Distributed Consensus / The Blockchain

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Outline

1. **Background**
   - Hash functions
   - Digital signatures
2. **Distributed consensus**
   - Definition
   - Byzantine Generals Problem
   - Dynamic Membership Multiparty Signatures (DMMS)
   - The Blockchain
3. **Practical applications**
   - Timestamping
   - Cryptocurrency (Bitcoin)
   - Smart contracts
4. **Conclusion**

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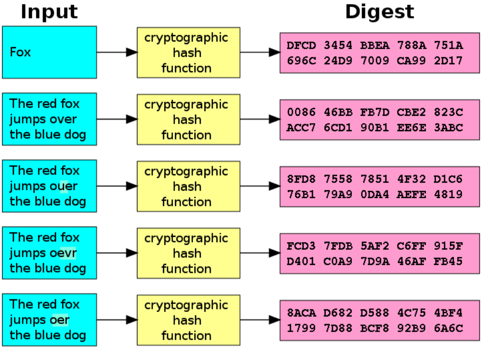
  - **second pre-image resistance**
    Given an input m it should be difficult to find another input m' such that $m \neq m'$ and $hash(m) = hash(m')$
  - **collision resistance**
    It should be difficult to find two different messages m and m' such that $m \neq m'$ and $hash(m) = hash(m')$

Cryptographic hash functions



Input

Digest

Fox → cryptographic hash function → DFCD 3454 BBEA 788A 751A 696C 24D9 7009 CA99 2D17

The red fox jumps over the blue dog → cryptographic hash function → 0086 46BB FB7D CBE2 823C ACC7 6CD1 90B1 EE6E 3ABC

The red fox jumps ouer the blue dog → cryptographic hash function → 8FD8 7558 7851 4F32 D1C6 76B1 79A9 0DA4 AEFE 4819

The red fox jumps oevr the blue dog → cryptographic hash function → FCD3 7FDB 5AF2 C6FF 915F D401 C0A9 7D9A 46AF FB45

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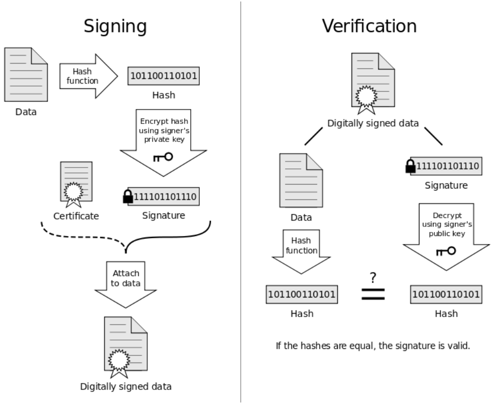
- **Proof-of-Knowledge** - Proof that you know the private key

Digital signature



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- The consensus problem illustrated - Byzantine Generals Problem

Distributed consensus

Two Generals Problem

- Players: Two generals, their respective armies and their messengers

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  - Messengers must pass through town (insecure communication channel)

Distributed consensus

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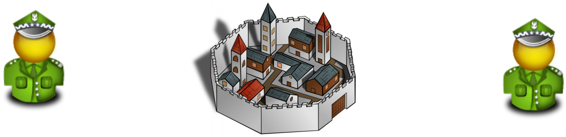

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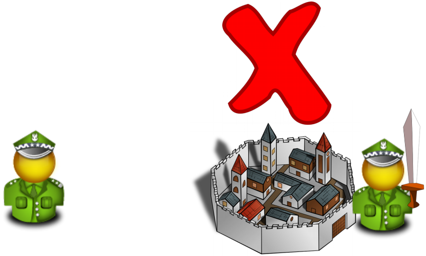

Distributed consensus

Two Generals Problem

Alice

Mallory

Bob

Message:
Attack at time X

Distributed consensus

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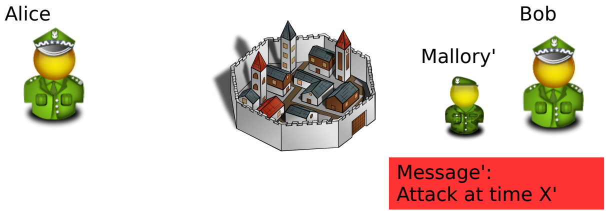

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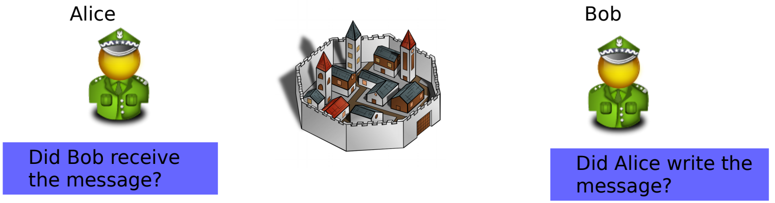

Did Bob receive the message?

Did Alice write the message?

Distributed consensus

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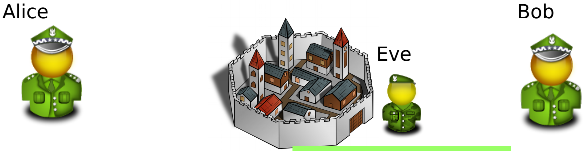

Message:
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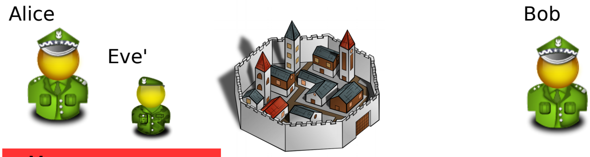

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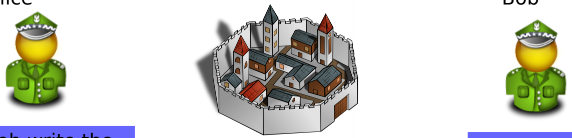

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Byzantine Generals Problem

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- DMMS signers are called miners

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- "Hello, world!4250" => 0000c3af42fc31103f1fdc0...

The Blockchain
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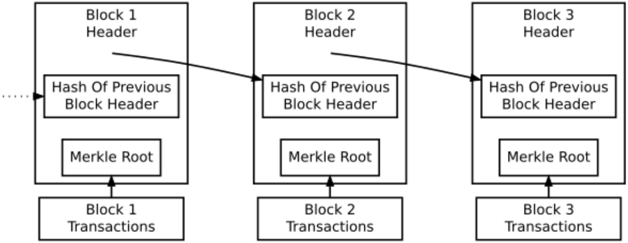
  - Not necessarily a valid DMMS

The blockchain
Illustrated



Simplified Bitcoin Block Chain

The blockchain
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- Clear differences between a DMMS and regular digital signatures

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- Modifying data in the block invalidates the DMMS
  - Possible to produce another valid DMMS

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- The longest chain with most work performed on it is the "real" chain
- Secure under the assumption of an honest majority

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- Who will put work towards extending the blockchain?

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    - Correct proof-of-work doesn’t equal a valid DMMS

The blockchain
Operating modes

- Nodes connect to eachother in a P2P network

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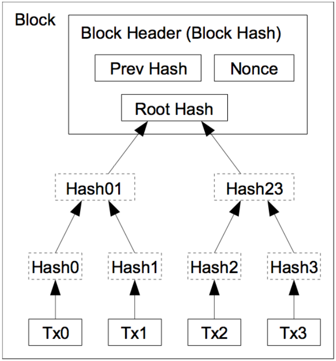
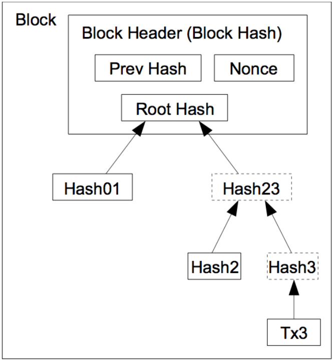
        - Privacy issues

The Blockchain

Merkle trees and proofs



Transactions Hashed in a Merkle Tree



After Pruning Tx0-2 from the Block

The blockchain

Consistency vs. Correctness

- Normally protocol specification is the definition

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  - Bugs may become part of the specification

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Forking

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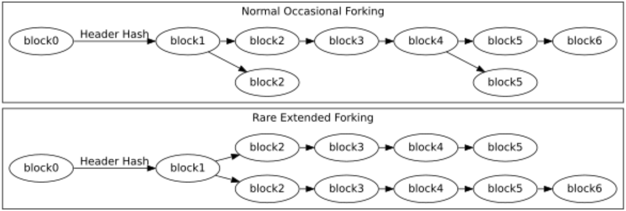
    - Can be intentional and unintentional



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Proof of existence

- Proof of data existence at specific point of time

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- Hash of data included in a specific block

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- http://www.proofofexistence.com/
- http://factom.org/ - Large scale timestamping

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  - Maximum 21 million bitcoins
- Total hashrate ~350 Petahashes/second
  - "If all Googles servers would start hashing they would have <1% of total network hashrate"

Smart contracts

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3. **Practical applications**
   - Timestamping
   - Cryptocurrency (Bitcoin)
   - Smart contracts
4. **Conclusion**

Conclusion

- The blockchain achieves
  - Distributed consensus
  - Decentralization
  - A complete public record of immutable history
  - Censorship resistance

Questions?