Electronic Cash and Blockchain Security

Yongge Wang

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Outline

1. Background
   - David Chaum

2. Bitcoin
   - BTC Transaction
   - Merkle Tree
   - BTC Transaction scripts

3. Ethereum and General Block Chain
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- Real cash could be anonymous though theoretically it is not (sequence numbers, but who record them?)
- Easy to design e-cash using PKI, but traceable
- e-cash or e-wallet is convenient for online small payment
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Requirements for e-cash

- anonymous (non-traceable)
- no double spending
- easy to pay a few cents on line
- many others
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- The concept of e-cash was originally based on Chaum’s blind signature (1984)
  - Untraceable Electronic Cash (Chaum, Fiat, Naor 1990)
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Blind Signature (Chaum)

- the Bank has an RSA public key \((e, N)\) and private key \(d\)
- Alice has a coin \(m\) (e.g., $10)
- Alice chooses a random number \(r\), and computes \(m' = m \cdot r^e \pmod{N}\)
- bank signs \(m'\) with signature \(s' = (m')^d\)
- Alice calculates signature \(s\) on \(m\) as

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s = s' \cdot r^{-1} = (m \cdot r^e)^d \cdot r^{-1} = m^d
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- Alice spends \((m, s)\) as $10 while bank cannot link this coin \(m\) to Alice’s account
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Challenges in Blind Signature Scheme

- What happens if $m = 100$ instead of $10$ unless all coins have same value?
- Seller must contact bank to make sure $m$ has not been spent yet when accepting the money from Alice.
- Can we remove the online restrict? In other words, seller does not need to contact bank: Chaum, Fiat, and Naor Scheme (1988)
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Bitcoin: a high level description

- $w_0$ is the start coinbase by Satoshi Nakamoto
- you find a random number $r_0$ such that $H(w_0, r_0) = w_1$ such that the first two bits of $w_1$ is 00, you will be rewarded with one BTC
- Another person will mint BTC by finding another $r_1$ with $H(w_1, r_1) = w_2$ such that the first two bits of $w_2$ is 00, you will be rewarded with one BTC
- this process continues until computer becomes fast and you have to find a random $r_i$ such that the hash output contains a long prefix of 0
- transactions are included in the hash in order to be verified

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the BTC is a chain $w_0, w_1, \cdots, w_n$ where $w_n$ is the current BTC HEAD that everyone works on it

based on P2P protocol, all person work on the longest chain. If you work on a shorter chain, you waste time and the transaction included in these chains will not be valid

$w_n$ has prefix of 0...0 where the number of 0 is determined by voting algorithm so one BTC is minted each 10 minutes

$w_{i+1} = H(w_i, TR, r_i)$ where $TR$ is the Merkle hash output of the transactions that you want to include and $r_i$ is a random number that you find to make $w_{i+1}$ has a certain number 0's in its prefix
Bitcoin with transaction

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Merkle Hash Tree

\[
\text{root: } TR = H(H12, H34)
\]

\[
H12 = H(H1, H2)
\]

\[
H1 = H(D1)
\]

Data D1

H2 = H(D2)

Data D2

H3 = H(D3)

Data D3

H4 = H(D4)

Data D4

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BTC transactions are described using Forth-like Scripts (https://en.bitcoin.it/wiki/Script)

- the scripts enable smart contract (e.g., the transaction will be valid if two persons sign the contract, valid after certain time etc.)
- A transaction means Alice pays $x$ BTC to Bob
- This is achieved by Alice signing the message “reference number, Bob’s pub key, BTC amount”
- “reference number” should be contained in some block of the current BTC chain $w_0, w_1, \cdots, w_n$. E.g., $w_i$
- Alice’s public key should be included in the block $w_i$ transaction with the given reference number
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Example Forth Script

In order to compute $25 \times 10 + 50$, we inputs: `25 10 * 50 + .` in the calculator.

It works the following way by stack.
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- It works the the following way by stack

```
10 25 250 50 250 300
```
Example Transaction

- **scriptPubKey:** `OP_DUP OP_HASH160 <pubKeyHash> OP_EQUALVERIFY OP_CHECKSIG`
  
- **scriptSig:** `<sig> <pubKey>`

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Example Transaction 2

scriptPubKey: <pubKey> OP_CHECKSIG
scriptSig: <sig>

Checking process:

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Anybody can upload programs to the Ethereum World Computer and anybody can request that a program that has been uploaded be executed.
What is New in Ethereum

- BTC scripting language has limited capability while Ethereum script is Turing complete
- Ethereum is a blockchain with a built-in Turing-complete programming language, allowing anyone to write smart contracts and decentralized applications where they can create their own arbitrary rules for ownership, transaction formats and state transition functions.
- BTC only supports “Proof of work” while Ethereum also supports “proof of stake”
- Proof of stake: calculating the weight of a node as being proportional to its currency holdings and not its computational resources.
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Ethereum

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- Based on the Ethereum Virtual Machine (EVM): the runtime environment for smart contracts in Ethereum.
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Based on the Ethereum Virtual Machine (EVM): the runtime environment for smart contracts in Ethereum.
Ethereum Accounts and Smart Contracts

- **Accounts:** 20 bytes string.
  - An account contains four fields: nonce, ether balance, contract code (optional), and storage (empty by default)
  - Externally Owned Accounts (EOAs), which are controlled by private keys
  - Contract Accounts, which are controlled by their contract code and can only be “activated” by an EOA. Contract accounts are governed by their internal code which is programmed to be controlled by an EOA with a certain address,
  - “smart contracts” refers to code in a Contract Account: programs that execute when a transaction is sent to that account.
  - Users can create new contracts by deploying code to the blockchain.

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- Users can create new contracts by deploying code to the blockchain.
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  - Deliberately introducing errors under benign miners’ names, this attack can fool the mining pool administrator into punishing innocent miner;
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  - An attacker needs only a small fraction (e.g., one millionth) of the resources of a victim mining pool,
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Q&A?

Yongge Wang