

Public Verifiable Identity based Multi-Proxy Multi-Signcryption Scheme from Bilinear Pairings

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ABSTRACT

This paper presents public verifiable identity based multi-proxy multi- signcryption scheme from pairings. In this scheme a proxy signcrypter group could authorized as a proxy agent by the cooperation of all members in the original signcrypter group. Then the proxy signcryption can be generated by the cooperation of all the signcrypters in the authorized proxy signcrypter group on the behalf of the original signcrypter group. As compared to the scheme Liu and Xiao, the proposed scheme provides public verifiability of the signature along with simplified key management.

Keywords

Bilinear pairings, Identity-based cryptography, ID based Signcryption, multi signature, proxy signature.

1. INTRODUCTION

In 1996, Mambo et al [1] first introduced the concept of a proxy signature scheme, which allows the original signer to delegate his signature power to a designed signer, called the proxy signer. Then the proxy signer is able to sign on the behalf of the original signer. Several other multi proxy signature schemes [2], [3], [4], [5], [6], [7], [8] were proposed. In 2001, Hwang et al [3] first proposed the concept of multi-proxy multi-signature scheme. In a multi-proxy multi-signature scheme, only the cooperation of all the signers in the authorized proxy group can generate the proxy signature on the behalf of the original signer group.

A new type of cryptographic primitive called “signcryption” which combines a function of digital signature scheme with a symmetric key encryption algorithm was introduced by Zheng in [9]. Signcryption not only provides authenticity and confidentiality in a single step, but also gives more efficient computations than traditional signature-then-encryption. Steinfeld and Zheng [10] and Malone-Lee and Mao [11] proposed efficient signcryption schemes that are based on integer factorization and using RSA.

An identity –based cryptosystem is a novel type of cryptographic scheme proposed by Shamir [12], which enables any pair of users to communicate securely, and verify each other’s signatures without exchanging public or private keys, without keeping any key directories and without using the services of any third party. Problem with the traditional public key cryptosystems (PKCs) are the cost of the infrastructure needed to manage and authenticate public keys, and the difficulty in managing multiple communities. In an ID-based PKC, everyone’s public keys are predetermined by information that uniquely identifies them, such as their email address. There is no need for any public key certificate. A trusted key generation center (KGC) generates the private keys of the entities in the group using their public key. First ID-based signcryption scheme was proposed by Malon-Lee [13] in 2002, Libert and Quisquater [14] proposed a provably secure identity-based signcryption

schemes from pairing. Several other ID-based signcryption schemes were proposed. Li et al [7] have proposed a proxy signcryption. However, none of existing signcryption schemes is multi-proxy multi-signcryption scheme. In 2005, Liu Jun Bao and Xiao Guo Zhen [15] proposed multi-proxy multi-signcryption scheme from pairing.-

In this paper we propose public verifiable ID-based multi-proxy multi-signcryption scheme from pairing. In this scheme, only the cooperation of all members in the original signcrypter group could authorize a proxy group as his proxy agent. Then only the cooperation of all the signcrypters in the authorized proxy group can generate the proxy signcryption on the behalf of the original signcrypter group. As compared to the scheme in [15] the proposed scheme provides the public verifiability of the signature. Further the scheme is ID-based therefore; the key management problem is simplified.

The rest of the paper is organized as follows. Some definitions and preliminary work are given in section 2, Liu-Xiao scheme is described in section 3, and proposed scheme is given in section 4. The security of the scheme is discussed in section 5. Finally, the conclusions are given in section 6.

2. PRELIMINARIES

In this section, we briefly describe the basic definition and properties of the bilinear pairing.

2.1.Bilinear Pairings

Let G_1 be a cyclic additive group generated by P , whose order is a prime q , and G_2 be a cyclic multiplicative group of the same order q . Let a, b be elements of Z_q^* . A bilinear pairings is a map $e : G_1 \times G_1 \rightarrow G_2$ with the following properties:

Bilinearity

$$e(aP, bQ) = e(P, Q)^{ab}.$$

Non-degeneracy

There exists P and Q such that $e(P, Q) \neq 1$.

Computability

There is an efficient algorithm to compute $e(P, Q)$ for all $P, Q \in G_1$

The security of our scheme described here relies on the hardness of the following problems:

2.2. Decisional Bilinear Diffie-Hellman

2.3. Problem (DBDHP)

Given two groups G_1 and G_2 of the same prime order q , a bilinear map $e: G_1 \times G_1 \rightarrow G_2$ and a generator P of G_1 , the Decisional Bilinear Diffie-Hellman problem (DBDHP) in

(G_1, G_2, e) is to decide whether $h = e(P, P)^{abc}$ given (P, aP, bP, cP) and an element $h \in G_2$.

2.4. Computation Bilinear Diffie-Hellman Problem (CBDHP)

Given two groups G_1 and G_2 of the same prime order q , a bilinear map $e: G_1 \times G_1 \rightarrow G_2$ and a generator P of G_1 , the Computational Bilinear Diffie-Hellman problem (CBDHP) in (G_1, G_2, e) is to compute $h = e(P, P)^{abc}$ given (P, aP, bP, cP) .

No algorithm is known to be able to solve any of them so far, through DBDHP is no harder than CBDHP.

3. BRIEF REVIEW OF B.LIU AND G.Z.XIAO SCHEME

This scheme consists of four phases:

3.1. System Initialization

Let A_1, \dots, A_n be n original signcrypters. Each A_i chooses secret key $x_{ai} \in_R Z_q^*$ and computes public key $y_{ai} = x_{ai}P$

Let P_1, P_2, \dots, P_l constitute the group of proxy signcrypters. Each proxy signcrypter chooses secret key $x_{pj} \in_R Z_q^*$ and computes public key $y_{pj} = x_{pj}P$. Let C be the unsigncrypter with secret key $x_c \in_R Z_q^*$ and $y_c = x_cP$. Let E and D be the encryption and decryption functions respectively and let $H_1: \{0,1\}^* \rightarrow Z_q^*$, $H_2: \{0,1\}^* \rightarrow G_1$ and $H_3: G_2 \rightarrow \{0,1\}^n$ be the hash functions. System parameters are $(G_1, G_2, e, P, q, H_1, H_2, H_3, E, D)$.

3.2. Proxy Key Generation

The original signcrypter make the signed warrant m_W and broadcast proxy signcrypter. Through the following protocol, each proxy signcrypter P_j gets a proxy key S_{pj} .

a) Each of the original signcrypter computes

$S_{ai} = x_{ai}H_2(m_w)$ and broadcast it all the proxy signcrypter.

3.2.1. The proxy signcrypter group verifies the correctness of

each S_{ai} by the equation $e(P, S_{ai}) = e(y_{ai}, H_2(m_w))$

b) If each S_{ai} is verified, then each proxy signcrypter

group P_j computes $S_A = \sum_{i=1}^n S_{ai}$ and his proxy

signcryption key $S_{pj} = S_A + x_{pj}H_2(m_w)$.

3.3. Multi-Proxy Multi-Signcryption Generation

Given a message m , the private keys of t members $\{S_i\}_{i=1,2,\dots,t}$. One proxy signcrypter in the proxy signcryption group is designated as a clerk, whose task is to combine partial proxy signcryption to generate the final multi-proxy multi-signcryption.

a) Each P_j selects an integer $t_j \in_R Z_q^*$, and computes

$$r_{pj} = e(P, y_c)^{t_j}$$

b) P_j broadcasts r_{pj} to other proxy signcrypters,

$$P_1, P_2, \dots, P_{j-1}, P_{j+1}, \dots, P_l.$$

c) Each proxy signcrypter P_j computes

$$k = H_3\left(\prod_{j=1}^l r_{pj}\right), \quad c = E_k(m), \quad r_p = H_1(c || k),$$

$u_{pj} = t_j P - r_p S_{pj}$, and sends u_{pj} to the clerk P_1 as his partial proxy signcryption on m .

d) P_1 computes $u_p = \sum_{j=1}^l u_{pj}$, $S = lS_A$ and sends

(m_W, S, c, r_p, u_p) to the unsigncrypter C as multi-proxy multi-signcryption of m .

3.4. UNSIGNCRYPTION

After receiving (m_W, S, c, r_p, u_p) , C computes

$$k = H_3(e(u_p, y_c)e(S, y_c)^{r_p} e(H_2(m_w), \sum_{j=1}^l y_{pj})^{r_p x_c})$$

and accepts the multi-proxy multi-signcryption if and only if $r_p = H_1(c || k)$ then recover $m = D_k(c)$.

4. OUR PROPOSED SCHEME

To make the proposed scheme identity based, we introduce the Private Key Generator (PKG) along with original signcrypter group (A_1, A_2, \dots, A_n) , proxy signcrypter group $\{P_1, P_2, \dots, P_l\}$ and unsigncrypter C .

4.1.Set up

Given a security parameter k , the PKG chooses group G_1 and G_2 of prime order q , a generator P of G_1 , a bilinear map $e : G_1 \times G_1 \rightarrow G_2$ and hash functions

$$H_1 : \{0,1\}^* \rightarrow G_1, H_2 : G_2 \rightarrow \{0,1\}^n \text{ and}$$

$H_3 : \{0,1\}^* \rightarrow Z_q^*$. Then PKG chooses a master key $s \in_R Z_q^*$ and computes $P_{Pub} = sP$. It also chooses a secure symmetric cryptosystem (E, D) . The system's public parameters are $P = (G_1, G_2, n, e, P, P_{Pub}, H_1, H_2, H_3, E, D)$.

4.2.Keygen

Given an identity ID , the PKG computes user's public key $Q_{ID} = H_1(ID)$ and secret key $S_{ID} = sQ_{ID}$. Each signcrypters A_i has a public key $Q_{ID_{A_i}} = H_1(ID_{A_i})$ and secret key $S_{ID_{A_i}} = sQ_{ID_{A_i}}$. Similarly each proxy signcrypter P_j has a public key $Q_{ID_{P_j}} = H_1(ID_{P_j})$ and secret key $S_{ID_{P_j}} = sQ_{ID_{P_j}}$.

The unsigncrypter C has a public key $Q_{ID_c} = H_1(ID_c)$ and a secret key $S_{ID_c} = sQ_{ID_c}$.

4.3.Proxy Keygen

To delegate the signcrypting capability to a group of proxy signcrypters, the original signcrypters make the signed warrant m_W , which includes an explicit description of the delegation relation including the identity of the original signcrypters and the proxy signcrypters, the message to be signed, and so on. Then clerk broadcasts m_W to the l proxy signcrypters.

Each proxy signcrypter P_j recover the proxy key S_{P_j} in the following manner:

a) Each A_i computes $S_{A_i} = S_{ID_{A_i}} H_3(m_W)$ and broadcasts S_{A_i} to each proxy signcrypter.

b) The proxy signcrypter group verifies the correctness of each S_{A_i} by the equation

$$e(P, S_{A_i}) = e(P_{Pub}, Q_{ID_{A_i}})^{H_3(m_W)} \quad i = 1, 2, \dots, n$$

c) If all the above equation holds, the proxy signcrypter group computes $S_A = \sum_{i=1}^n S_{A_i}$.

Each proxy signcrypter P_j computes his proxy signcrypter key S_{P_j} as

$$S_{P_j} = S_A + S_{ID_{P_j}} H_3(m_W)$$

4.4.Multi-Proxy Multi-Signcrypton

Generation

Here we assume that one member of the proxy signcrypter say P_1 , is the clerk who combines all partial proxy signcryptons.

a) Each P_j selects an integer $t_j \in_R Z_q^*$ and computes

$$k_{1j} = e(P, P_{Pub})^{t_j} \in G_2$$

$$k_{2j} = e(P_{Pub}, Q_{ID_c})^{t_j} \in G_2$$

b) P_j broadcasts k_{1j} and k_{2j} to the remaining proxy signcrypters.

c) Each P_j now computes $k_1 = H_2(\prod_{j=1}^l k_{1j})$ and

$$k_2 = H_2(\prod_{j=1}^l k_{2j}) \in G_2, \quad c = E_{k_2}(m),$$

$$r_p = H_3(c || k_1), \quad u_{pj} = t_j P_{Pub} - r_p S_{P_j} \in G_1,$$

and sends u_{pj} to the clerk P_1 as his partial proxy

signcrypton on m .

d) The clerk computes $u_p = \sum_{j=1}^l u_{pj}$, $S = lS_A$ and

sends (m_W, S, c, r_p, u_p) to C .

4.5.Unsigncrypton

After receiving (m_W, S, c, r_p, u_p) , C computes k_1 and k_2 as follows:

$$k_1 = H_2(e(u_p, P)e(S, P)^{r_p} e(r_p P_{Pub}, \sum_{j=1}^l Q_{ID_{P_j}})^{H_3(m_W)})$$

$$k_2 = H_2(e(u_p, Q_{ID_c})e(S, Q_{ID_c})^{r_p} e(r_p S_{ID_c}, \sum_{j=1}^l Q_{ID_{P_j}})^{H_3(m_W)})$$

And accept the proxy signature if and only if $r_p = H_3(c || k_1)$. Satisfied, she may recover the message $m = D_{k_2}(c)$.

5. SECURITY ANALYSIS

5.1.Correctness Proof

The correctness can be easily verified by the following equations.

$$\begin{aligned}
 k_1 &= H_2\left(\prod_{j=1}^l k_{1j}\right) = H_2\left(\prod_{j=1}^l e(P, P_{Pub})^{t_j}\right) \\
 &= H_2\left(\sum_{j=1}^l e(u_{pj} + r_p S_{pj}, P)\right) \\
 &= H_2\left(e(u_p, P) e\left(\sum_{j=1}^l (S_A + S_{ID_{pj}} H_3(m_W), P)^{r_p}\right)\right) \\
 &= H_2\left(e(u_p, P) e(S, P)^{r_p} e(r_p P_{Pub}, \sum_{j=1}^l Q_{ID_{pj}})^{H_3(m_W)}\right)
 \end{aligned}$$

$$\begin{aligned}
 k_2 &= H_2\left(\prod_{j=1}^l k_{2j}\right) = H_2\left(\prod_{j=1}^l e(P_{Pub}, Q_{ID_c})^{t_j}\right) \\
 &= H_2\left(e\left(\sum_{j=1}^l (u_{pj} + r_p S_{pj}), Q_{ID_c}\right)\right) \\
 &= H_2\left(e(u_p, Q_{ID_c}) e\left(\sum_{j=1}^l (S_A + S_{ID_{pj}} H_3(m_W)), Q_{ID_c}\right)^{r_p}\right) \\
 &= H_2\left(e(u_p, Q_{ID_c}) e(S, Q_{ID_c})^{r_p} e(r_p S_{ID_c}, \sum_{j=1}^l Q_{ID_{pj}})^{H_3(m_W)}\right)
 \end{aligned}$$

5.2. Analysis of scheme

5.2.1. Unforgeability

As for multi-proxy multi-signcryption, there are mainly four kinds of attackers: any third party, who do not participate the issue of the multi-proxy multi-signcryption; some proxy signcrypter, who play an active in signcryption process; the original signcrypter and the signcryption owner. Because the

multi-proxy multi signcryption $u_p = \sum_{j=1}^l u_{pj}$ contains

secret key information $S_{ID_{pj}}$ of each proxy signcrypter P_j in the proxy multi-signcryption key generation phase, without secret key information S_{ID_c} of P_j , any third party, some proxy signcrypter, the signcryption owner and the original signcrypters cannot generate a valid multi-proxy multi-signcryption scheme by themselves.

5.2.2. Strong Identifiably

The unsigncrypter can distinguish proxy's normal signcryption from his multi-proxy multi-signcryption, because the multi-proxy multi-signcryption key is different from his own private key.

5.2.3. Strong Nonrepudiation

In our scheme, each proxy signcrypter P_j cannot repudiate his participation on multi-proxy multi-signcryption while illegal attacker cannot claim that he is proxy signcrypter,

because $u_p = \sum_{j=1}^l u_{pj}$ contains secret key information

$S_{ID_{pj}}$ of each proxy signcrypter P_j , at the same time, warrant m_W also contains identity information of P_j , in addition

$$k_2 = H_2(e(u_p, Q_{ID_c}) e(S, Q_{ID_c})^{r_p} e(r_p S_{ID_c}, \sum_{j=1}^l Q_{ID_{pj}})^{H_3(m_W)})$$

contains $Q_{ID_{pj}}$ and m_W .

5.2.4. Confidentiality

Because the secret key k_2 contains secret key information S_{ID_c} of C, only C can compute k_2 and recover m.

5.2.5. Prevention of Misuses

No proxy signcrypter P_j can repudiate his participation on multi-proxy multi-signcryption, in addition, m_W includes the message to be signed, so our scheme can prevent the misuse.

5.2.6. Public verifiability:

Any third party can verify the multi signature directly without knowledge of secret key of receiver. The third party firstly computes

$$k_1 = H_2(e(u_p, P) e(S, P)^{r_p} e(r_p P_{Pub}, \sum_{j=1}^l Q_{ID_{pj}})^{H_3(m_W)})$$

. Then, he accepts the proxy signcryption if and only if $r_p = H_3(c || k_1)$. So our scheme provides the public verifiability.

6. CONCLUSION

In this paper, based on Liu Jun Bao and Xiao Guo-Zhen [15] we construct a public verifiable ID-based multi-proxy multi-signcryption scheme from pairing. As compared to Liu Jun Bao and Xiao Guo-Zhen scheme the proposed scheme provide the public verifiability of the proxy signature. Further the scheme is ID-based therefore; the key management problem is simplified.

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