Anonymous Decentralized E-Voting System

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Abstract. This document describes the principles for building an anonymous decentralized e-voting system. It is proposed to use a ring signature mechanism to ensure anonymity of voters and blockchain technology to ensure the integrity and transparency of the transaction history. Thus, it can be beneficial to use such a combination to ensure the maximal robustness of the systems in the real-world conditions with the persistence of a potential malefactor that is interested to disrupt the work of the system, change the data in some way or influence the processes that are happening inside of the system.

Keywords: blockchain technology; public key infrastructure; decentralized system; e-voting system

1 Introduction

Voting is a method for a group, such as a meeting or an electorate, in order to make a collective decision or express an opinion, usually following discussions, debates or election campaigns [1-3].

Traditional voting systems have ceased to be effective in terms of their requirements [1, 4-7]: paper ballots, pseudo-anonymity of voters, non-transparency of the vote count (this is especially critical for the current field of research), the dependence of (the entire) voting procedure on the central organization. In fact, these are only the most critical problems existing in existing voting systems.

In recent years, the digitization of the voting process is developing more and more actively. The most prominent examples are the introduction of a digital voting system for electing local authorities in Estonia since 2005 and attempts to introduce such a

system in Switzerland, Netherlands, India and Namibia [8-10]. However, existing solutions still have several flaws, in particular, vulnerabilities associated with the central authority checking all results [11-14].

The described approach allows conduct e-voting while ensuring the transparency of processes and the integrity of the voting history [8, 9]. However, some voting systems also require another property for system users anonymity [14-17]. It is necessary to further investigate the methods and mechanisms of cryptographic protection of information [18-29], various protocols for ensuring integrity, authenticity, confidentiality and other security services [30-37].

Further, we will describe how to ensure voters' anonymity while maintaining all other properties of an accounting system.

2 Ring signature mechanism

Ring signatures are used to ensure the anonymity of users among a specific set of other members of a group (ring). To generate such a signature, the user uses the public keys of other users and his key pair. When verifying a signature, a verifier can verify that it was calculated by one of the members of the ring, but it is not known by whom exactly [38].

Imagine a group of n users, as in Figure 1. Each user has his own key pair — a secret and public key (sk, PK). Secret keys are known only to their owners, public keys - to all participants of the system.

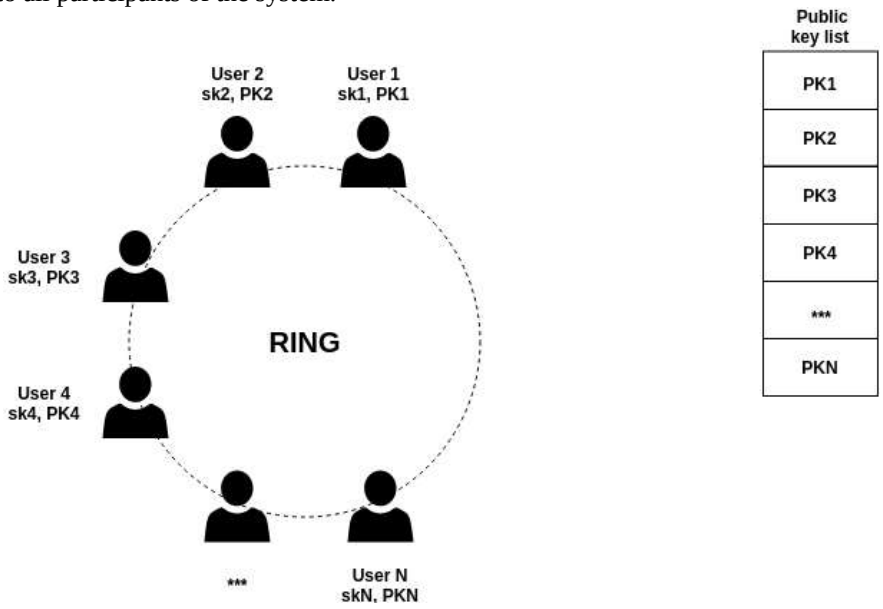

Fig. 1. Ring formation process

In order to form a signature on behalf of the group, the user must input the public keys of all the ring participants (including his own) to the algorithm input, and use his own private key as a secret. Recall that the public keys of each of the participants are publicly available. Figure 2 shows how the ring signature is generated by the user number 4.

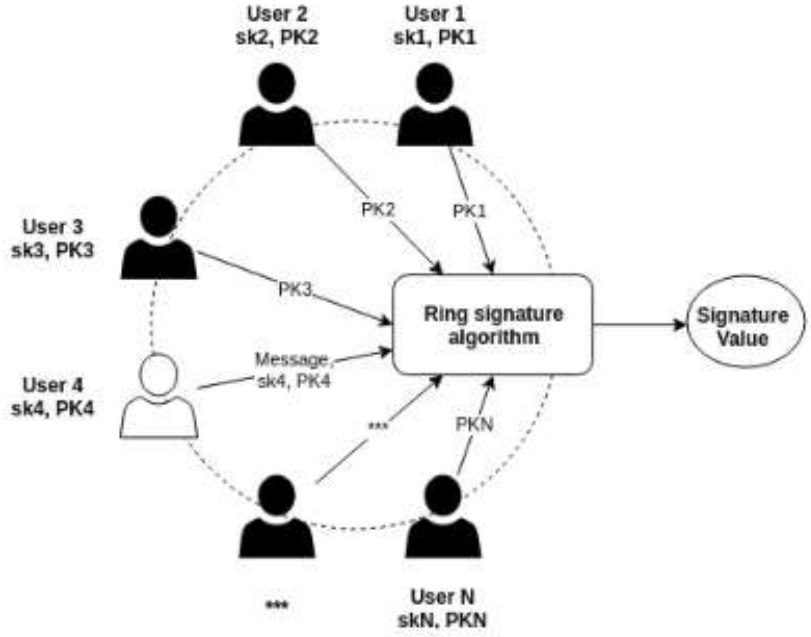

Fig. 2. Signature calculation process

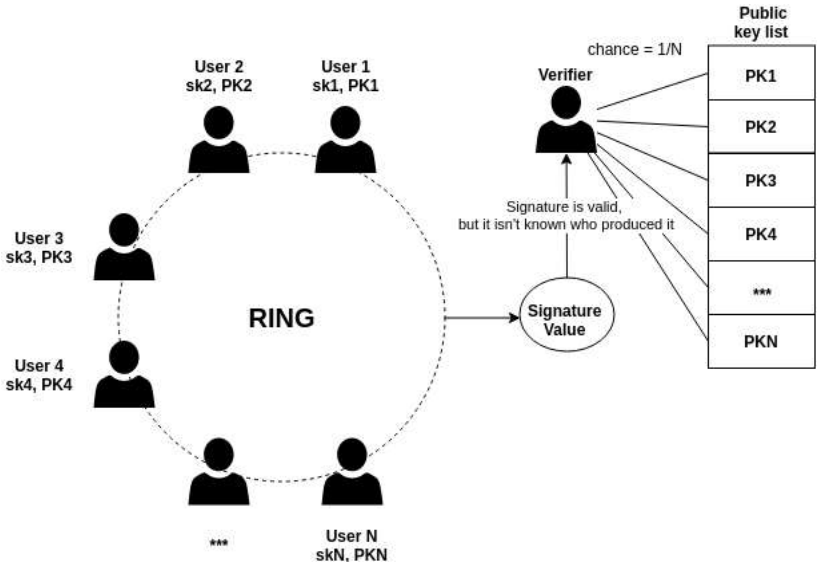

Fig. 3. Ring signature verification process

When the verifier verifies the value of the signature, he can verify that the signature was generated by one of the group members, however it is unknown by whom. Only with a probability of 1 / n can he determine that the signature was calculated by a specific participant in the ring (Figure 3). It is worth noting that the user can be disclosed only in the case of collusion of all the other members of the group [39].

3 Architecture of Decentralized E-Voting System

The decentralized anonymous voting system consists of the following elements:

- Validators;
- User identity system;
- End users.

Schematically, the arrangement of components and their interconnection can be represented in Figure 4.

Nodes validators are the main nodes of the system. They process user transactions and reach consensus on a distributed database.

User identification systems are required to provide information about user identifiers with which users will prove their right to vote. The identification system can be either a centralized internal (or external) identity provider, or a distributed identification and certification system.

End users perform the role of voters in the system. They independently vote for making a certain decision. It is important to ensure their anonymity, and at the same time transparency in the voting process.

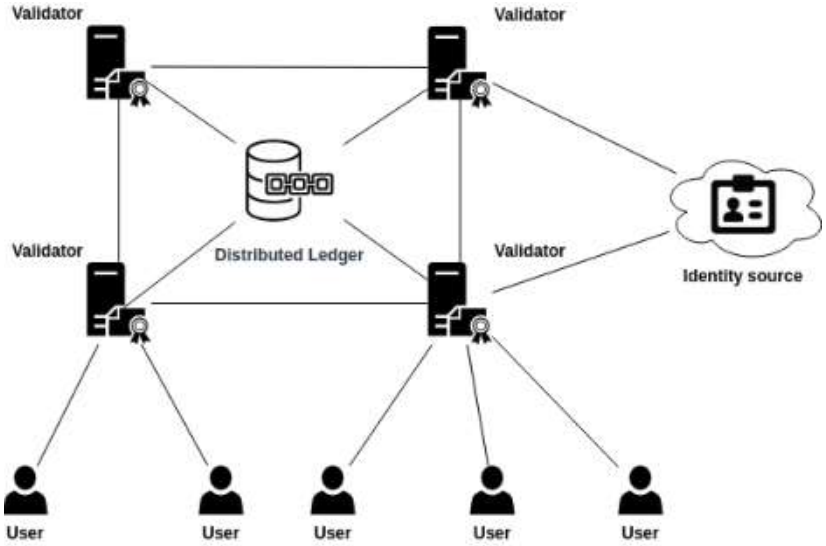

Fig. 4. E-voting system components

In order to vote, the user needs to form and sign the corresponding transaction. The transaction structure is as follows (Figure 5):

- Transaction ID
- Nonce
- Candidate ID
- Timestamp
- Public keys of group
- Signature

Fig. 5. Transaction structure

Now let's look at the transaction class that was implemented using the Java programming language and make a quick overview of its methods.

```
public class Transaction {
  private byte[] txID;
  private int nonce;
  private byte[] candidateID;
  private long timestamp;
  private byte[] signature;
}
...
public void printTxID();
private byte[] generateTxID(int nonce, byte[] candi-
dateID, long timestamp, byte[] signature);
public void printTransaction();
private byte[] signTransaction(int nonce, byte[] candi-
dateID, long timestamp);
```

- *printTxID* allows to see the transaction identifier in HEX form to verify it and use in other parts of the real system;
- *generateTxID* implements a SHA-256 algorithm to hash transaction contents. The resulting hash is used as an ID;

- *printTransaction* allows to see the transaction contents in the console and can be modified so these contents can be used in other parts of the real system;
- *signTransaction* implements the ring signature mechanism to sign the contents of transaction.

The transaction identifier is a hash value from all other transaction fields. The nonce field contains a random value and is used to make the transaction unique. Candidate ID contains the identifier of the voting entity for which the voter wants to cast his vote. Timestamp - UNIX value of the transaction formation time. Public keys of group is a list of public keys of the participants of the ring (those used to generate the signature). Among these keys is also the voter's public key, but his position is unknown. Signature is the transaction signature value. Note that this transaction structure is not strict, additional fields may be present.

In order to sign a transaction and at the same time ensure the anonymity of the vote, the user selects a list of keys of other users. At the same time, it is important that the selected public keys really belong to other voters (they had permission to vote). The list of public keys of voters should be open to all participants in the system. This list is formed before the start of voting (registered and provided the public key - got into the voter list).

The number of selected keys depends on the level of anonymity of the voter. If the selected group is small, then the probability of de-anonymization of the voter is much higher [40].

After the user selects a set of public keys, he calculates the value of the ring signature for the transaction. After that, it sends the transaction to one of the platform validators (or several) as in Figure 6.

After the validator receives a transaction, he must verify that the sender has the right to vote. Note that the validator does not know the identifier of the sender of the transaction (or rather, he does not know which of the public keys specified in the transaction belongs to the voter). Therefore, it needs to check the permissions of all keys specified in the transaction.

If all the specified keys have permission to vote, then the transaction is correct and can be confirmed [41]. At this stage, there is also a need to check that the user cannot conduct several transactions from different groups (since the sender of each transaction is unknown, then without a protection mechanism, the attacker can conduct transactions by constantly changing groups, and all of them will be valid). The image of a secret key is used as a protective mechanism [39].

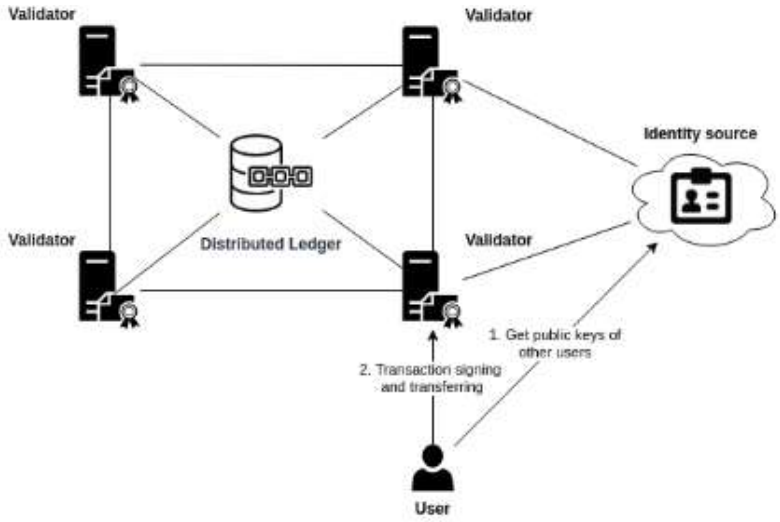

Fig. 6. Transaction formation process

Since this image is unique for each key pair (and it is used in creating and verifying signatures), the user cannot sign several transactions using the same secret key. The transaction confirmation process is shown in Figure 7.

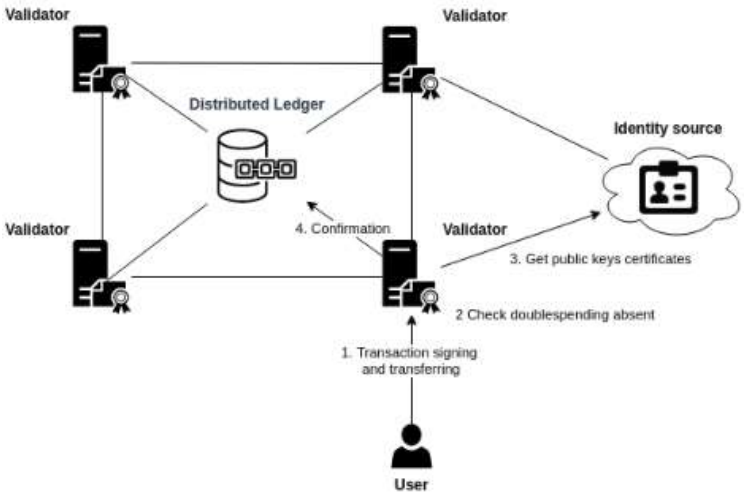

Fig. 7. Transaction verification process

4 Conclusion

Using the described approach to build an anonymous e-voting system allows you to achieve the following benefits:

- the ability to verify voter permissions (voting rights);
- anonymity;
- the ability of the voter to verify the correctness of his vote;
- inability to conduct a double waste attack.

On the one hand, this approach allows validators to check whether the sender of a transaction has the right to vote (if he used the existing public keys of other participants to form the ring).

At the same time, a specific voter can only be determined by validators with a certain probability (the larger the ring size, the less likely it is). In addition, a user can be completely deanonymized if all of the other members of the group collude (and reveal their votes).

Each user can make sure that his voice has been added to the distributed registry (request to the validator or using SPV-approach [42-43]). In addition, each owner of the complete history can verify that the voting results correspond to the set of completed transactions.

The user cannot create new transactions with different groups, if you use the mechanism of protection against attacks with double costs (the image of the private key, details with signature mechanism in [39]).

Also based on this scheme, the user may be allowed to change the value of his voice. In this case, not one transaction will be counted, but the last transaction that was added to the block chain. However, in this case it is necessary to develop and implement security measures to prevent spam attacks and other attacks that may affect system performance [44-48], as well as data stored in the chain [49-53].

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