A Blockchain-based Certificable and Redactable E-taxing Protocol

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Abstract: *Taxation is a primary source for the government revenue, and its complexity of the tax administration creates loopholes that can be exploited by dishonest taxpayers to minimize the tax paid to the government. We utilize the blockchain technology to create a transparent and secure tax system as well as to simplify the process of administering taxes. However, due to the decentralized and untamperable nature of blockchain may have limitations in tax system applications. In this paper, we propose a blockchain-based certificable and redactable scheme for e-tax. We adopt self-certified public keys to authenticate taxpayers and chameleon hash function to delete (merge) the tax information of related users on the blockchain while keeping the block header unchanged.*

Keywords: E-taxing, Blockchain, Certifiable, Anonymous.

1. Introduction

Taxes are a major source of government revenue. As one of the largest sources of national revenue, the tax sector should always be able to adapt to any development that could occur. With the arrival of bitcoin technology[1], blockchain has also received a considerable amount of attention as the underlying application technology for bitcoin, its application scenarios can be used not only in the context of cryptocurrencies, but also for a wide range of applications in various government[2] and business sectors[3]. In addition, blockchain technology can also be applied efficient tax administration[4]. There has been a lot of research on blockchain applications for taxation, Saragih and Setyowati's research[5] aims to explore the benefits of blockchain and the factors affecting blockchain technology in tax administration. Meanwhile, it is also stated in[6][7] that can reduce the risk of tax avoidance, fraud and evasion, speed up transaction completion, increasing transaction auditability, and increasing the effectiveness of supervision.

However, most blockchains have the property of joint bookkeeping by multiple parties, and when a transaction has been completed, no party can change its transaction records[8]. Although the authenticity of business processes is ensured at the root, with the exponential growth of the equipment performance, some security problems begin to show in the blockchain. Powerful attacks, such as 51% attacks, will cause wrong data being recorded on the blockchain and lead to catastrophic consequences[9]. An unchangeable record is not useful for the applications that area used for blockchain. The non tamperability of blockchain could limit the wide uses in financial sector for the services, such as changing and shredding data, an oversight, an attack, or coding and transaction mistakes, which can be undone through redaction[10]. While this is an essential feature of most blockchain scenarios, it is still often desirable at times it may be even legally required to allow for breaking this immutability in a controlled way. For example, the upcoming general data protection regulations(GDPR) of EU imposes the Right to be Forgotten as a key Data Subject Right. So, the redactable blockchain were invented to allow the ledger to mutate in a controlled manner[11]. The application of

blockchain in e-tax system is relatively new and not widely accepted. Although many scholars have discussed the advantages of combining blockchain with e-tax system, they have not proposed its specific and relevant scheme construction.

Contributions: We constructed a specific blockchain-based protocol in the e-tax system for solving the current challenges it faces. The main contributions of this paper can be summarized as follows.

- We proposed an identify self-certified scheme for e-tax system. Taxpayer's private key can be jointly computed by the taxpayer and the certificate authority. The certificate is embedded in the selfcertified public key. Verifying validity of the signature and the public key can be concurrently accomplished in a logically single step. Therefore, it can further realize the privacy protection, and reduce the computation and storage overhead.
- We further provide an efficient blockchain redacting method by using chameleon hash. Tax authority can modify illegal information on the blockchain at any time, or merge huge financial data. Tax authority can rewrite the contents of the block so that overwriting the improper information in the blockchain.

Organization. In section 2, we review the background knowledge and basic definition. Then, we introduce the e-tax system model and security requirements in section 3. A detailed description of proposed e-tax protocol in section 4. Finally, the security analysis of our scheme is given in section 5.

2. Preliminaries

In the section, we illustrate background knowledge used in the paper.

2.1 Self-certified Public Key

In 1991, Girault[12] first proposed a self-certified public key system to resolve the problem of public key verification. Self-

certified public key is intermediary between certificate-based[13] and identity-based[14]. It are neither certificate-based, since there is no separate certificate, nor identity-based, since the public key is not restricted to identity. They contribute to reduce the amount of storage and computations while secret keys are still chosen by the user himself and remain unknown to the authority.

2.2 Chameleon Hash Function

A chameleon hash is a cryptographic hash function that contains a trapdoor, it is anti-collision for outside, and it uses a trapdoor information to generate the collisions efficiency.

Definition(Chameleon-Hash) The chameleon hash function[15] consists of four algorithm $CH=(HGen, Hash, HVer, HCol)$. The algorithm details are follows.

$HGen(1^\lambda) \rightarrow (hk, tk)$: The key generation algorithm inputs the security parameter λ , and outputs the public hash key hk , and a secret trapdoor key tk .

$Hash(hk, m, r) \rightarrow h$: The chameleon hash algorithm takes the hash key hk a message m and random number r used to generate the hash value as input, and output as $h = Hash(hk, m, r)$.

$HVer(hk, (m, h, r)) \rightarrow d$: The verification algorithm takes the hash key hk , a message m , and (h, r) as input, and outputs $d \in \{0, 1\}$. It returns $d = 1$ if and only if $Hash(hk, m, r) = h$. Otherwise, d equals 0.

$HCol(tk, (m, h, r), m') \rightarrow r'$: The collision algorithm inputs the new message m' , the random number r , the private key tk and the origin message m , we can output a new r' satisfying $Hash(m, r, hk) = Hash(m', r', hk)$.

3. System Model and Security Requirements

In the section, we introduce the system model and components, security requirements of our proposed scheme.

3.1 System Model and Components

Figure 1: The framework of the blockchain-based e-tax system

As shown in Figures 1, five entities are involved in our system, namely, the certificate authority(CA), the third-party tax-related institutions(TE), the tax authority(TA), the taxpayer(TU) and smart contract (SC).

Certificate authority is in charge of the initialization of system parameters and the registration of all third-party institutions, such as financial institutions and medical institutions, etc, the tax authority, and taxpayers. Meanwhile, it can also reveal the real identity of a malicious taxpayer. We assume that certificate authority is fully trusted and cannot be compromised. In our scheme, tax authority deploys smart contracts and audits the tax return. Third-party tax-related institutions publishes the tax payment information of the corresponding taxpayer to smart contracts.

3.2 Security Requirement

In a blockchain-based e-tax system, we aim to achieve the following goals.

Anonymity: anonymity in our solution refers to the anonymity of the user's identity. Usually, anonymity is only for legitimate taxpayers, whose data security is crucial.

Unforgeability: the unforgerability of tax returns is also the guarantee of taxpayers' rights, so the unforgerability of tax returns is realized to ensure the uniqueness and authenticity, so that each process can be verified.

Accountability: the accountability should be done for an illegal taxpayer. When a tax return is falsified or a taxpayer tries to evade taxes, authority can track the tax return of the malicious taxpayer and reveal his/her true identity.

Efficient: e-tax system must be efficient. It means not only should tracing (anonymity revocation) be performed efficiently, but the adding burden to the basic system should be minimal for all involved parts - certificate authority, tax authority, third-party institutions, taxpayer. In particular, certificate authority must be involved only when revocation is required and remain off-line otherwise.

4. Construction

Here we give a detailed description about our proposed system, which have six phases: 1) Initialization phase. 2) Register phase. 3) Declaration phase. 4) Audit phase. 5) Transactions block generation phase. 6) Redacting phase.

1) Initialization phase. The initialization phase can be divided into two phase. One part is the certificate authority initialization, the other part is tax authority and third-party institutions, which generates the its secret key and public key. The detailed steps are described follows.

- The CA inputs a security parameter $\lambda \in Z^*$ and returns system parameters. Given a group G_p over a finite field F_p of prime order p where P is a base point generator. The CA chooses a secret value $S_{CA} \in Z_p^*$ as his private key and computes his public key $P_{CA} = S_{CA} \cdot P$. The secure hash

function $H : \{0,1\}^* \rightarrow G_p$.

- The TA inputs random value $S_{TA} \in Z_p^*$ as the secret trapdoor key, and computes the public hash key $P_{TA} = S_{TA} \cdot P$.

- Similarly, TE_j randomly chooses its own private key $S_{TE_j} \in Z_p^*$ and calculates their public key $P_{TE_j} = S_{TE_j} \cdot P$

- At the end of setup phase, each party keeps their own private keys, and CA preloaded with the public parameters $\{G_p, F_p, E/F_p, P, P_{CA}, P_{TA}, P_{TE_j}, H(\cdot)\}$.

2) Register phase: A user needs to register to become a legitimate taxpayer. Get a tax identification number by registering with CA , which is unique.

- A user's real identity is RID_i , every user chooses a random secret $x_i \in Z_p^*$ then computes $X_i = H(RID_i \parallel x_i) \cdot P$.

Thereafter, the user sends a message $\langle RID_i, X_i \rangle$ to CA through a secure channel (SSL) that sets up an encrypted connection between the user and the server.

$$user_i \rightarrow CA : \langle RID_i, X_i \rangle$$

- CA maintains an initially-empty registry list. The CA receives the message tuple from user, and chooses a random secret $k_i \in Z_p^*$ to compute user's partial private key $\bar{S}_i$ along with a witness W_i to verify his legitimacy as follows.

$$\begin{aligned} e_i &= H(RID_i \parallel k_i) \cdot S_{CA} \\ TID_i &= X_i \oplus e_i \\ W_i &= X_i \oplus k_i \cdot P \\ \bar{S}_i &= H(TID_i \parallel W_i) \cdot S_{CA} \oplus k_i \end{aligned}$$

After that, CA sends the value $\langle RID_i, TID_i, W_i, \bar{S}_i \rangle$ in a secure SSL channel to the user. TID_i is taxpayer's tax identification number.

$$CA \rightarrow user_i : \langle RID_i, TID_i, W_i, \bar{S}_i \rangle$$

- After receiving the message, user computes a pair of his own private key S_i and extracts public key P_i .

$$\begin{aligned} S_i &= \bar{S}_i \oplus H(RID_i \parallel x_i) \\ P_i &= S_i \cdot P \end{aligned}$$

Further, the keys can be verified as $S_i \cdot P \stackrel{?}{=} [H(TID_i \parallel W_i)]$, if this function holds correct then user accepts his/her private key else rejects. The correctness of the public key derivation follows.

3) Declaration phase: Taxpayer submits tax returns to TA within deadline online using a web application. SC allow taxpayer to check tax information and fill out the tax return. The TU_i generates a time-stamp T_i and tax return $m_i \in \{0,1\}^*$, which we denote by m_i contains: public key P_{TE} of third-

party tax related institutions, TU_i 's tax identification number TID_i , TA 's public key P_{TA} , etc. In this phase, the TU_i computes signature, the sends a computed list of parameters encrypted using a symmetric encryption algorithm (AES) to establish a secure connection with TA .

- Firstly, TU_i chooses a random value $\alpha_i \in Z_p^*$, and computes signature. The steps are shown as follows.

$$\begin{aligned} \alpha_i P &= R = (R_x, R_y) \\ \sigma_1 &= R_x \\ \sigma_2 &= \alpha_i + H(m_i \parallel \sigma_1 \parallel P_{TE_j}) \cdot S_i \end{aligned}$$

- Second, TU_i generates a symmetric session key and encrypts the signature. The specific steps are as follows.

$$W_i = TID_i \oplus W_i$$

TU_i chooses a random value $d_i \in Z_p^*$ and computes symmetric session key key_i .

$$key_i = H(S_i \cdot P_{TA} \parallel d_i \parallel T_i) = (key_{ix}, key_{iy})$$

where key_{ax} is an x -coordinate derived using ECC-point on the curve to encrypt the message and signature.

$$M_1 = H(d_i \parallel W_i \parallel key_{ix})$$

Thereafter sends the message tuple $\{(\sigma_1, \sigma_2), m_i, TID_i, M_1, W_i, d_i, T_i, P_{TE_j}\}$ encrypted with key_{ax} .

$$\begin{aligned} TU_i &\rightarrow TA : \langle P_i, d_i, T_i, TID_i, \\ &En_{key_{ax}} \{(\sigma_1, \sigma_2), m_i, TID_i, M_1, W_i, d_i, T_i, P_{TE_j}\} \rangle \end{aligned}$$

4) Audit phase: Upon receiving the message from taxpayer, TA verifies whether the timestamp T_i is within the allowed range compared to current time. If not, TA rejects the request, otherwise, TA decrypts message get the message tuple, and verifies the signature.

- Firstly, TA computes the symmetric key for decrypting the received message as following.

$$key'_i = H(S_{TA} \cdot P_i \parallel d_i \parallel T_i)$$

Once key'_i is computed then its x and y coordinates are identified. Using the x -coordinates key'_{ix} , the message is decrypted to obtain $\{(\sigma_1, \sigma_2), m_i, M_1, P_{TE_j}\}$, then performs a mutual verify process using the received parameters.

- It is worth noting that in the process of verifying the signature, TU_i need not provide any additional certificate to prove the authenticity of P_i , the public key can be completed logically at the same time as signature verification. TA computes as following.

$$\begin{aligned} W'_1 &= TID_i \oplus W_i \\ M'_i &= H(d_i \parallel W'_1 \parallel key'_{ix}) \\ P'_i &= H(TID_i \oplus W_i) \cdot P_{CA} \oplus W_i \end{aligned}$$

$$\alpha_i \cdot P = \sigma_2 \cdot P - H(m_i \parallel \sigma_1 \parallel P_{TE_j}) \cdot P_i$$

$$R_x = \sigma_1$$

5) Transactions block generation phase: In this phase, creating a block that contains all the taxpayers' identities, public key, and signature of the tax return.

- First, for each taxpayer TID_i , set $\lambda_i = \{TID_i, P_i, Sig_{S_{TU_i}}\{m_i\}\}$, $\omega_j = \{\lambda_{1j}, \lambda_{2j}, \dots, \lambda_{ij}\}$. TE generates signatures for all user's tax returns, i.e. $Sig_{S_{TE_j}}\{H(\omega_j)\}$, set $M_j = \{TE_j, \omega_j, Sig_{S_{TE_j}}\{H(\omega_j)\}\}$.

- Second, TA computes the message M hash value.

a. Select random value r_1 , where $r_1 \in Z_p^*$;

b. Compute chameleon hash value $h = H(M_j, r_1) = f(M_j) \cdot P_{TA} + r_1 \cdot P$. TA adds the taxpayer's transaction information to blockchain.

c. Tax return $tr_j = \{M_j, h\}$.

6) Redacting phase: In general, TA needs to maintain and periodically update a block. In our scheme, we utilize chameleon hash to modify block information instead of the old one. If a user can be considered as an illegal network user. In order to delete the tax information on the blockchain, the TA generates a new transaction that does not contain illegal user's tax information on the blockchain. After the new message is verified by TA , it replaces the original message. The specific redaction blockchain steps are as follows.

- If TA needs to revoke user TU_i , whose information is contained in tr_j , TA first generates a new message $M'_j = \{TE_j, \omega'_j, Sig_{S_{TE_j}}\{H(\omega'_j)\}\}$, where $\lambda_{kj} = \{TID_k, P_k, Sig_{S_{TU_k}}\{m_k\}\}$, $\omega'_j = \{\lambda_{1j}, \lambda_{2j}, \dots, \lambda_{(i-1)j}\}$. M'_j is the same as M_j except that M'_j does not contain the tax return information of U_i .

- TA generates chameleon hash collision with M'_j and its private trapdoor key.

a. Compute updated $r'_1 = r_1 + S_{TA} \cdot [f(M_j) - f(M'_j)]$

b. Updated tax return $tr'_j = \{M'_j, h\}$.

5. Security Analysis

In this section, we analyze the security of our proposed scheme according to the design scheme described in the previous section.

Theorem 1 The proposed protocol can preserve taxpayer's anonymity.

Proof: In our scheme, the taxpayer TU_i sends the message $\langle P_i, d_i, T_i, TID_i, En_{key_{ax}}\{(\sigma_1, \sigma_2), m_i, TID_i, M_1, W_i, d_i, T_i, P_{TE_j}\} \rangle$

to the TA where the taxpayer's identity is encrypted using a symmetric-key operation over an insecure channel. In the process of tax authority and taxpayer session, even if an adversary intercepts the message, he cannot obtain the real identity of taxpayer, because the tax return includes an identity TID_i instead of RID_i , i.e. $TID_i = X_i \oplus e_i$, where e_i is computed by CA using a one-way hash function and two random secrets k_i and S_{CA} . Also, X_i is computed by the TU_i using a random x_i and a one-way hash function. Therefore, it is difficult for an adversary to compute a real identity without the knowledge of these random secrets. Thus our scheme preserves user anonymity.

Theorem 2 The proposed protocol can preserve trace attack.

proof: In our scheme, during the declaration phase, each message is encrypted and sent along with his/her tax identification number, not their real identity. Therefore, it is infeasible for an attacker to intercept messages and track their private information related to their current salary, lifestyle habits, etc. Therefore, our scheme protects taxpayer's privacy by achieving untraceability.

Theorem 3 The proposed protocol can preserve replay attack.

proof: TU_i and TA uses timestamps and random numbers as interrogation responses during the transmission of messages. We consider the following attack scenarios. Suppose an adversary intercepts the message in declaration phase, and tries to replay the message $\langle P_i, d_i, T_i^*, TID_i, En_{key_{ax}}\{(\sigma_1, \sigma_2), m_i, TID_i, M_1, W_i, d_i, T_i, P_{TE_j}\} \rangle$. Then the TA accepts the message and computes key_i^* . Here, the original key_i is infeasible to compute due to difficulty in solving computational Diffie-Hellman problem. The adversary cannot compute the correct key based on different timestamps $T_i \neq T_i^*$ and unknown TU_i 's private key S_i . Thus our proposed protocol preserves replay attack.

Theorem 4 The proposed protocol can preserve a known-key attack.

proof: In our scheme, our protocol is said to be known-key secure if the previous declaration key disclosure will not affect the future declaration. Suppose the current declaration-key $key'_i = H(S_{TA} \cdot P_i \parallel d_i \parallel T_i)$ is compromised, which does not reveal any information about other declaration keys. The declaration key is hashed with one-way hash function, and solving the key problem requires not only knowing the random number d_i and the private key S_i , but also solving the $ECDLP$ problem in polynomial-time, which is apparently impossible. Therefore, the proposed protocol can preserve a known-key attack.

6. Conclusion

In this paper, we propose an efficient certifiable and redactable scheme using self-certified public key and

chameleon hash function. Selfcertified public key technology not only reduces the leakage of privacy, i.e. taxpayers' identifying information is completely controlled and managed by the owner, but also implements identity verification at the same time as the tax authority verifies the signature phase. Moreover, by applying chameleon hash function in our scheme, tax authority can actively maintain and redact the blockchain. Finally, after an extended security analysis, we proved that our scheme is suitable for e-tax.

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