Blockchain 4

PoW and Forks

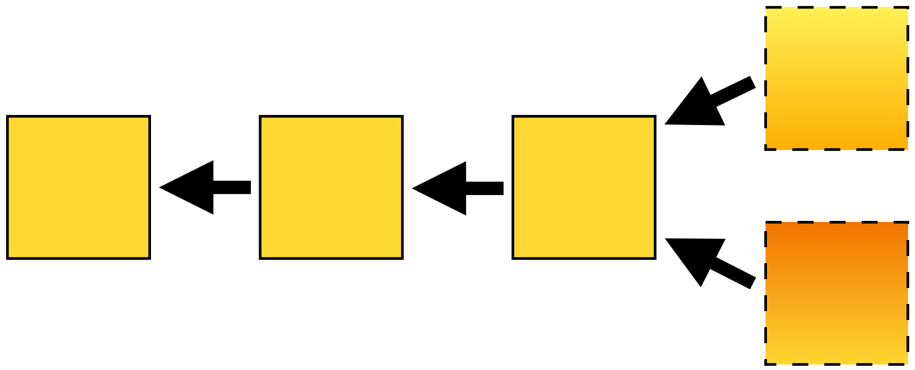
Leander Jehl

DAT650 Blockchain technology

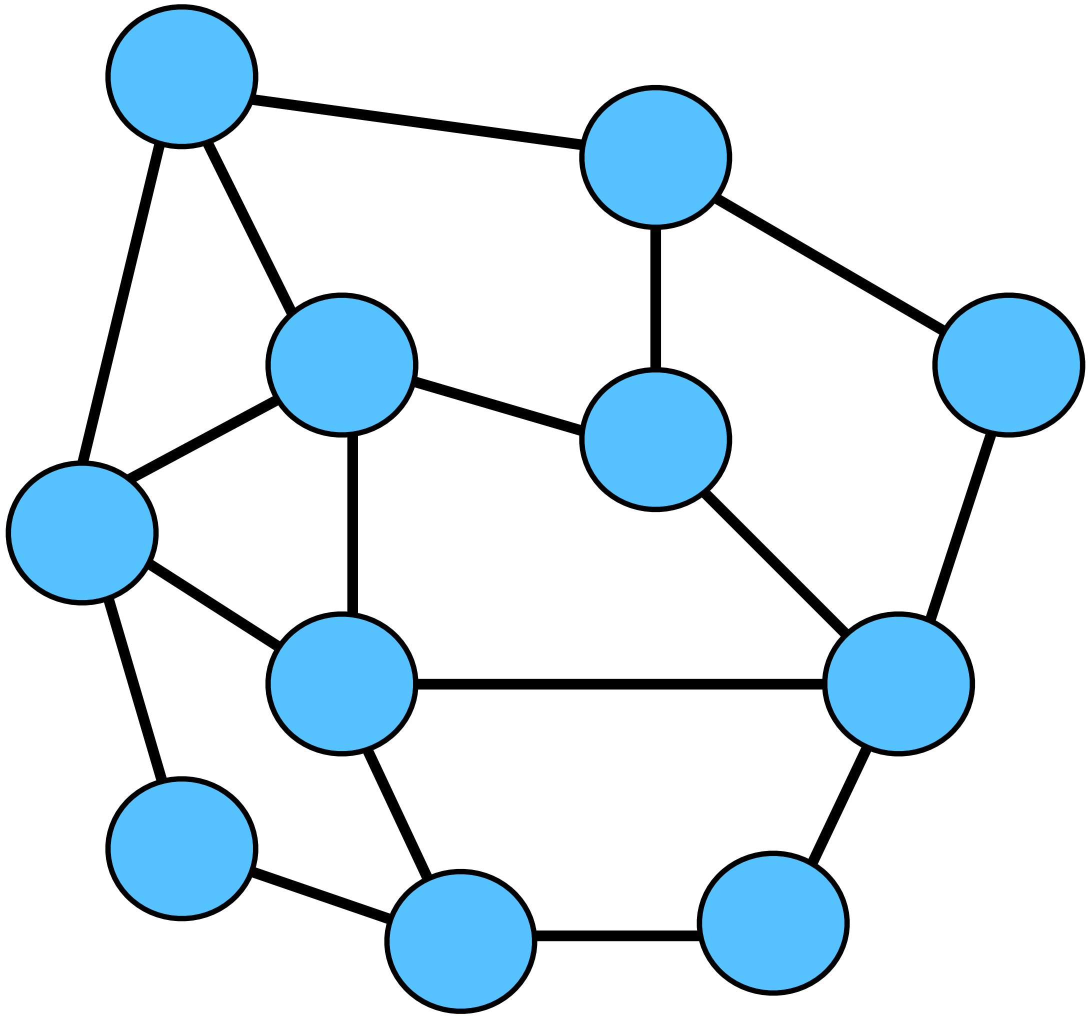
Forks and longest chain rule

Forks

- A fork is if multiple blocks have the same predecessor



- Why: Two blocks found “concurrently”



Forks

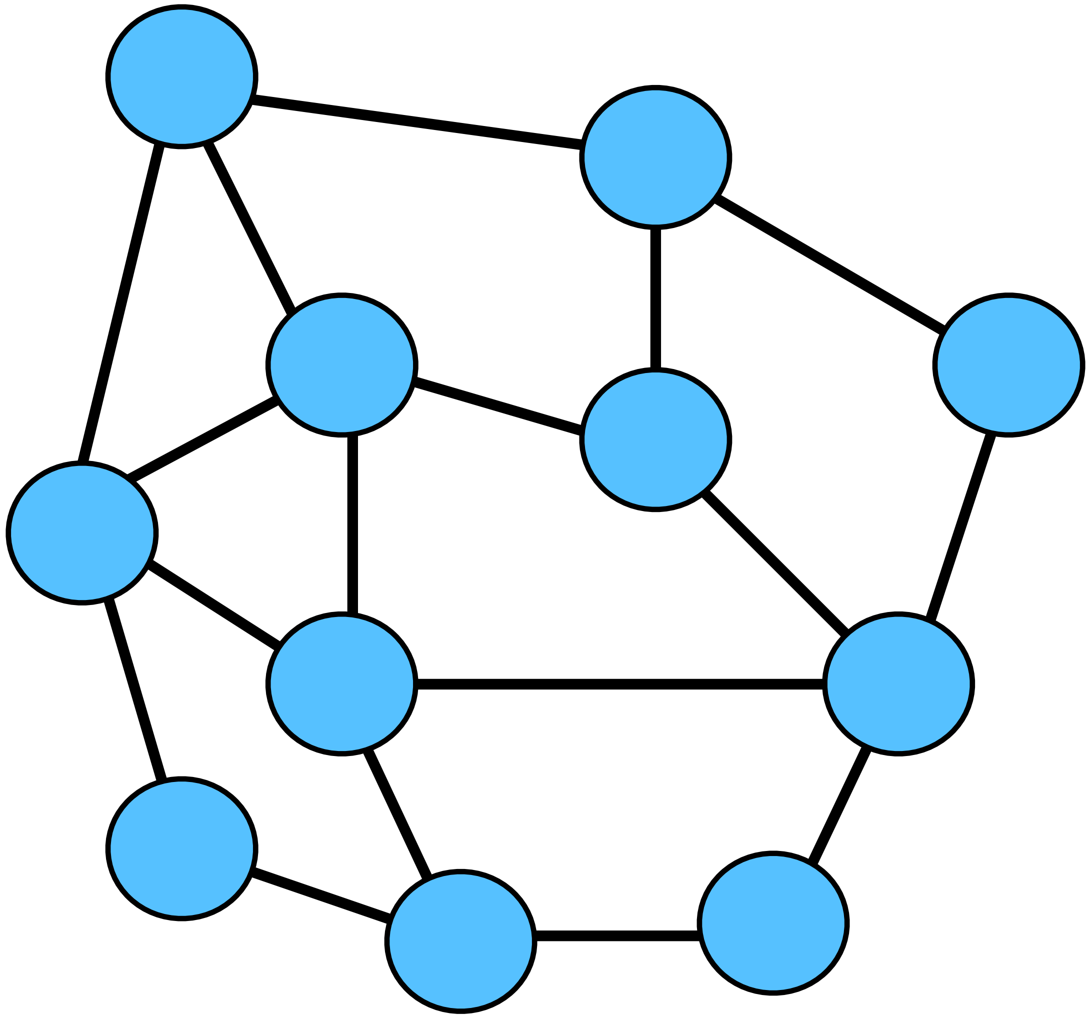
Proof of work workflow

Every node does:

- collect transaction to form block data
- try to solve PoW (*find nonce*)
- the first to solve PoW publishes block to everybody

another block found
before end of propagation

- all check PoW,
  validate Block,
  apply transactions,
  continue



Forks

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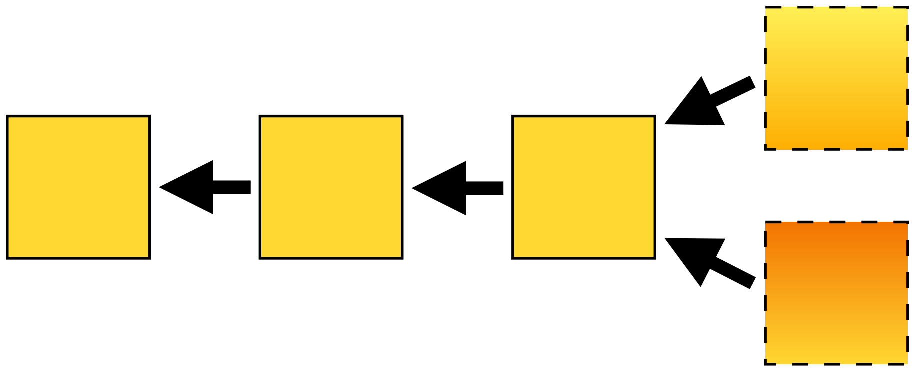
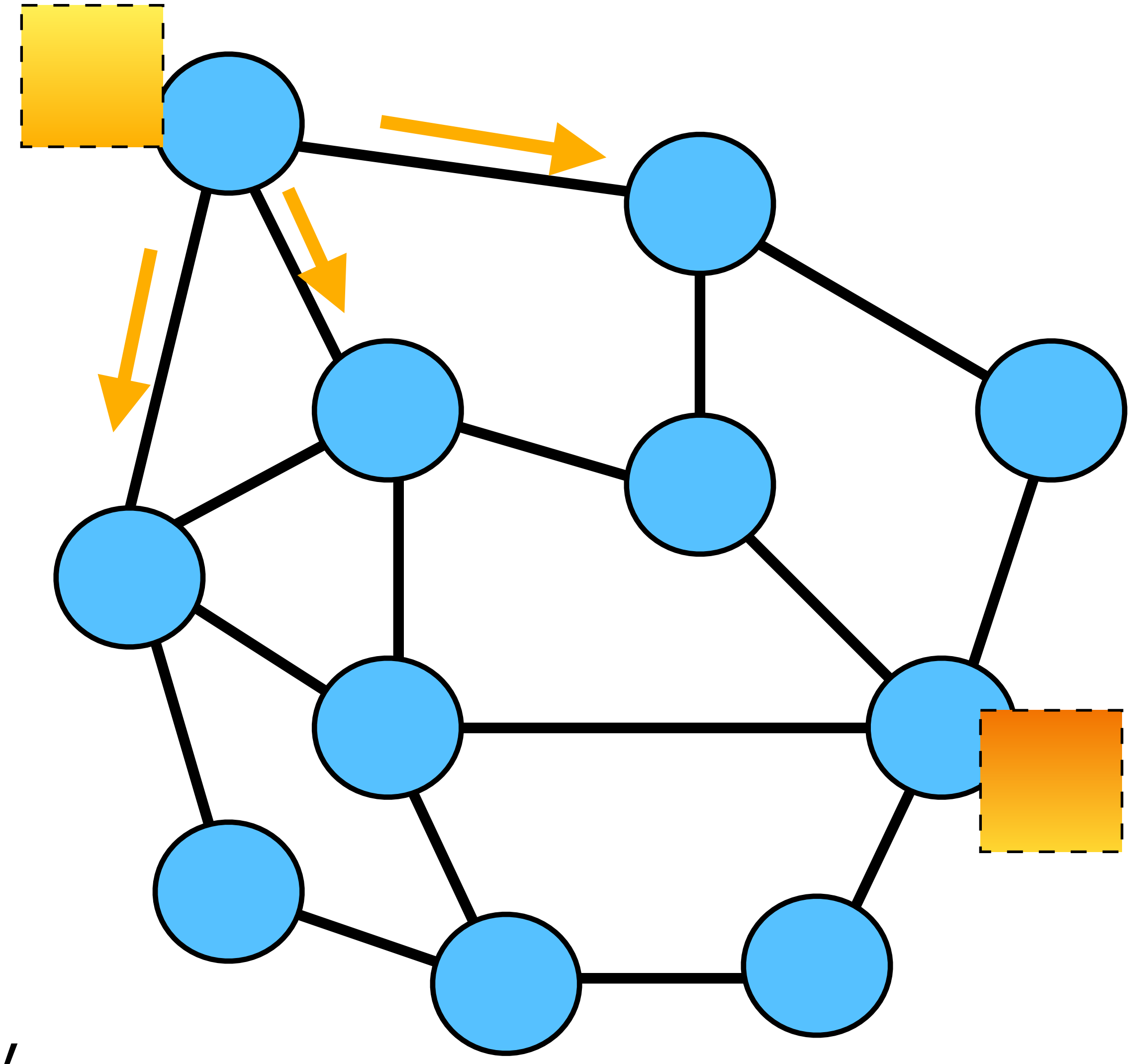




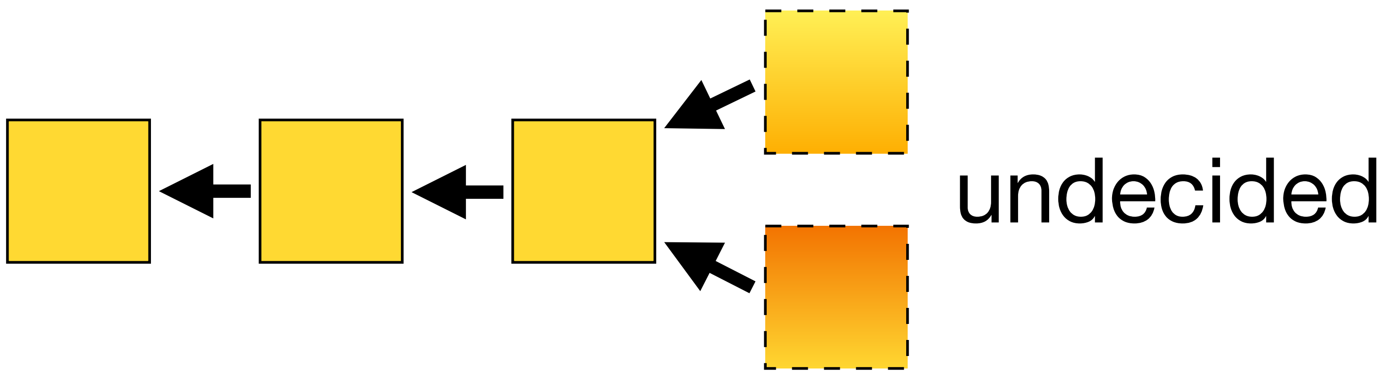
- Why: Two blocks found “concurrently”

- Bitcoin 2013: avg. 12.6sec block delivery [Decker, Wattenhofer]

Forks

Longest chain rule

- If a fork exists, all nodes should adopt the longest chain.



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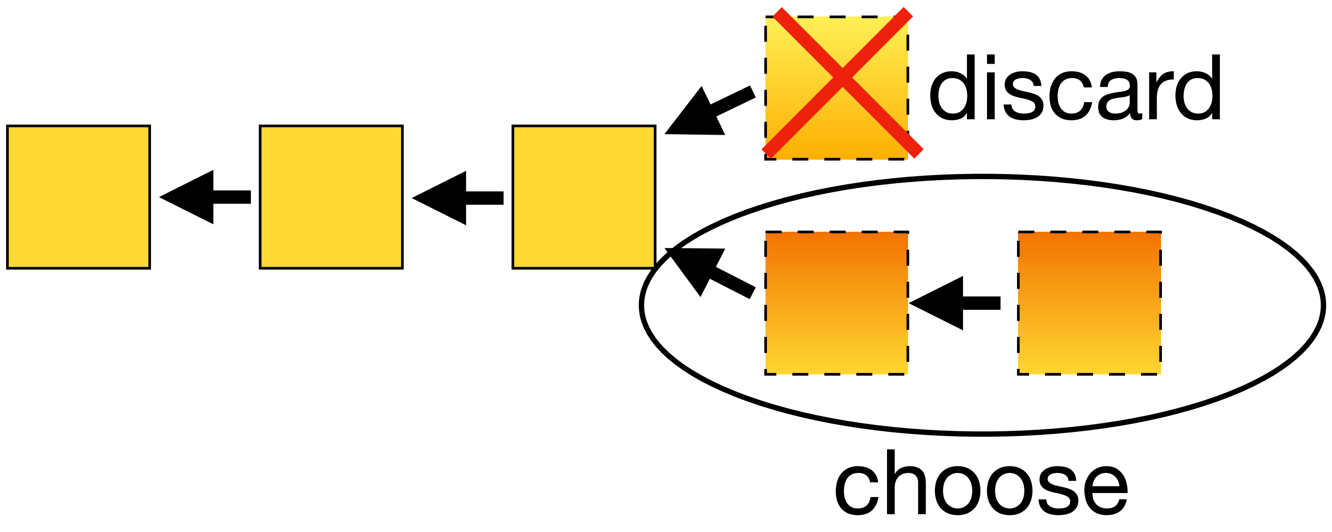


Forks

Longest chain rule

- If a fork exists, all nodes should adopt the longest chain.

Problems:

- Blocks & Transactions in smaller chain are discarded
    - Miners loose reward
    - Some transactions may be only in one fork
    - Two conflicting transactions may be included in different forks (double spend)

Forks

Math: How likely is a fork

p_{sec} probability a block is found in one second

δ average time to get a block from the network

Theorem:

$$P[\text{fork}] = 1 - (1 - p_{sec})^{\delta}$$

Forks

Reparametrization

Fork probability depends on

- Network delay
  time to propagate a block
- PoW difficulty

lower difficulty → more forks

lower difficulty → faster blocks → more throughput

Forks

Reparametrization

Fork probability depends on

- Network delay
  time to propagate a block
- PoW difficulty

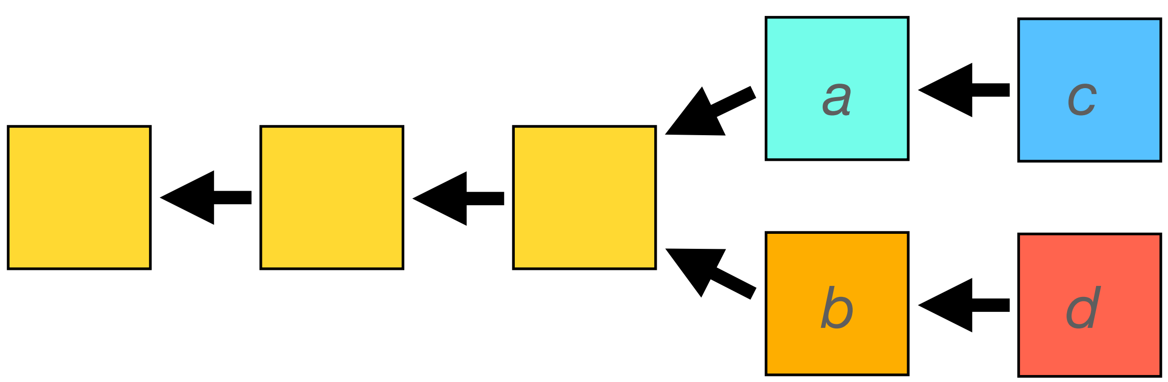
larger blocks → more throughput

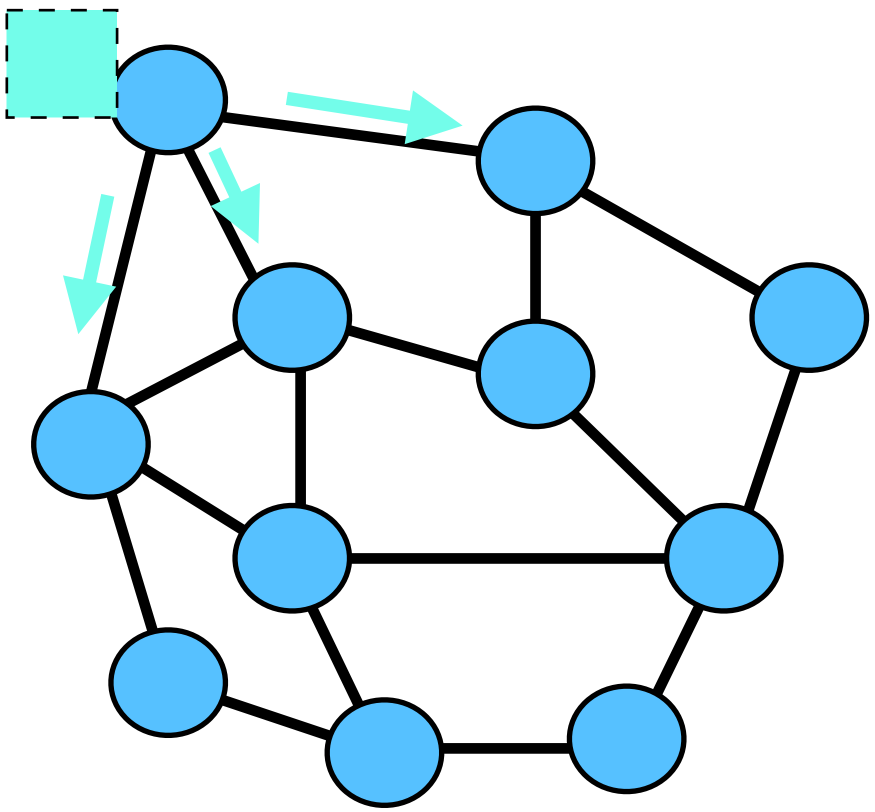
larger blocks → slow propagation → more forks

Forks

Multiple forks

- Multiple forks may arrise after each other.
- E.g. *b* found while *a* was propagated,
  - *d* found while *c* was propagated.





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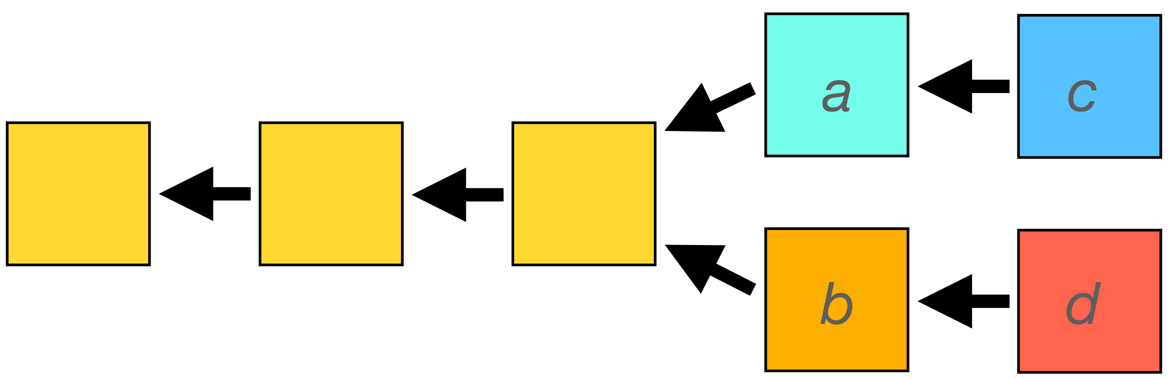

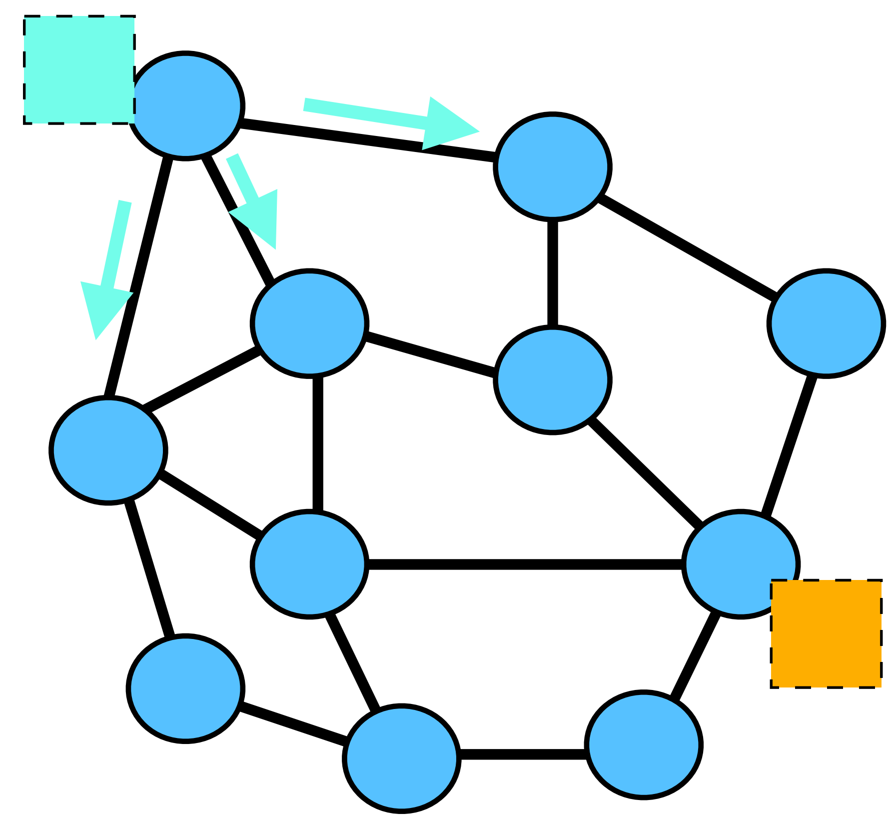

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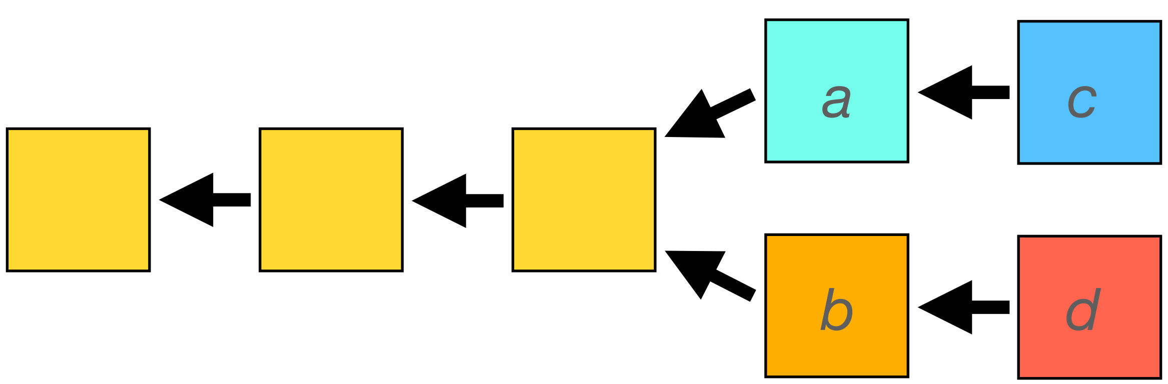

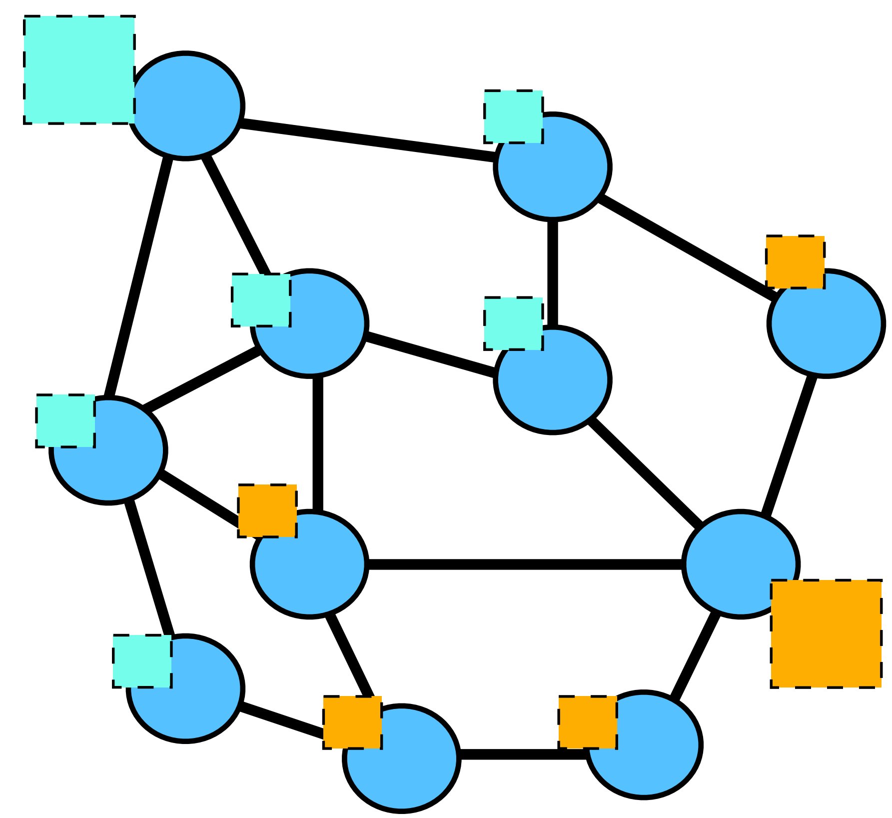

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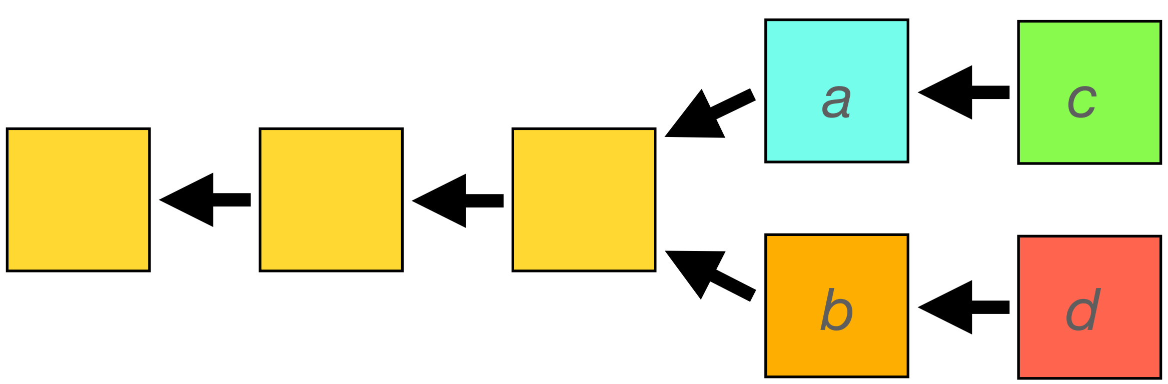

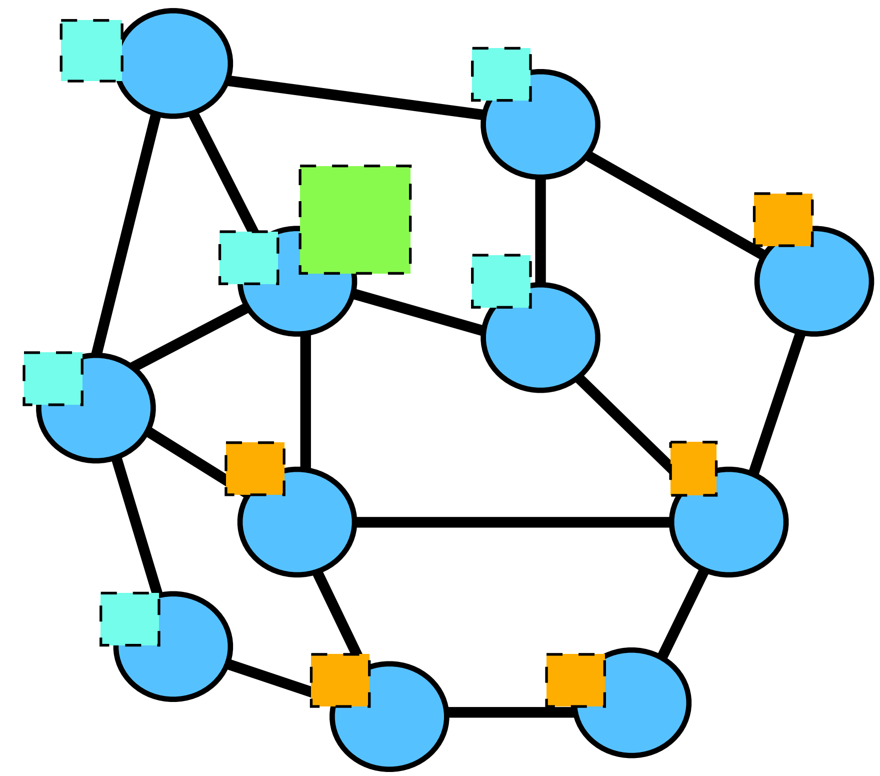

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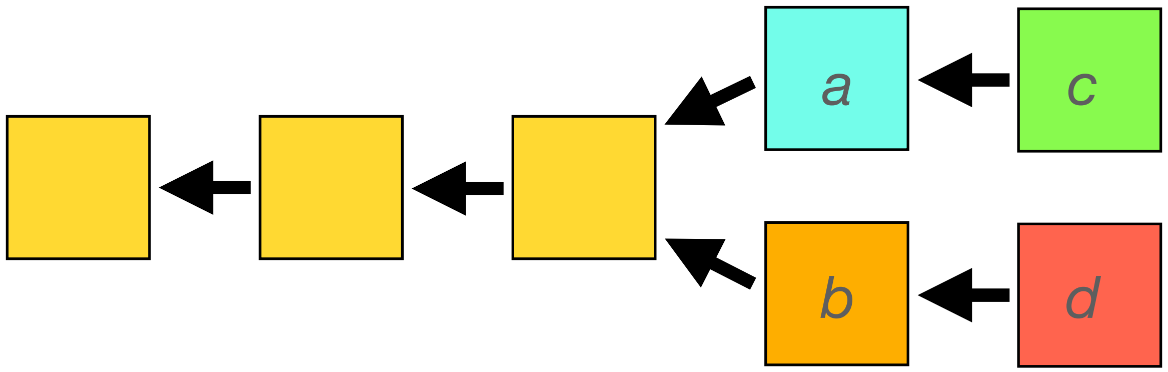
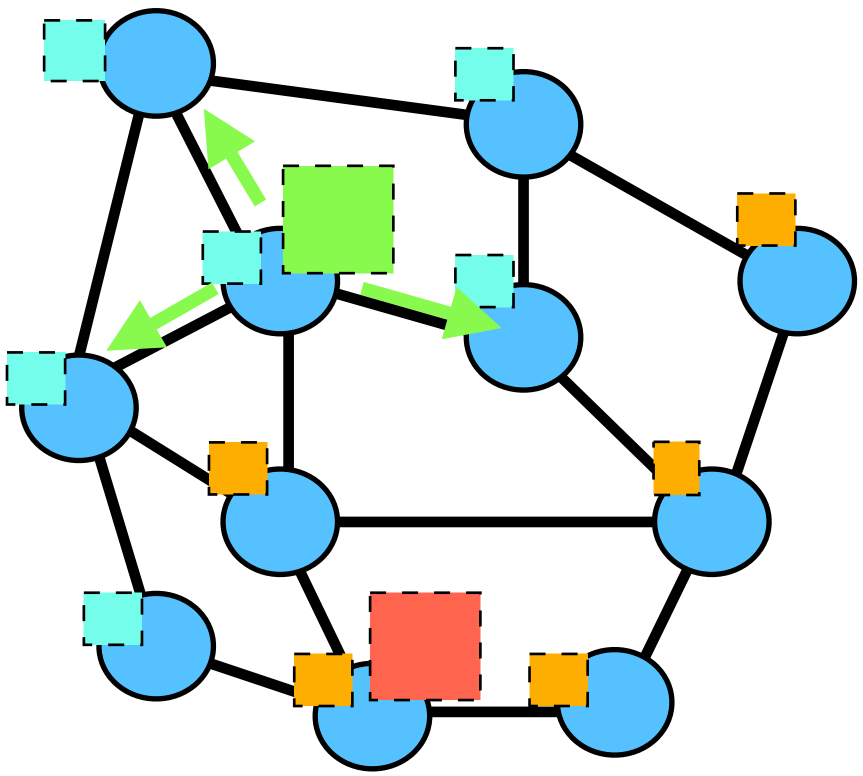


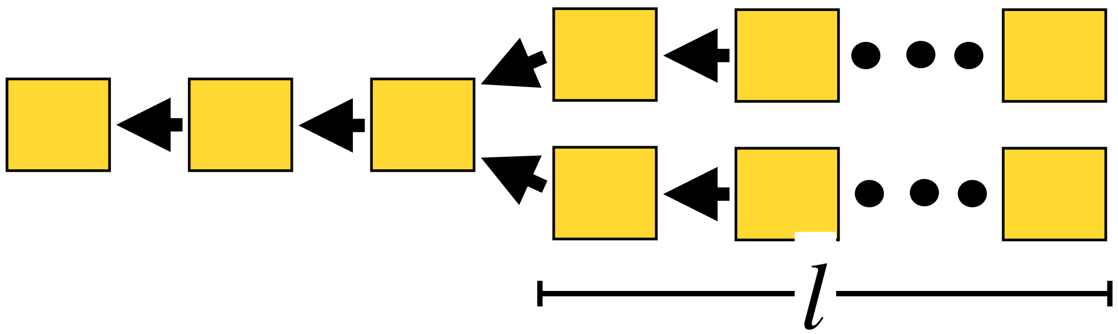


- Probability for second for smaller than the first.

Forks

Multiple forks

- Multiple forks may arrise after each other.
- Probability for second for smaller than the first.
- Probability for l forks decreases exponentially
- $P[l \times \text{fork}] \leq P[\text{fork}]^l$



Wait for l blocks to consider a transaction confirmed.

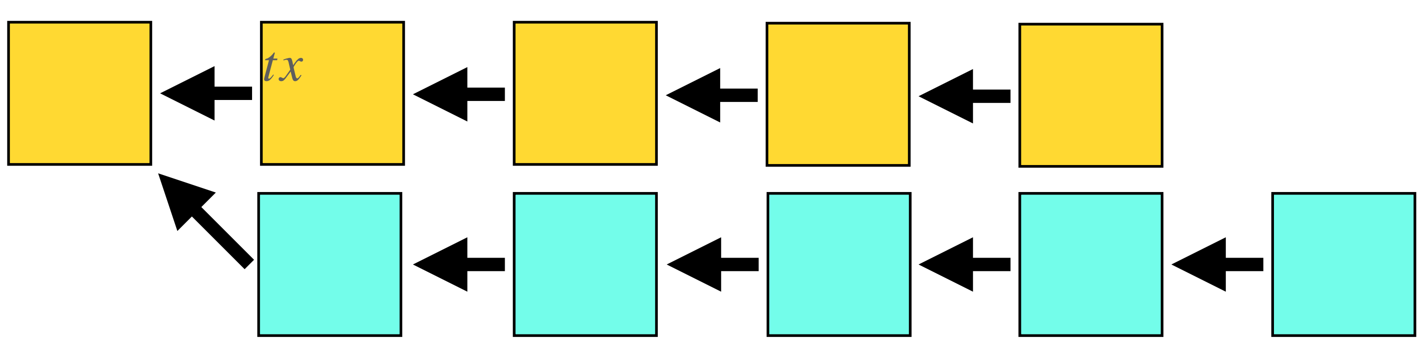
Attacks

Attacks

51% attack

- Assume the attacker has $\alpha > 50\,\%$ of the hashing power.
  - Attacker can grow a private chain faster than the public chain.

A private chain is a fork with blocks not propagated through the network.



Attacker can:
- Double spend
- Get all the reward

Attacks

Stubborn mining:

- Attacker does not follow longest chain rule.

Selfish mining:

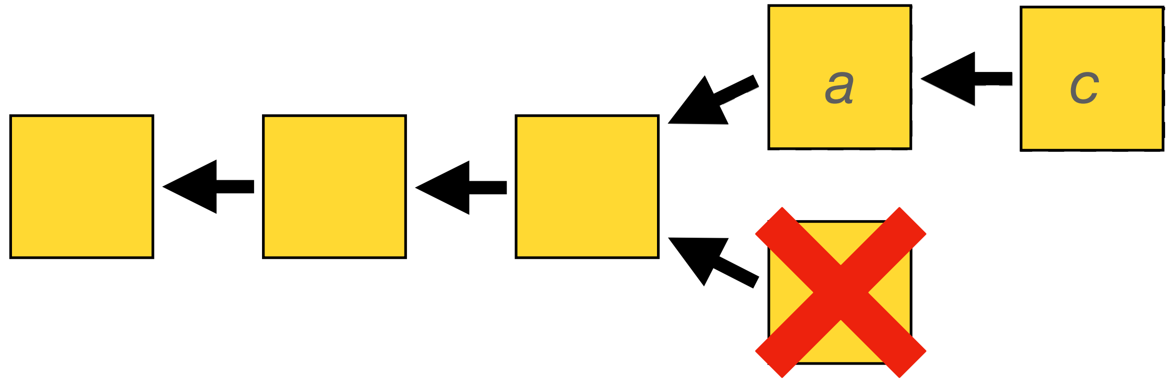
- Attacker keeps blocks secret.

Attacks

Selfish mining

Case 1, successfull attack:

1. attacker finds block *a,* keeps it secret
2. attacker finds block *c,* keeps it secret
3. other nodes find block *b* and propagate it
4. attacker propagates blocks *a* and *c*

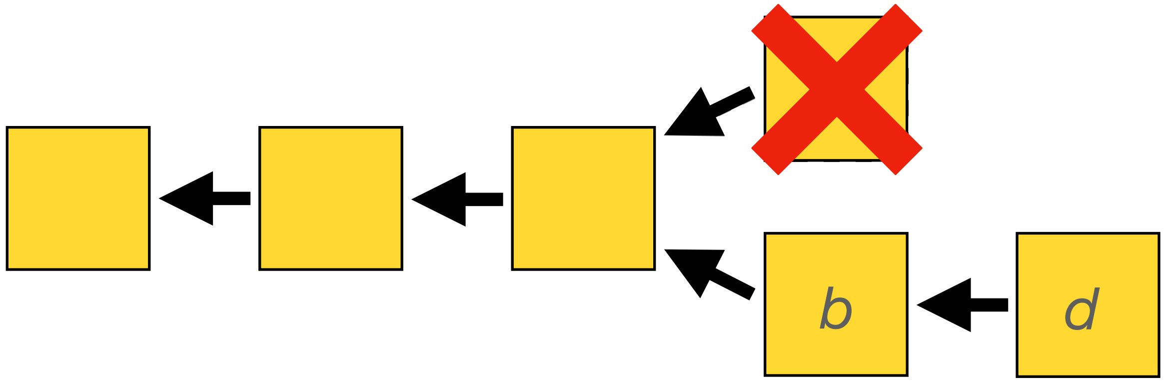


Attacks

Selfish mining

Case 2, unsuccessfull attack:

1. attacker finds block *a,* keeps it secret
2. other nodes find block *b* and propagate it
3. attacker propagates block *a*
4. other nodes find block *d* extending *b*

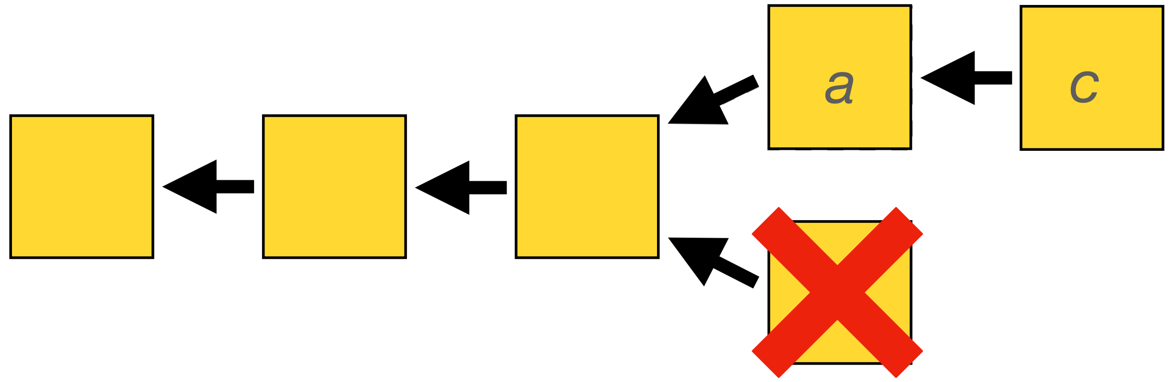


Attacks

Selfish mining

Case 3, kind of successfull attack:

1. attacker finds block *a,* keeps it secret
2. other nodes find block *b* and propagate it
3. attacker propagates block *a*
4. some node finds block *c* extending *a*

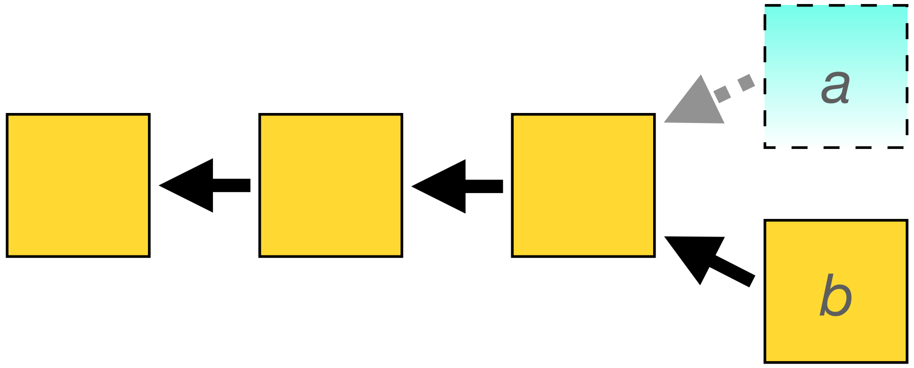


Attacks

Selfish mining

To get Case 3 instead of Case 2 attacker needs to

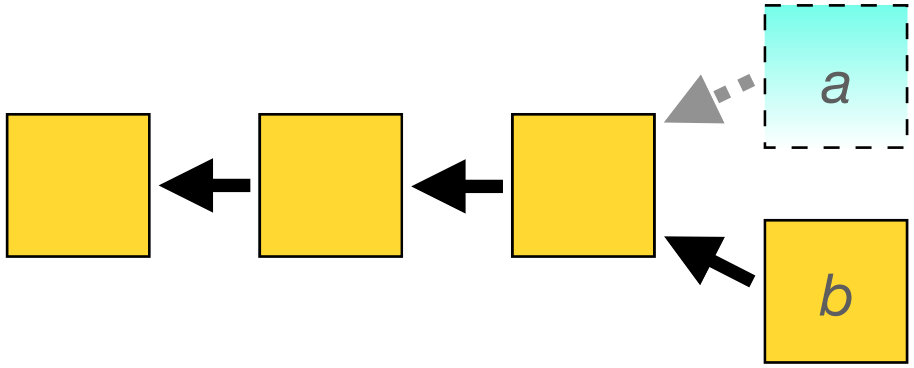
- detect new blocks fast
- propagate its block faster



Attacks

Selfish mining

- Attacker does not get more blocks, but others get less.
- Good control of network makes attack work better.



Attacks

Selfish mining

Algorithm 6 Selfish mining

Idea: Mine secretly, without immediately publishing newly found blocks
Let l_p be length of the public chain
Let l_s be length of the secret chain
if a new block b_p is published, i.e. l_p has increased by 1 **then**
    if $l_p > l_s$ **then**
        Start mining on b_p
    else if $l_p = l_s$ **then**
        Publish secretly mined block b_s
        Mine on b_s and immediately publish new block
    else if $l_p = l_s - 1$ **then**
        Push all secretly mined blocks

Attacks

Selfish mining

α the attackers hashing power, and
γ be the attackers network power.

Selfish mining is profitable, if

$$\alpha > 0.33$$

$\alpha > 0.25$ and $\gamma > 0.5$

$\alpha > 0$ and $\gamma = 1$

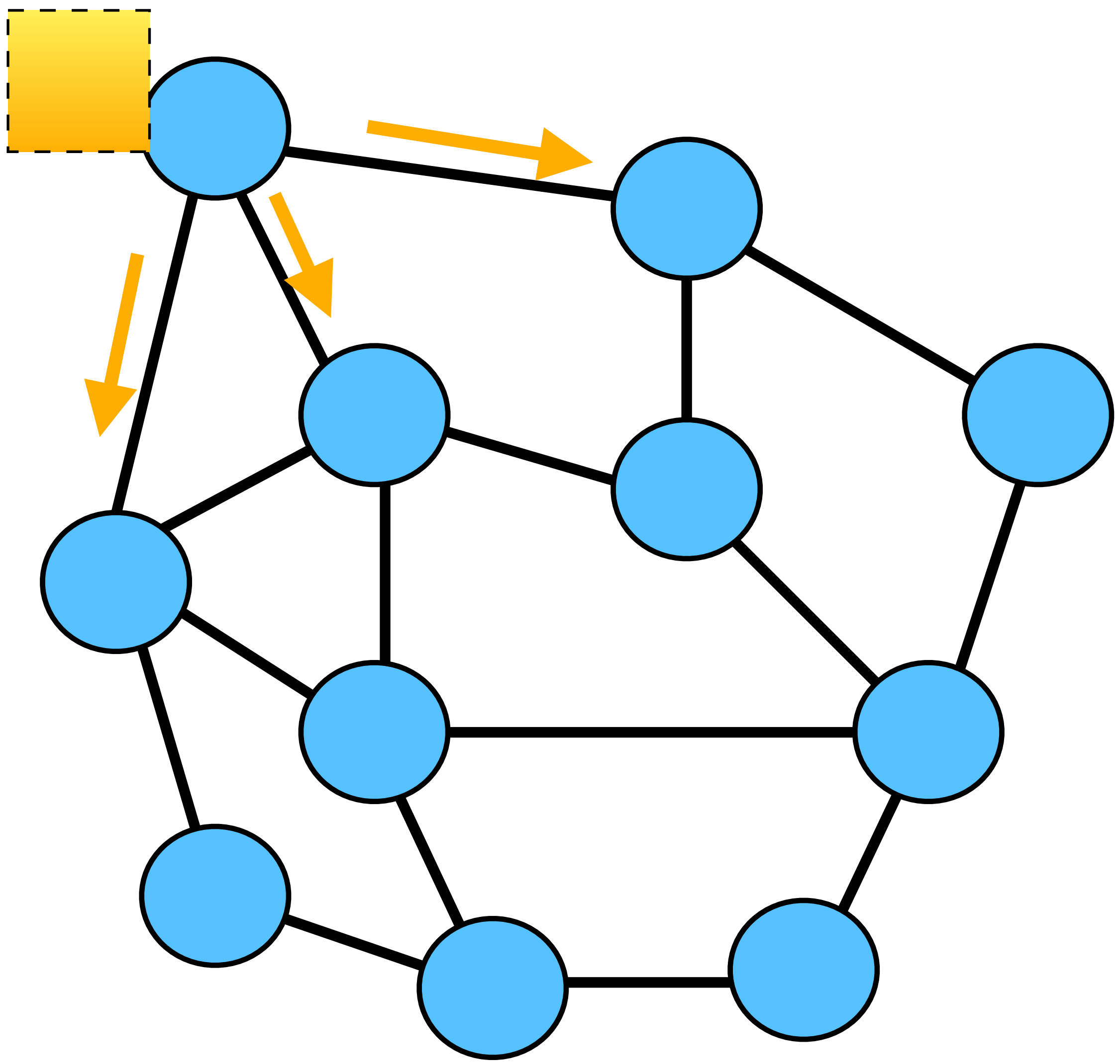
Attacks

Delivery denial

Broadcast block:

- Broadcast inventory message including block hash
- Receiving new inventory, request block
- Send block

Block is only send from one neighbor



Attacks

Delivery denial

Broadcast block:

- Broadcast inventory
- Request block
- Send block

Attack

- Broadcast inventory
- Do not send out blocks

  Victims wait for timeout.

Bitcoin

Downsides

Throughput at most 7tx per second

Confirmation latency approx 1h

Enormous energy consumption