513794\text{F}8\text{DC}539\text{CAF}8296\text{D}1\text{AC}5734\text{B}03262143615\text{F}1\text{BAB}4\text{B}95\text{A}06\text{EC}95046\text{C}4\text{E}15\text{DF}0\text{FC}6 \text{7D}67\text{E}63\text{EAD}2\text{F}4\text{A}85\text{DF}121481944\text{CED}4\text{CDBDE}8\text{FF}4\text{DF}40\text{CC}0\text{FEE}82\text{E}34\text{D}16\text{B}4017\text{E}1\text{D}49\text{D}86\text{AA}29\text{B}34\text{EBBBD}4253\text{E} \text{9A}516\text{F}4\text{D}2\text{DD}17\text{D}6\text{FE}9\text{D}92\text{D}6782497\text{A}45\text{F}583\text{AE}96\text{F}708588\text{EBD}436\text{A}2382\text{E}7\text{AD}520786\text{A}6\text{C}1\text{FE}398\text{F}9038984\text{E}5\text{C}6 \text{FF}76\text{DAB}893002\text{A}2197\text{C}41\text{F}7\text{D}6768\text{F}6\text{E}24\text{E}69\text{EDA}12336\text{FCEB}7\text{EF}67\text{C}59\text{E}64016\text{B}88\text{C}26\text{BAC}81\text{D}443\text{A}6\text{B}92378\text{B}8\text{A}5 \text{67BCB}38840801\text{CE}3\text{C}10\text{B}2\text{CC}1\text{E}14\text{D}27\text{FEA}87\text{E}724\text{A}1\text{E}60\text{DD}99\text{FB}066\text{A}2\text{E}46858629\text{C}827\text{D}0526\text{BD}8\text{F}981315\text{A}34\text{A}4\text{F} \text{226C}31\text{C}9\text{E}3\text{D}782722\text{BBA}6394650\text{ECE}5\text{E}186\text{F}77\text{F}31541\text{C}33352\text{EB}408\text{C}7215\text{A}5\text{AA}860028\text{C}$
$x_2 = 49\text{BD}832\text{F}7\text{E}7782027\text{BD}193619\text{BA}875\text{A}472\text{CF}60\text{AAE}58\text{EBFA}08\text{E}49\text{FD}74\text{A}382\text{D}858366\text{D}199922743817\text{D}72\text{C}4 \text{DC}628\text{ED}3700\text{FEB}4\text{A}00\text{DB}5\text{F}7\text{D}8\text{CC}871\text{E}48941\text{A}1\text{EFC}9\text{EEDD}5\text{A}242317\text{F}7\text{D}7288\text{A}43\text{FF}791\text{C}31\text{BBD}6967\text{A}1568\text{E}0777 \text{3978}1842\text{A}5307082471117\text{A}3452\text{E}8842\text{F}7898\text{C}9\text{CA}5\text{AD}01\text{CC}57\text{B}28\text{AB}0\text{EF}92\text{B}3942\text{EB}3\text{ED}76856074\text{CC}8\text{DC}428\text{B}97 \text{E}1\text{ADE}C4\text{CBD}8\text{CBEB}4\text{F}86\text{D}4285\text{BAD}8\text{FF}950\text{F}3\text{D}7286\text{D}418\text{FFF}9\text{E}6381\text{CB}2\text{BC}463\text{E}4463\text{E}413\text{F}01\text{B}77\text{AB}969\text{D}7\text{B}5627 \text{A}61\text{BFE}88\text{F}541\text{EAC}8\text{B}89\text{A}8549\text{A}3926402\text{C}43377\text{AC}57\text{A}5978\text{C}89\text{B}550\text{FAB}723\text{E}09\text{ED}0484906909232293\text{AB}76\text{EAA} \text{935ED}4\text{A}50959\text{D}6\text{AD}2\text{A}307\text{FD}6\text{E}04542798\text{E}6\text{C}24\text{D}0785\text{E}4911\text{FBB}83822\text{BAFB}5\text{C}7\text{F}0\text{CB}931\text{F}$
$y_1 = 96\text{E}8259\text{D}67\text{F}21\text{A}85678\text{E}8\text{C}1\text{E}5\text{D}5\text{DE}247\text{CC}4\text{E}29562\text{A}8838\text{C}18409\text{A}94\text{DF}453\text{FC}72\text{EE}02\text{ACE}C\text{DC}7812\text{A}5\text{E}4\text{BF}5 \text{E}31\text{CBE}6595\text{B}76269\text{C}0\text{E}9\text{F}5\text{DF}5\text{BCE}86\text{D}05625\text{C}7822\text{F}41\text{B}4569\text{A}57\text{E}10\text{DB}612\text{FE}4127275\text{E}59\text{BEE}0\text{F}80\text{BF}34\text{B}9\text{DFD}6 \text{5846A}65\text{E}87\text{BB}9\text{D}33250\text{E}57952\text{DBC}24994\text{A}9\text{B}3\text{F}236\text{F}3\text{A}1\text{D}A1\text{C}84044183596\text{A}464\text{C}61\text{C}2\text{F}9\text{BD}0\text{C}95\text{E}221\text{C}4987861 \text{D}7197\text{F}6\text{B}35\text{FBE}14\text{B}9\text{B}7\text{B}5\text{B}4\text{F}2\text{E}537813\text{EAC}3\text{D}8264\text{A}762\text{D}2\text{FAE}28\text{A}1\text{BD}0\text{D}94\text{DEC}F98\text{CDAA}954\text{BEA}25\text{AE}9621\text{A}4054 \text{3301FF}9\text{D}35971\text{C}83928\text{B}5\text{F}2\text{AF}27469\text{ABED}085141\text{E}834\text{CFB}93910\text{E}50\text{CA}238\text{CD}289\text{F}105210033778\text{DDD}836\text{B}8\text{B}96 \text{35B}821260\text{BB}73\text{B}002\text{D}78\text{E}6\text{F}2\text{C}4\text{A}870\text{D}7\text{DB}253848\text{AFD}0530\text{BC}1\text{FCCC}5\text{E}10\text{ADE}7713\text{C}4850\text{A}$
$y_2 = 7\text{DF}9\text{DC}446\text{A}691\text{B}3\text{C}3514\text{A}502\text{DA}0\text{F}733\text{A}6\text{EE}3\text{C}3\text{C}59899\text{A}8\text{E}6345\text{BDED}78\text{B}8\text{A}0\text{C}737\text{D}564718042\text{D}95\text{B}055575 \text{68680}10\text{E}2\text{A}63\text{DF}17\text{BAD}02\text{B}28\text{D}585\text{F}9\text{E}6\text{F}85\text{DF}7976\text{ED}8\text{B}2713\text{D}61\text{B}08\text{E}0817225\text{B}4\text{EDE}3\text{BEE}7791\text{A}0947\text{CA}4\text{D}4\text{F}0 \text{61281A}ED58\text{BD}0\text{CACB}3\text{E}850\text{D}64841\text{AD}322\text{AB}9\text{DCD}4\text{BC}3083\text{D}490\text{F}1\text{A}9\text{B}8\text{E}5\text{CF}75\text{CF}0\text{FFC}999139\text{D}3716\text{BCA}406111 \text{C}3\text{B}1\text{AD}7\text{F}6\text{D}563\text{CE}0\text{F}710061\text{C}442\text{E}5\text{FB}10\text{A}09\text{F}279\text{CF}210\text{CE}499\text{D}19241529\text{E}380\text{CC}4\text{BD}5930\text{B}5\text{D}8\text{B}888110\text{F}096 \text{8AAFE}1\text{EF}2\text{FBE}17946\text{B}205997\text{B}8437\text{ED}77\text{A}0\text{A}17987\text{D}2\text{AA}874\text{BA}753\text{C}3\text{B}82\text{F}7\text{AB}12\text{DB}242\text{FA}1\text{B}9\text{C}18317\text{ABE}4\text{E}61 \text{DB}93522\text{C}940\text{A}68\text{A}274\text{F}362699\text{FC}87\text{AAA}9\text{D}454\text{EDEBDD}13\text{C}1\text{E}533805\text{FD}1831084\text{CF}858745\text{E}52$
$W = \text{D}07\text{DEDBDE}93\text{A}7\text{E}376\text{A}50\text{B}05417\text{B}35\text{C}62\text{E}92\text{C}5777\text{CBDAF}44\text{FBE}90926\text{F}$
$Z = 96\text{E}8259\text{D}67\text{F}21\text{A}85678\text{E}8\text{C}1\text{E}5\text{D}5\text{DE}247\text{CC}4\text{E}29562\text{A}8838\text{C}18409\text{A}94\text{DF}453\text{FC}72\text{EE}02\text{ACE}C\text{DC}7812\text{A}5\text{E}4\text{BF}5\text{E} \text{31CBE}6595\text{B}76269\text{C}0\text{E}9\text{F}5\text{DF}5\text{BCE}86\text{D}05625\text{C}7822\text{F}41\text{B}4569\text{A}57\text{E}10\text{DB}612\text{FE}4127275\text{E}59\text{BEE}0\text{F}80\text{BF}34\text{B}9\text{DFD}6 \text{5846A}65\text{E}87\text{BB}9\text{D}33250\text{E}57952\text{DBC}24994\text{A}9\text{B}3\text{F}236\text{F}3\text{A}1\text{D}A1\text{C}84044183596\text{A}464\text{C}61\text{C}2\text{F}9\text{BD}0\text{C}95\text{E}221\text{C}4987861\text{D} \text{7197F}6\text{B}35\text{FBE}14\text{B}9\text{B}7\text{B}5\text{B}4\text{F}2\text{E}537813\text{EAC}3\text{D}8264\text{A}762\text{D}2\text{FAE}28\text{A}1\text{BD}0\text{D}94\text{DEC}F98\text{CDAA}954\text{BEA}25\text{AE}9621\text{A}40543 \text{301FF}9\text{D}35971\text{C}83928\text{B}5\text{F}2\text{AF}27469\text{ABED}085141\text{E}834\text{CFB}93910\text{E}50\text{CA}238\text{CD}289\text{F}105210033778\text{DDD}836\text{B}8\text{B}963 \text{5B}821260\text{BB}73\text{B}0\text{D}3557\text{D}2\text{D}15850544\text{E}80303\text{D}8\text{A}2\text{B}06193\text{A}54\text{C}243\text{DACE}5\text{D}2\text{C}6\text{D}2551778$
$r_1 = 30655322\text{A}2\text{C}0\text{EF}24383\text{D}7\text{C}067\text{E}5604\text{C}31734\text{F}2496\text{ACCE}4\text{B}82\text{EC}69367$
$K_s = 987\text{D}985\text{F}935\text{BCA}9\text{B}8\text{A}8\text{A}9\text{B}957\text{FE}86\text{E}17\text{A}54258\text{C}6709\text{B}452\text{FFEE}98\text{ABB}$
$K_i = 8\text{A}8\text{DA}8\text{F}8\text{E}2\text{A}5\text{A}423\text{D}7241\text{ED}5\text{A}75\text{A}098\text{FC}2\text{BA}4\text{A}5\text{AE}4\text{F}4\text{BC}6\text{F}03\text{F}915\text{F}02\text{CEA}5\text{ABC}$
$K_m = 129\text{E}32\text{E}1\text{A}344038\text{C}10\text{A}4\text{C}0\text{F}362\text{F}8\text{EE}88\text{E}4\text{EEB}17\text{D}060010\text{E}56\text{E}62\text{D}415\text{A}7995060$
$o_A = \text{BD}5031\text{C}6826659\text{E}0\text{E}67\text{B}013\text{D}14\text{BEF}2\text{A}46\text{C}235\text{DD}8816\text{B}9564\text{DABBE}2\text{F}2$
$o_B = 1822\text{C}7497\text{A}6\text{D}1\text{C}62001\text{ED}42017279\text{C}28430\text{BF}9259\text{E}7\text{E}9\text{D}16\text{DF}75\text{CC}9\text{B}$

$A'_2 = 336340FCA1772464BC92C7FA5FA634EA8D57C6D2C6A8FA537DD3A267$
$A''_2 = AABE1BE5A6C800EAC7F35671C5DEBC6B7106A23F65C1BDA248FE35EF$
$u_2 = 7D2C7C1F5E92D8797D41DD1A3C5ECB54CFA3A5432D2E1988737A5933$
$v_2 = 9B51CB336BAABA675100907ABF1407D62374F0E9BE1BF75E6305AF22$

$e = 02800000000000000000000000000001$ for $L_K = 128$ (RSA-3 072, SHA256), HMAC
$A (= \text{lkam2user1@aist.go.jp}) = 6C6B616D32757365723140616973742E676F2E6A70$
$B (= \text{lkam2server@aist.go.jp}) = 6C6B616D3273657276657240616973742E676F2E6A70$
$H(I2OS(4) \text{password} A B) = E8F2C5A73E78E95ADE261F29CE9ABB008E4BABD2B8B1CA6EA2C52005CB2C705F$
$A'_1 = B83D73D145CA980A5C4D69D83236205C58B436668CDAE250E26DCC073475F9A2$
$A''_1 = 8F3B63C968E2E24BE9AB40677BFB7D3F1EE68FEF9B16E8C35F23B101C13FD0DB$
$n = A9C583F716E704397B805A482B4C150223D1CEA6BBCDC878D8EE254D6A10B3111C322C07C89057CD5AAF326E75138227FB6D0B7FB5DB3CE202A34D5461EEE7813B4DFA356E9890C4843369B93D787CFB01D7F62C752A4B50F9B194AC36D19ED9CB64B29F30E795572F9354785876597F71B03FAD997CB57499B96498C7CDDF4DC236DAAEB52BF3087107FA52749DC354DF60AC4A96C9012CDD6E7FF07203B3578D3CE716B787E911044D0FE289EB77942437B88DF6ABF9859FB33A53725C4AD36F03328AD07F7459BC82679CFD109FC2BC44D4812380CAE9152D8D453CAACB8F85F6FD0293803F745739FB65417D5E732DE54478762A5D68261A03E30BCBE7C24880B1501BE7728F3405A616CBA966B5BA210F340FA16784EA41FD0129BA2AE915FA8C8C7FBCC9BFB3E09FE56A08A6A3FEDB4B1A29E08BEF0461F10A53B5B3E998AB0928094038C5B4A18F4E8D89694857ECAE8FEBB110E1110E06B33000F3DDDE6E6CAD39DF905E1D57C0C382333778D36BD5C247DB02E25017E2232316C21$
$d = 77CE26735E4EFEB4C0C542F42CF47CBE56454739C991AFD85405DC1655733BD7EA1EAAFBBC7964DEE11FC666CE4A56416B0E0FD4C5F3635B29EE813E9D1947C8F3CF8922FFD4E83A238026962652AF6EC3A14F70D801385EF99E056285E3C42E7E5A10A7E9B69521C837D29624BB2B09E51EBED8927E005597D7A0A03F39AEBD4D23BA331CFAB88D2D4188757F3B1B89BD878BB7CC2D88076A41279262B9457B047CA9900FAE7258388DF6CAD36A3D3A8FD44619DB02CE54C86369E44122B4CE6098E3A769BE44406FE93C1E50DC2AF99E9F19F2F66F07AF47716BC0FADC712CC84A3640D6D5E0AA66773D3BA7AFE0BE3AB4B5EAC6FE643121D71EBED7C40380EA233DAC0949C8FF56EC419AF19598F616A75A6AA8423F7028509D2222E89B8A155DDE689A508EDE33468B0E8B7964730AA8B544887CA1FB0B4CF8E6B43311F89C096F92D5711FBFEDACE7D974DED09182A7F6B9C1A4B35A393639F0A6DC3A302DDA491E0EA73CB74F4813F4487686A5051FA36F6E81E1B38702B1380003A9$
$u_1 = E66117C724A338F4BE799CBB62BDFF59840483D56071125D6404975ECE321015$
$v_1 = 0E93D2601ADBD1AE605F8392AC2744590A4F2807D8C0D833C6C1B75B051E604A$
$x_1 = 5C6FA7C304D3963962F88FBD931649BFA6AAC95C119C548FAD411390D09E864BFEC3D5565992D805599F50B85B13A51BF2AA57BCB5073AE3ED01C05B4AE09EEB0E6C9C7F8250985462DBF6327A99115D582C832F4C86B6A840B3594D48B0D4E08FB5078D75A6B1E64CE424C95DFFC09A4E73AF0F142DF8FC0BDA04223A11A71316F9E8D9794B02F8D5A483BCAA65C20D0C066B6CAF7DE69F1DE1BFC9B2BA3F84F300C444293477AC85A96740DF7580F3EF90E207129F1A2AE8E7B9E7BB319DBDD90348AD28088BC4C26CE70B6B5058009FF0847EB1EF223EE0B87B972A7CCAED0FEA345595D1120AA6A4BEB967EB4798A89F9247EBA8F523AD7F48A469844A9124FDCE243CD4E923AFC24AD0B87EE380991E45D4AE3F49867C936F8EBA75EA7550FEEDE221A6FBCC2ED4A746B139BAAA2DD5DC73749C544FBC356C7F97ED3E5B8775F4689C41EE1E74CAD1B649CBABD35747D76694BAD48F0CDEBD5AAF362BDC2540A97D7EC74801D89516953E263339A278C619421CBA4BE698A5B177272$
$x_2 = 98FD69C9B7EC99BC3BC5BB8654A05F2579275817F7623C327BEE5E1ECB6380A709905BDE1F13678268E07554C099C6E06BC9B6751C994AA2B6046CDC3812CBE2ED0D98C9CEF00741ADFEE1982FEB3E20775AEF65416EC43289FA3020A88FD630413C79F232CD5E553BE8CE978710EBAC9A9B687A7E0D396591322BD98DD99027379AC3B5FEE8C0737449344EF23D5AE39664B07ABA081B87074FDEDE1E3F547BDA679DA472B2E7490E8FD07617CEB765C1E1292CD540089FFFC1155B98F8E97D686144D3F2A2793E08E417A48488819801533037065B1FFCFC6BF5E5582A912FA06564FEF4A21B1B5DF62262BE274F6B375280DF05BC904D32D5D6D86BF1FBE898D18C0D1947D2F39E8D997BD3B48C3A1790BCB37D9A31A48DCB05EB6F08244EF44AC8021FF2FFB277F66352A8CACEA5403DAA590B2ACEED664A1E8D757D3050023E5050EEA050B4EB0A65084DACA41BA7EB5FF557322E8CD36DA51B27CDCEDEB483DFA3F73D7A7523E30405BBE584FB0B245DD079B7DF38EFD7CF1561BC5$
$y_1 = 7D8EAC856546CDB16684FAEC8E07D4A0D84B9DA80077CC27ABF42E858805DD6CD65FDD3D5747D5FECB9A43FA1D2F465240657248A475A0979A175088829289841A0110DE638A2EB0C68FD93552B9FA092A22DD9A1A2F94E95BF426303682C6B26D1107274C767D43DDF6C4081BBB3400026ABAB3FD81FEE601166ECE7DC15E60878825842068DB34D161F6312A371F727BE9D75B0A99E8E2C31433ED48F905ED7D727C81DCBA3F4D2FA3147DB71FC7B9EE8DD0C8621F671ED58DB6A5C2C14DA4556329F08688230C1321EAEBB3A7BA571D45B70CE65485555F810C91912DBFF2887468BF3AF37F9DB14995500BDD67F29ADD95C23486EB0E0589B14EC675B54BF5D836F1E23C3EE2F2D681631B7B7AB12C9B59DFDB5460C611F35D8F2A38A97E0F90B6D1575D475F09CF973512F6F60B49DA9A1F303780D7C65FD4C54D52EA6FFBA7DCC29B5C02E320A629D25BAF54AD1EF108538A270F2E70256E8853F1D76D186928E2A15420FDC80A23825F25CC449CCEB2AB8B0DD46D6FAF68FD2C9552F$

$n =$ B5A4678602A7AA2B1F3290854AF40C8B99ACF9BC5787B9CE1349E9F27A8A845ABDE5693FF9C1446CE08B14
 B2CEF444028948E5171F485B99629D2EABA6826EC328A82F424741F84E5E57E70B7555BCFF538AFB2EA4F7E8B
 64FDF9EC8466A4A03AAE81D1952517AE982F162FD5D4B63FC5C468DC024F7064A76FE64E763C77235B9447770
 0931A56D034716E182B7061308D858BBA54AF8DEE5DB6DA3653B6951D31D74AD313D4BE3F99ED3CEB6734C972
 D97710AC8E1A07AB2ED5BD0879CC52EE108686E450C4649D392F765712C362F25A8A9936BEF3E928478D44970
 8F0FD2705D26914DB7035B7A6A108F1AF04408CA1A801BBF8ED38FBBDC2CBBFB7166562FB18BE0E1A1733F124
 2DD0AA17D955EB4D631858AB8107677DCC5682F64FFFF11F4AB14EFDC13ECF3232E2D7C6D44DE15382A0E4161
 7DCD8CD7B046849E69311A505036C82576F45DF7C53AE7D30D07CEE6091DD925399F3E3D97915164A1C015E95
 4EA5B696C680284B6311294D4D0E4D56E8F26347353943FBEB1131245694090276221338B8DC5B7DE61659381
 85C0DAF25E440655E792B7C8E413861571FDF8A0935B0250D7E33B3290C61CDB3B2D90C5F9347D8889741117A
 1F2163F290CDA615136203C90AE82B40B368AED0FEF88045CBC68AE4814FF9AFB717AB58529D196A94D2D44D7
 DC9622E632CCA0DA76EB4837410A6991F880CBF7B20C99C1B0AB82A25B95C3C2E913C0B6E9FB12373B479CE42
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$d =$ 9459A737844885ACF7F22D576CB398C424BF9939EF09A54EC32BF858934E646ABADEFC356B620869E9CA05
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$u_1 =$ 5A62851B9A0CB2D2AD34BE3332BA68CCD1B239BE00DCBB4EF6864FA48F923F55EC3D4CFB92E15309D4909
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$v_1 =$ 91F20FF5D1DE36056CAF3170FEC61C0D68830BA5C63F9518F49F581991B14800697FE464FADA759CE730E
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$X_1 = 93A8601D782445DC1EBAC0F9120927A8A4182F8FEA6911242919B07E8DC865A2E606AB07D090F9E770D641F90B1E3136B4DC212843C54C901198779F35EB480C196BB7B6E17E0B510654CB7A979B3F59B7B21C2827ED76F34A4D61FAC82DCEF80B2AD83A527A60E92544F0C4DA03179ECE2E6FA80D8626E6BB43F3D92C7211FB28E0546E00A93B7F4105DCE30BC9E63CA4F1A0E2244841686D9CD4BAD169502F7988A68D872CE3E2E44D0E8677CA30475F54D68A84B4985AE5D27C9BD32D494656A44D9898D848BFAC2066CB090CC38D6FCEFE2ED35F61FAFAB1DC86F6E4D53CA50B716C2C2E0285A8AA93268A4144BA3CCEADBF7E62233391D42836978EC81D24A9D10FD435353C9685030E8D84D373674AA11E6AA946361E57DA187591B32B138CD0262861990528F19A73E40DB39D48790A2EDAD6074C211532321BCDDF3EFAA2BE93018C24E17F4459A96D0CFCAB1189D10FBA5B871EA0AE8893AE5922F9211443DBFBC755CFF226DFF30CE54B17DB4270C8ABE0712CD36015831A9BA2CD6545516175C5858FD6FAFFAB36DCA8DAA230406A3B85FD992B30E4FA45B365A8A6ACFD821E303290C70173E34ABFB26E08D9A55A697469740C8C7E4F55AFD8EEF47C2E23779F9BC4764CB187A362D6D2F60399E42E8BEF3942F635824BC2CE81571DB744D0CDD1FF3847A4469F81B1BB7FDE2071E0745A9D43ECD6D707C2947199AF6C79D72DA85DD7C3E90FB628F6EAA2C7B28F8C3F44C88F594B216C61E0CAC0724BB775B9F6AFBF987BF37875B0F0A9C8783AD0BCBEA756CF8837CF7F30B8D74C5E6F385399F27B5E230E85D4C6DBAB6C0451DAA9E185EB521B08CD86D63CF41FBE9B32AA262F5E81ED0CC86E25DAF990ED48D00ED87D3C3C2E85739F2D76F46A42F1526C1D0B33C194C04D0AE664FB4F6E8EE5D943012CCCD2AFE3DB6DB950119605EE07907AC4361ABB49CAFB014DF323F35B62274D30FEC629CB786879341516371A16C9EBFF05575B96329B02A91B2B6BEA6616261FC2F0DD1FE3466126FA97B4001DAE95D98943A4DA388014AEB79BFC3707F2CACC5EC2BDEFB0B7712C190B8893AF2511412074BB68A51FE89D0AA1268701C3E4362BAE68662BBD72EDF83E74404EF5615E57BA72A7B4844C582501AE808AB5415189CB386C9DB6D59BE3C2375C6F15A455550EB57FD9EE31D98BA85EBB09DFC6979F4065D8DFADED7560CD90E489E4827DA6D72C05E89001F9C4863AAA7182D9C1A6350BD51E81A9B4E80ECC75051AB785B13B358B951ED404B80BBF310336698BEC6385FF2FBF8266F86C2AF798AAA0956F7A6C061964BCDABDC42B9302921474B4D78F40454B538$

$X_2 = 09FD33030A7821B9E43C16C7557C87DFC6E98F1A4A671668D6C7F92EAF9ADC8F39ADDE212F41719249B16A01E3702F9F0857185FBBC7B20066E2EAB57CC718C362007B2B4EB797A732BBF9DD3DCAE5612A2516C146E628631319FC5D97F0BEED2B7CBDFE5DC191C4947FAE15BA95D3EF47E6B0541D3A23CDD7152F4834935590ECF4A02F2669B276E73E466B3073BCB862B5BA027793FB6D81F9E04452173100C497E88B11FA790134C9E53919D80ED5FC826511062F2EA8747B499FD472D7D41848EC1A7D5B56C6AD3087C5F3EEC3910C6678FE1934C758CEC76E062CACE36E1F098F91C99ECECFF7D53D262344C38E4CECFD0957661A55AC7364A20DC1CC8FAED16D9A2EC682B657BE551F6EE9C3825929831E6A4C05EDF85D5676121C451C6BDA9A20D7D8DA26580DD647AC1930D9664FF3853CE9AA1A9D41758DD30B4ED4BD2470C8C0FAFBFF8E1D67BEC7EE7E898E81D029B5D71C16F581975E9A776C1FEC40CF1EA152B1A0793D0A86BF8CC1B6DF947D35FE1537A44A1E1D2812C74BBC16C8D302F42A5971719003BA73AC0C16BA6B269BC98C6242EFEB231549C7CC805BD99349883DB967994D87A32EB249C03CD7CFA4F81C954AB6D55E2778EB54339794481A93B0A8E754E4E49B78D12308A0400E6E425AE21EC9242F5F246B5888CD20DA459DAB42DA89ABCD850E6C9BBEFE15BB5E55846282EB2179F9CE47461C08F50C24F786EE4C2CB6E91FE67A0671EABFE584A4511CF2A0D78A19E7AA10CDCB1C964CED1182A1EA396196EFB4DC71AE509D5A5EDC65BB8C16175D85A005B448B464FB405004151CB8FABE169CF269D40280E3F8FAE875BB46E9195210F2D2832CCB2AD773D05671C5AC069ED0DA9EA02440C12029FAAD71DA18EE8B7850FE58985905ACD33D36BCEA4FCA7871578550A2C6E4FB5A13E1782878BE16FB6D8C6C639780ECDBDCBAF7CDA221E2FA2ED10C47ACC172017A0945923F0A1FC17F532B5EB2FB5132C9F77EE75DF32B69513A70CD7B04DB0213BD0457D54E6A3D7D2657D7CB96A8B31E8CE759D965F8C7593BE1703F63C4D0D07C7D6471B98D0232D659182DA59B371784F2681A43C375056D63A7B084A022CA126E8CD7D387346432A3548858BF32DBA9B026A6A4C7E09E292F115F41E330E60924C84EBDBC0ABC0634A9EB1B97C5CC083D6BAA55DC94E4B8A18FADAE75D2C17B25D7DB8BD7BB9987ADEB6A89570886ABBD4E4D12129379751898E2C946515A29F82743E1A180D8C61F62ECE97A3E4ED8595C3556C47E783C8DE7C88B006A9F34B763F11494FB5D5C3DEBCFE2A9A2B7C548A12E9C3BECA133F3BBC5B011EADB25E89659D94CB5$

$Y_1 = 0A97F7C49E6D6AC4F496B7971C842F549D10CD350F34B69132F055B938CF1A7FF95B4B17993D0256A777FB9A5186F18A53F7D04FE32F6879E3DDD947B2AC53A58FBA85F7C37AC98059F43CC5D35071D7C9FF6327B04DBD060B742EF2577C09A895E0AC08E7B37BE7FCB717A423B691055FC90A40B29BF848996D39233721C65953E25FCB8B2AF5F928900164DBC208A559830131E2590C7CE900376CF0963812F17E14FF67C0CD8B26FE616CFE26AA40E964DDA8484328A3E3E16D63A703FBBCAA7DDB73A04A665375C65E394AA68B602626C0C31394B4B7C1F57F631F581B9BD6493AB103C59A08EDCDBCC587484D5724A7511CB551334EC2DA897779D7D8A2EA9986DD790BDA15B30F9614063C0AC5F40A318E171A44D02095F0ED08FDF5954BE62EECAC41227A5D5428FA149D70307C1043A9A9FD72A3AE7A6EF8E139286DC7CA952AFD95F478B0E71B91303F234513DAE34CA1DC24A13262A8C621E86A1D173E08EB5A236E6DC80E2710C31502A6031F83C18B7986FBFA9F9D29D172AE22566590104001FB260AF1340435184BE606B560DE14F73FD6F7ED021A6D12CFB161CF75F324E81923BF3F4616302BB6970A4743D2AD9AC29F12D6CEDC9B855424C40F9187843A2AB368A6BACA0BBDD1530BF24DCBDA410F50177A791A78E1ADF4778292F0A7824533CAFBDD5D6526197AD24E5BF5B3D99F24093D26398751219A642AE54E54B879D8E135B33D9934D90690E3E08604B1442A415AD0BB02F3693F7D55F6135637BC653645AF830939B12A2BCC539A4CD72D04D84716D60A642C38C24A4653632BB683B01FD2C3806452E34267C2ADAF369ECC5F65B6B1F749B3BD9BB48D02C7337077396ECC40CF2DB77F92C4F8474907EE87C607C9D2BC5A8F39DBB2AD2CF6754FA5836CA88EC1320FD020014142CAE9DA9F5744392F92B9501B9D887507089BC4369B125EDDA068078254C57F08E76807B1DC2A9F1DE52A32D58119FAD45FC2626AFC7F07F9273C1161164EECF7AD8F5B40820C25143D64954E6BCC9B983681228F2791D99E1331534D92BDA50FD529685072D071A851E4D484D2E2DE9BC34E127EAB63F64DA07EF365086C1C7B1BDB27E6FDF603CA2A4E44DD4224FE9DC6DF6BE969D2255E8CA224D328BBB710B45F7CE5D6A0D3459BE9127112E6DA86B0063DC897880316E78E3DC13C729DD65DD0A0A14CB93FD582A88846338E94543CC1909FFCB0DE7B3653DF434C7E1B174463B4DE7C90EF1EDCF57CA0F088C997796956BD21CE5CD5743401BB0AA979CB142937275FCB64672CD12109DB06215A234BE7C9BAEA365FFECE59827274848BDE94D1089D063832F3762A34$

$y_2 = 02AC72611D95F6D5043F9B94D7C1E3BB9AB9C7B82AB41DAD21C99AD81B21A90DA555308D548FEAA9FFB745A92BF68A704F5BBD6C804B9357C05D0A3B48FBB45DAE68E2092FE066692E7E61CE10D8E161136D46E6D3A4E50A5AF1234CB26D439BBEB2F1588ED369DBDD1C42E93CB40766BF4C0F506B499B36E34110606BD150DAD9A14DA0F8D6C8445CD128A25AAC4D88BE4774D3485BA8B5498E5CCBB70A68344D02E6DA82E650BD6DCA9034D82D7A63C61DF9E41061791DE306F1A30C01C5178DDAF8D2A77B093CEF7BBDBD77CCB7ADAAE057F4261AB4CB4BB2EA29DBD66C22CA666389CDFA4569A5FF597EE6D7138B46323E04A358C0EB89BC234D01C026AB72A8C500CC4790E7E3C2A2D84C581EFB27C86D9AA68B77F079699E79D76C7A6B221404257205C679FA3FBEDC063AD2CDFE5A61E383FABAECF5D2C2D34434D8321D2C48AC520B716C0C25BA5EA710FE6CCC266C9F26C495F56D6EE2F3D9A7AD03DB6EECCF4B678D10AC0ADF952780CA07375AE1B1F9559B45E240DF2FEB4C819CCEBE1D21C9FEE88C053776C9565E699C6AC12B491296DD851DFB84602C2C81548838358360A0B0A53E643B5B116488E8A43F1DF26E1B4FE374A85DA2C9874E939128B0E26C32B3E61CE5995A48CEE1A956F8FFA90C8747CD4E6075BEA8A1CE91D32E3514113902353A1EEBB4DFF4F84DEBD5DE50C17742641C109314FD6D1D69F415D108B2ED8A924A1632CAD2E924FE7BA8E4B79DCEDA4CFEE70586642B29908E6A19FCD0DD57BBB0EEFAF036156388018CA4CE5D862EEAB13BEBA8CA43CA9953BBF95A50E4AABE1D41233153DD205E98C7271EF5122816461592C9AB1A4FDB50A9AC90744886F1448399E1C482B2509FAB3C41EEA5A7D7EA1A84D1390922DC8D62C5314360731DBB958506FE08C6E51E71726D0043E3257C47251E32C5EEE1B8B8AE4C8A0A3F988A4B0978051EED06C33ABA2473C50D18F5EE67EA8CE148593AAE7E71C29C5ABA2DBBC123194AAF8BD63D450B03C23CBEE18623E7C1E1CF6D9271396AB8D186C5655F99BF4C068778C0ABCD8F5D71A0F30D80510830B530D7E8BE6AC231EB528379109A8EE4A2709CF492B9DCD6EF006DD92F93D47C9C223B6AEE3C2CE3CE71115A98CA41DAA22E7B2CF7E7B764FB878D2787A06298AE8C8276F131E32E316BAC153499B856C4A9401E573AD9024A584D2EF772F944D377D032A6CAAE998F05C8C11B8DF19BD62C8E199A1B59AA76A24044AD50867526BEEE1E295BD7668B40CD010F655292E4C22BB87B6425B5EDC6AB115CF505B8B3A4C64BCB81AC855C232433ABABB492DCDE2E2329F5A030EB11760DBB2B90E130AC7A$
$W = AF166E359F433B2EF82CFE0AAF61C20256578692F108F1277E3B255AEE41F87CC1FB181093D4A29BD40B29EC2069CFF4$
$Z = 0A97F7C49E6D6AC4F496B7971C842F549D10CD350F34B69132F055B938CF1A7FF95B4B17993D0256A777FB9A5186F18A53F7D04FE32F6879E3DD947B2AC53A58FBA85F7C37AC98059F43CC5D35071D7C9FF6327B04DBD060B742EF2577C09A895E0AC08E7B37BE7FCB717A423B691055FC90A40E29BF848996D39233721C65953E25FCB8B2AF5F928900164DBC208A559830131E2590C7CE900376CF0963812F17E14FF67C0CD8B26FE616CFE26AA40E964DDA8484328A3E3E16D63A703FBBCAA7DDB73A04A665375C65E394AA68B602626C0C31394B4B7C1F57F631F581B9BD6493AB103C59A08EDCDBCC587484D5724A7511CB551334EC2DA897779D7D8A2EA9986DD790BDA15B30F9614063C0AC5F40A318E171A44D02095F0ED08FDF5954BE62EECAC41227A5D5428FA149D70307C1043A9AEFD72A3AE7A6EF8E139286DC7CA952AFD95F478B0E71B91303F234513DAE34CA1DC24A13262A8CB621E86A1D173E08EB5A236E6DC80E2710C31502A6031F83C18B7986FBFA9F9D29D172AE22566590104001FB260AF1340435184BE606B560DE14F73FD6F7ED021A6D12CFB161CF75F324E81923BF3F4616302BB6970A4743D2AD9AC29F12D6CEDC9B855424C40F9187843A2AB368A6BACA0BBDD1530BF24DCBDA410F50177A791A78E1ADF4778292F0A7824533CAFBD5D6526197AD24E5BF5B3D99F24093D26398751219A642AE54E54B879D8E135B33D9934D90690E3E08604B1442A415AD0BB02F3693F7D55F6135637BC653645AF830939B12A2BCC539A4CD72D04D84716D60A642C38C24A4653632BB863B01FD2C3806452E34267C2ADAF369ECCC5F5B6B1F749B3BD9BB48D02C7337077396ECC40CF2DB77F92C4F8474907EE87C607C9D2BC5A8F39DBB2AD2CF6754FA5836CA88EC1320FD020014142CAE9DA9F5744392F92B9501B9D887507089BC4369B125EED0A68078254C57F08E76807B1DC2A9F1DE52A32D58119FAD45FC2626AFC7F07F9273C11161164EECF7AD8F5B40820C25143D64954E6BCC9B983681228F2791D99E1331534D92BDA50FD529685072D071A851E4D484D2E2DE9BC34E127EAB636F4DA07EF365086C1C7B1BDB27E6FDF603CA24E44DD4224FE0DC6DF6BE969D2255E8CA224D328BBB710B45F7CE5D6A0D3459BE9127112E6DA86B0063DC897880316E78E3DC13C729DD65DD0A0A14CB93FD582A88846338E94543CC1909FFCB0DE7B3653DF434C7E1B174463B4DE7C90EF1EDCF57CA0F088C997796956BD21CE5CD5743401BBB9BFE800B36C725657F86271DC32E30C315DA7ED1454D8F139255BBAED1051FF346F9C9C726973A47111621F13DFFA27$
$r_1 = 4309185486A772069D990EBE263177A7D7C04C0A5F6EA68CD47FDE6418CF2E61A4A88A0D82DDBE329CEBA8428B570FA0$
$K_s = CEE44B1E0A9526F24896D8A6DDAAE1BE32119AFB1778F3D2E9B8FBEB3777F33D191D6AB5B5CD1602B2BA534D0D8A4D0DB$
$K_i = 3D91FE92FEF4E0D5DF7216BDD1195AE79B7117AECF310803DA7CCA3E6A7653D$
$K_m = 0A7169591AD386DD260AD9E9646172FCB8F7ACE21D4C3365E35734F96849D94F$
$O_A = 97670EDC5E22426AA6981937D58BE6958D3B924AC0ED15BD6002B569745BBAF8AAA474CD4BF2137B85B819F00AA7D430$
$O_B = 00D9E7420DA93D12B42B1BA67283FA4FD83BECED41E31AB9A8514775118B561AAD7555F04B87C2E82B4C5C550DCBFEB1$
$A'_2 = 5F0E2CD39855B80A7429EFA92393EC249F07DDC3639943AF14306F08874C32F44E02CBCABDF2F986028246BFA9BD5BEE$
$A''_2 = 8C0244895B7594E9092C487D5C2BE85B4C68DE6F76EECD8B1125FA5E72F050B538E8F4FE5FD775D1A7063BF0A6C52A0B$
$u_2 = AAC834DB0AA695B18FBC70F7BC2D763181386B992B7D5D2F32D6E175D8E43443BD329D4F507A166389BDF73F6B63F2B6$

for $L_K = 224$ (RSA-15 360, SHA512), HMAC

$B (= \text{lkam2server@aist.go.jp}) = 6C6B616D3273657276657240616973742E676F2E6A70$

$H(\text{I2OS(4)}||\text{password}||A||B) = 403ACE79AFC2A31D2C84DD89BA6DDE18F0173827CB0FE94EC5DC04E31BD934900BAEC3BD98C205BD1AFB34EFF4686CEF8376D72A8C0DDB61C27936AE2D5F13E5$

$A'_1 = \text{F2ED23688D292688B6F9884F99ACB0BD5F57B7820BAB2732F1EC8B9E0C734791DF2764E5BE9C59CA87627C693FE1FE7B86FD688018D25964EF455815BA4632AB}$

A''₁ = 32A217F531944B5E315A07C6439BA2BBAAE2338F4A80E79A2A17B0E62DA906D34628CD21D3387DC315DF25784BB5BD4C8F03365648F2045DBC2DBF8003F9D385

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$u_1 =$ 92768C04926084AD2D2C109140F6D66A53A5DE776A149B248FB06757EED8B2A62F94174531D594CA24472
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$X_1 = 94CE793F64C3CD5A6A948418D855C9094468ED6EF31F30EF0E5E2D19C84D2D3932B6DC95EE5CEC6D16240$
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$W = 1E44DD50F00E24D170C7425ADA4004B67F5784BAFA47C7E93BB2C9F64922711CC65998BAC411611F5D9E0$
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$Z =$ 8CC4BADCC047A06B396C4EA13D26E088A7C6F91E056EBBF3B7B4A131C17C8DB5F886A78562F27AB72B931B3F55DBC65023BE9BCB24931BB26163D444D04216A5F2075A3F632AB224D33BFD99AC1496763BABC33EE65420810FE7CDE3C69371630B2EAE4F7AB30D23B4A38B5303A6693DE0C6B4D6A358B66F4E17834A2939EA9169B09D945E2670A879D501533928623AD717148D3FF2F769648F22D7E39907B48991B8ADA001811100B5A95F7301A608181C09D3D9AA9DF90C35B37E367805B7C8FBE1677774EC67E5D0F85E4B59437C3A18D71F22128E5787827D8E27990788661BE6E41E516B76BA4235A33B85F6D2B41788A1DFB272962E371797B3123F480EA1AA1E98F313368EE0241980A27B013AB14C00144529EE2C665E1376AD0C901162334881F1CEEAAABABD687AE0244BE98D39100576932FB9F83599A2F6E0C93EBF7883CBAA7BD9196ED86B61CA686C0A456DE62FBF247EE997B9CDAD7FEA51F36DEDEF28BE5BF74E7CB2ACCD2471FAEFAD5259CF8FDA580CD11575B6443CEE53D8E1A683538EC20EE6FB44ED9F1CBCDB3C281075397CF6880216B4443A8E7F38D9A6FE5F724373EE077A59632E661058FC77ADEFBD902E396CCBCF72AC94BDF6B2ABOC43DC994228BB51EAF62E156D068834E6D10E8E5A9CED3ABAB7D4F89F86A09251593DE28033A5BA3772406509D307FD8D925DB095C61E6B892C43AF1E18130E2FEBD9142764818C6C9665203CFC2F86F1A5E6A3CA8E64405DF929F5B64307E0B4475125B7DA14512192F4E4AEBBAA2F8DB7248D96ABEB41B375B4FC8FACEEB96ACA326D8668484451259D5625B8FEB9C91CFB67728D6149A0D1832FE29747AFE4D8C9237292E466ECF5B38ECF52DA9C0AFDA624A85F52994700346C419FD8C6DE7CEE5F5821702C8CC85CBC331BD258A767AE0E71CA6F0E719BD08B9A930588A41570580B241789EDD420B50A8480E909D6B05DEB1FC382A0A7C13B9540259E72666747CB3A6282B29B2E56658B866976DF5A4A88777AB094528C5474BA2FBC14C0CDA5D7E47B3DDDBDE7A4BF79000BA6CF71635F752E8CA7062EB96FAE66D0C22CD13455F8E3C43B420E0DADBBE25E9FA9338DDD4BD1501A19B104E2AFD8B04F6FAD859188364533C2656024DD7827E802B6E9409A6F6C9654AEF63F6AE9C8DF692968B5D6CAF4C866CD195FDD30F5C7EEDA2F3336A9C07AA6487353C725D1A8C9B81FEB156078C68D15C09B04C79BBB64C1A894B2053CF7FD91E91C2C270450D80947C6AE956184F83E816D67ACFA4D2C5308E70B82DCD44F90F68A72713FC70731D437C22D2B016CCF8BE156D325974BFA3C4EB53F643A0CD7E92AD2DC05F6BB596F2B63C21BE426B8D9C734BA154DD274478C5E60D275032B0A348967448F3136A4F88ABEAD5E43DBE6C4F1E5CDD22062B0759DC8881CB9B56F29C36832FE911BA9B171E45A9C109C95E876685247C6EDA92B7C015DA05E90C219477D8F1ABCF35F2FE82C89F474BAF70F84851B7CFDDEC318CB7EF76CE5E962E6FD4EC200826ED59E318C8FE2C6BDCDB445C1340AFB69E95C5D66FA6967BC8C53F244B3E2EA1A3B80125582689B7916A4053F87AA1C86DDBDCE2C79250CC5F96B1FA11C6B5E4B05DA526BBEE5F43FC432B9D67093A705F4C444912D9FACB014CBF6BD09D7933FCF3582D09CB980034E4F68FC405FDADFA77DBC7B93198CBF65B51D254CD2A7ECBDC860462BC8FFF2A616C1618585E57C72ABB9A48C53305B664D0A779DE9908322A805A121550C530C2C99F01AD1397C307470596838E11746F2DA3CB6AA7F66DE2115DC8B9DA5D549960F3AE98E0D02BD43DEA3FF9E5F61140A576C87DC66194F8F3C0B8F9923EFE6FBF4FE78981045E18341FEDD5C540D24D36CD04D4D7061C9ADFB94F4BBA64A605EA93D02B4C2952AC38650CB32A32D25E61781165995980EE0DA8998D116C5E195BCF13DD31F61E5879A8D391558D7567DD54960DA0C8E02CCC F93453A6767399647A2D576573FBFE77AA0E41DA1B1D90AFCB7E3FCF7D1E256FAAA716F43E637417B1231B49942FF9A5E3399A15F48EADAE90D0810A39ACFAE4E3662C7B61C9F834CFB5F889D38DC222C5A91E69660D1534D9270A2B1958188A7B09C27BC65DC05C1F08033AD6B2B881D5D4A63783EE5B5131994B2EAA14E3259941394F379E7D2373A4A35BE8FA2773A551E51FD6FB209F55CA5F6923EA1496CF3C136282425E7EA848C32800AD32B9825035FF023445BE2E9E394E6750B7424BEEA531EECE67CE9220463265C82342515C626E89DB8940402AEAB744F77DA6141B149FF2D282873CF3A3D4EAE8BF33D7DE5A67C906B740FA6DA2393C32C8A1CEE06530D27221EEA27C8F5FC7C68B0D18EBA16F8C025D8DC401381523396FD4432E3054463B73D61F6DBBD4529404BCFB4127428F7172B36FCEBD495C19B10DBFAB629025F6C55219139D66DA304982D468311C28820B1C826552557257925902F2991F011D223C7478560A09431B2209F42CF60C25F39277D4B53652903FD33B11ED4EABAF1E4603683F390E5CA3EF9BABFC7D6098D300A8AA3EB8B9061A34C2CD34DA1DF407C5DB2311CE22A7F1348A3D46F8B937FA8ACF3ADCB80468276843FB4EBB4C512E35189A78901635DEFD9F24DD9301AECEED42854BF127EB1EC52AF416D82096E7B6E1A2C8E1345D5803F0C337F16BDDC
$r_1 =$ 0F274329DE32A41AB862AA6F2A133003999DDABB4EE9B9DA184C46159429C90BE93D43B365E8C6D4709EB A73F9095CB34CD9CAF216B6581F700E8F698C6E4806
$K_s =$ D411C17E9EE99AC3C9EA219444EAF16C98E6C501E66EB8F3F9EA44371E623A90A3574484217B720ECAD52 209C61A1A25A765112B2E2C483E7CD49B459261E8C2
$K_i =$ E532EA12755FBAE2EE90F898BF74DEC92B8C0CFE583AF0EC667AA11500949C9A
$K_m =$ 350FB5D79B79A7E52696FEC3E393781FE33B4FCE47D5237E30DB1C9A3E414641
$O_A =$ F81DF642047CB3E6839B74C90769F11A877BDC2F8E0C8422AA306342E1DB8322DDFD87E99399F8E7DA97B 19F70AD1F57C30FE9EB552094D33B9D68F21FD237A0
$O_B =$ 86823B6BD9A3B05632D596CF95A2DE0B6F7390E6674F89C0799C2ECF1E2A96AD011F27C0C54AFD2E14811 E3D91E681F81D76BD227055968EE7DF0E9E37152110
$A'_2 =$ 9828A952FC383373C545645A0F55566563E6388A7E4C4B4B9A2CA6B9D44FED5C5E43515FE3FAE29F8454 52F415EB747969C9116209B83D6A2B3F4FF0B9A0AAB7
$A''_2 =$ 2A3A220C175BAF8CD0992F74E7932FA1A358D57EB5E23466D7542D5C430F344435E61830CBB6F18263CD C8892A8B7A803DD59DF3D6508B2799A3F3BE2D95A0A4
$u_2 =$ 2548B0FDCBE747981F69F7B49839F0F08D18B797C3D1D3071DCD969EC504A864FC5921A6DAC5D4743412D 115F360A7604BDC0978875352377D54B4B0820B51AF
$V_2 =$ D24C427D3DA227B001A8CD18FA9B0872A3B2E650A11B726A4A6C63B4F5018636243AD4F8A91791773EBC1 4E26B05D6A2AF834F1A15D3ED48C87C4FC43432F50F