Towards a decentralized identity management solution based on blockchain — proof of concept

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Outline

Background on public key infrastructure (PKI) and blockchains

How blockchains could enhance PKI

Existing approaches

Multichain-based certificate management

Conclusion
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Conclusion
Public-key encryption

Recipient

decrypt

ciphertext

public key

_encrypt_

plaintext

Sender

secret key

 setBackgroundColor(0x0)

decrypt

plaintext

Sender
Public key infrastructure (PKI)

- A set of roles and procedures ensuring secure distribution of public keys.
- Based on digital certificates.
Digital certificate

Certificate authority (CA)

Entity’s data (ED)
- unique identifier
- public key $pk_E$
- ...

Digital certificate
- CA’s identifier
- $\text{Sign}_{sk_{CA}}(ED)$
- ...

CA certifies: $pk_E$ is indeed the public key of the entity E.
Chain of trust

Root CA
- Root CA’s name
- Root CA’s public key
- Root CA’s signature

Intermediate CA
- Int. CA’s name
- Int. CA’s public key
- Issuer’s name (Root CA)
- Issuer’s signature

End-entity CA
- Owner’s name
- Owner’s public key
- Issuer’s name (Int. CA)
- Issuer’s signature

self-sign

reference

sign

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Revocation of certificates

- Compromised certificates are revoked by the issuing CA.
- CA adds revoked certificates to its certificate revocation list (CRL).
- CA publishes updated CRL ~every 24 hours.
Problem: single point of failure

- Corrupt CA = illegitimate certificates.
- Single CA corrupt = PKI's failure.
Problem: single point of failure

- Corrupt CA = illegitimate certificates.
- Single CA corrupt = PKI’s failure.

Possible countermeasure

- Store certificates and CRL in an external ledger.
- What kind of ledger?
Blockchain

Definition

• A public, transparent, append-only ledger.
• Created by members of a peer-to-peer network.
• Immutable and unforgeable records (blocks).
Blockchain

Structure

- **Transaction**: atomic event allowed by the blockchain protocol (‘Alice sends Bob 0.1 BTC’, ‘CA issues a certificate’).
- Transactions are **validated** and **broadcasted** throughout the network.
- Validated transactions are stored in **blocks**.
- Blocks are linked together, forming a **chain**.
- **Consensus process**.
Blockchain structure

Block

- hash of the previous block
- creator’s of the block (miner) ID
- set of transactions
- ...

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Current scenario
user:

1. connects to a website
2. browser verifies identity of webserver using PKI

Future scenario
user:

1. connects to a website
2. browser verifies identity of webserver using PKI
3. browser verifies identity if webserver using Blockchain
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Public key infrastructure

Problems

- No way to know if CA is corrupted.
- CA producing certificates for domains they don’t own (Iran with Google).
- Some web browsers don’t check for certification revocation.

Solution: blockchain

- Another channel for verifying certificate’s validity.
- *Transparency* and *traceability*.
- Secure distributed log that cannot be altered.
- The whole chain of trust is stored.
- Revocation lists are stored.
Applications

Web browsing

- Privacy and confidentiality issue: are visited websites what they pretend to be?
- Millions of certificates, with variable lifetime

Connected cars

- Safety issue: connected or even autonomous cars might need to check that the surrounding cars are legitimate
- Thousands of certificates, with a one-week lifetime
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Blockchain and smart contracts

Smart contracts in Ethereum

- Ethereum is a blockchain that supports **smart contracts**
- Smart contracts are special entities, written in the blockchain
  - Execution conditions predefined and agreed on
  - Execute when these conditions are met
  - Each transaction with a smart contract is a transaction in the blockchain
Existing approaches

Ethereum smart contracts

- Each certification authority has **smart contracts** that store a list of issued certificates and a revocation list.
- Specific format for certificates: **hybrid certificates**

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Data fields in Bitcoin-based blockchains

- Special **OP_RETURN** field can contain arbitrary data
  - Many applications, such as Intellectual Property
- Bitcoins: maximum size of 80 bytes
- Several blockchains could be used, such as Bitcoin or Namecoin
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Multichain-based certificate management

Multichain

- fork of the Bitcoin source code
- hugely simplifies private Blockchains creation and management
- lot of settings available
- node permission control
- arbitrary-sized data field in transactions
- very well documented
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>Smart contracts</th>
<th>OP_RETURN</th>
<th>Multichain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usability - customization</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Cost</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Compatibility with existing PKIs</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Permissions</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Size of certificates</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Scalability</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Design

CA
Scenario

1. final user visits a website with web browser
2. classical identity verification is used (PKI)
3. browser plug-in installed on the user browser
4. local daemon is running, waiting for queries
5. plugin-in retrieves certificates, asking to daemon if such a certificate is valid
6. displays whether certificates should be trusted or not
Demo
Use case: Let’s Encrypt

- Certification authority
- Delivered 100M certificates over 20 months
  - More than 160K per day

Application to multichain-based certificates management

- Around 280 Go of memory for 100M certificates
  - Bitcoin: around 90 Go over 20 months
- The whole blockchain has to be read when searching for a specific certificate
  - Ideally, only the delivery day would have to be checked in the blockchain
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**Problem**
How to detect a malicious CA?

**Solution**
Add an extra channel to verify certificates using the blockchain
Future Work

- Implement PKI functions using the blockchain
- Explore the use of smart contracts
- Elaborate a business model
Feedback

• Interesting topic with no previous knowledge
• Working PoC with exciting perspectives
• Pleasant teamwork and environment
Thank you for your attention. Questions?