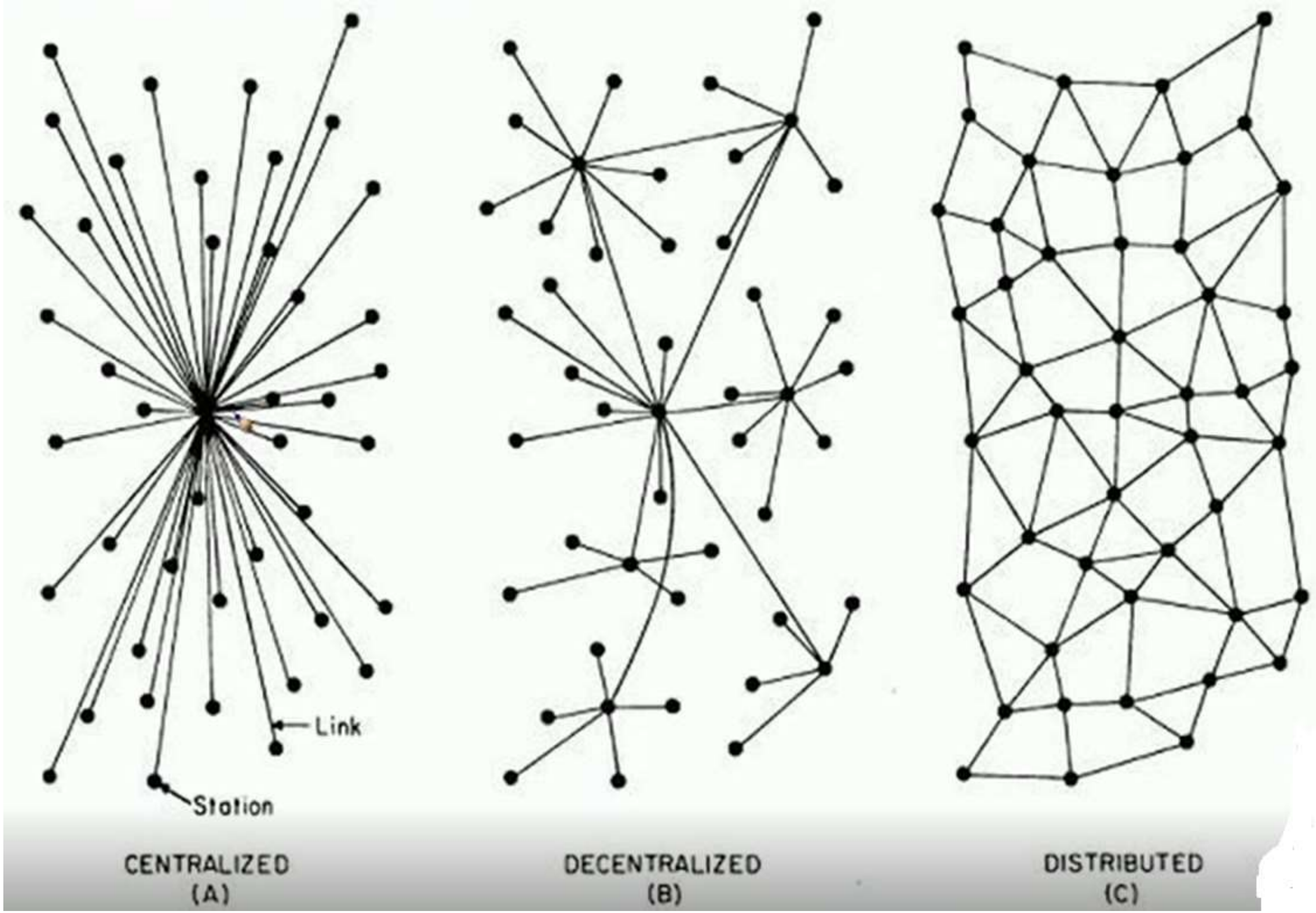
Introduction and Basics of Blockchain

Outline

- What is a blockchain?
- Differences among centralized, decentralized, and distributed systems
- Distributed Ledger

- **Blockchain** is a distributed and immutable ledger, shared among multiple parties **who do not trust** each other, to cooperate, coordinate, and collaborate in a business process.
- The ledger contains number of blocks.
- One block is chained with next block by hash value.
- Existing blocks can not be modified.
- New blocks can be added if it is valid and accepted by a majority voting.
- Every node can check the validity of a new block, so they may agree or disagree to add it.
- If a majority of nodes agrees then the new block can be added.



- **Centralized**- complete reliance on a single point, not safe
- **Decentralized** - Multiple points of coordination
- **Distributed**- Everyone collectively execute the job

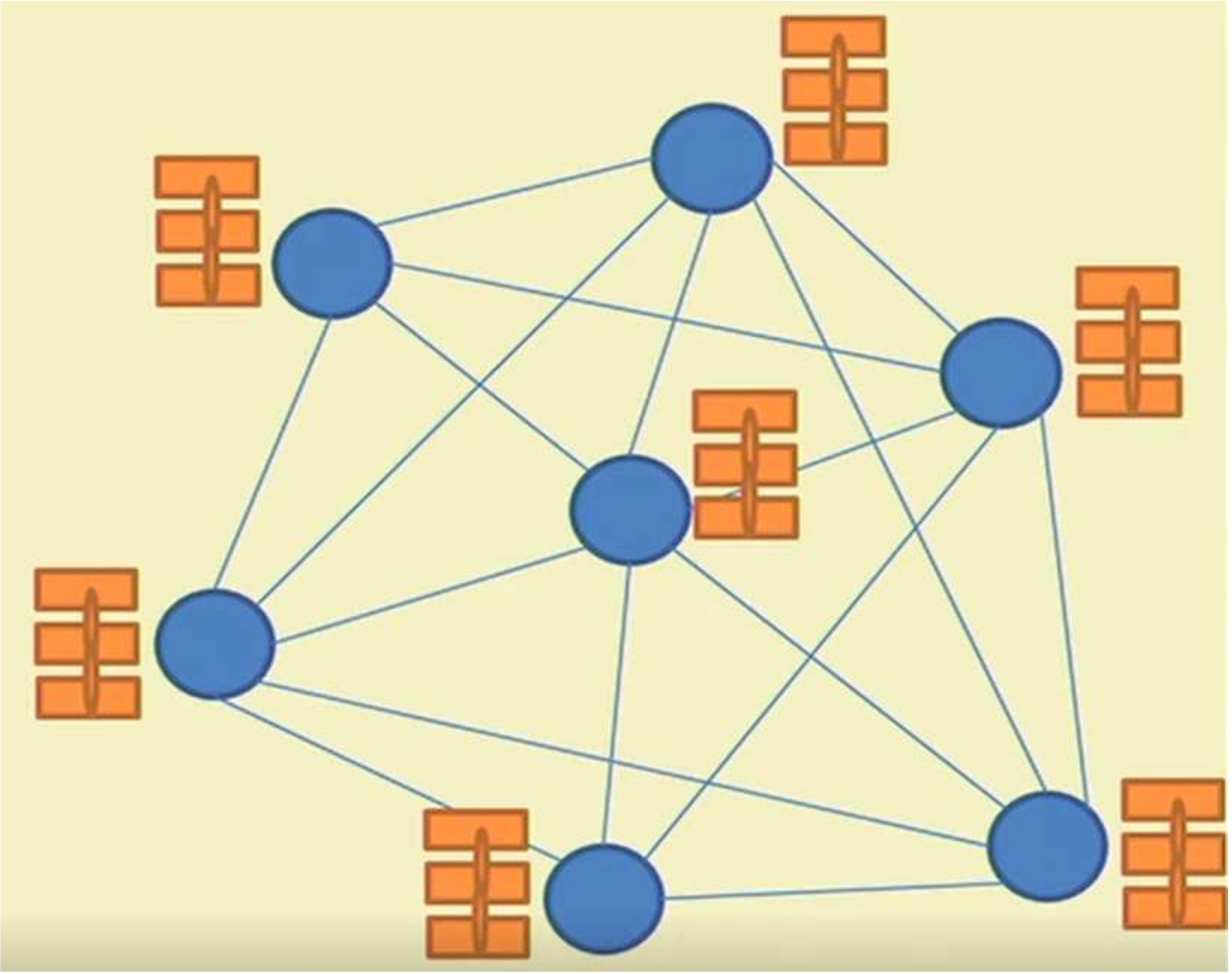
Blockchain

- Every node maintains a local copy of the global data sheet.

- The local copies are identical.

- The local copies are always updated based on global information.

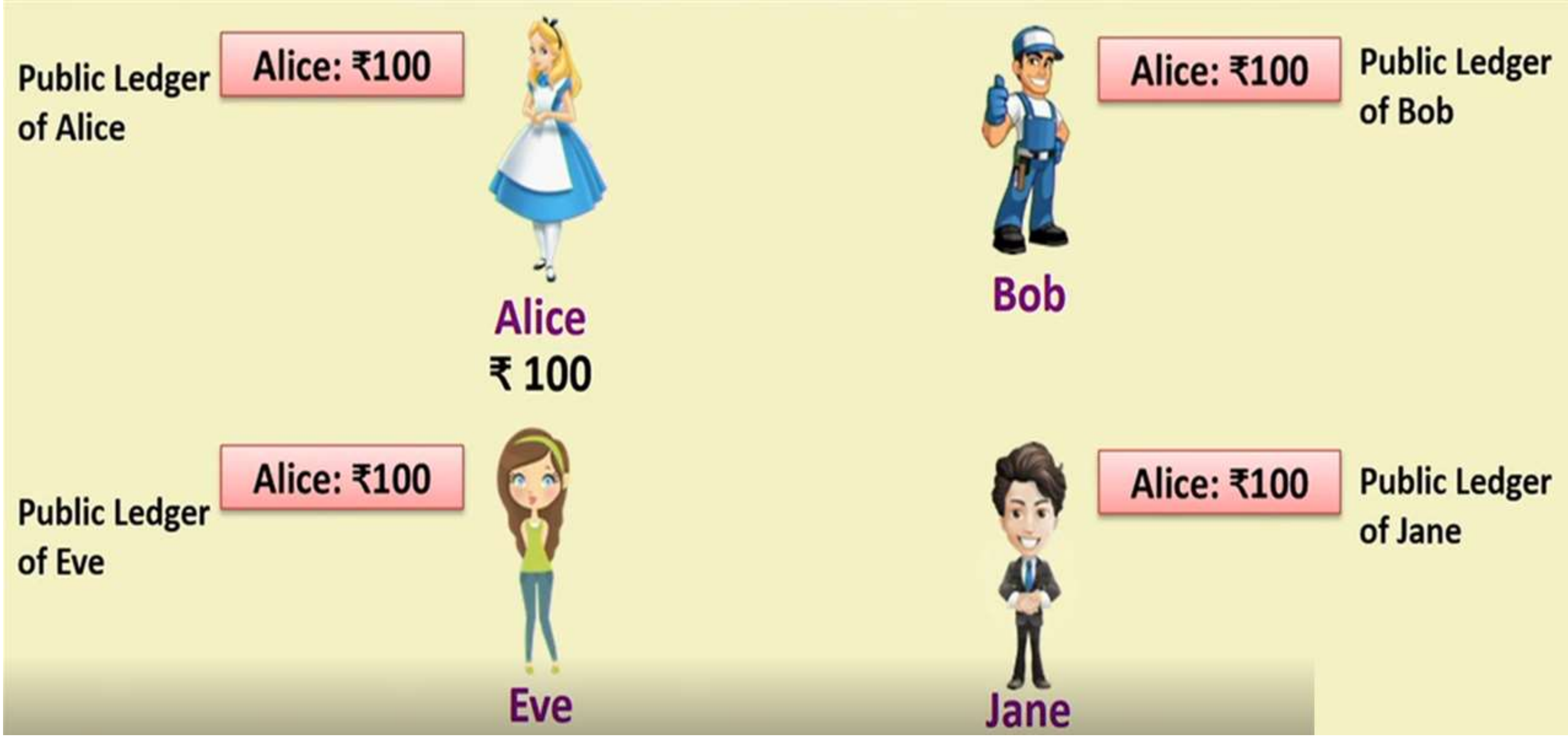
- But the local copies can not be modified.



Blockchain Basics

- This local copy is called as **public ledger.**
- It is a database with historical information available to everyone.
- Old information is used to validate the new information
- In traditional system the ledger is with the bank and bank validates any new transaction based on the ledger.
- In decentralized system any new transaction is validated against the old transactions present in the public ledger.

An Example of Public Ledger from Banking Sector



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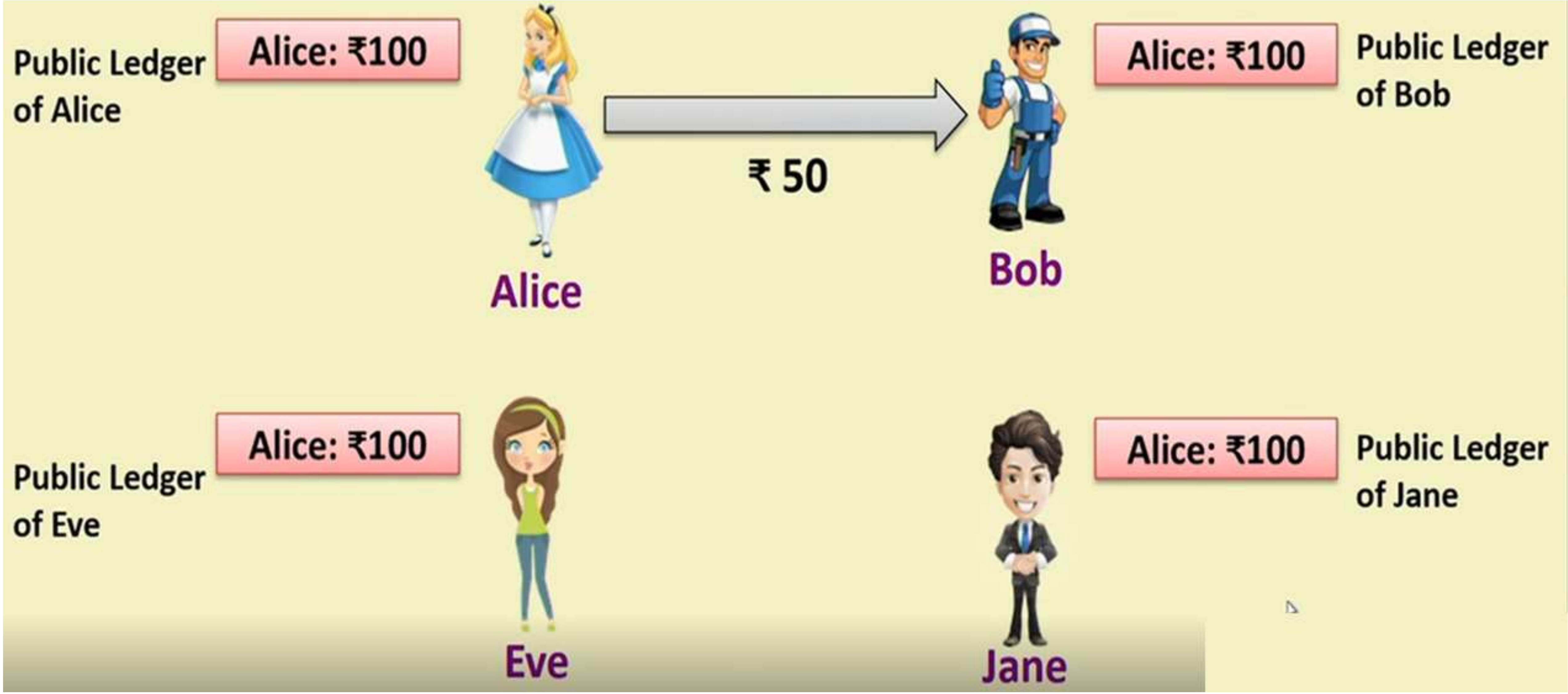

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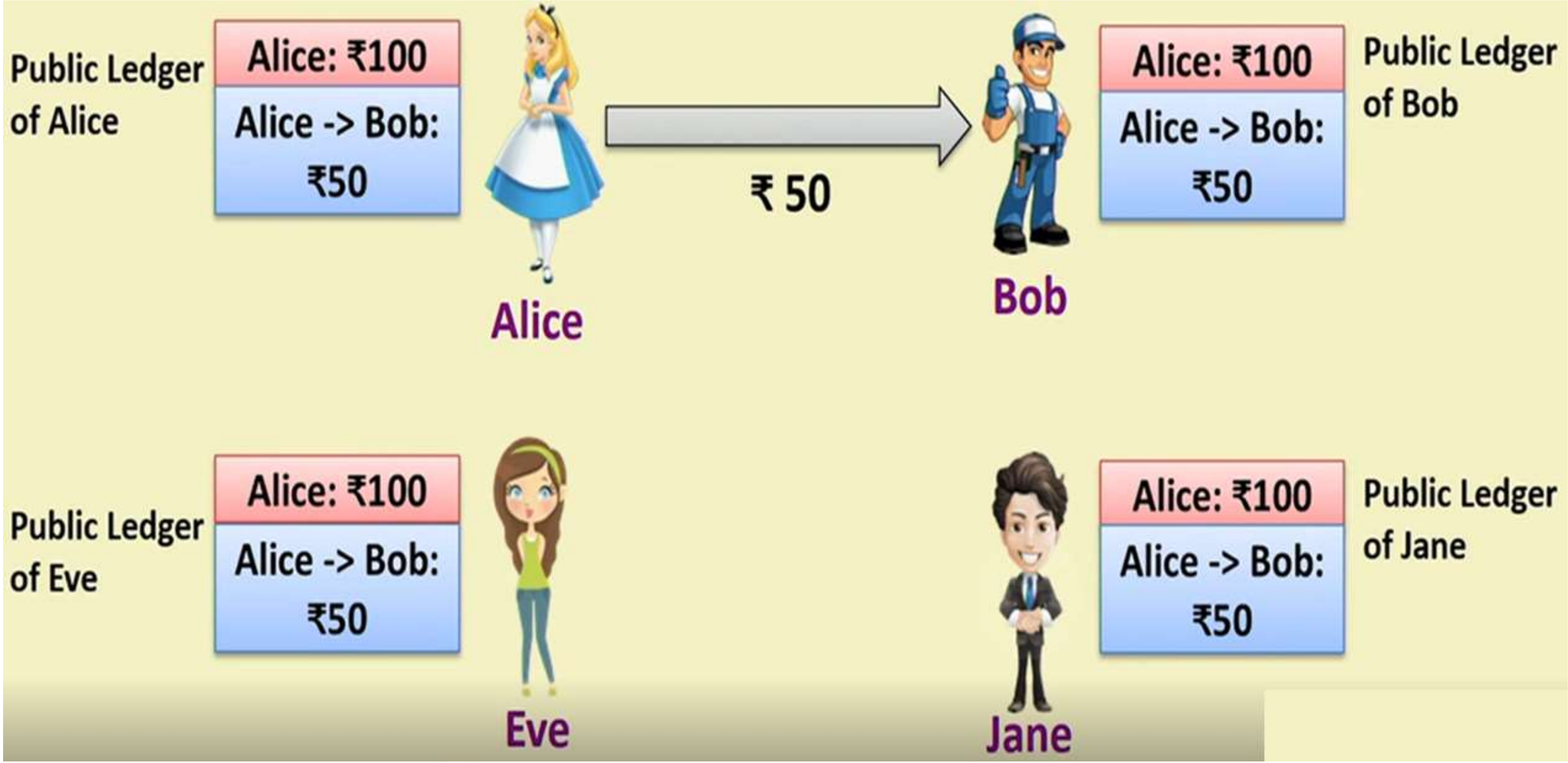

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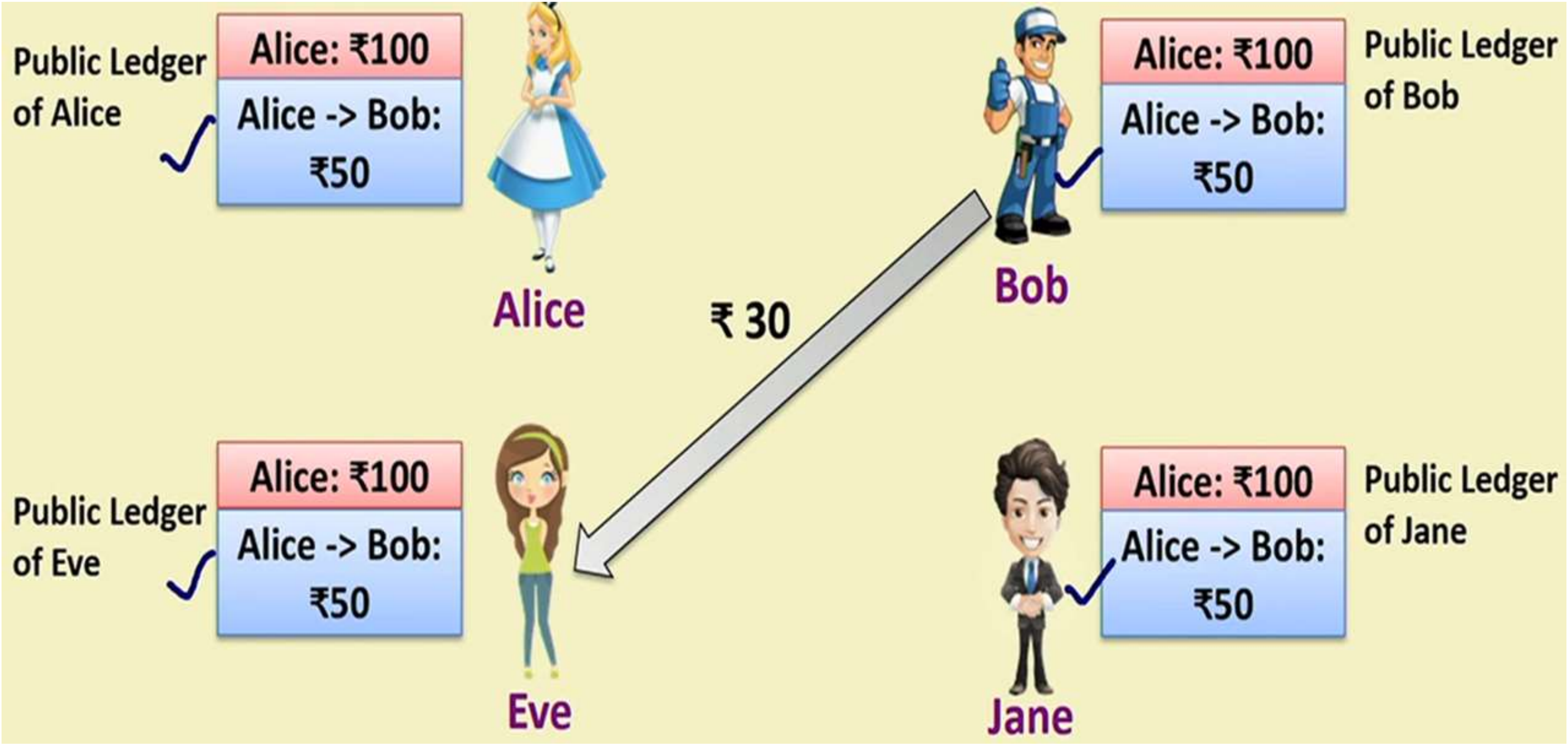

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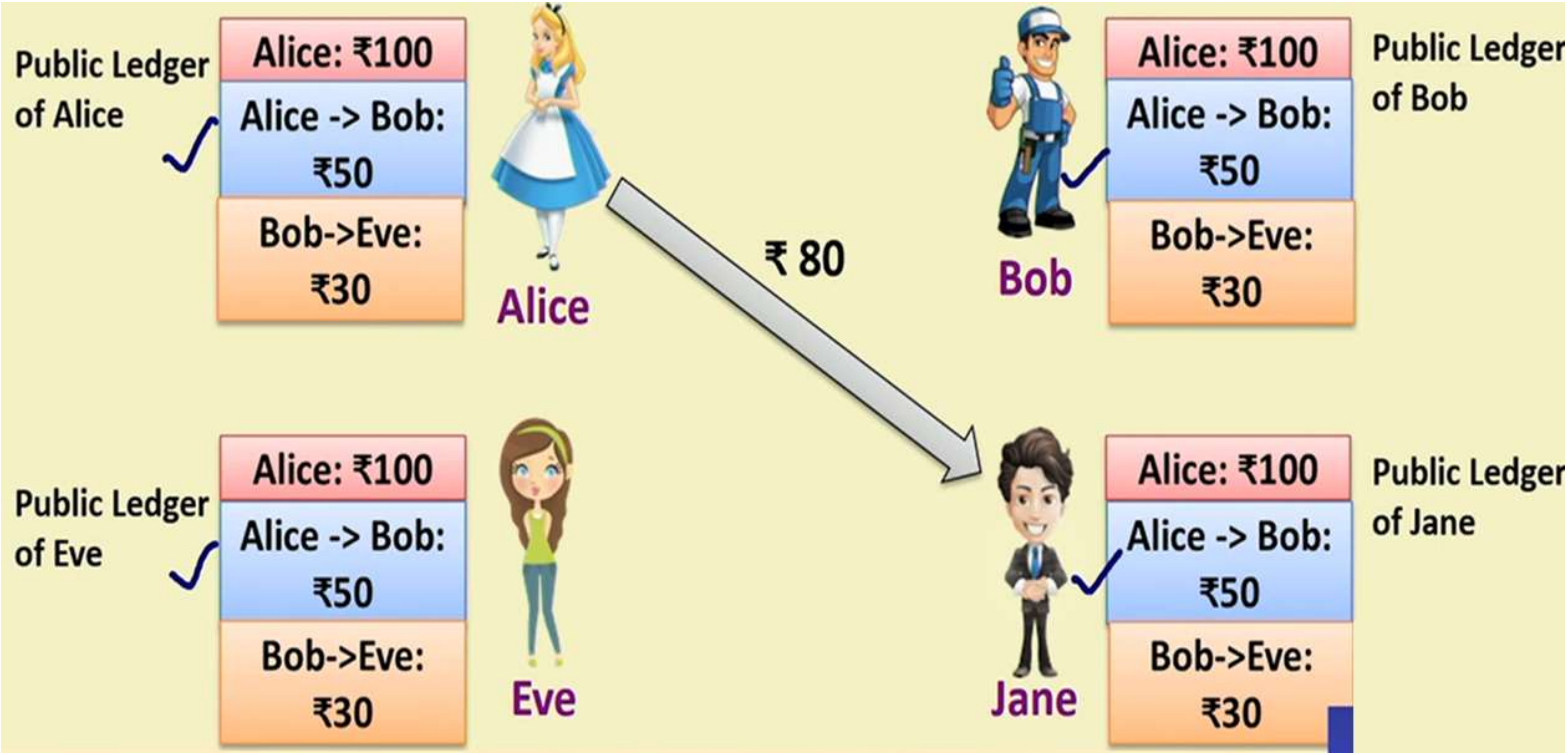

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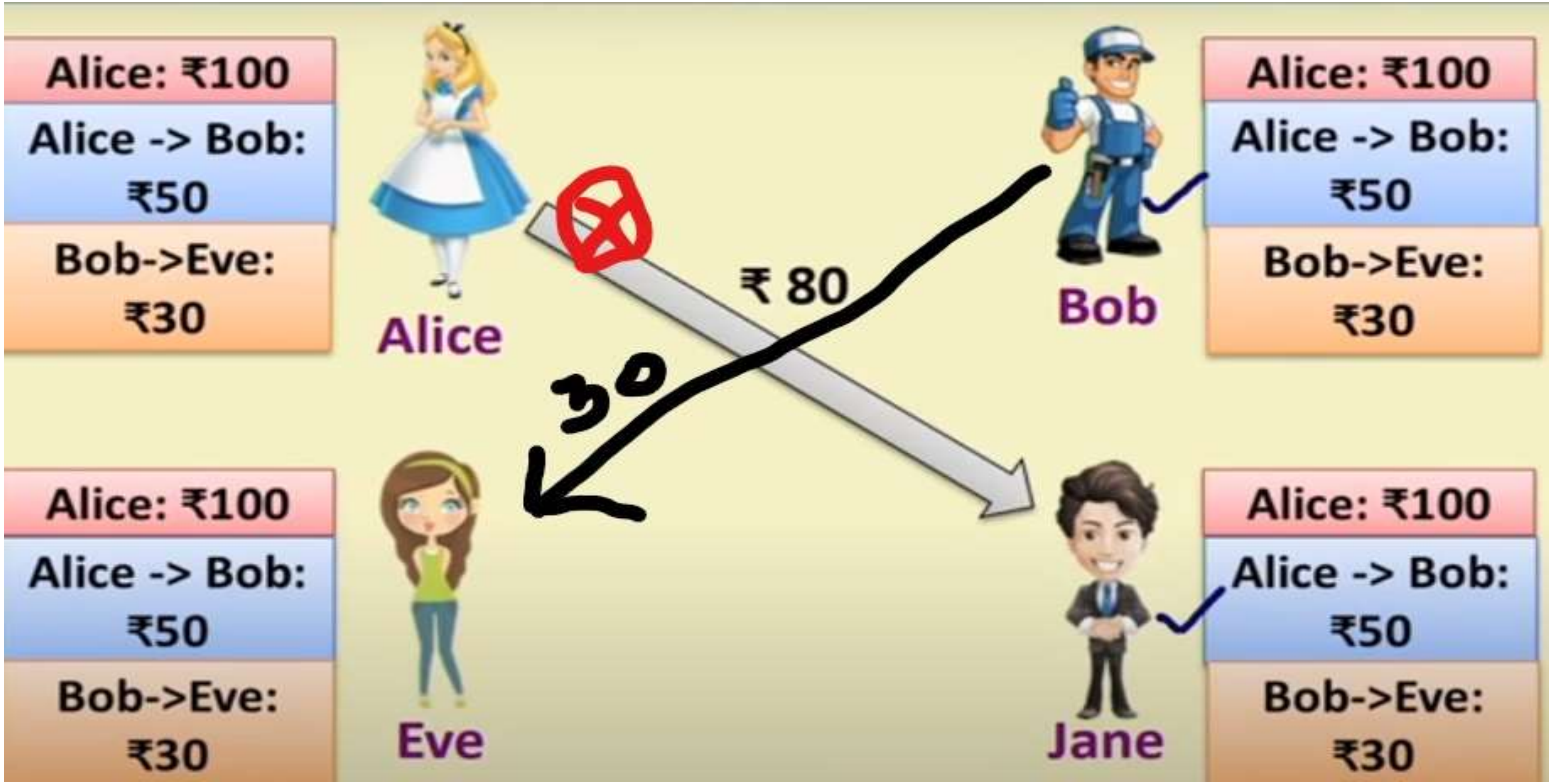
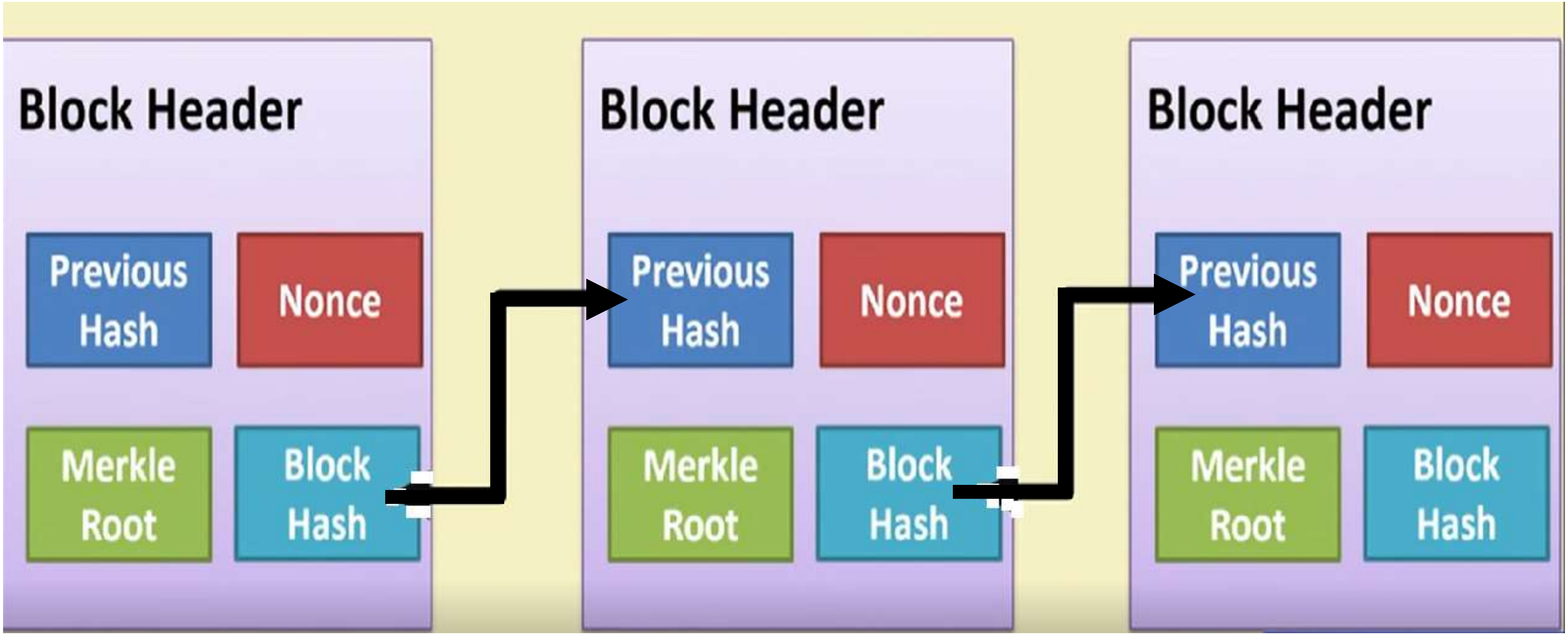


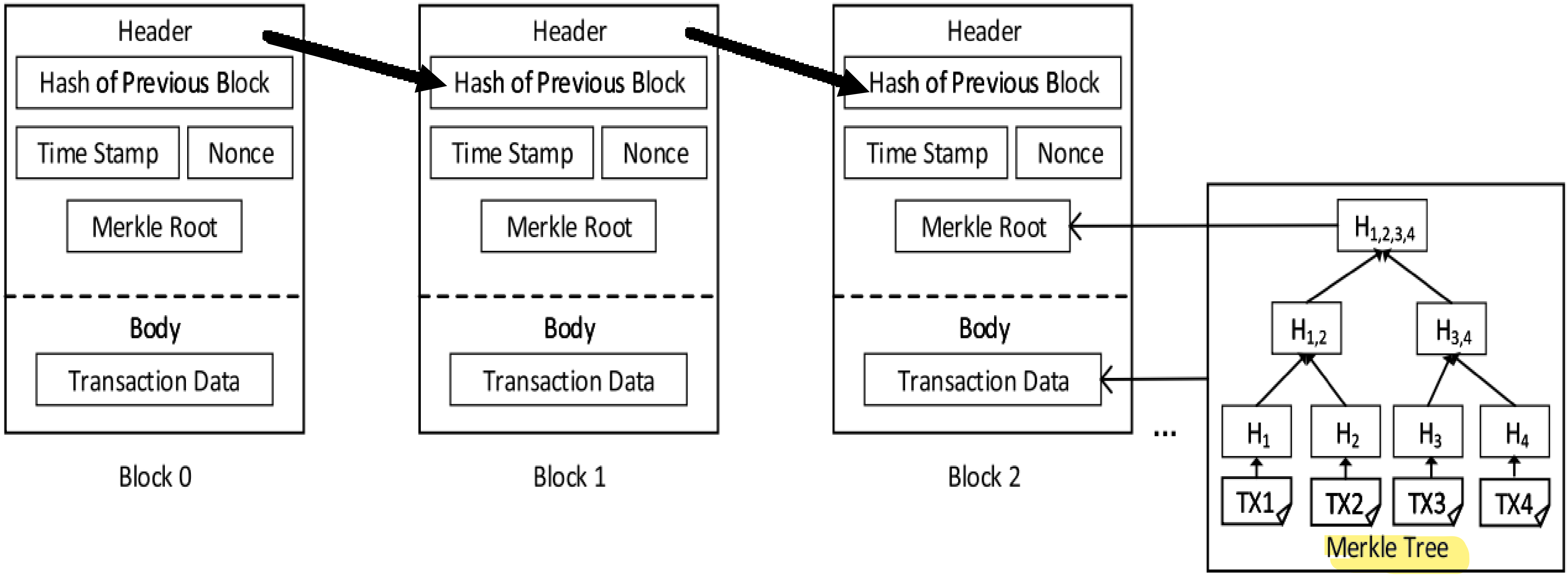
Blockchain and Public Ledgers

- Blockchain work like a public ledger
- Need to ensure different aspects:
  - **Protocols for commitment:** Ensure that every valid transaction from the clients are committed and included in the blockchain within the finite time.
  - **Consensus:** Ensures that local copies are updated and consistent
  - **Security:** The data needs to be temper proof. Note that the client may act malicious or compromised.
  - **Privacy and Authenticity:** The data / transaction belongs to various clients So, privacy and authenticity need to be ensured.

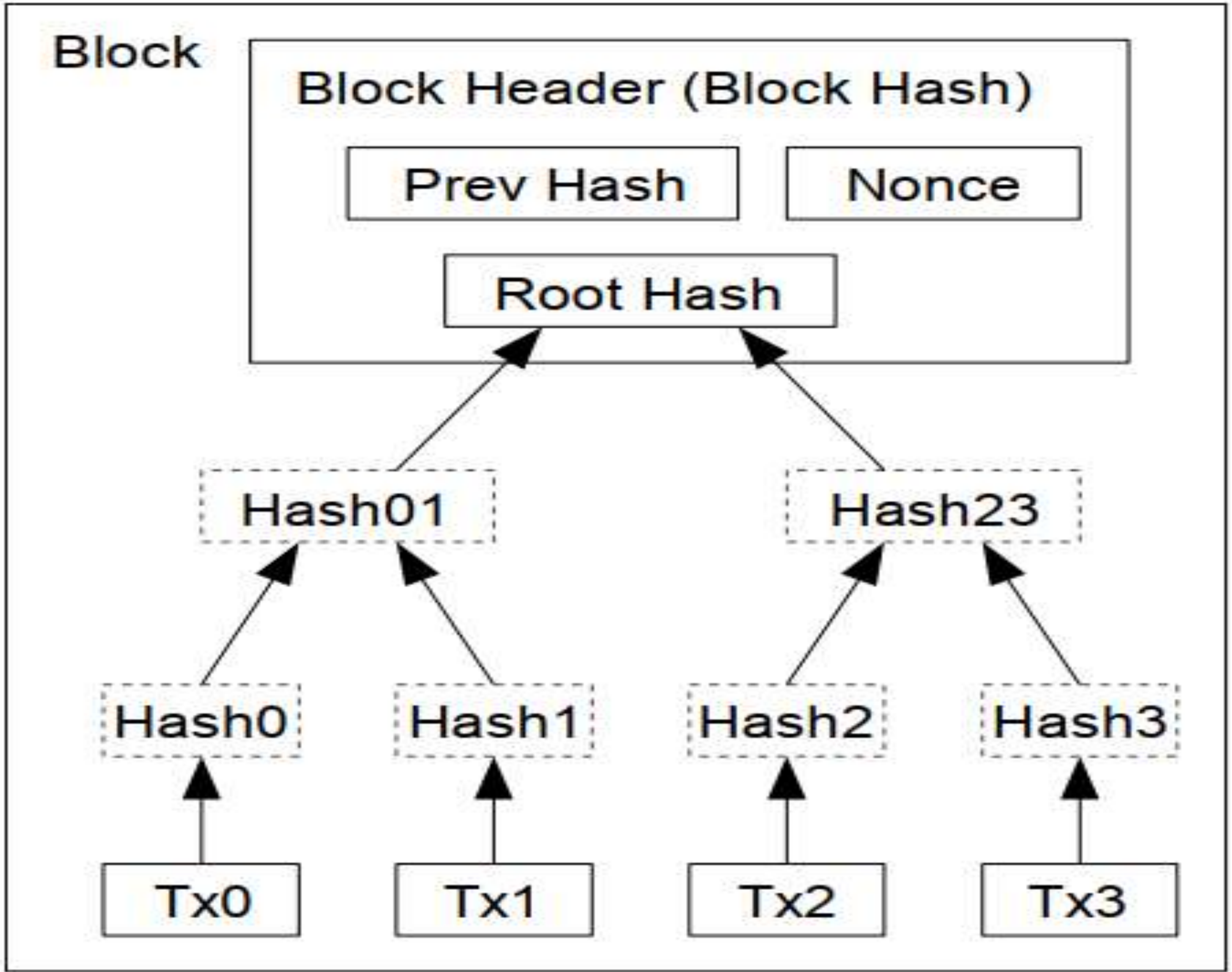
Blockchain Structure as Hash Chain



Blockchain Structure



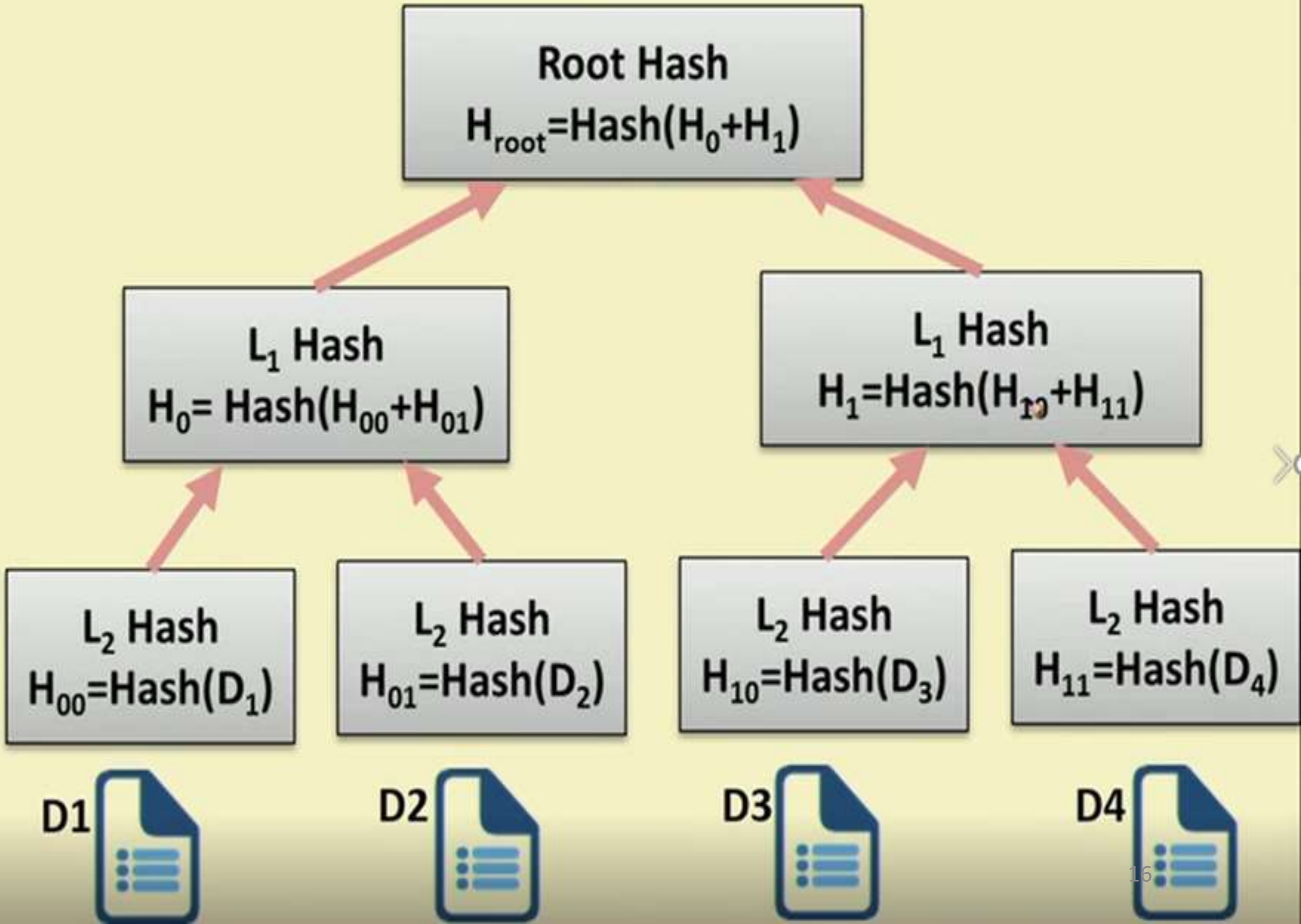
Merkele Tree



Merkle Trees (Ralph Merkle, 1979)

Also known as **hash tree**

- *every leaf node* is labelled with the hash of a data block
- ***every non-leaf node*** is labelled with the cryptographic hash of the labels of its child nodes



Root Hash

H_{root}=Hash(H_0+H_1)

L_1 Hash

H_0= Hash(H_{00}+H_{01})

L_1 Hash

H_1=Hash(H_{10}+H_{11})

L_2 Hash

H_{00}=Hash(D_1)

L_2 Hash

H_{01}=Hash(D_2)

L_2 Hash

H_{10}=Hash(D_3)

L_2 Hash

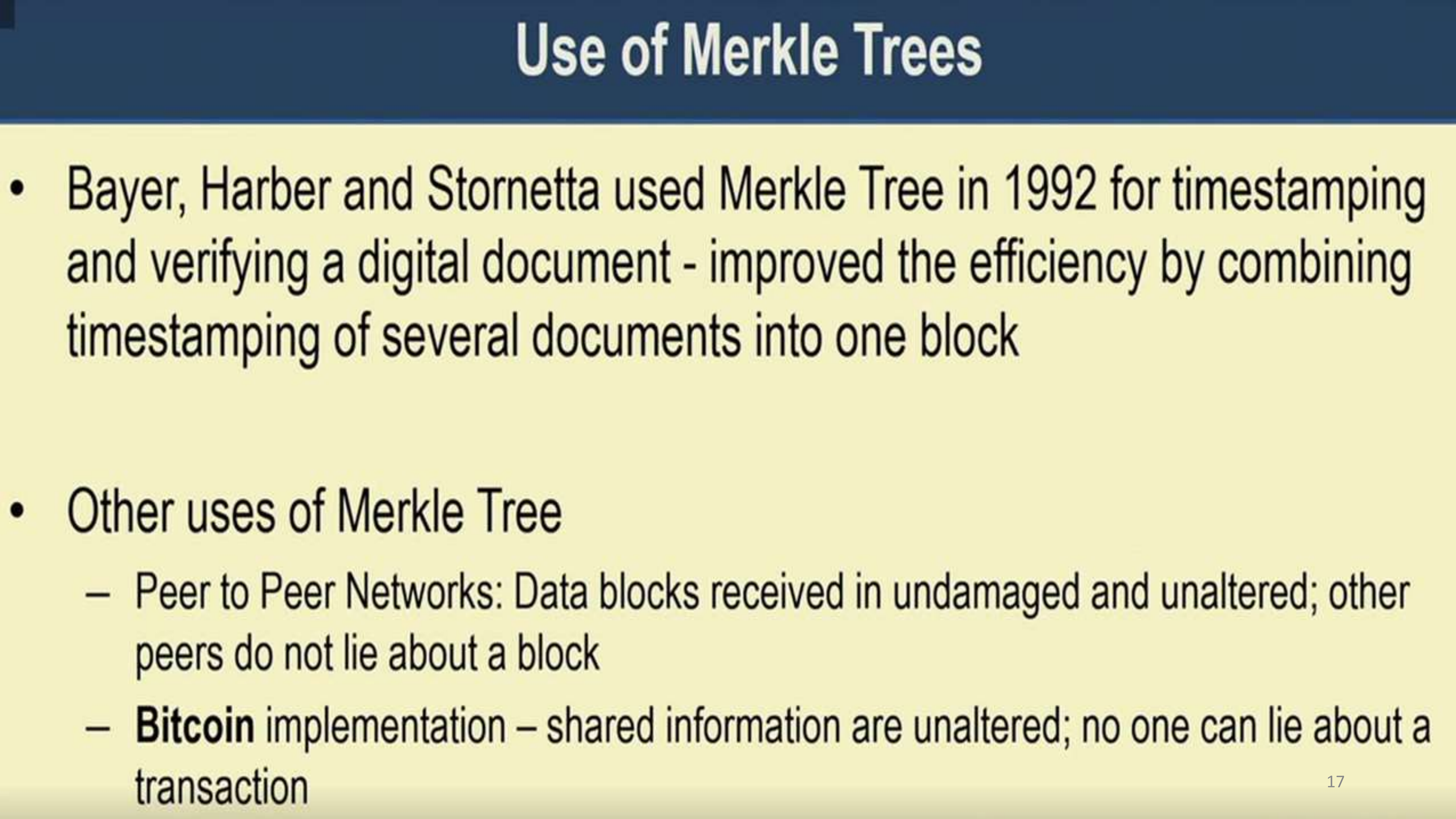
H_{11}=Hash(D_4)

D1

D2

D3

D4



Use of Merkle Trees

- Bayer, Harber and Stornetta used Merkle Tree in 1992 for timestamping and verifying a digital document - improved the efficiency by combining timestamping of several documents into one block

- Other uses of Merkle Tree
  - Peer to Peer Networks: Data blocks received in undamaged and unaltered; other peers do not lie about a block
  - **Bitcoin** implementation – shared information are unaltered; no one can lie about a transaction

- Is Bitcoin same as Blockchain
- Similarity ??
- Difference ??

Modes of Blockchain

- Permissionless Blockchain (Open Environment):
  - Suitable for open control-free financial applications e.g. Cryptocurrencies (BitCoin, Ethereum, Ripple, LightCoin etc.)

- Permissioned Blockchain (Close Environment):
  - Suitable for business applications e.g. Smart contracts

The Permission-less Model

- Works in an open environment and over a large network of participants

- The users do not need to know the identity of the peers, and hence the users do not need to reveal their identity to others

- Good for financial applications like banking using cryptocurrency

Privacy and Security

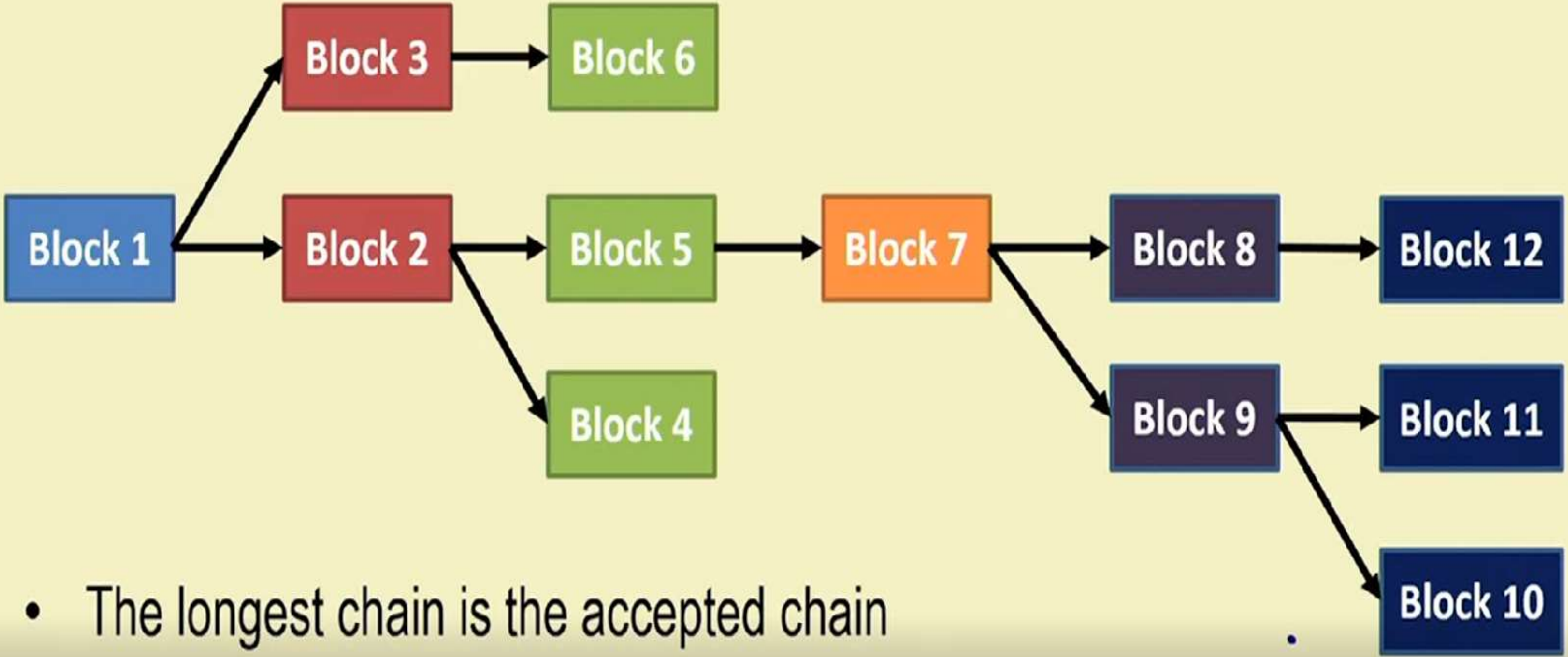
- **Tamper proof:** Extremely hard to change in blockchain
  - Becomes harder as chain grows

- Transactions are pseudo anonymous
  - Transactions sent to public key address (OR)
  - Cryptographically generated address (OR)
  - Computed by wallet applications

Privacy and Security

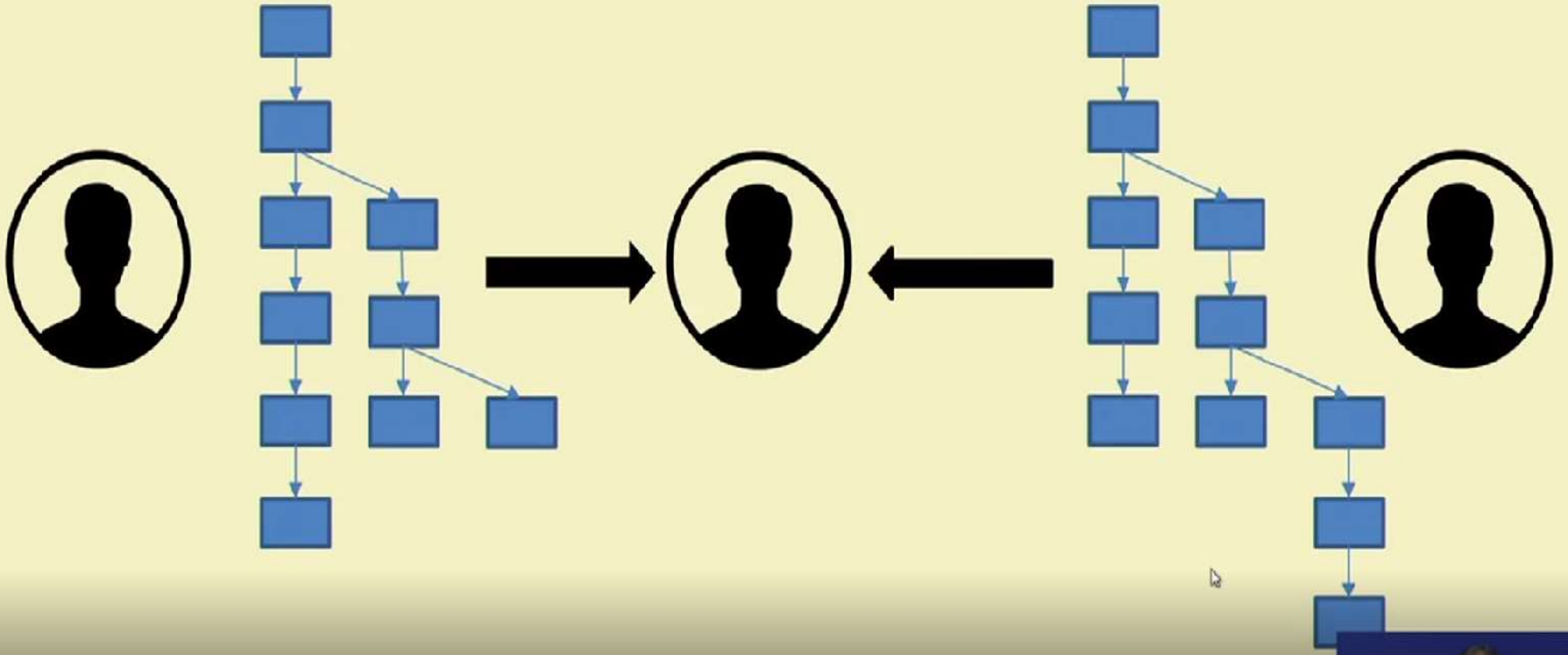
- **Peer Address:** Similar to bank account number
  - Becomes harder as chain grows
- Wallet listens for transactions specified by address
  - Encrypts the transaction by public key of target address
  - Only target node can decrypt and accept
- Actual transaction amount is open to all for validation
  - Anyone can validate

Blockchain (at Permission-less Model) as a Tree



- The longest chain is the accepted chain

Accepting the Longest Chain



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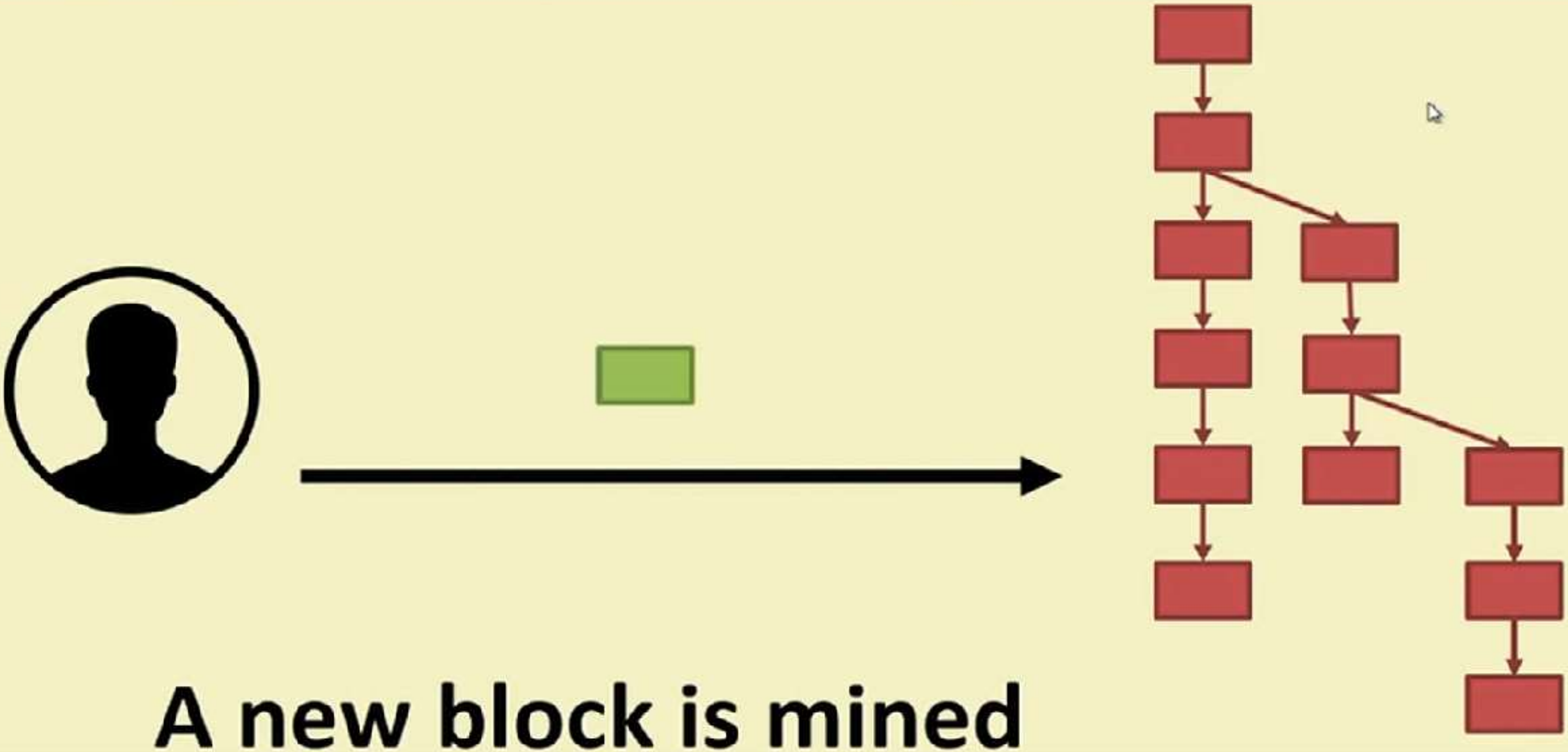
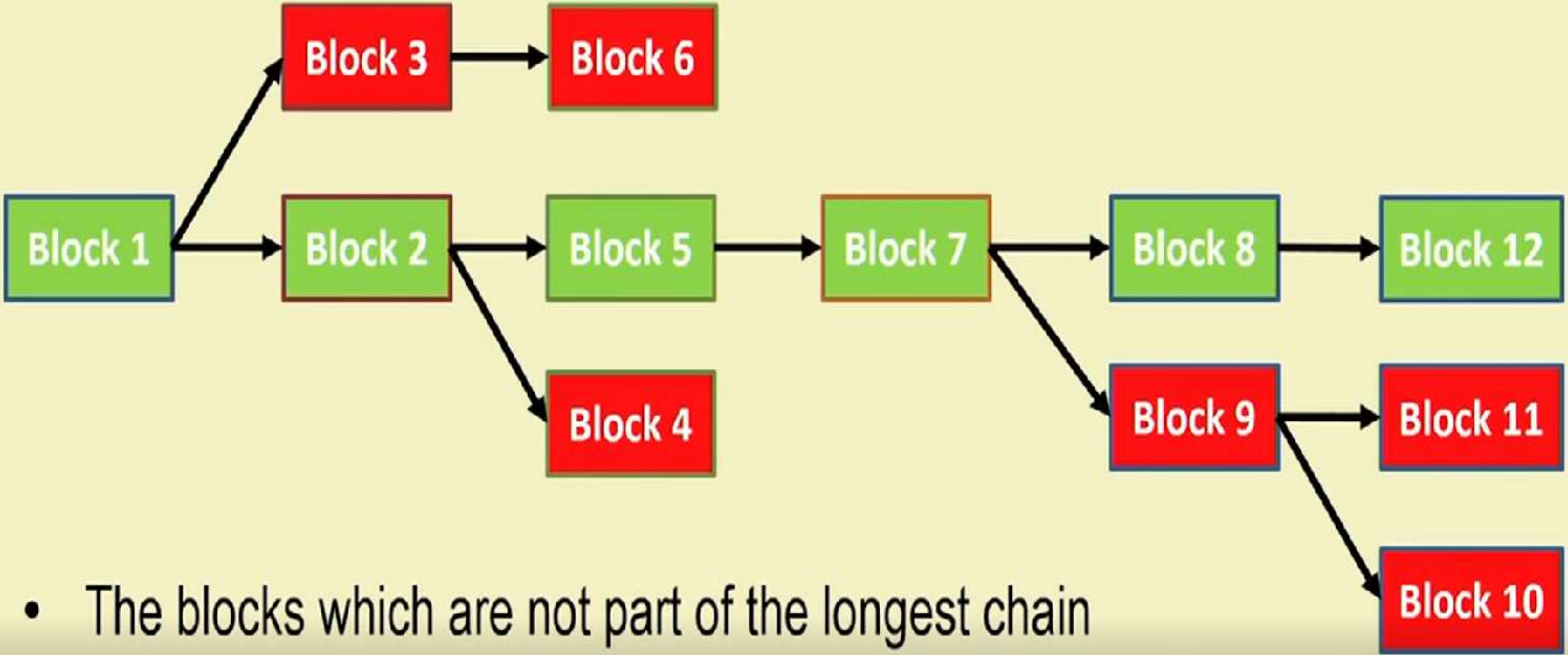


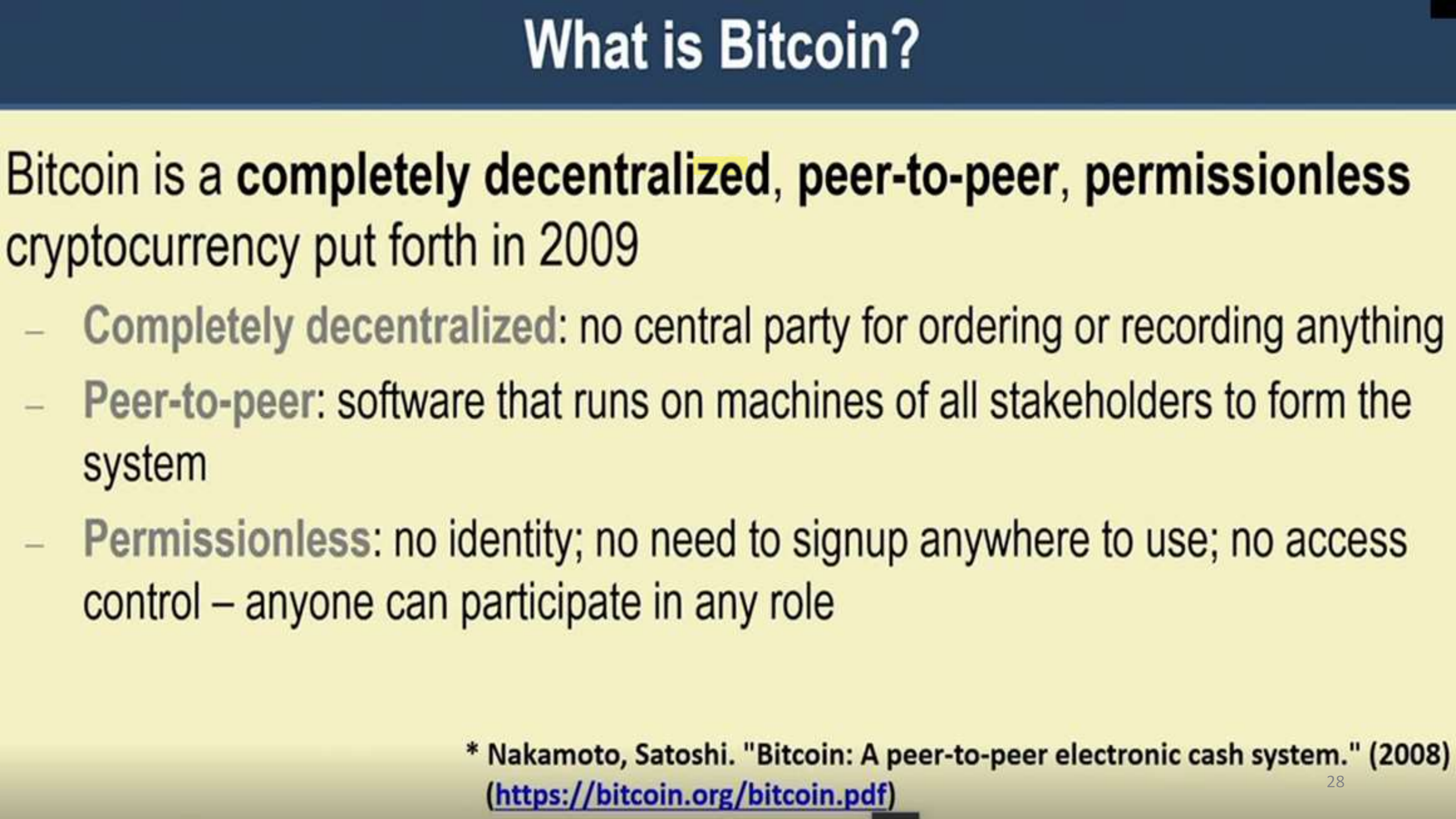
A new block is mined

Orphaned Blocks



- The blocks which are not part of the longest chain

- Is Bitcoin same as Blockchain
- Similarity ??
- Difference ??



What is Bitcoin?

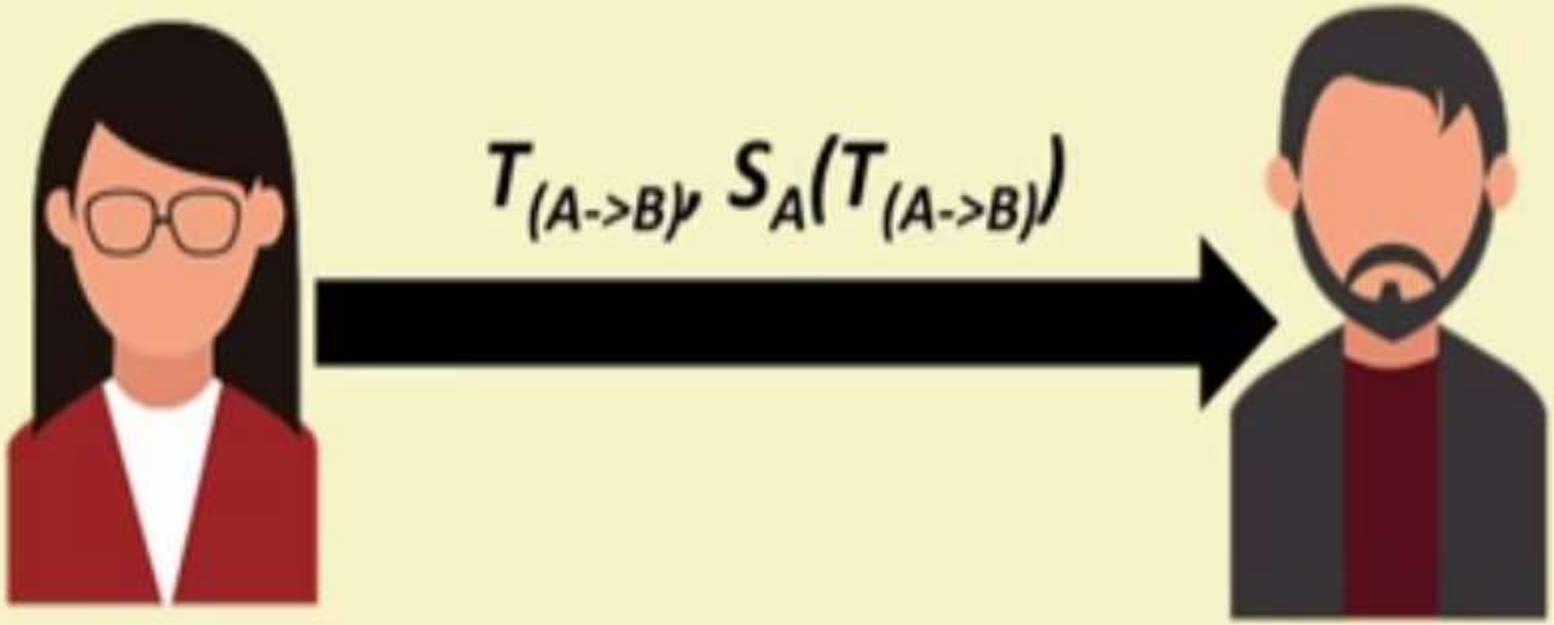
Bitcoin is a **completely decentralized**, **peer-to-peer**, **permissionless** cryptocurrency put forth in 2009

- **Completely decentralized**: no central party for ordering or recording anything
- **Peer-to-peer**: software that runs on machines of all stakeholders to form the system
- **Permissionless**: no identity; no need to signup anywhere to use; no access control – anyone can participate in any role

[*] Nakamoto, Satoshi. "Bitcoin: A peer-to-peer electronic cash system." (2008) (https://bitcoin.org/bitcoin.pdf)

Bitcoin Basics – Sending Payments

- Alice wish to transfer some bitcoin to Bob.
  - Alice can sign a transaction with her private key
  - Anyone can validate the transaction with Alice's public key



$T_{(A\text{->}B)}, S_A(T_{(A\text{->}B)})$

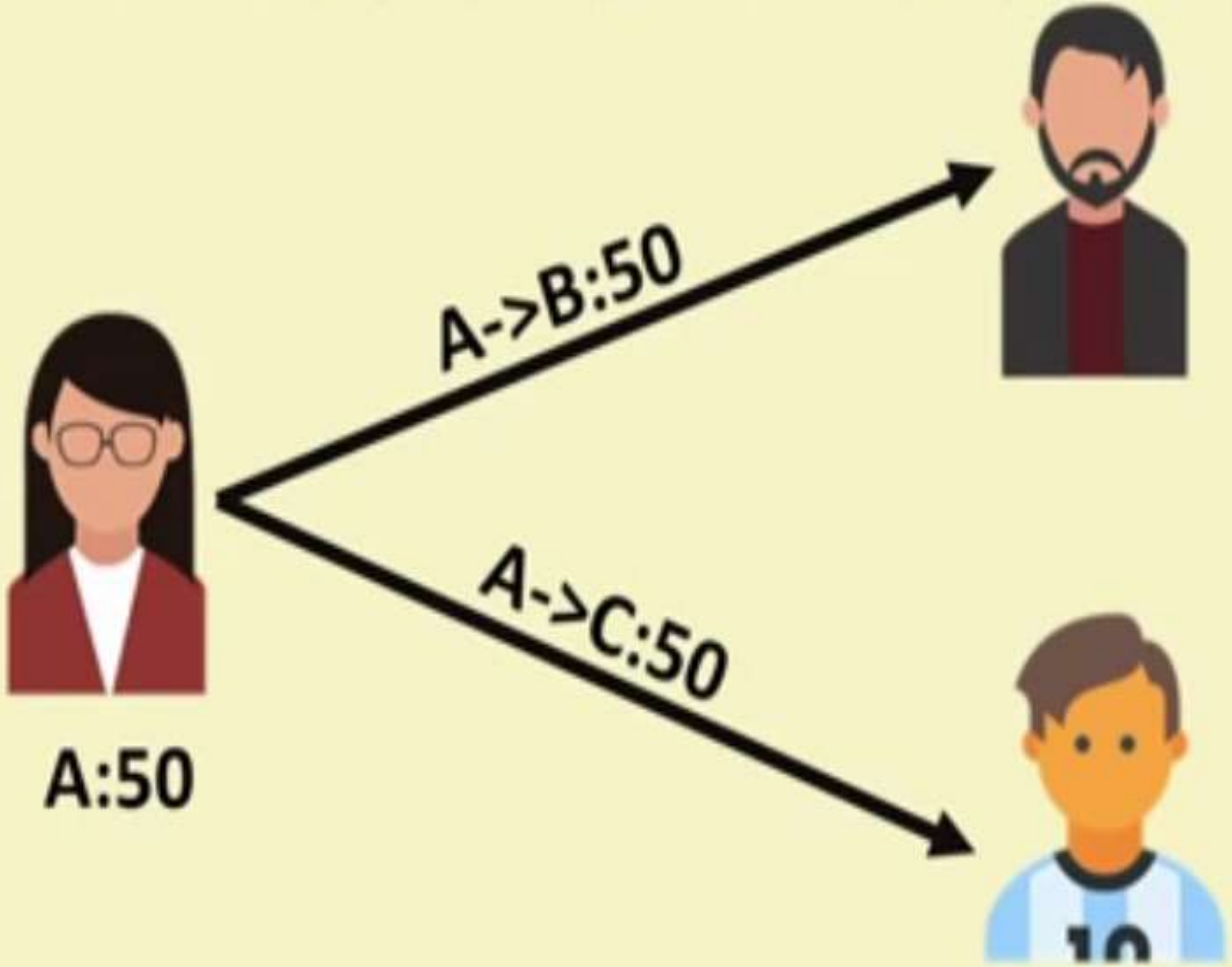
Bitcoin Basics – Sending Payments

- Alice wants to send bitcoin to Bob
  - Bob sends his address to Alice
  - Alice adds Bob's address and the amount of bitcoins to transfer in a "transaction" message
  - Alice signs the transaction with her private key, and announces her public key for signature verification
  - Alice broadcasts the transaction on the Bitcoin network for all to see

Information Source: https://en.bitcoin.it/wiki/

Double Spending

- Same bitcoin is used for more than one transactions



- In a centralized system, the bank prevents double spending
- **How can we prevent double spending in a decentralized network?**

Handle Double Spending using Blockchain

- Details about the transaction are sent and forwarded to all or as many other computers as possible

- Use **Blockchain** – a constantly growing chain of blocks that contain a record of all transactions

- The blockchain is maintained by all peers in the Bitcoin network – everyone has a copy of the blockchain

Information Source: https://en.bitcoin.it/wiki/

Handle Double Spending using Blockchain

- To be accepted in the chain, transaction blocks must be valid and must include **proof of work** – a computationally difficult hash generated by the mining procedure

- Blockchain ensures that, if any of the block is modified, all following blocks will have to be recomputed

Handle Double Spending using Blockchain

- To be accepted in the chain, transaction blocks must be valid and must include **proof of work** – a computationally difficult hash generated by the mining procedure

$$\leftarrow \underline{\underline{Y}} = H(\underline{\underline{X}} \,\|\, \underline{\underline{\text{Nonce}}})$$

- Blockchain ensures that, if any of the block is modified, all following blocks will have to be recomputed

$$Y \approx \underline{0000 \ldots 00F}1G2FD$$

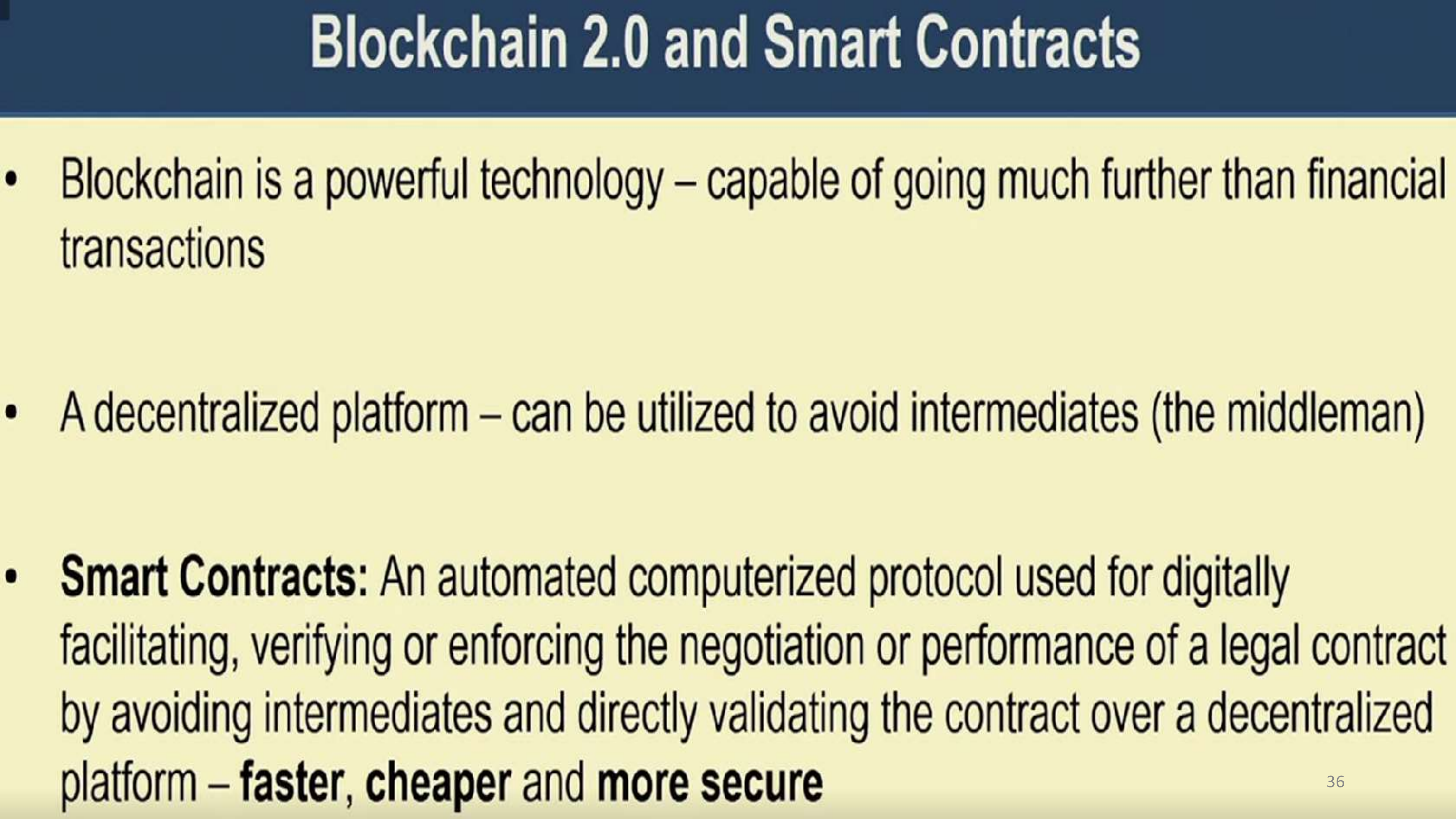
Handle Double Spending using Blockchain

- When multiple valid continuation to this chain appear, only the longest such branch is accepted and it is then extended further **(longest chain)**

- Once a transaction is committed in the blockchain, everyone in the network can validate all the transactions by using Alice's public address

- The validation prevents double spending in bitcoin

Information Source: https://en.bitcoin.it/wiki/



Blockchain 2.0 and Smart Contracts

- Blockchain is a powerful technology – capable of going much further than financial transactions
- A decentralized platform – can be utilized to avoid intermediates (the middleman)
- **Smart Contracts:** An automated computerized protocol used for digitally facilitating, verifying or enforcing the negotiation or performance of a legal contract by avoiding intermediates and directly validating the contract over a decentralized platform – **faster**, **cheaper** and **more secure**

Thank You!