# Bitcoin and Cryptocurrency Technologies
# Lecture 7: Bitcoin Protocol

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# Bitcoin Protocol

- **Bitcoin Protocol** is a distributed protocol that allows to produce a **limited amount** of digital tokens, **provably assign ownership** of the tokens to certain entities and ensure that the tokens can be **spent** by transferring the ownership to other entities, but cannot be spent **twice**.
- Previous attempts at digital currencies were unable to resolve the problem of **double spending** without central authority.

# Bitcoin Network Roles 1/2

- Entities on the Bitcoin network are divided into the following classes:
  - **fully validating nodes** - entities that run Bitcoin node software, propagating and validating blocks and transactions; these guarantee the *strength-in-numbers* policy of the distributed Bitcoin protocol;
  - **miners** - entities that compute blocks and generate the *computational security* of the network;
  - **"light" nodes**, e.g. **SPV (Simplified Payment Verification) nodes** - nodes that are only interested in particular parts of Bitcoin protocol, e.g. transactions and their corresponding blocks; usually mobile wallet software.

# Bitcoin Network Roles 2/2

- **Full nodes** ensure that miners do not mine invalid blocks (i.e. low work blocks or blocks with invalid transactions);
- **Miners**
  - cannot mine invalid blocks because these will immediately be rejected by the *fully validating nodes*, which results in immediate loss of all resources spent on computing PoW,
  - heavily invested in the hardware and their only income is block rewards, so if the network is compromised, they lose all their income,
- **SPV nodes** only keep a chain of block headers (56 Mb of data) and validate only specific transactions.

# Limited Supply 1/3

- Bitcoin Protocol incentivised miners to spend resources on PoW computation by allowing them to generate new bitcoin in the **coinbase** transactions.
- Additionally, miner claims fee of all transactions that were included in the block.
- Bitcoin is designed to have a strictly **limited supply** of the bitcoin tokens, so the amount of bitcoin generated in each new block is reduced over time.
- As block reward becomes smaller, miners rely more on transaction fees.

# Limited Supply 2/3

- Every 210,000 blocks the reward is decreased by a factor of 2:
  - 50 BTC (5,000,000,000 satoshis) in 2009-2012,
  - 25 BTC (2,500,000,000 satoshis) in 2012-2016,
  - 12.5 BTC (1,250,000,000 satoshis) in 2016-2020,
  - 6.25 BTC (625,000,000 satoshis) since 2020.
- Bitcoin block reward forms a geometric progression

$$a_n = ar^n,\ a = 50,\ r = \frac{1}{2}$$

- The sum of this progression represents a total amount of Bitcoin that will ever exist:

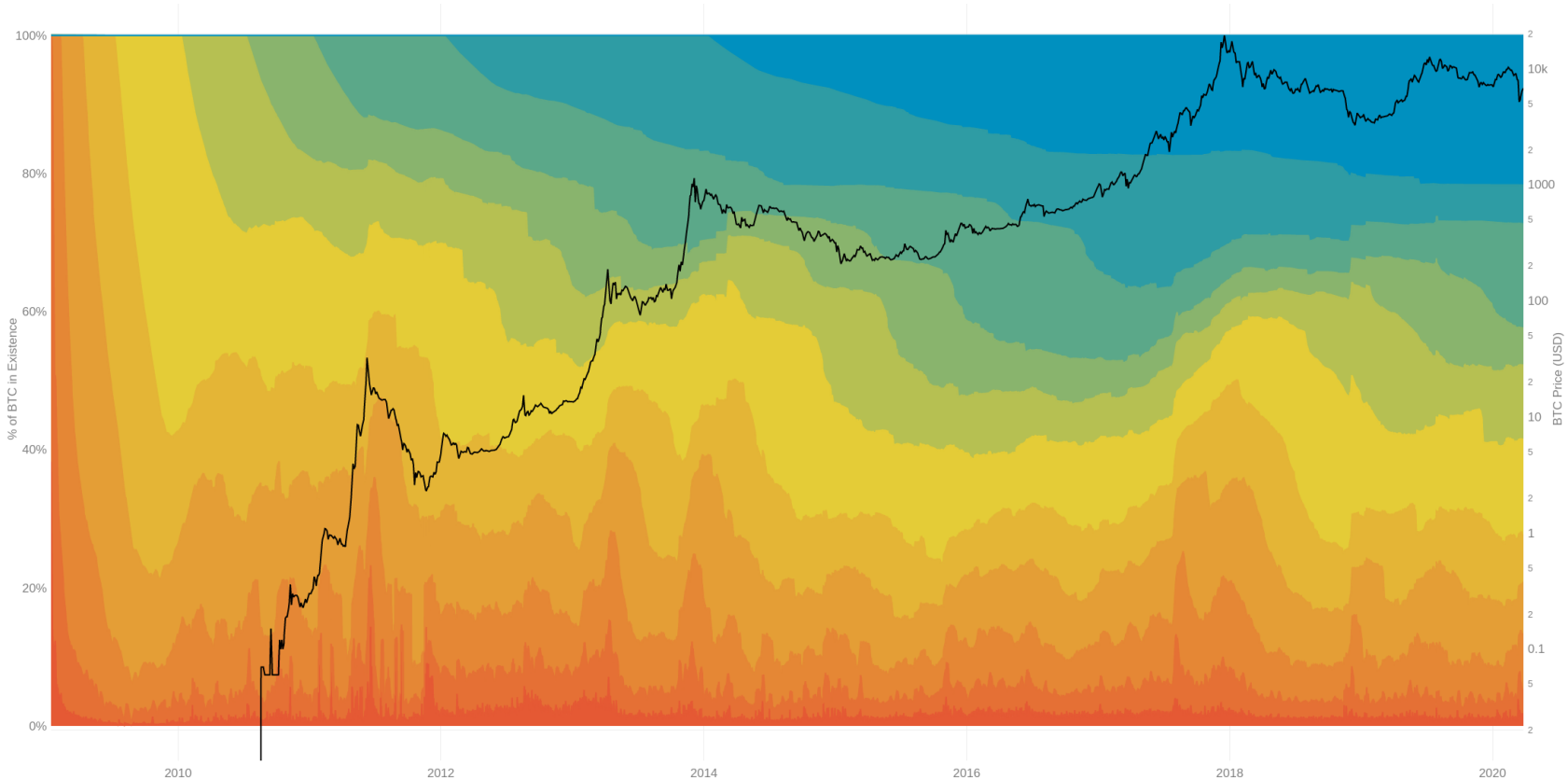
$$210000 \times \sum_{n=1}^{n:a_n \geq 1} a_n = 210000 \times \frac{a(1-r^n)}{1-r} = 21000000$$

# Limited Supply 3/3

- Bitcoins can be accidentally "lost" (the owner loses access to the key which is used in the lock-script) or intentionally destroyed (sent to an address with an unknown key, e.g.

$$1BitcoinEaterAddressDontSendf59kuE$$

- It is estimated that approximately 4-10 million bitcoins are lost



# Forks 1/2

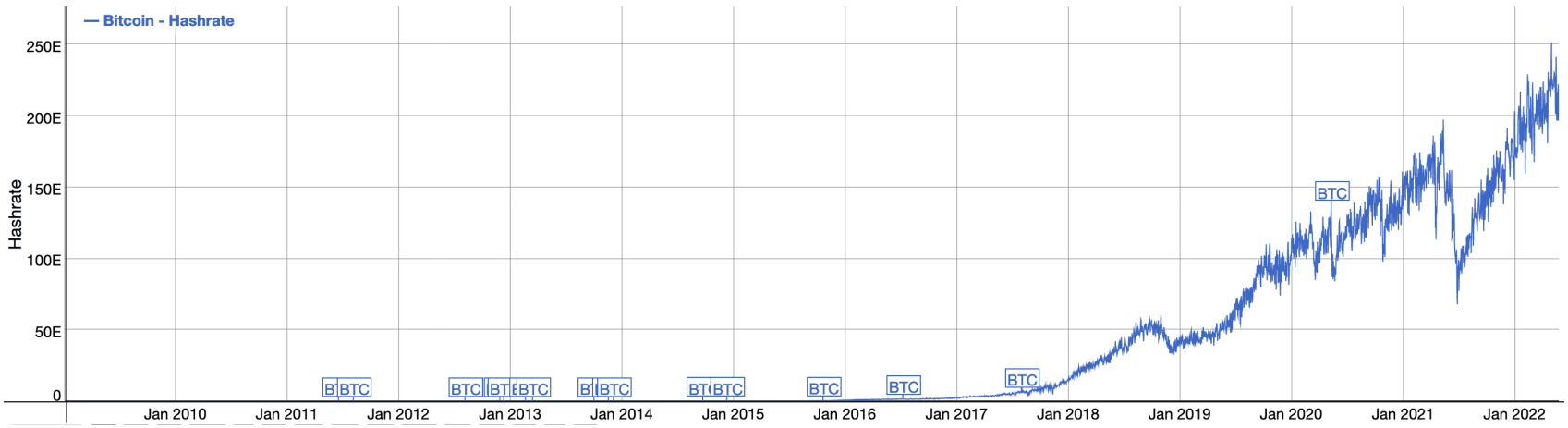
- **Soft fork** is a change to the Bitcoin protocol that **restricts** the set of rules applied to blocks and transactions:
  - **some** of the blocks or transactions considered **valid** by the **old (non-upgraded) nodes** are considered **invalid** by the **new (upgraded) nodes**,
- Soft fork does not drop any nodes from consensus, but requires majority of the nodes to upgrade for the new rule to be enforced.
- Old nodes can still "play by the old rules".

# Forks 2/2

- **Hard fork** is a change to the Bitcoin protocol that **relaxes** the set of rules applied to blocks and transactions:
  - **some** of the blocks or transactions considered **valid** by the **new (upgraded) nodes** are considered **invalid** by the **old (non-upgraded) nodes**,
- Hard fork effectively drops old nodes from consensus, so it requires all nodes to upgrade to avoid the network split.
- Nodes that "play by the old rules" are split into a separate network.

# Network Hashrate

- For **hash-based Proof-of-Work systems**, the computing power can be conveniently measured by **hashrate - hashes computed per second** (H/s).
- Current total **hashrate** of the Bitcoin network is approximately 375 Eh/s ($308 \times 10^{18} = 375{,}000{,}000{,}000{,}000{,}000$ H/s).
- As block rewards attract more miners, the total computing power of Bitcoin network increases.



# Difficulty Adjustment

- In order to accomodate to the increasing computing power of the network, Bitcoin Protocol includes the **difficulty adjustment process**.
- Every 2,016 blocks (approximately 2 weeks), the difficulty of the PoW task is recalculated based on the last 2,016 blocks:
  - if the averate time between last 2,016 blocks is *more than 600 seconds*, the *difficulty is decreased* (the *PoW target is increased*), otherwise the *difficulty is increased* (the *PoW target is decreased*).
- The PoW difficulty is represented as the **PoW target** 256-bit number, which is in turn encoded as **bits** value and included in the block header, so the PoW solution can be verified independently.

# The End

Thank you!