Bitcoin in a Nutshell I

- A distributed currency exchange medium open to anyone to join.
  - Powered by a peer-to-peer (P2P) network.
- Utilize basic cryptographic primitives to control the money flow in the system.
  - Hash functions and digital signatures.
- Building blocks:
  - Players: miners and clients.
  - Transactions: messages exchanged.
  - Blockchain: an append only log.
  - Mining: extending the blockchain.
  - Consensus: agreeing on the current state of the Blockchain.

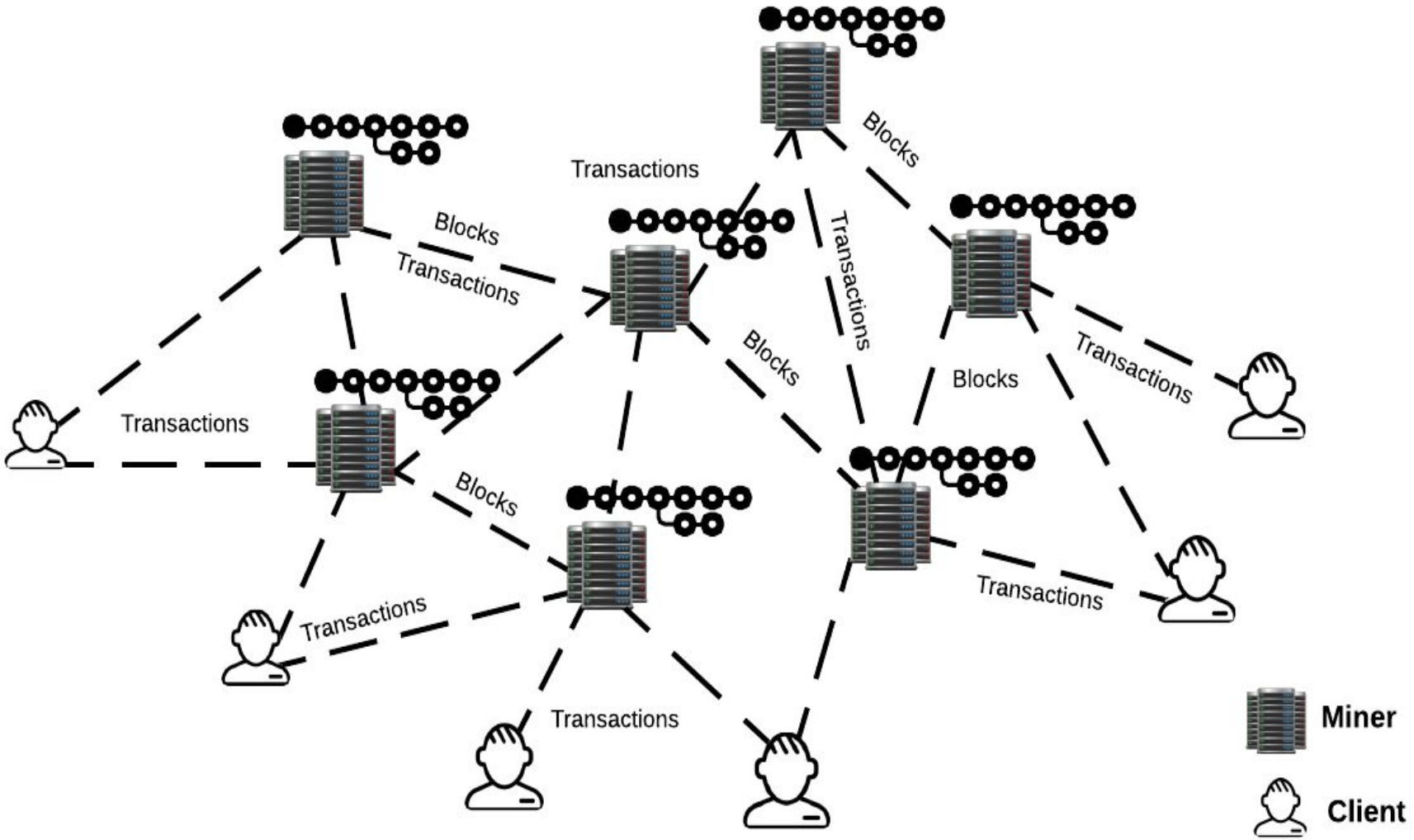
Bitcoin in a Nutshell II

- No real identities are required, just a key pair.
- Owning the private key of the destination address of currency transfer means you own the currency value of that address.
- Losing the private key of a specific address means losing the coins associated to this address forever.
  - Wallets take care of tracking coins, issue transactions, etc.
- Digital signatures are used to prove your ownership of the private key associated to the coins you want to spend.
- Everything is logged on a public ledger called a blockchain.
  - Built basically using a linked list and hash pointers.

Who is Who in Bitcoin

- Two types of nodes in Bitcoin network:
  - **Lightweight nodes or clients:**
    - Also called thin clients or simple payment verification (SPV) clients.
    - The vast majority of Bitcoin nodes are lightweight ones.
    - Do not store the whole blockchain, only specific parts to verify the transactions they care about.
    - They trust the miners in generating trusted and true blocks.
  - **Fully validating nodes or miners:**
    - Must stay permanently connected to the system.
    - Have a good network connectivity to be able to hear all transactions (hopefully).
    - Store a full copy of the blockchain.

Bitcoin Pictorially



Decentralization in Bitcoin

- **P2P network:** anybody can join and leave anytime.
- **Mining:** open to anyone but requires large computation power and resources.
- **Updates on the used software:** done by the community developers (through the Bitcoin foundation) with proposals submitted by anyone.
- **Maintaining the public ledger:** maintained by all miners within the network.
  - No centralized bank.
- **Transactions:** announced publicly to everyone.
- **Creating new coins:** miners can do that based on their work.
  - no central authority.

Bitcoin Addresses I

- Define users over the Bitcoin network.
- A Bitcoin address is a 160-bit hash of the public portion of an ECDSA key-pair.
  - Recall that ECDSA is used for digital signature in Bitcoin with key size of 512 bit.
  - The address is the public key hashed twice: using SHA-256 followed by RIPEMD-160 (RACE Integrity Primitives Evaluation Message Digest).
- An additional byte is needed since all Bitcoin addresses should start with either 1 or 3.
  - 1 for individual addresses as output destination.
  - 3 for scripts addresses as output destination (script hash).

Bitcoin Addresses II

- For readability, addresses are represented in alphanumeric (using Base58 encoding, binary to text encoding, (see .https://en.bitcoin.it/wiki/Base58Check_encoding) - E.g: 1B74t1WpEZ73CNmQviecbaciWRnqRhWNLy
- To promote ***privacy***, it is advised to generate a different address (or different key pair) for each new transaction.
    - Will look more into privacy issues and transactions linkability in Bitcoin.

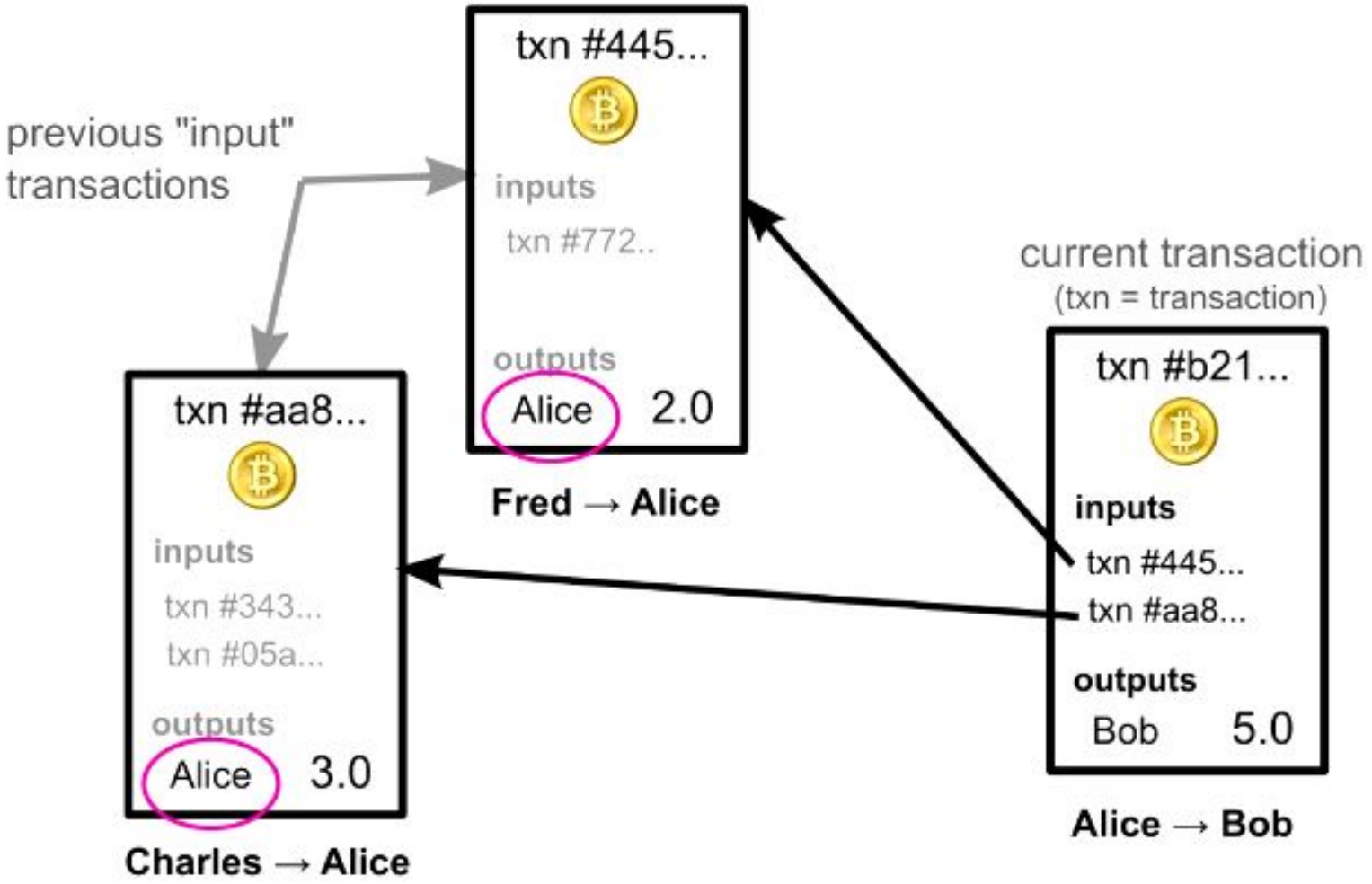
Bitcoin Transactions

- Transactions represent the digital token, or virtual coins, in Bitcoin.
- A new transaction is issued by any node as follows:
  - Fill the following fields:
    - Input section: list of pointers to previous unspent transactions owned by the sender.
    - Output section: the address of the receiver or the hash of the output script.
  - Sign the whole transaction (including the output section) using the private keys associated with the inputs.
- The sender then broadcasts the transaction over the network.

UTXO Model

- UTXO - Unspent transaction output.
  - No notion of accounts, track chains of transactions.
    - Wallets do that transparently for users.
- You cannot spend a portion of an input. All the input values will go to the output.
  - Like paying $2 cookie with a $100 bill.
- The solution?? Return the change to an address you own.
  - A transaction can have multiple inputs and multiple outputs.
- Transactions are irreversible.
  - A merchant who wants to issue a refund has to issue a new transaction that spends the original payment transaction back to the customer.

Bitcoin Transactions - Pictorially



Source: http://www.imponderablethings.com/2013/07/how-bitcoin-works-under-hood.html

The Public Ledger or Blockchain

- Append only log contains a full record of all transactions.
  - These transactions are recorded in blocks.
  - The blockchain is a linked list of these blocks, linked by their hashes.
- Miners extend the blockchain by mining new blocks.
  - Solve a proof-of-work puzzle.
  - Collect monetary incentives.
- Each block has a header and a body.
  - Header includes meta data, while the body include the list of transactions recorded in a block.

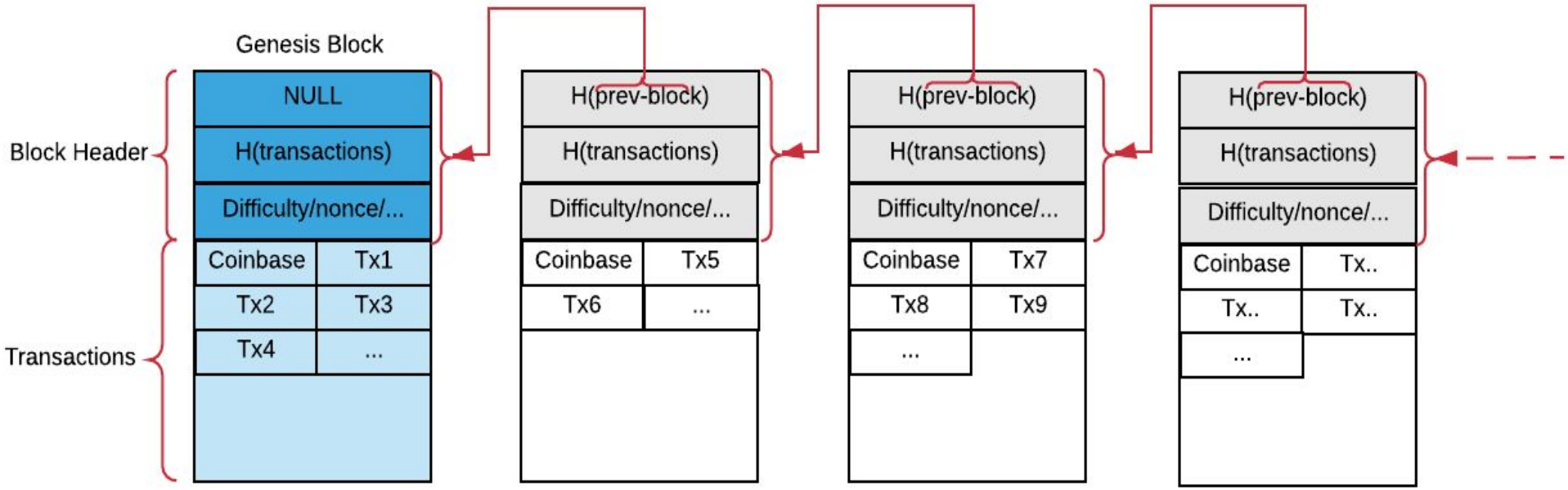
Block Header

- Block header:
  - 4 byte ➔Version: A version number to track software/protocol upgrades
  - 32 bytes ➔ Previous Block Hash: A reference to the hash of the previous (parent) block in the chain
  - 32 bytes ➔ Merkle Root: A hash of the root of the Merkle-Tree of this block's transactions
  - 4 bytes ➔ Timestamp: The approximate creation time of this block (seconds from Unix Epoch)
  - 4 bytes ➔ Difficulty Target: The Proof-of-Work algorithm difficulty target for this block
  - 4 bytes ➔ Nonce: A random value used for the Proof-of-Work algorithm

Block Body

- The content of the block is a set of transactions including:
  - Standard transactions broadcast by the users in the network. Only valid and unspent ones are included.
  - Coinbase transaction with value equals to the mining reward destined to the miner who mines the block.

The Blockchain Structure



Mining I

- The miners extend the blockchain with new blocks (and mint new currency).
- Done through proof-of-work.
  - Needed to prevent Sybil attacks.
- Miners solve a hash puzzle,

  SHA-256(SHA-256 (new block header)) < Difficulty Target

- For secure hash functions, the only way to find the hash with a given property is to try nonce values until a desired hash is found.
  - Hence it is solving a hash puzzle.
- Verification is very easy, other miners check the validity of the included transactions and then verify the solution of the hash puzzle.

Mining II

- Difficulty is adjusted periodically, roughly, every two weeks.
  - Keeps the block generation rate constant, 1 block every 10 minutes.
  - Accommodates the increasing computation power of miners.
    - New strong miners may join the network, hence, they will be able to solve the puzzle faster.
    - Affects the security of the blockchain, strong miners could be able to rewrite the blockchain and change its view.
- Miners are incentivised for mining by:
  - Mining rewards.
  - Transaction fees.

Mining Rewards

- Miners mint new coins as a reward for their work on the block chain.
- Each miner includes a special transaction destined to himself as a reward.
  - Called coinbase transaction.
  - This transaction becomes legitimate when the block becomes part of the blockchain.
- Currently the incentive is 6.25 BTC and it halves every 210,000 blocks (approximately every 4 years).
  - It started with 50 BTC.
- Total Bitcoin to mine is capped by 21 million BTC.
  - now there are around 18.5 million.

Transaction Fees

- Tips for blocks creators.
  - The issuer of a transaction selects to include a transaction fee that goes to the miner who publishes the transaction in a block on the blockchain.
- This is done by having the input value larger than the output value by the tip amount.
- Optional (it is a tip), but when mining rewards disappear they will become (implicitly) mandatory.
- When mining, miners give higher priority to transactions that include high tips.

Miners Hardware

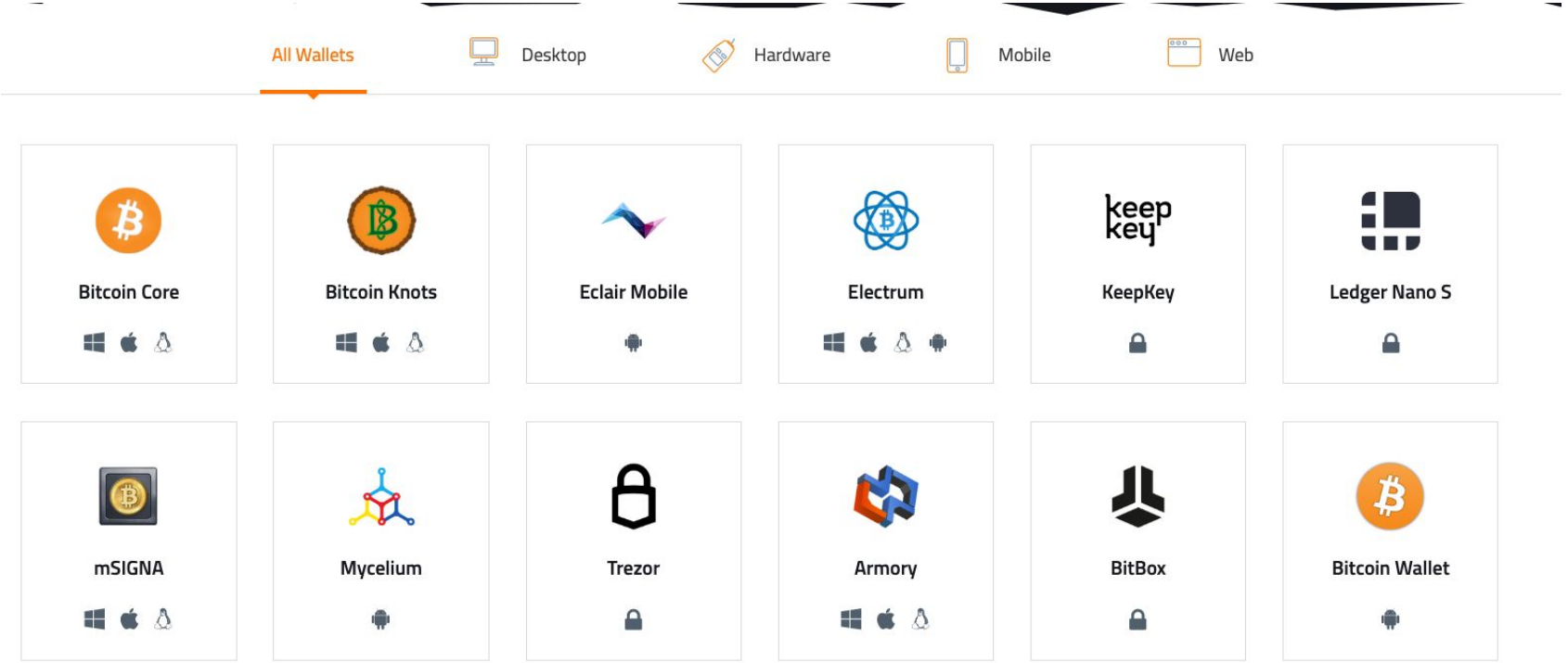
- Started by normal users and their CPUs mining, then GPUs mining, and then the ASIC (applications Specific Integrated Circuits) mining.
  - Now there are mining pools with huge data centers.
- Example: Bitfury miner center: http://www.bitfury.org/

Want to Mine Bitcoin

- Get a machine with good specifications.
- Download Bitcoin core code (see https://bitcoin.org/en/download),
- Run the miner module that does the following:
  - Discover the network by finding miners around to connect with them.
  - Retrieve a full copy of the blockchain from the discovered peers.
  - Get in sync with the network and start pooling transactions and mine new blocks.
- Costly process, nowadays individuals cannot mine on their own, they join mining pools instead (more about this later).

Want to Use Bitcoin I

- **First:** Install a wallet (e.g., visit https://bitcoin.org/en/choose-your-wallet).



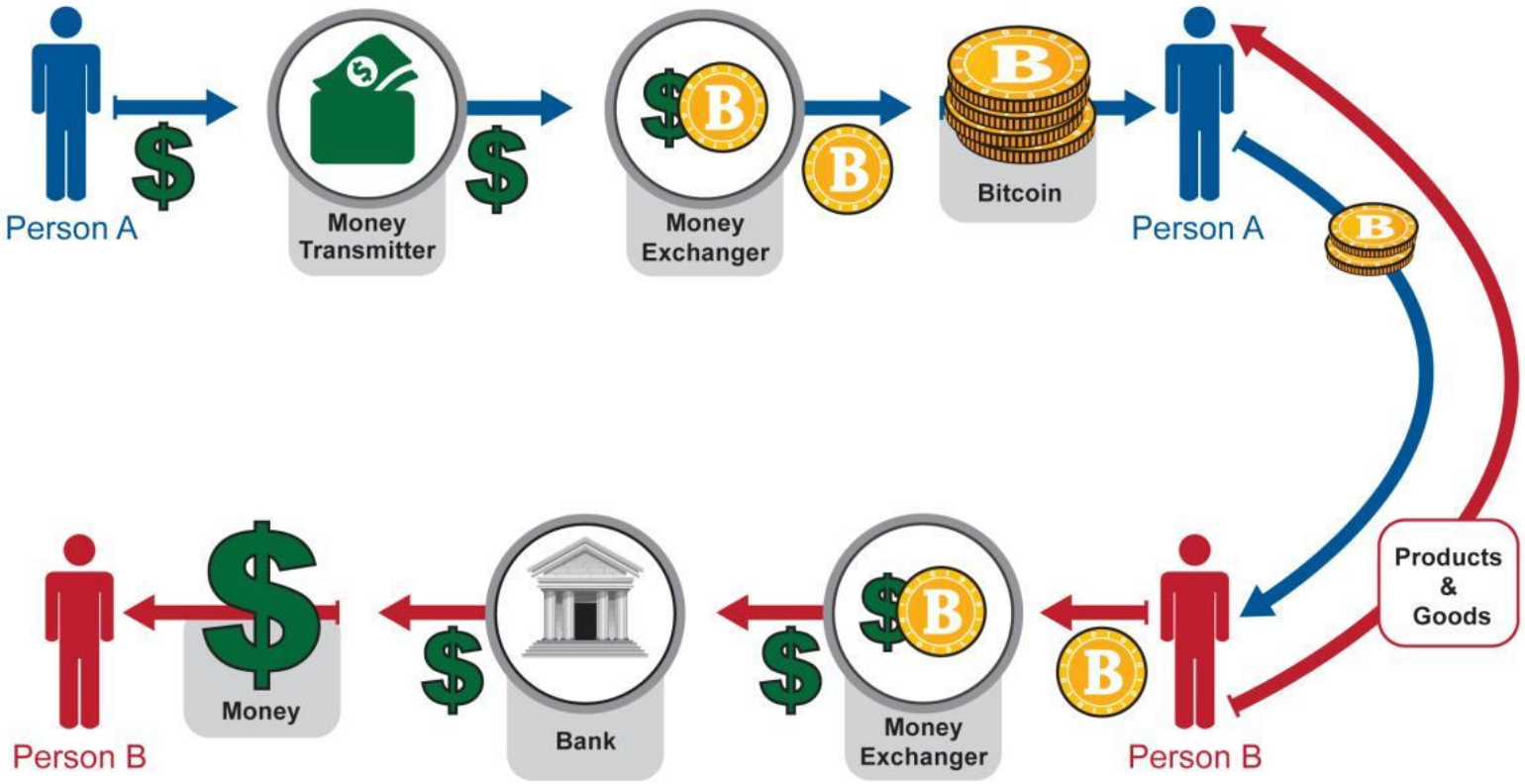
Want to Use Bitcoin II

- **Second:** Buy Bitcoin, multiple options:
  - Cryptocurrency exchanges, such as Bitstamp, Coinbase, etc.
  - Use a classified service to find people in your area to buy their Bitcoins, such as LocalBitcoin.com
  - Sell a product for Bitcoin.
  - Use a Bitcoin ATM in your city, see: https://coinatmradar.com/

Want to Use Bitcoin III

- **Third:** Spend your bitcoins 😊 (https://99bitcoins.com/who-accepts-bitcoins-payment-companies-stores-take-bitcoins/)
- Simply scan the address of the merchant and use your wallet to create a payment transaction.
- The technicality is as described before.

Bitcoin and Fiat Currency



Source: http://www.fincen.gov/

For a full list of Bitcoin exchanges see: https://en.bitcoin.it/wiki/Category:Exchanges

User Responsibility

- Maintain your set of private keys.
  - Remember without your private keys you cannot spend your previous transactions.
  - Your wallet takes care of this so be sure of selecting a trusted one.
- Change your public key periodically.
  - To hide your identity.
  - To make sure that your private key is not compromised.
- Be careful when and who to trust while using your Bitcoin.
  - Exchanges, merchants, etc.