Blockchain Workshop

Learn Blockchain by Building One

Presenter: Samaneh Miri

July 30, 2021

Outline

- What is a Blockchain?

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- What is a Blockchain?
- Hash Cryptography

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- Immutable Ledger

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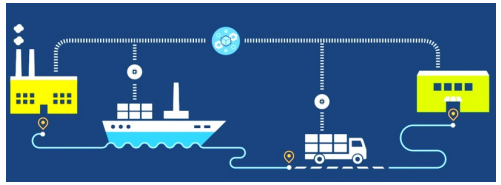
- Consensus Protocol

What is a Blockchain?

A blockchain is a growing list of records, called blocks, that are linked using cryptography (Wikipedia).

Blockchain Applications

- The blockchain technology first came into the spotlight through bitcoin.
- The technology is not only for cryptocurrencies.
- Features:
  - Immutability
  - Decentralized
  - Enhanced Security



What is a Blockchain?

Stuart Haber

W. Scott Stornetta

How to Time-Stamp a Digital Document*

Stuart Haber
stuart@bellcore.com

W. Scott Stornetta
stornetta@bellcore.com

Year: 1991

Goal: to implement a system where document timestamps could not be tampered with.

What is a Blockchain?

Bitcoin: A Peer-to-Peer Electronic Cash System

Satoshi Nakamoto
satoshin@gmx.com
www.bitcoin.org

Year introduced: 2008
Year Implemented: 2009

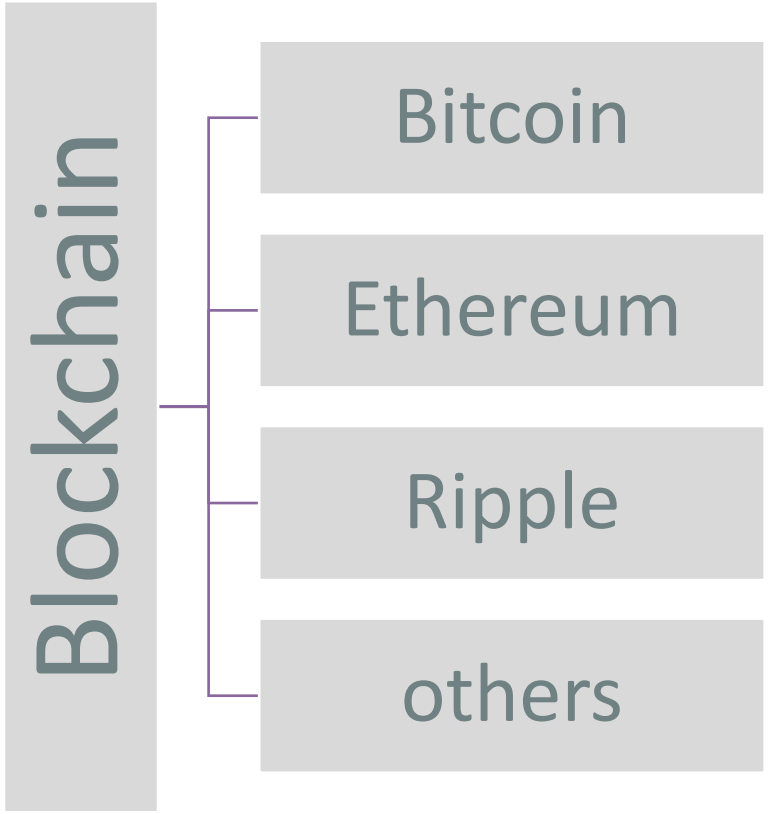
Goal: to timestamp blocks without requiring them to be signed by a trusted party and introducing a difficulty parameter to stabilize rate with which blocks are added to the chain.

What is a Blockchain?

Technology → Blockchain

Protocol → Bitcoin

What is a Blockchain?



What is a Blockchain?

A blockchain is a growing list of records, called blocks, that are linked using cryptography (Wikipedia).

Block

1. Index:
2. Timestamp:
3. Data:
4. Prev. Hash:
5. Hash:

What is a Blockchain?

A blockchain is a growing list of records, called blocks, that are linked using cryptography (Wikipedia).

Block

1. Index:
2. Timestamp:
3. Data:
4. Prev. Hash:
5. Hash:

Hash of data is like a fingerprint of a human being.

What is a Blockchain?

- A sequence of **linked blocks** creates **a chain.**

Genesis Block

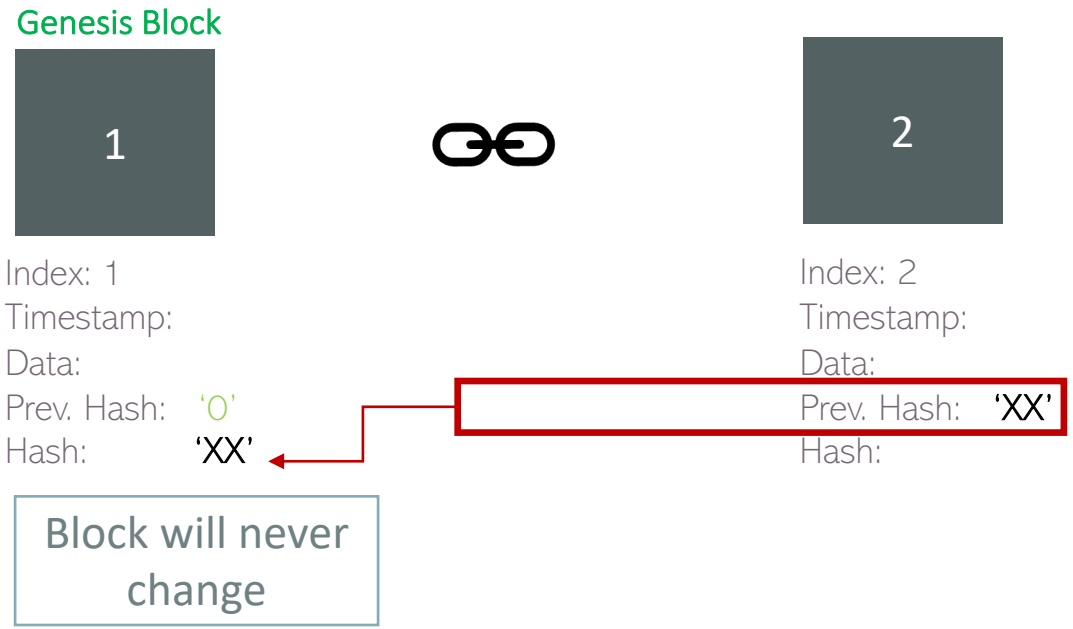
1

Index: 1
Timestamp:
Data:
Prev. Hash: '0'
Hash:

Block will never change

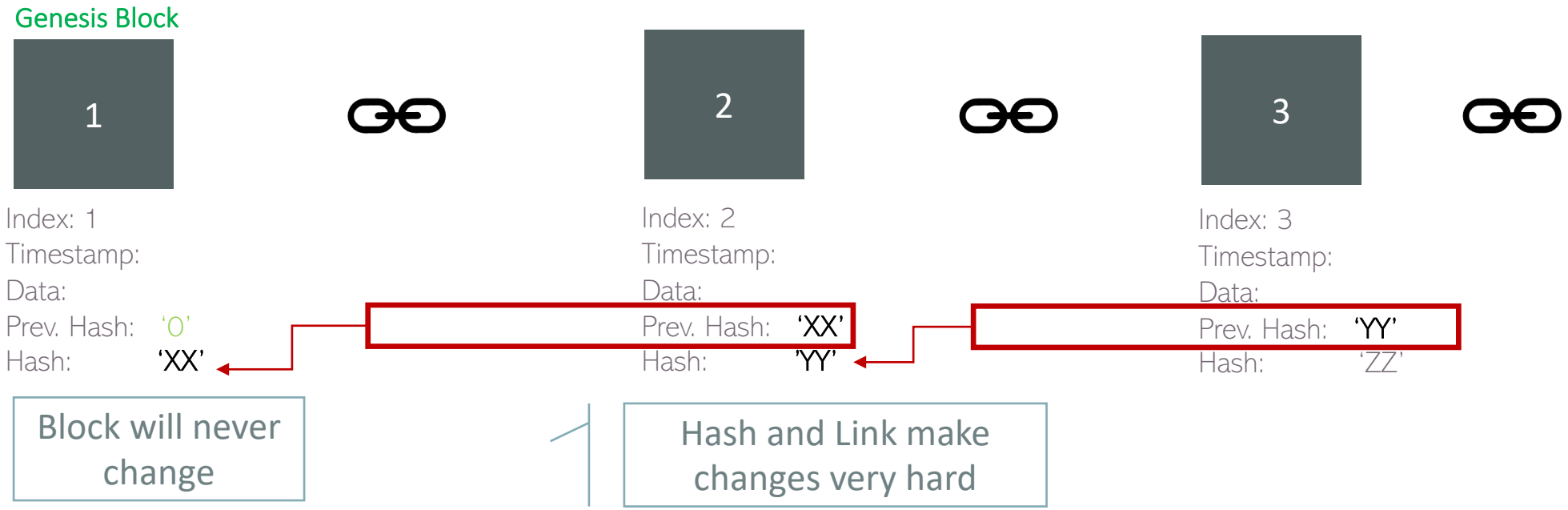
What is a Blockchain?

- A sequence of **linked blocks** creates **a chain.**



What is a Blockchain?

- A sequence of **linked blocks** creates **a chain.**



What is a Blockchain?

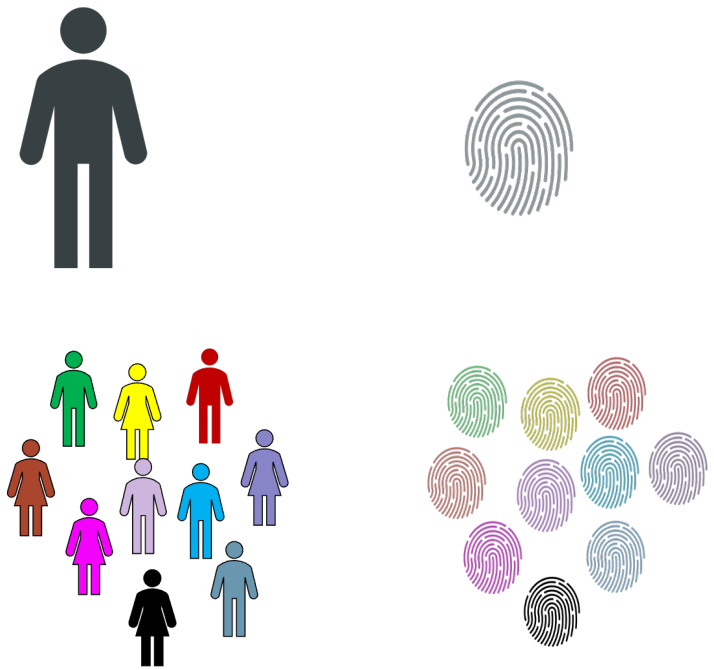
- Hash Cryptography
- Immutable Ledger
- Distributed P2P Network
- Mining
- Consensus Protocol

Hash Cryptography

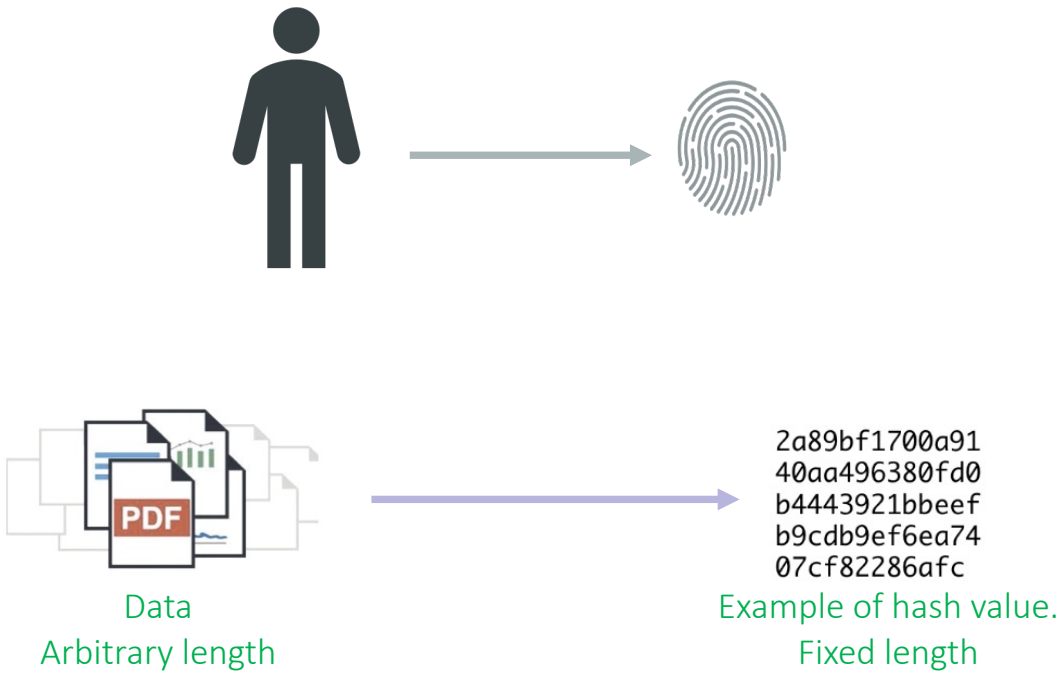
A hash function is a function which takes an arbitrary length input and produces a fixed length “fingerprint” string.

Hash Value

Different people have different fingerprints.

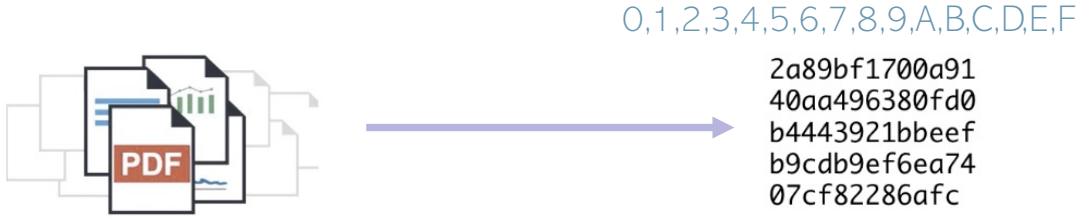


Hash Value


PDF
2a89bf1700a91
40aa496380fd0
b4443921bbeef
b9cdb9ef6ea74
07cf82286afc
Data
Arbitrary length
Example of hash value.
Fixed length

SHA256

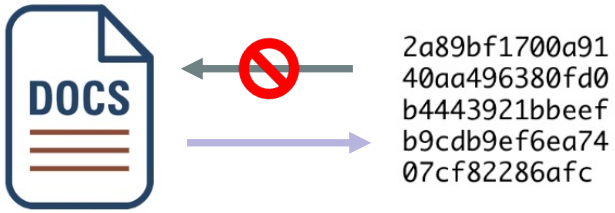
- Several cryptocurrencies use Secure Hash Function (SHA) family for verifying transactions or proof of work.
- Bitcoin uses SHA256.
- SHA256 is always 256 bits long, equivalent to 64 bytes in hexadecimal string format.



https://demoblockchain.org/hash

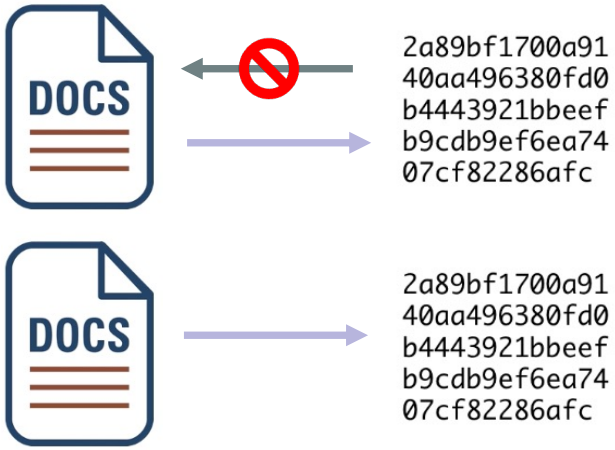
SHA256 Hash: Characteristics

- One-way



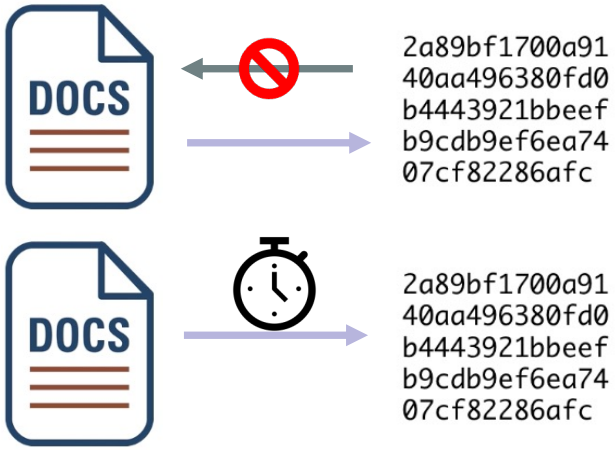
SHA256 Hash: Characteristics

- One-way
- Deterministic



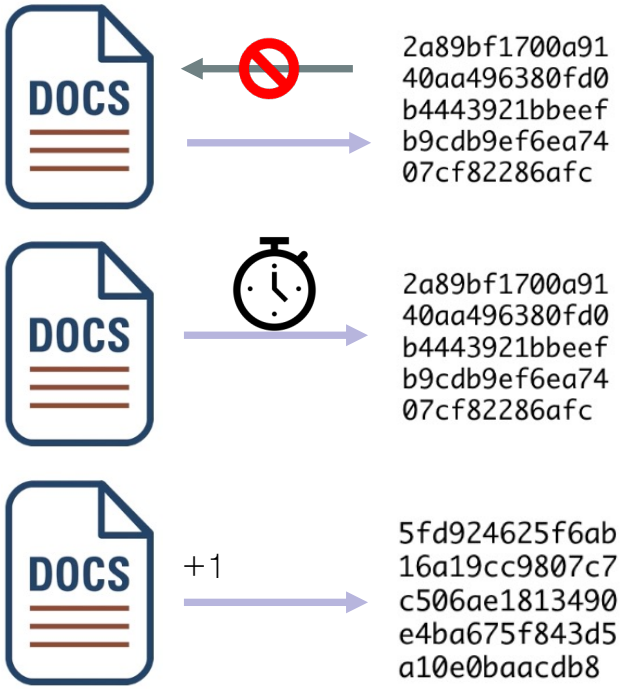
SHA256 Hash: Characteristics

- One-way
- Deterministic
- Fast Computation



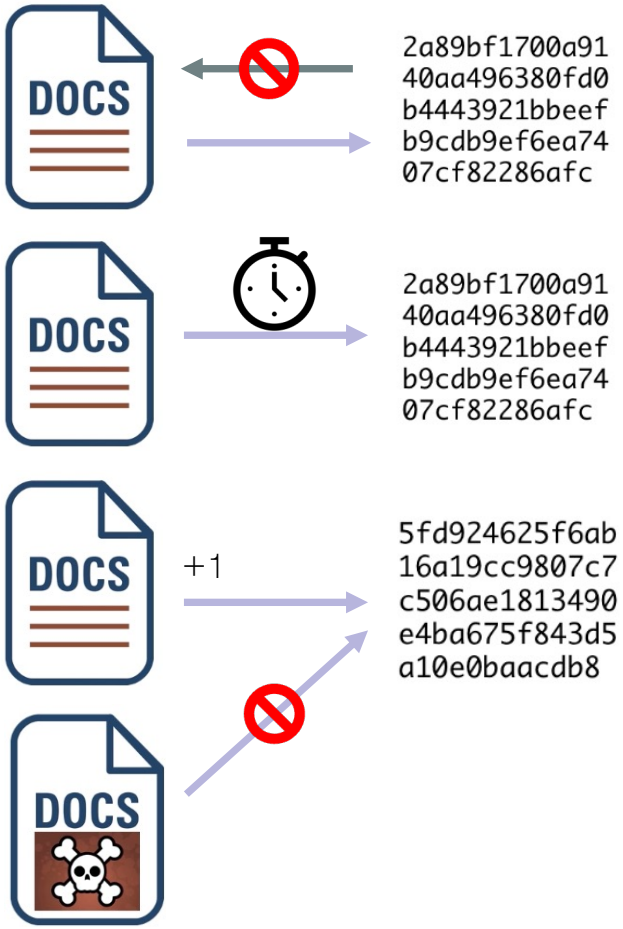
SHA256 Hash: Characteristics

- One-way
- Deterministic
- Fast Computation
- Avalanche Effect



SHA256 Hash: Characteristics

- One-way
- Deterministic
- Fast Computation
- Avalanche Effect
- Must withstand collision



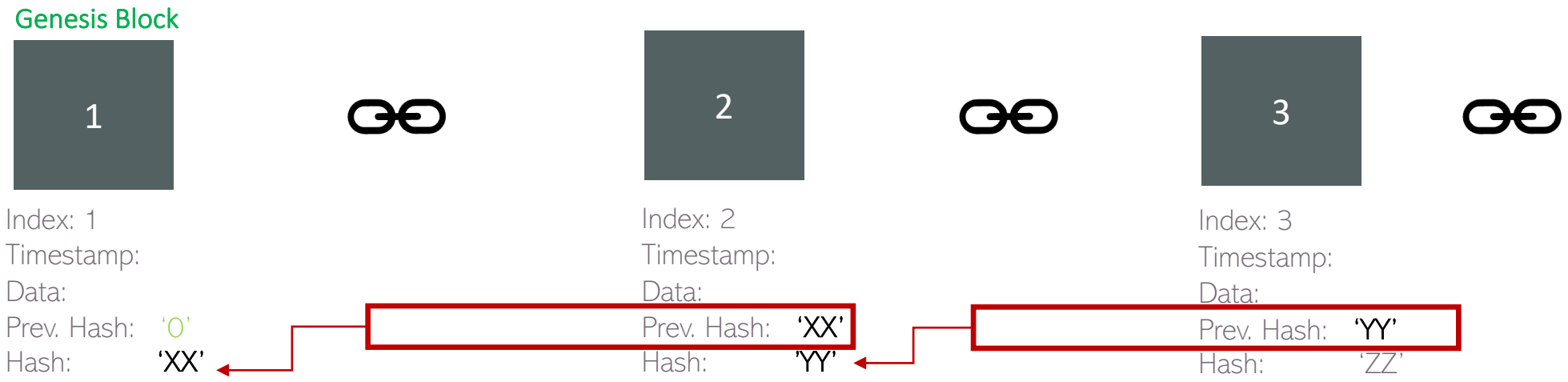
Blockchain Components

- Hash Cryptography
- Immutable Ledger
- Distributed P2P Network
- Mining
- Consensus Protocol

Immutable Ledger

An Immutable Ledger is a record that cannot be changed.

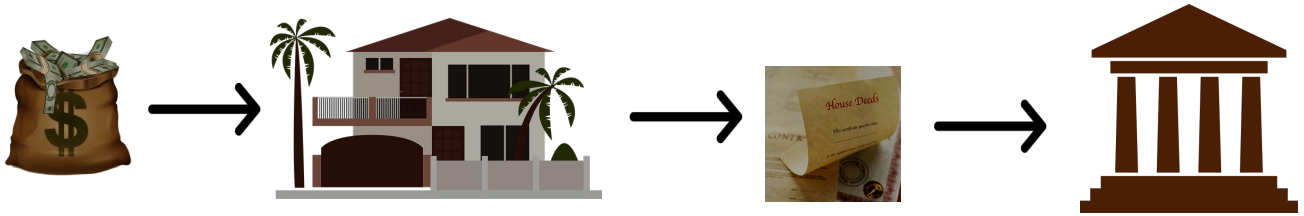
Immutable Ledger



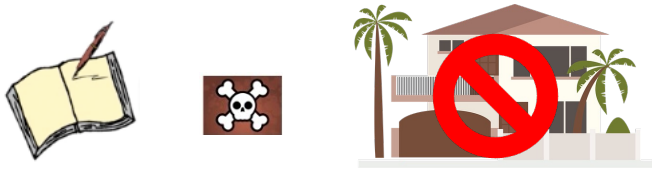
Blocks are cryptographically linked together.

Immutable Ledger

- Buying a house: from payment to a deed registration



- Traditional ledger



- Blockchain

Immutable Ledger

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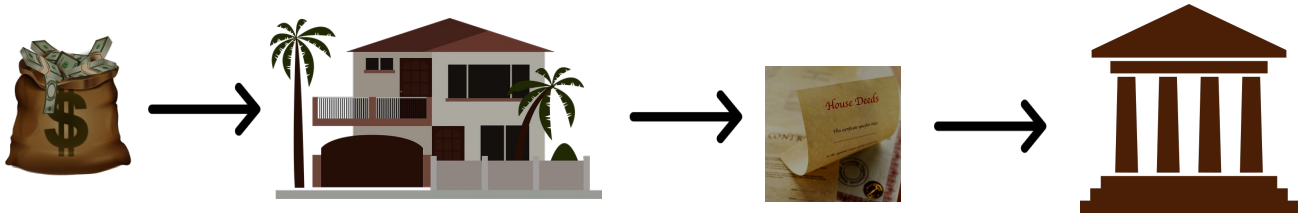
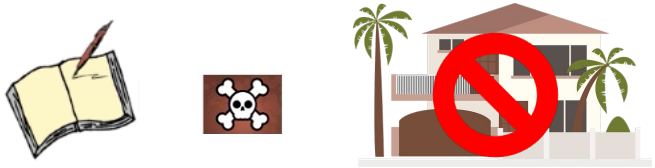


- Traditional ledger



- Blockchain

Immutable Ledger

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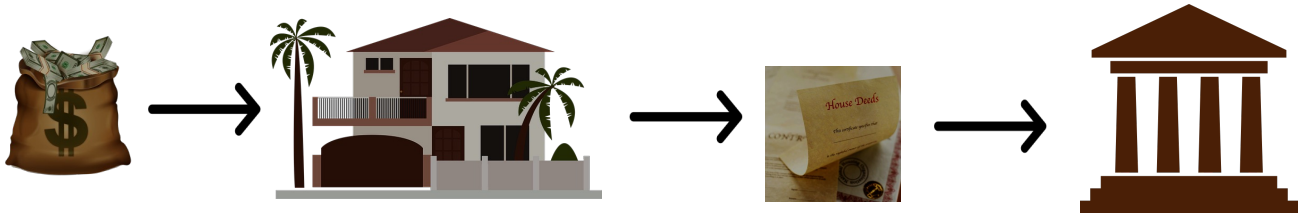

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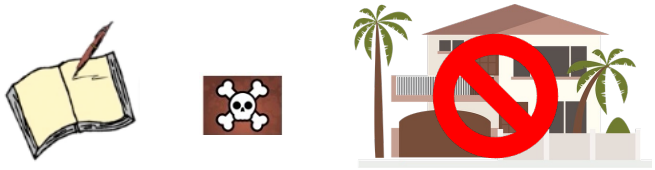
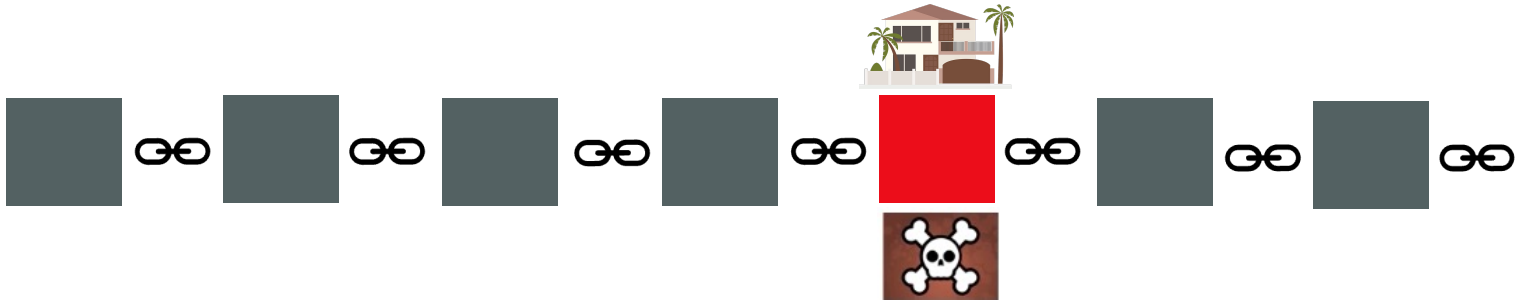


- Blockchain



Immutable Ledger

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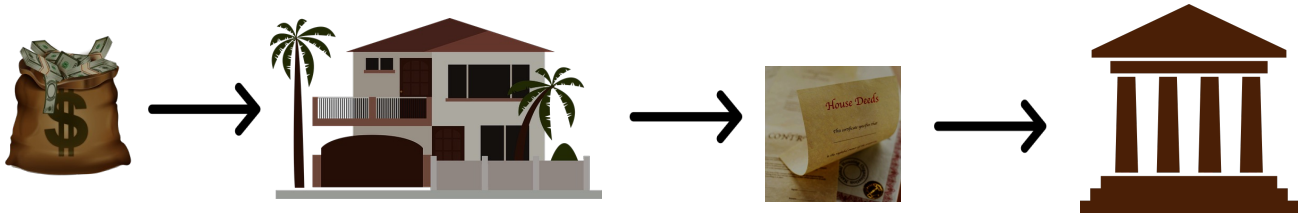

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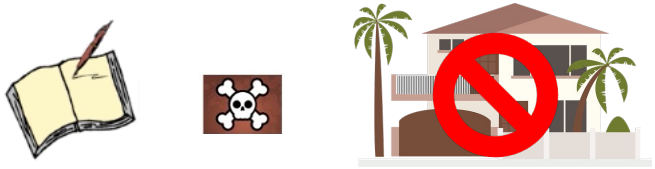
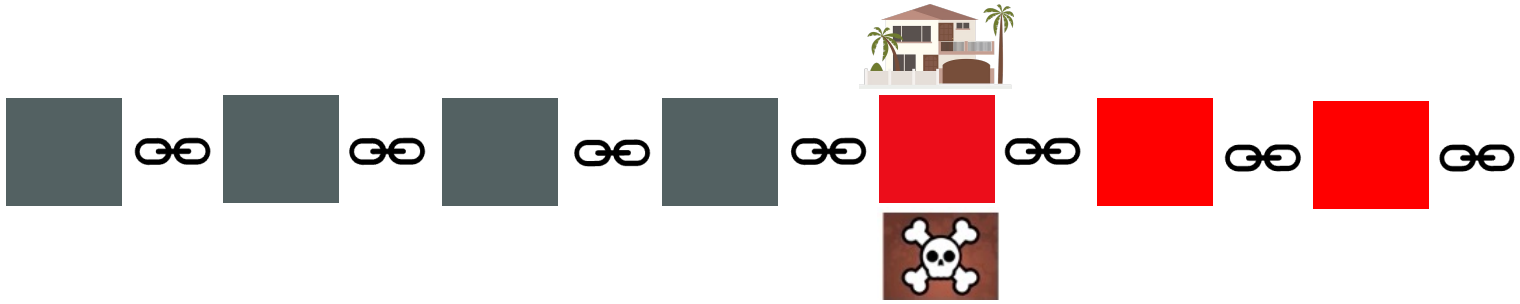


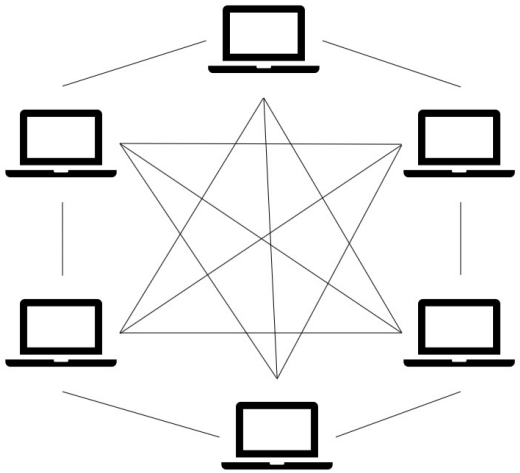
- Blockchain



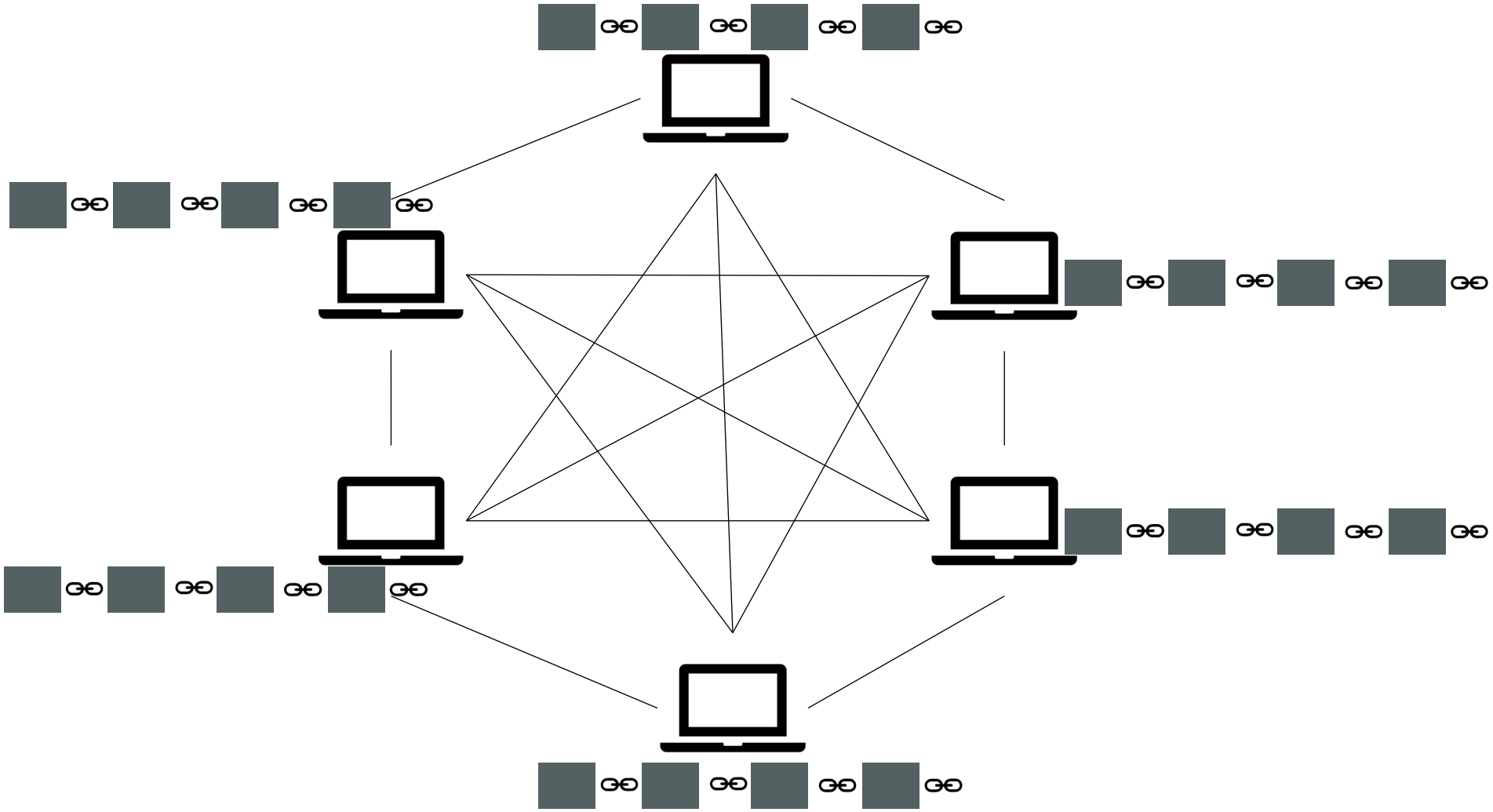
Blockchain Components

- Hash Cryptography
- Immutable Ledger
- Distributed P2P Network
- Mining
- Consensus Protocol

Distributed P2P Network



Distributed P2P Network



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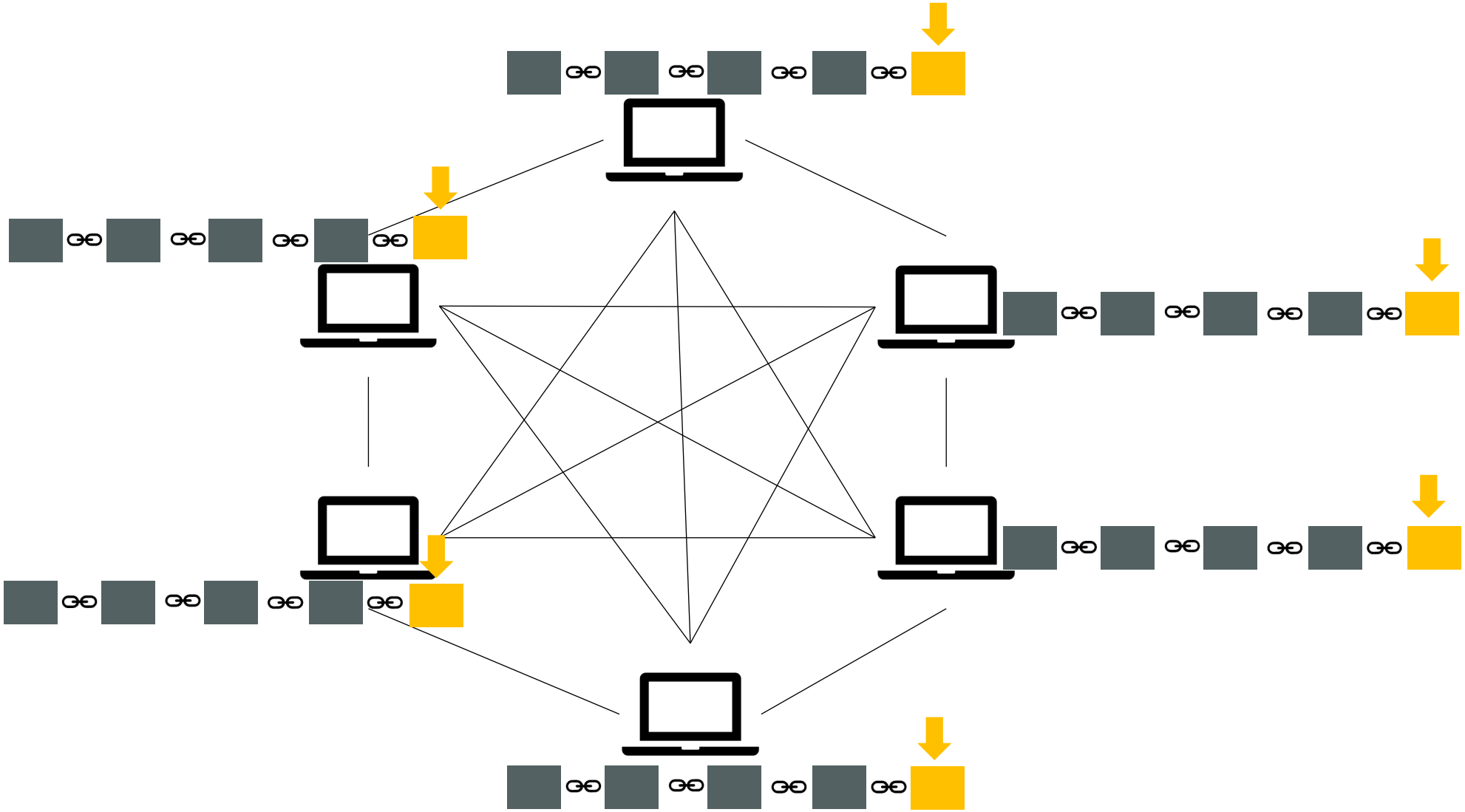

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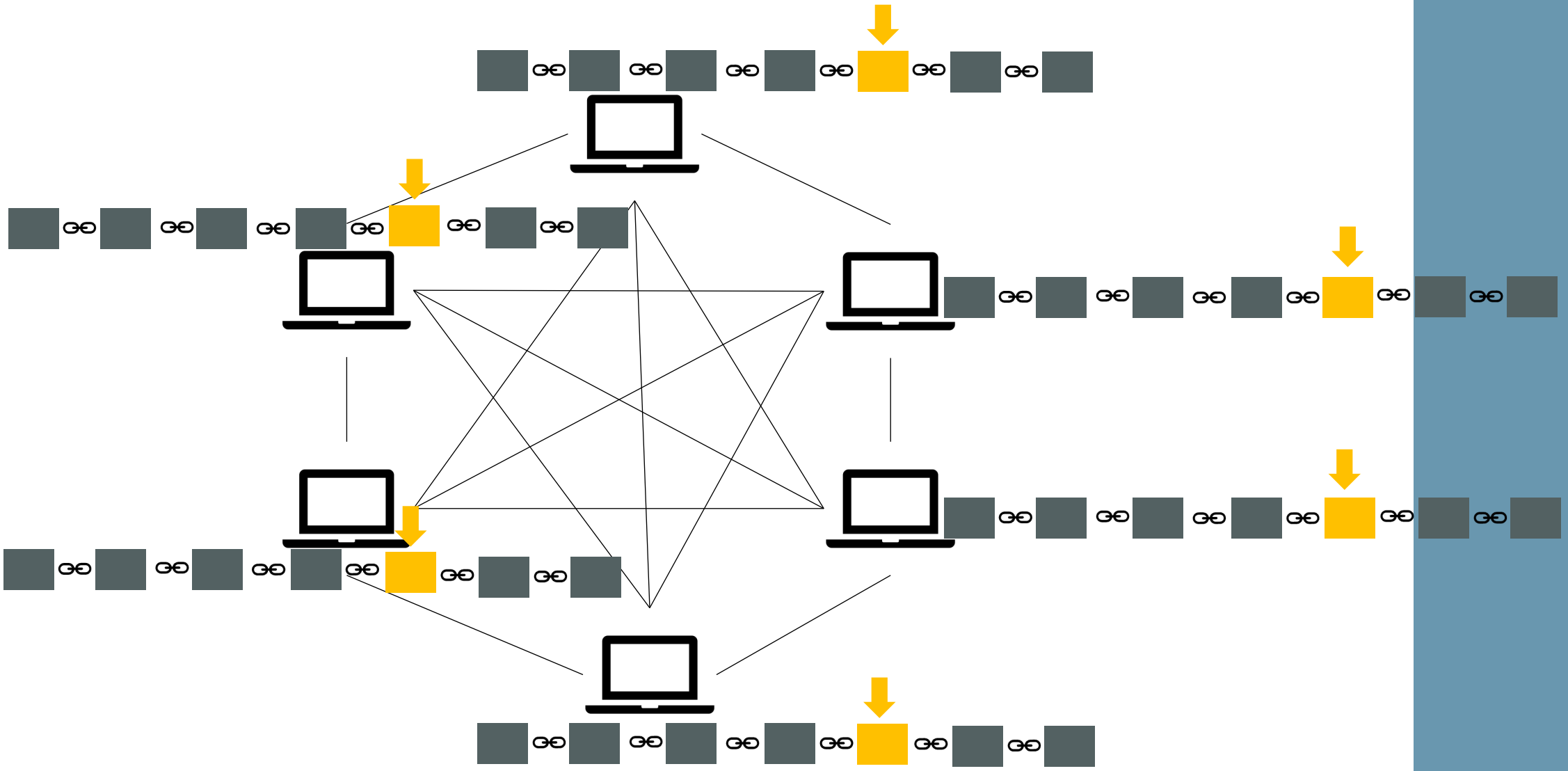

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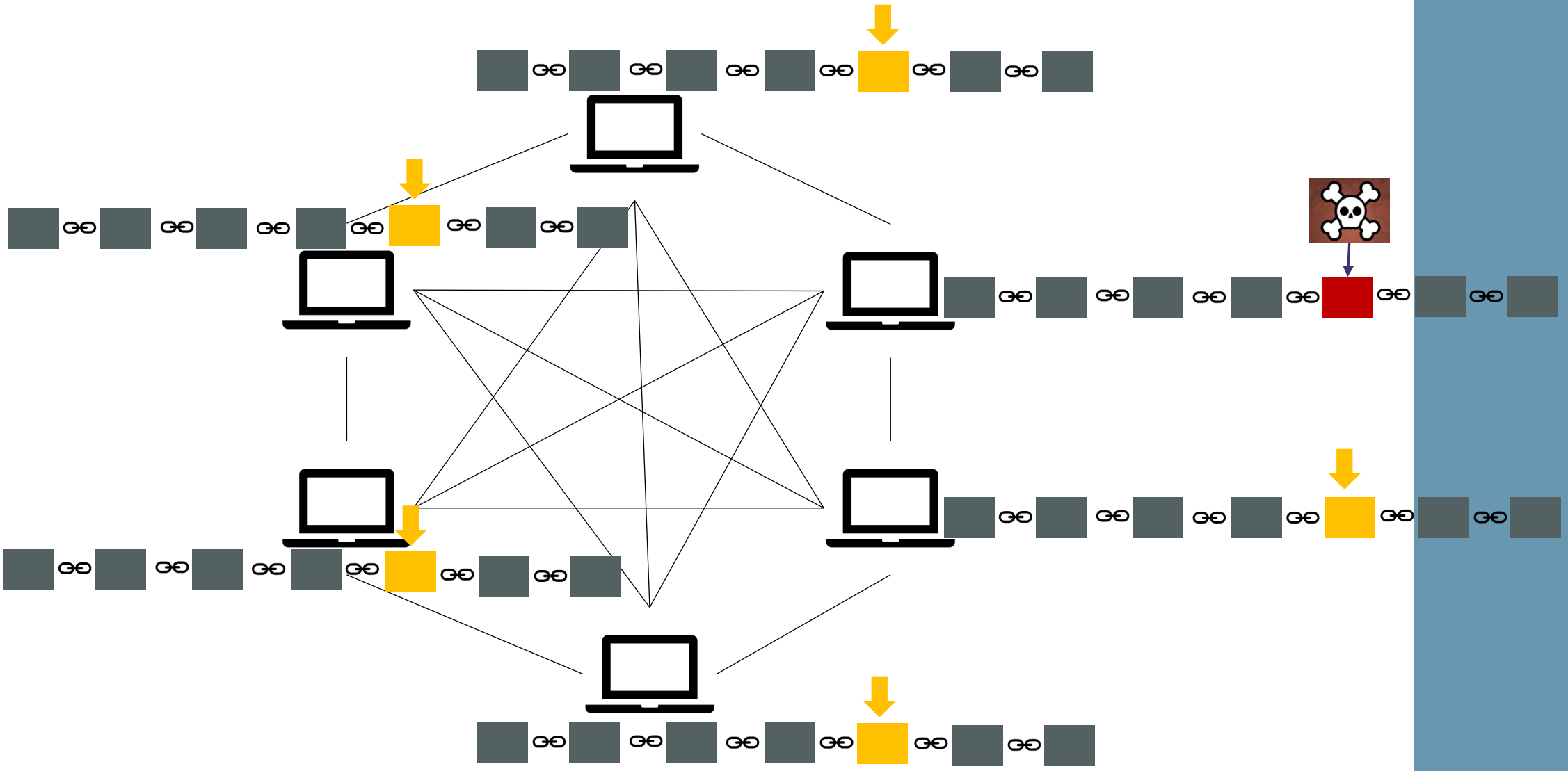
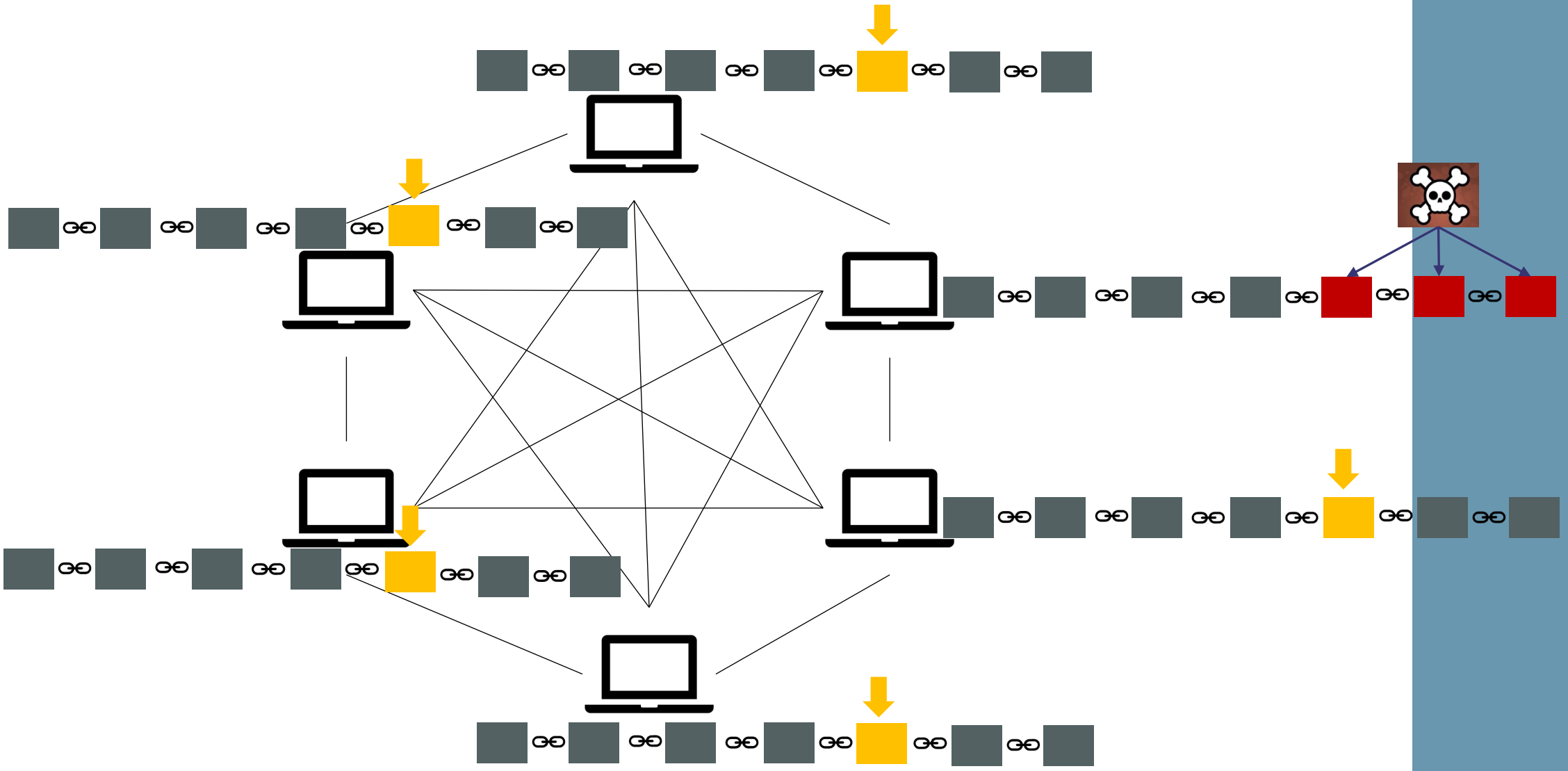
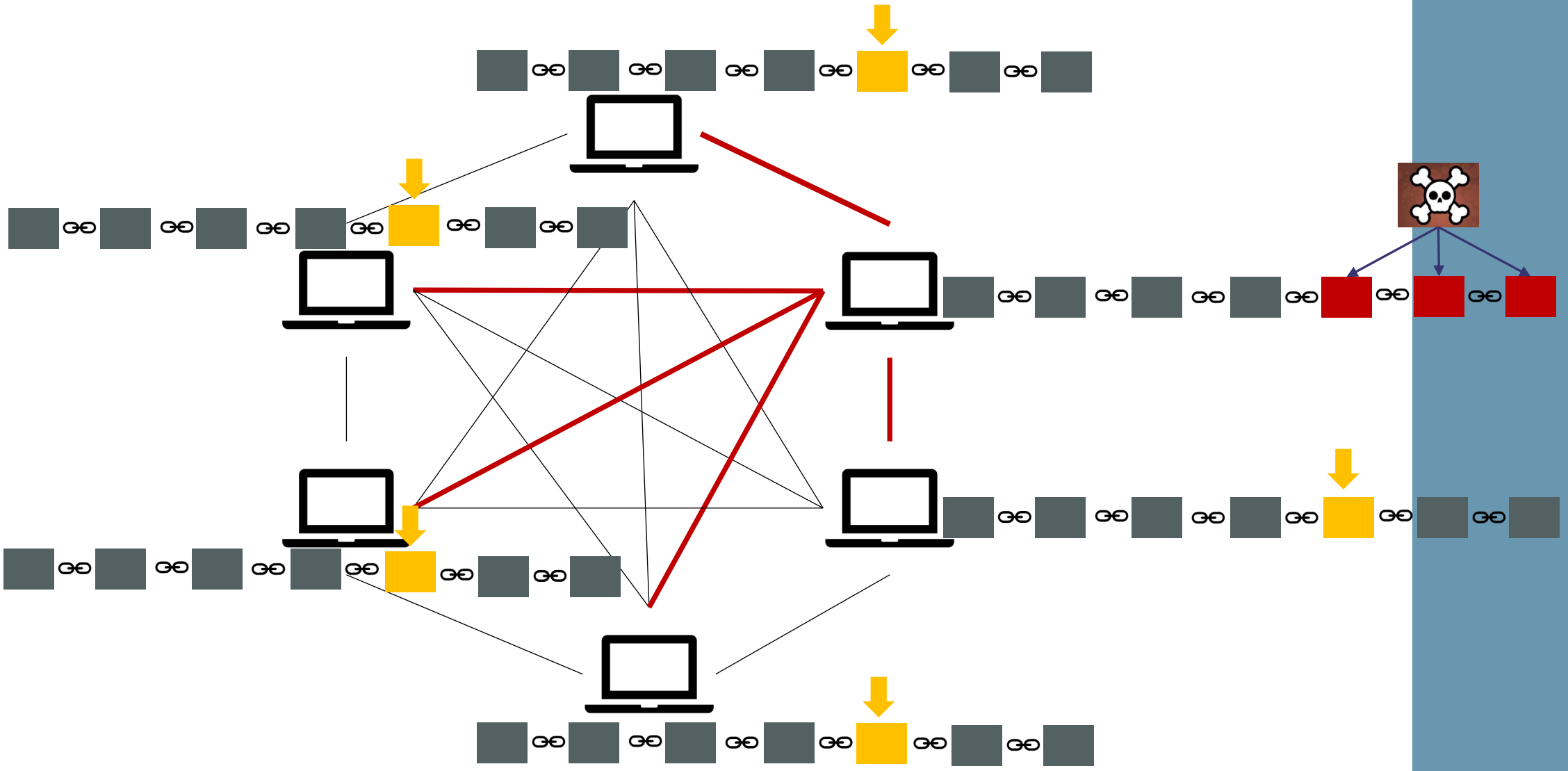


Distributed P2P Network



Distributed P2P Network



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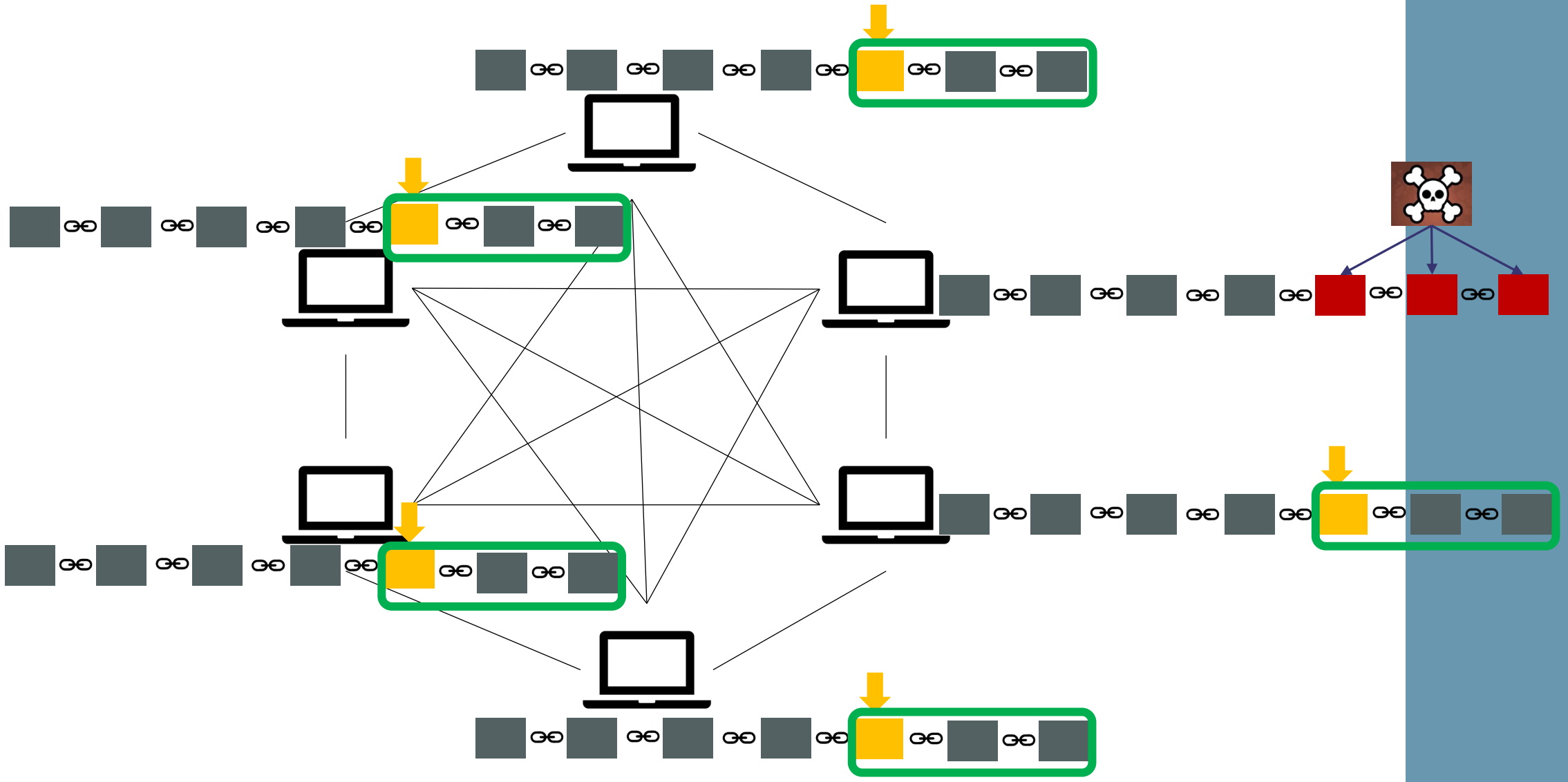
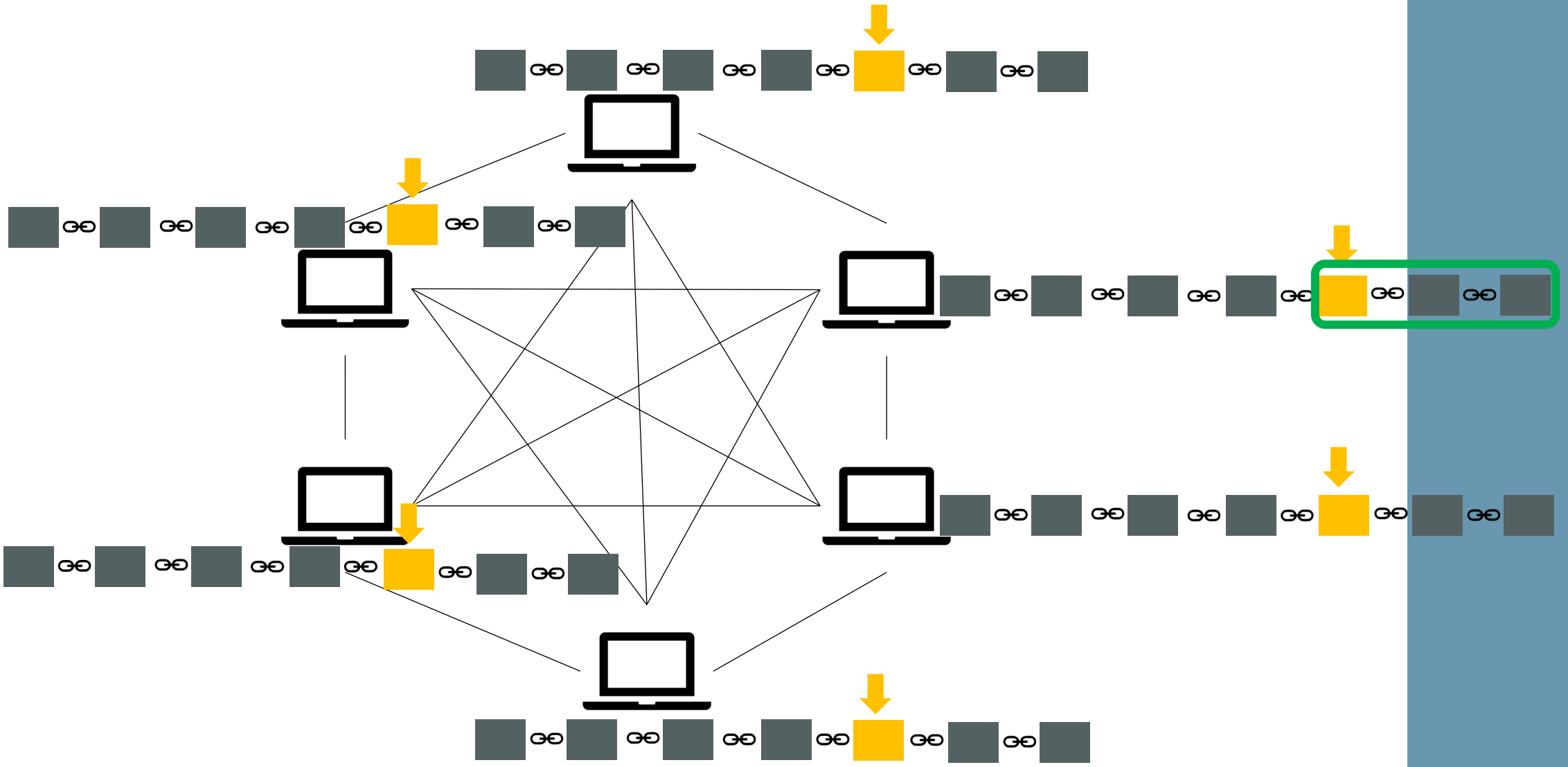


Distributed P2P Network



Blockchain Components

- Hash Cryptography
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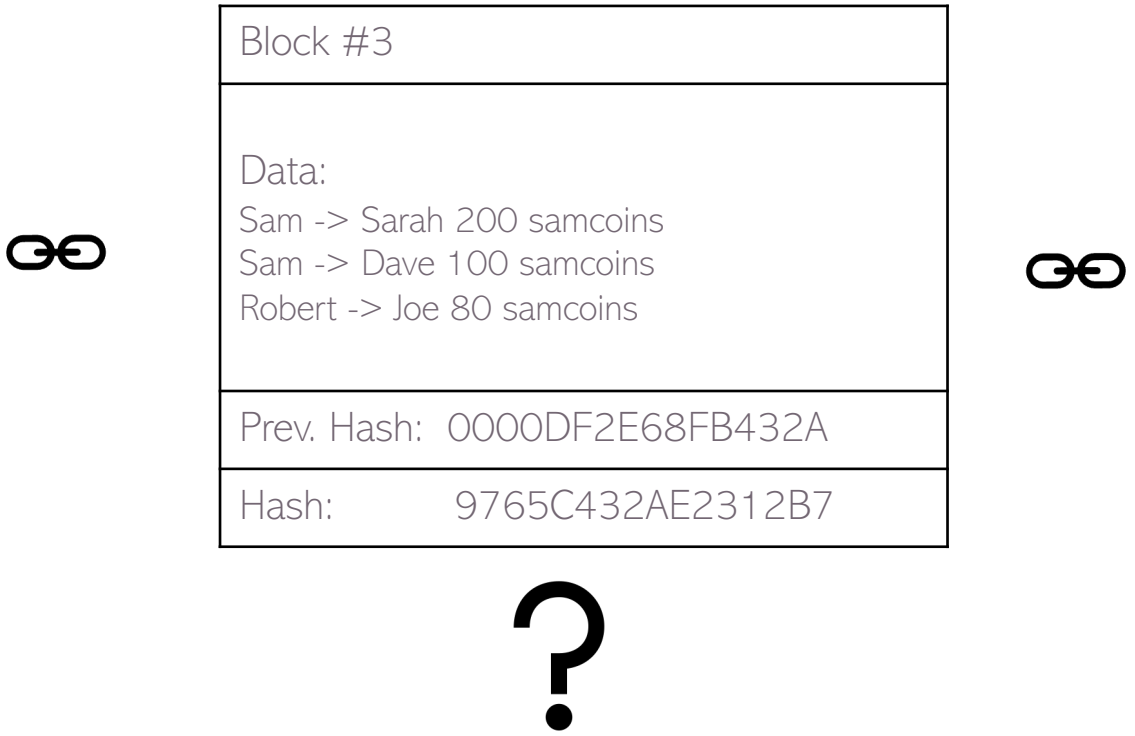
- Distributed P2P Network
- Mining
- Consensus Protocol

Mining

Mining is all about miners using their time and processing power to solve cryptographically hard puzzles.

How Mining Works

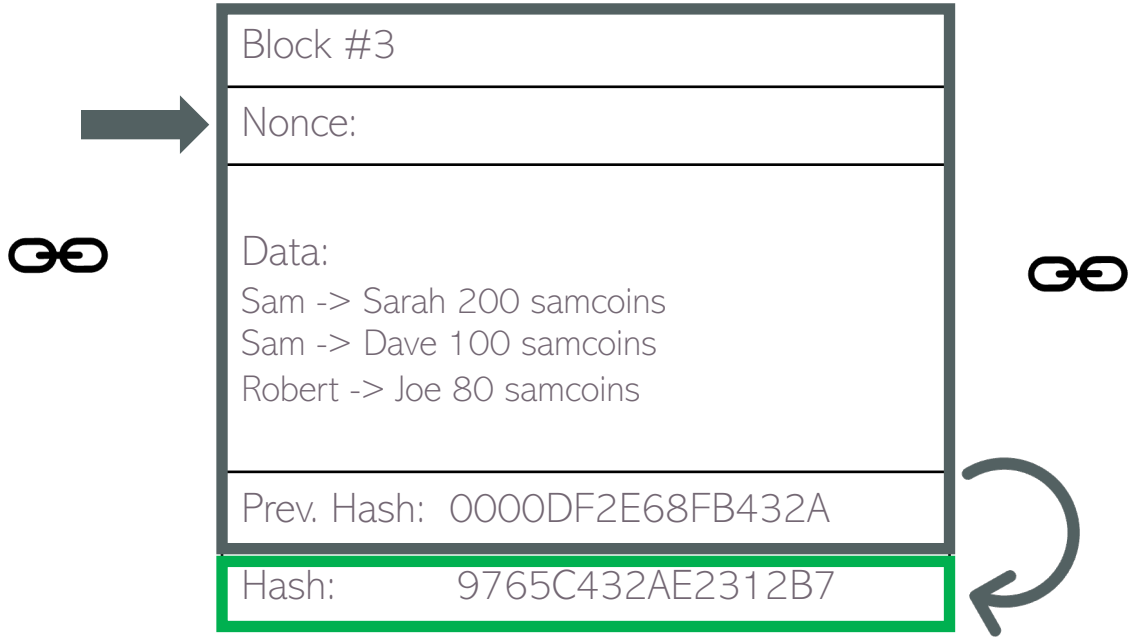


Nonce

Block #3
Nonce:
Data: Sam -> Sarah 200 samcoins Sam -> Dave 100 samcoins Robert -> Joe 80 samcoins
Prev. Hash: 0000DF2E68FB432A
Hash: 9765C432AE2312B7

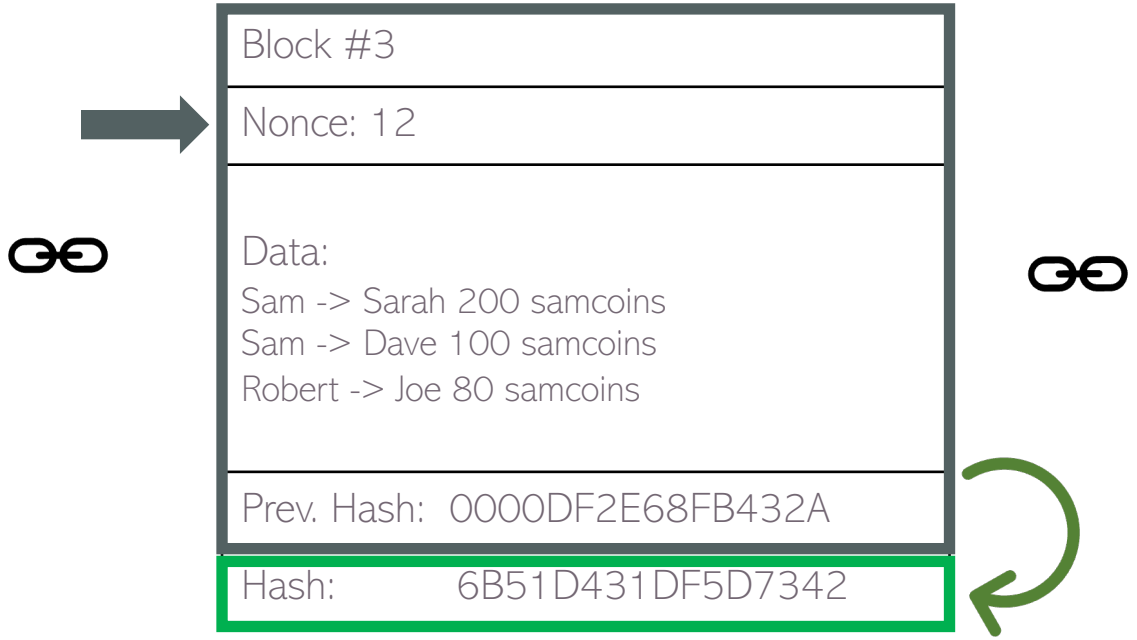
The nonce value helps miners to solve the puzzle.

Nonce

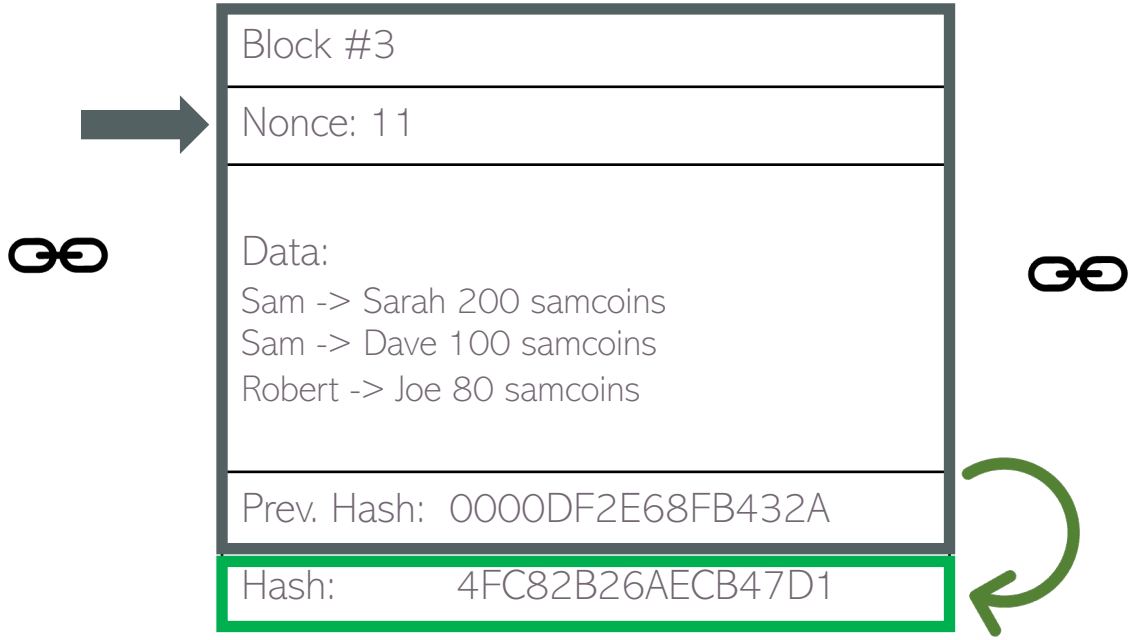


The nonce field gives miners extra control and flexibility to vary the hash of current block.

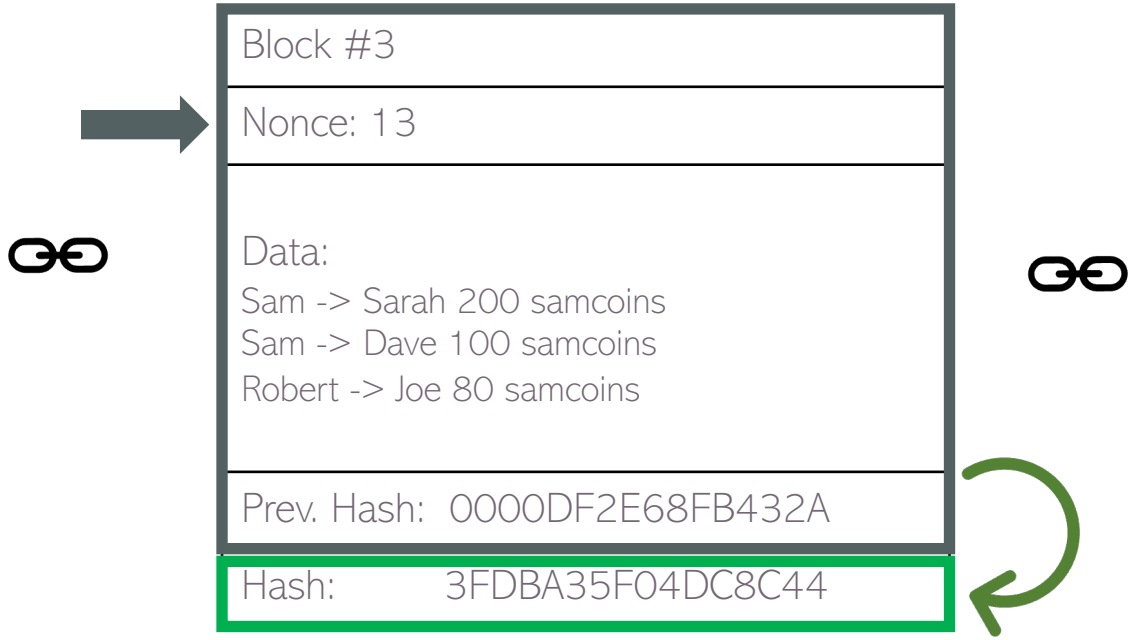
Nonce


Block #3
Nonce: 12
Data:
Sam -> Sarah 200 samcoins
Sam -> Dave 100 samcoins
Robert -> Joe 80 samcoins
Prev. Hash: 0000DF2E68FB432A
Hash: 6B51D431DF5D7342

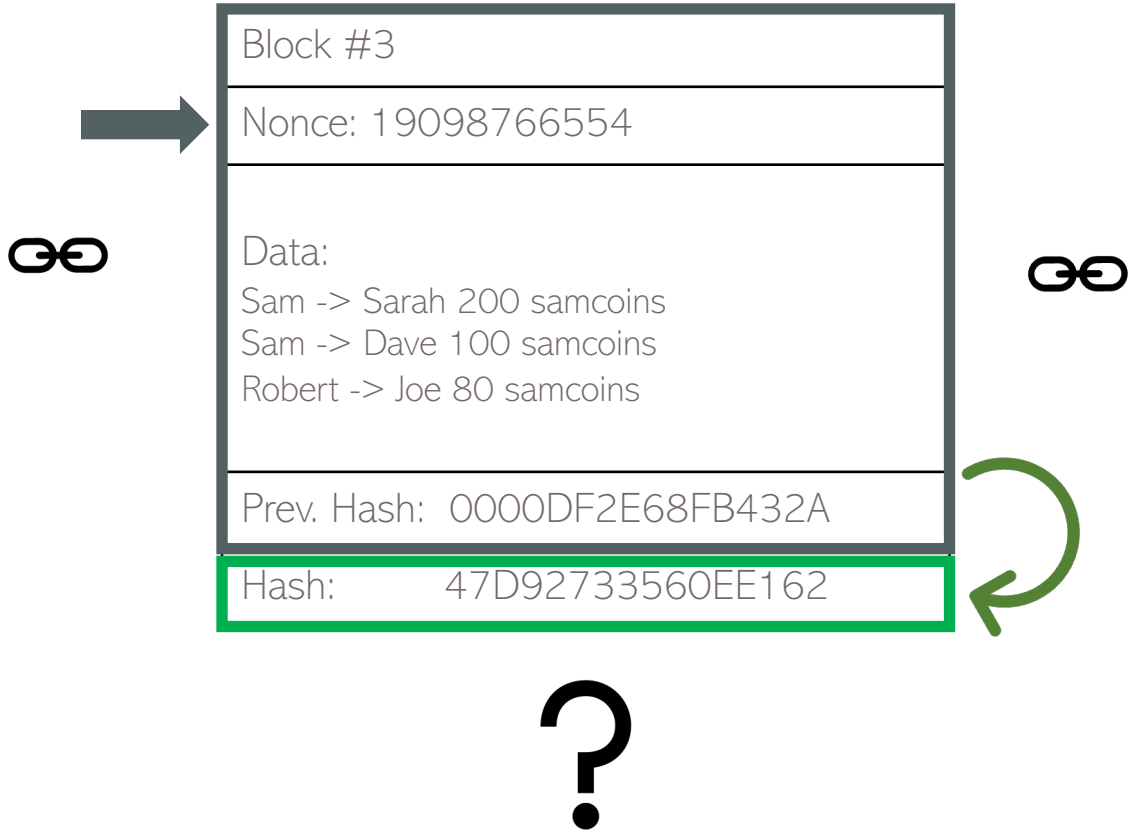
Nonce


Block #3
Nonce: 11
Data:
Sam -> Sarah 200 samcoins
Sam -> Dave 100 samcoins
Robert -> Joe 80 samcoins
Prev. Hash: 0000DF2E68FB432A
Hash: 4FC82B26AECB47D1

Nonce


Block #3
Nonce: 13
Data:
Sam -> Sarah 200 samcoins
Sam -> Dave 100 samcoins
Robert -> Joe 80 samcoins
Prev. Hash: 0000DF2E68FB432A
Hash: 3FDBA35F04DC8C44

Nonce


Block #3
Nonce: 19098766554
Data:
Sam -> Sarah 200 samcoins
Sam -> Dave 100 samcoins
Robert -> Joe 80 samcoins
Prev. Hash: 0000DF2E68FB432A
Hash: 47D92733560EE162
?

How Mining Works

- A Hash is a Number.
- Hash of number 1:

  Hexadecimal:
  6b86b273ff34fce19d6b804eff5a3f5747ada4eaa22f1d49c01e52ddb7875b4b

- Hash of “Hello World!”:

  Hexadecimal:
  7f83b1657ff1fc53b92dc18148a1d65dfc2d4b1fa3d677284addd200126d9069

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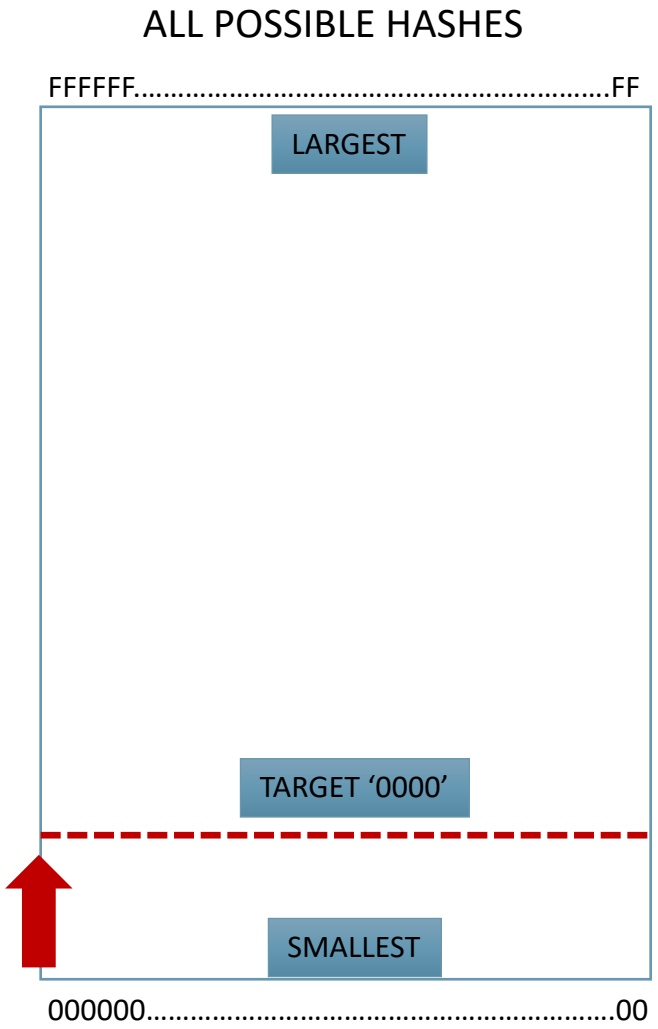
- Hash of “Hello World!”:

  Hexadecimal:
  7f83b1657ff1fc53b92dc18148a1d65dfc2d4b1fa3d677284addd200126d9069

TARGET Hash leading zeros (e.g. ‘0000’)

A **target hash** is a number that a **hash of** block must be less than or equal to it to be added to the chain.



How Mining Works

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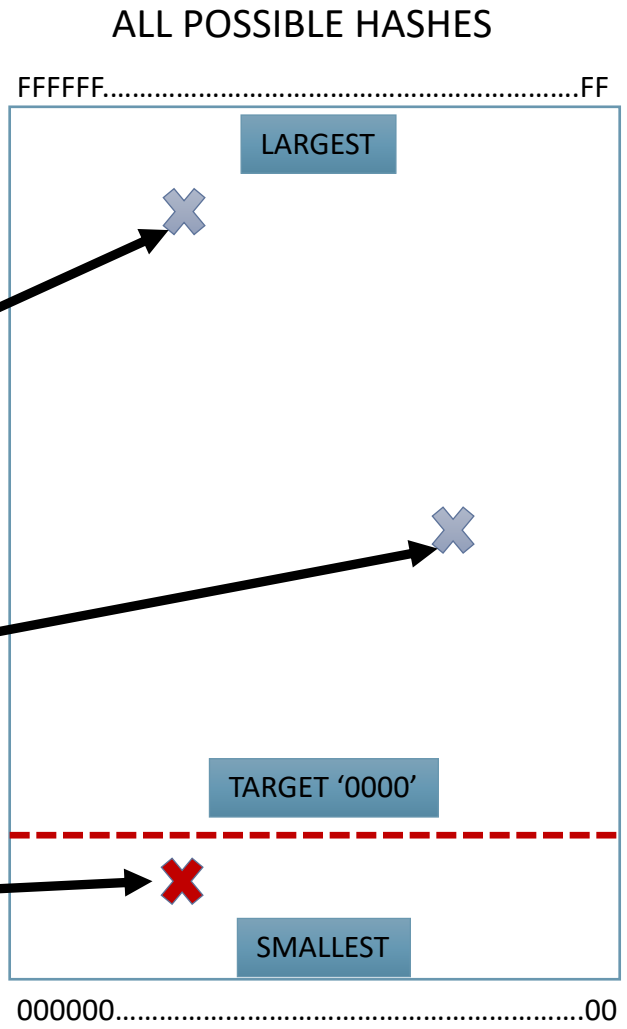
- Hash of number 1:

  Hexadecimal:
  6b86b273ff34fce19d6b804eff5a3f5747ada4eaa22f1d49c01e52ddb7875b4b

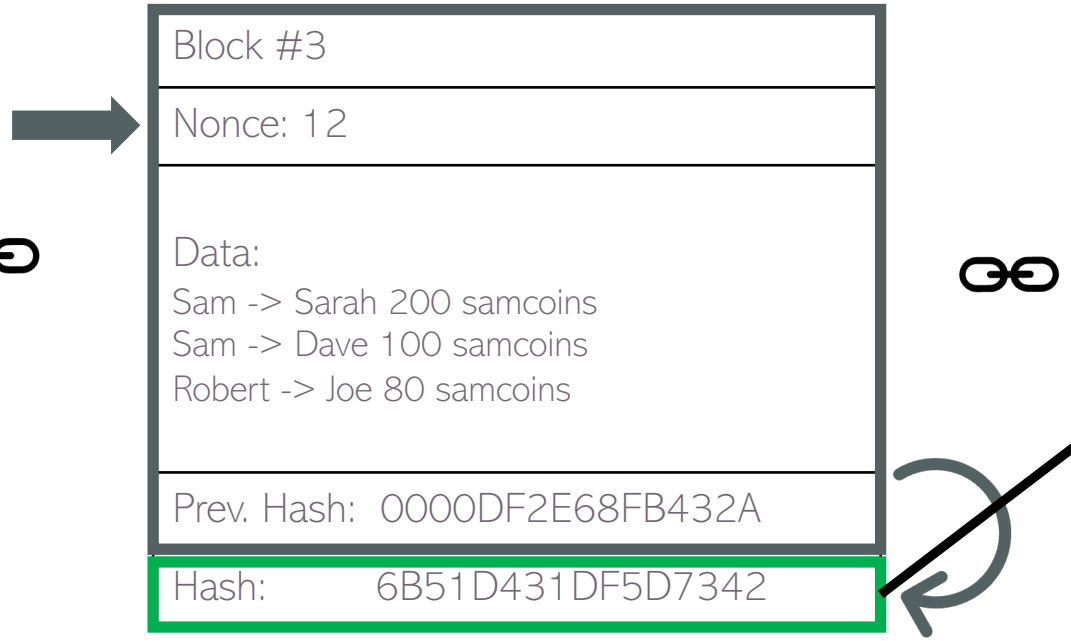
- Hash of “Hello World!”:

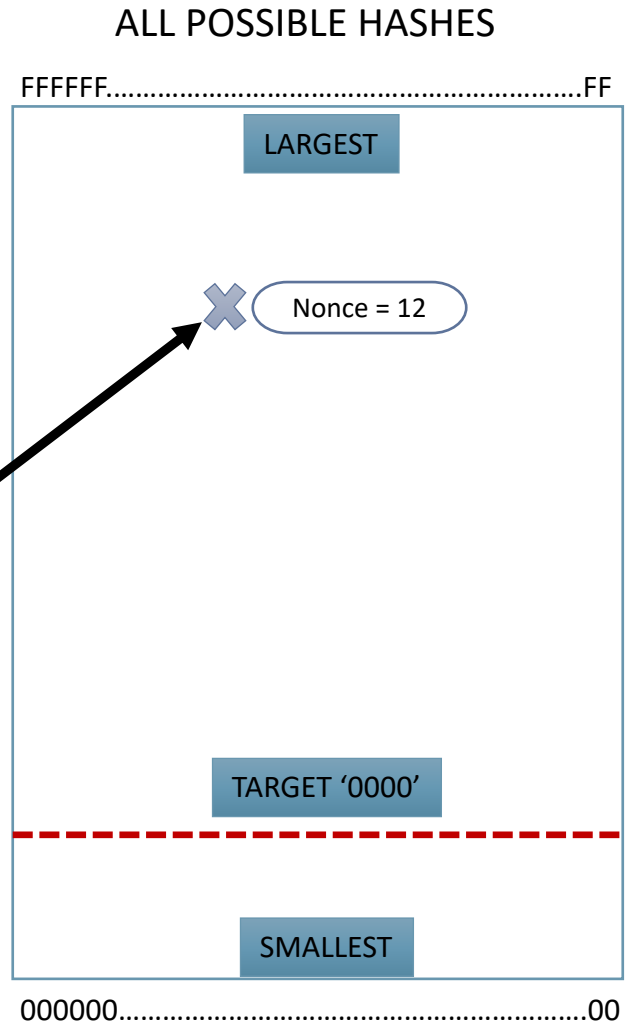
  Hexadecimal:
  7f83b1657ff1fc53b92dc18148a1d65dfc2d4b1fa3d677284addd200126d9069

TARGET	Hash leading zeros (e.g. ‘0000’)
0000000000000000000c18148a1d65dfc2d4b1fa3d677284addd200126d9069	



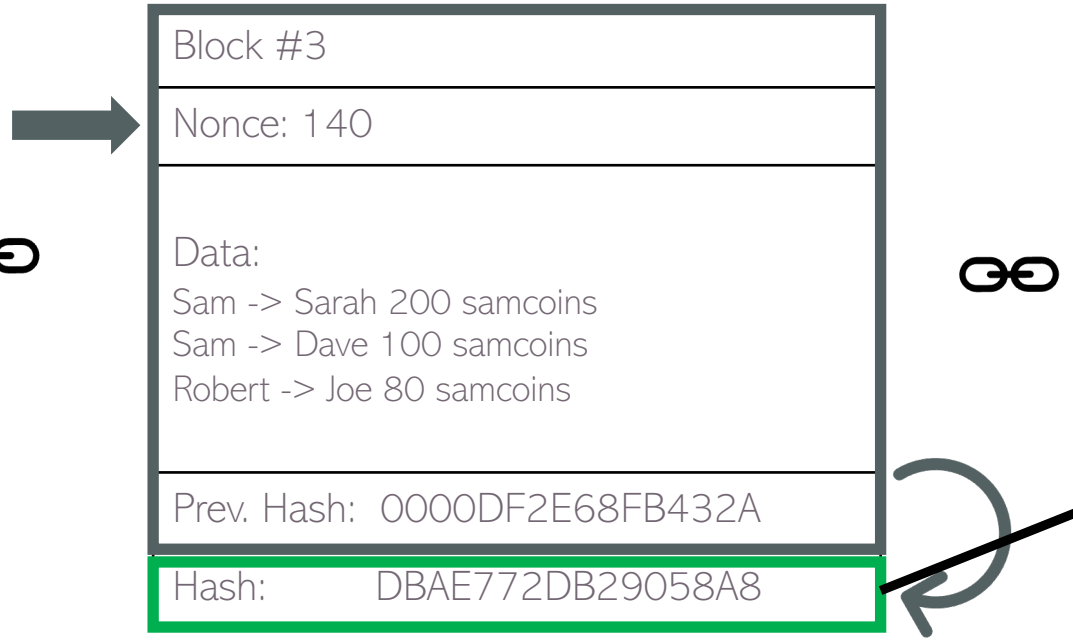
How Mining Works





TARGET Hash leading zeros (e.g. '0000')

How Mining Works



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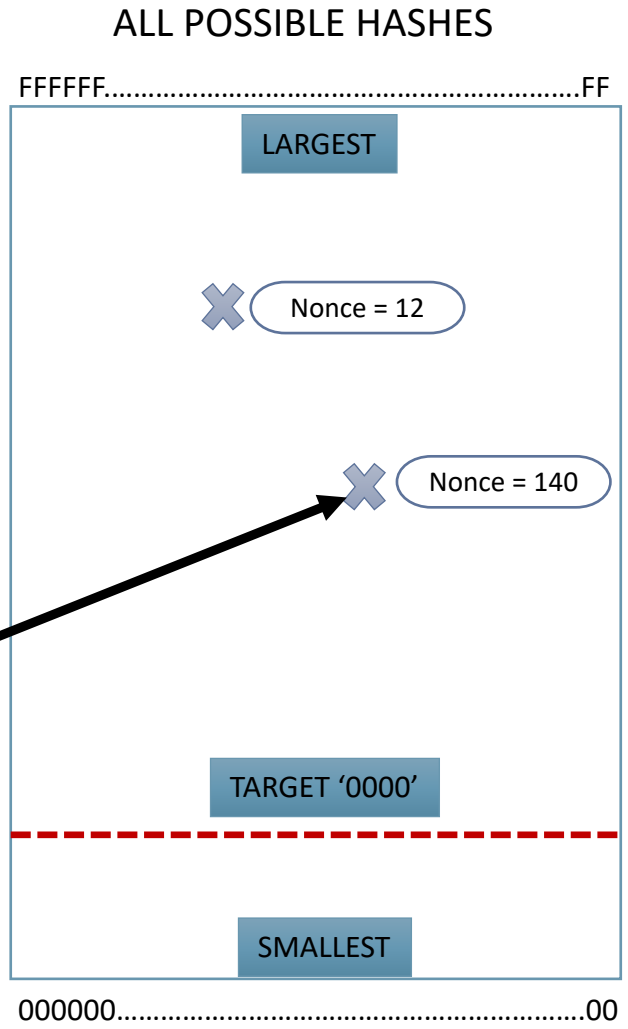
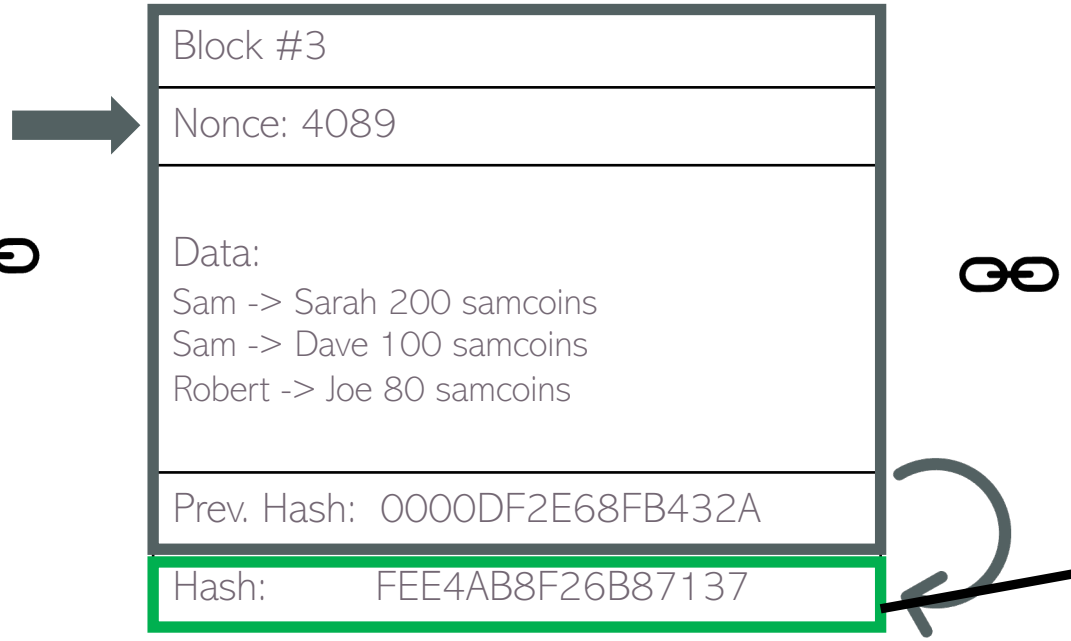
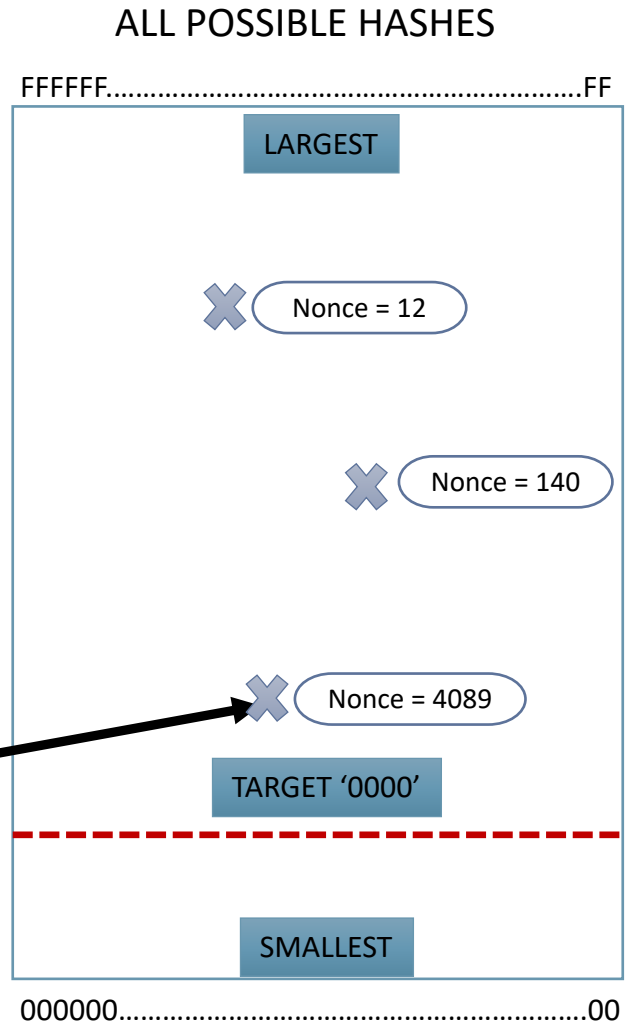


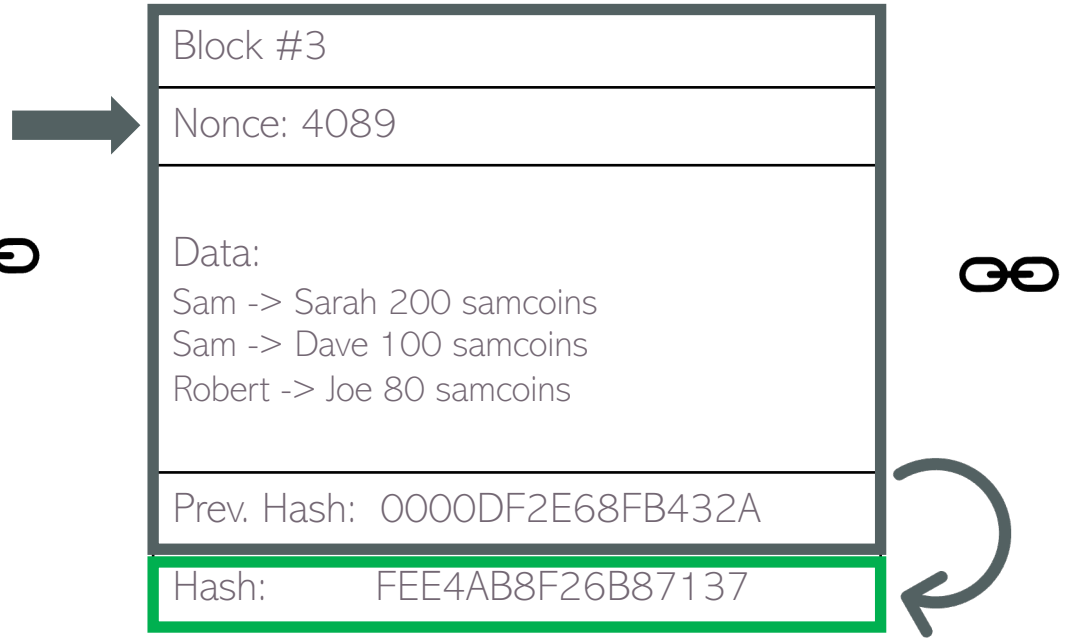
How Mining Works





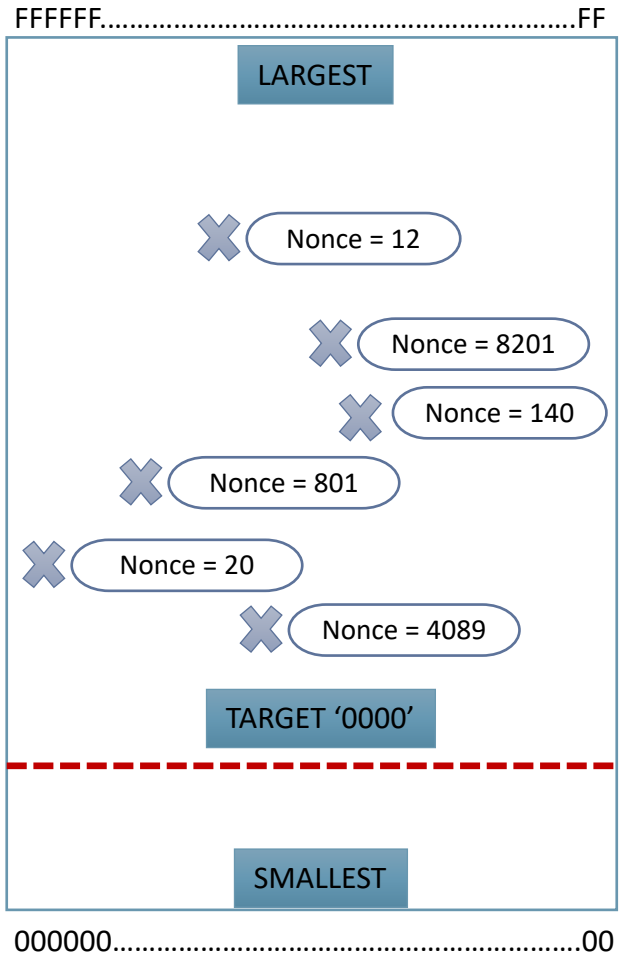
TARGET Hash leading zeros (e.g. '0000')

How Mining Works

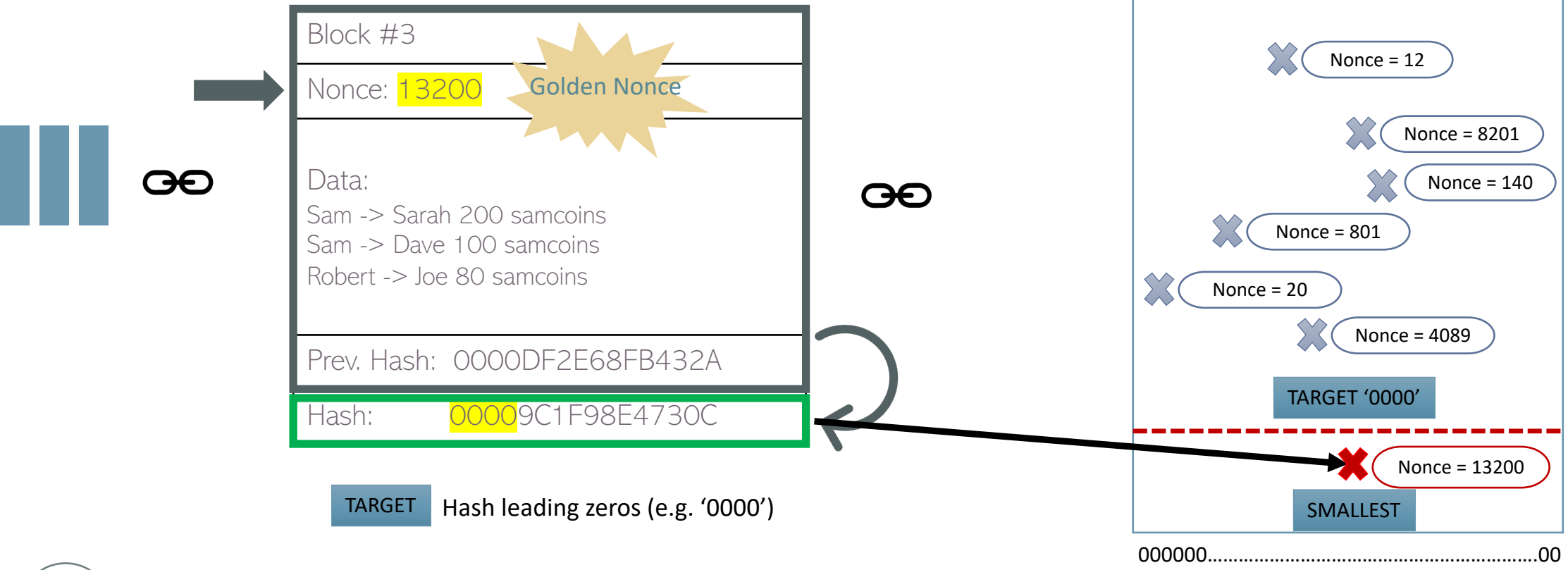


TARGET Hash leading zeros (e.g. '0000')

ALL POSSIBLE HASHES



How Mining Works

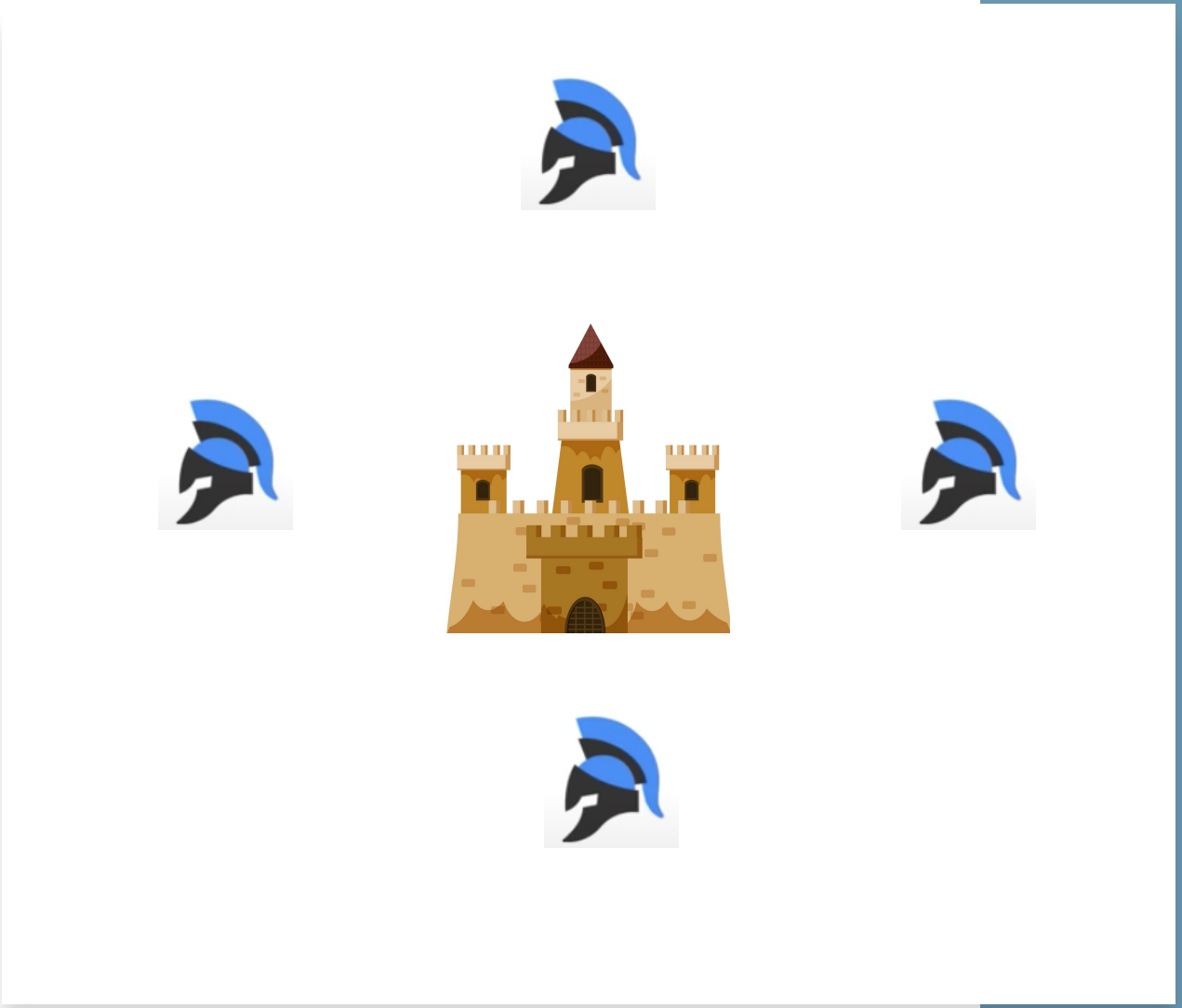


Blockchain Components

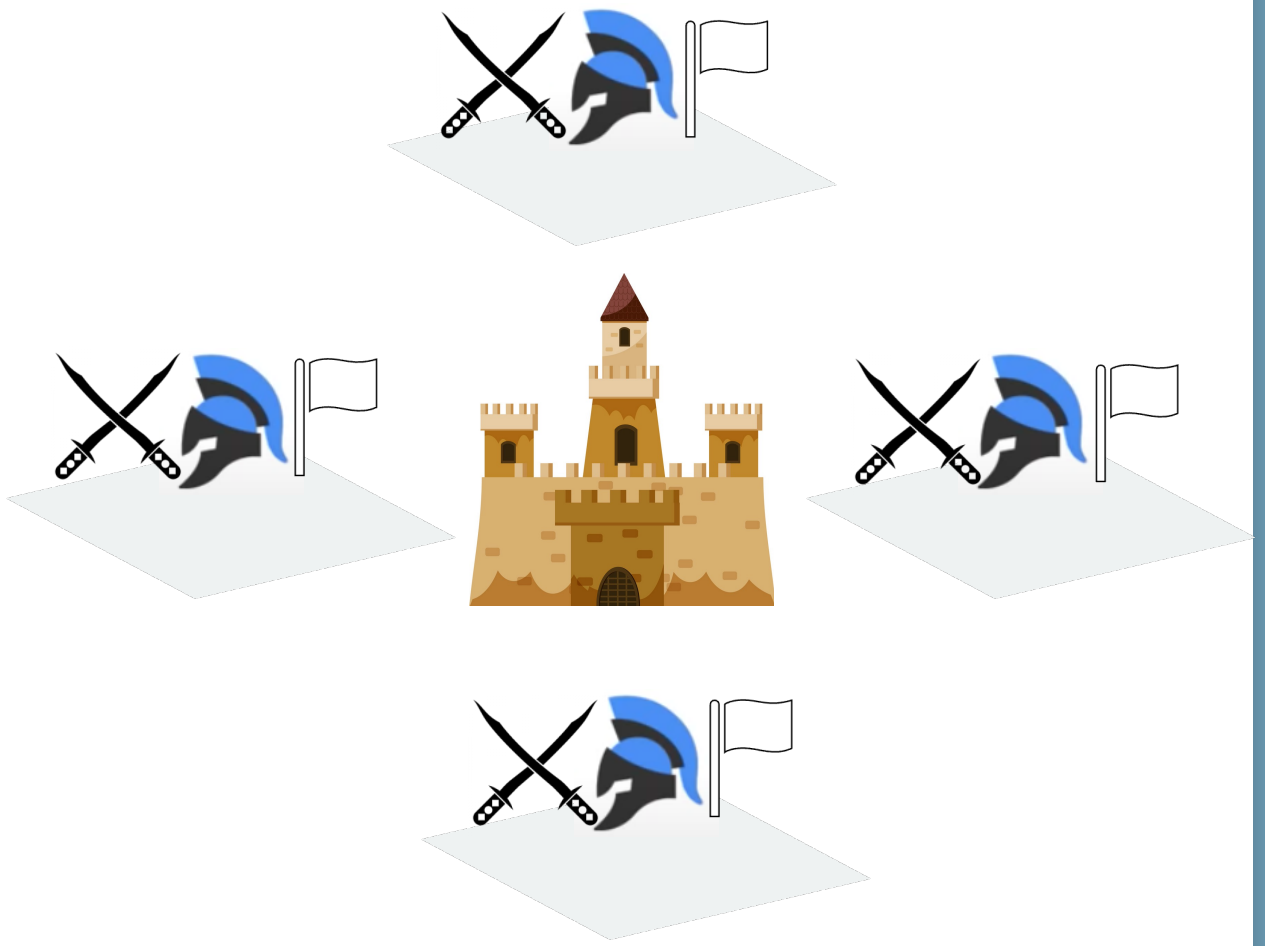
- Hash Cryptography
- Immutable Ledger
- Distributed P2P Network
- Mining
- Consensus Protocol

Byzantine Fault Tolerance

Byzantine Fault Tolerance

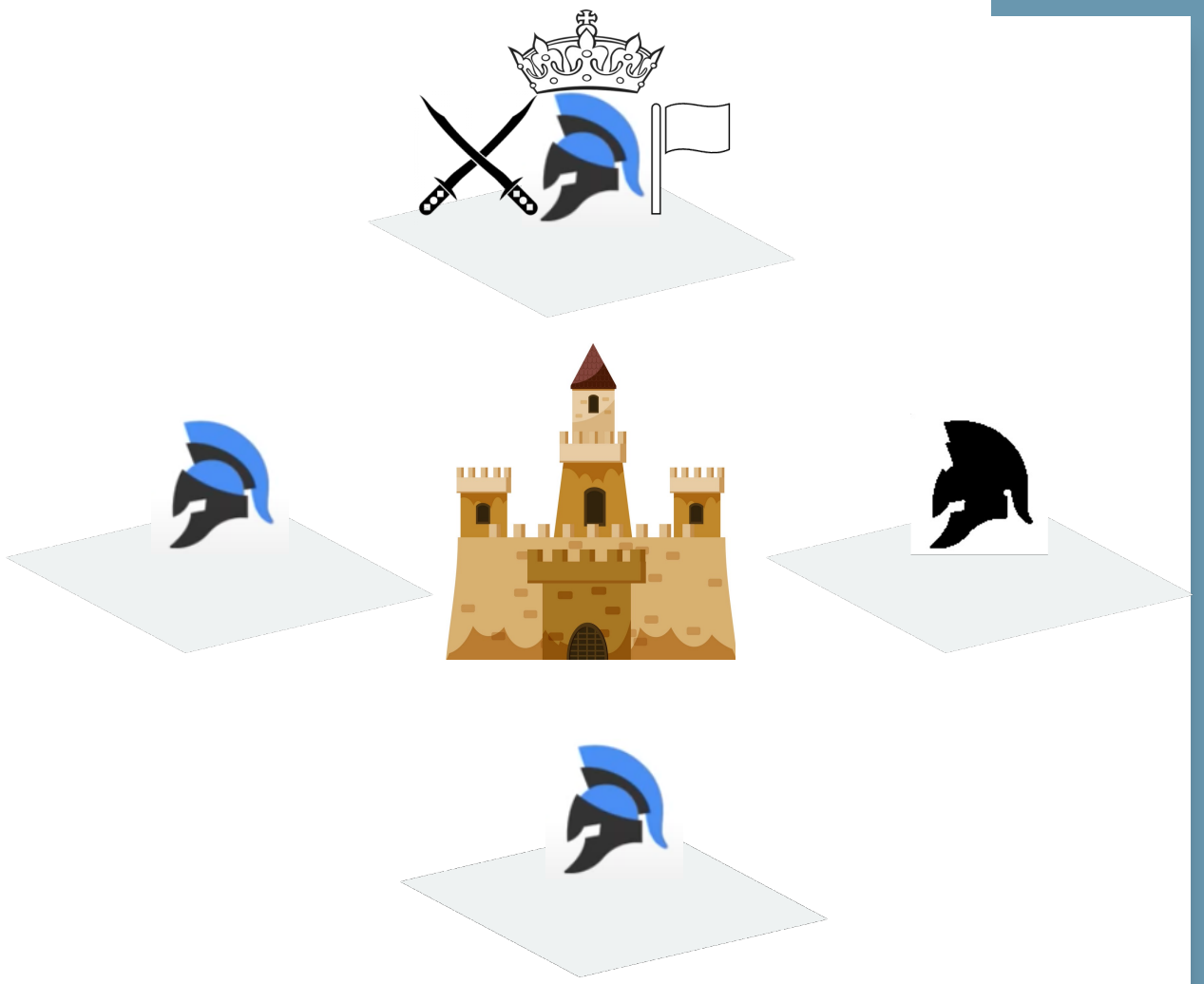


Byzantine Fault Tolerance



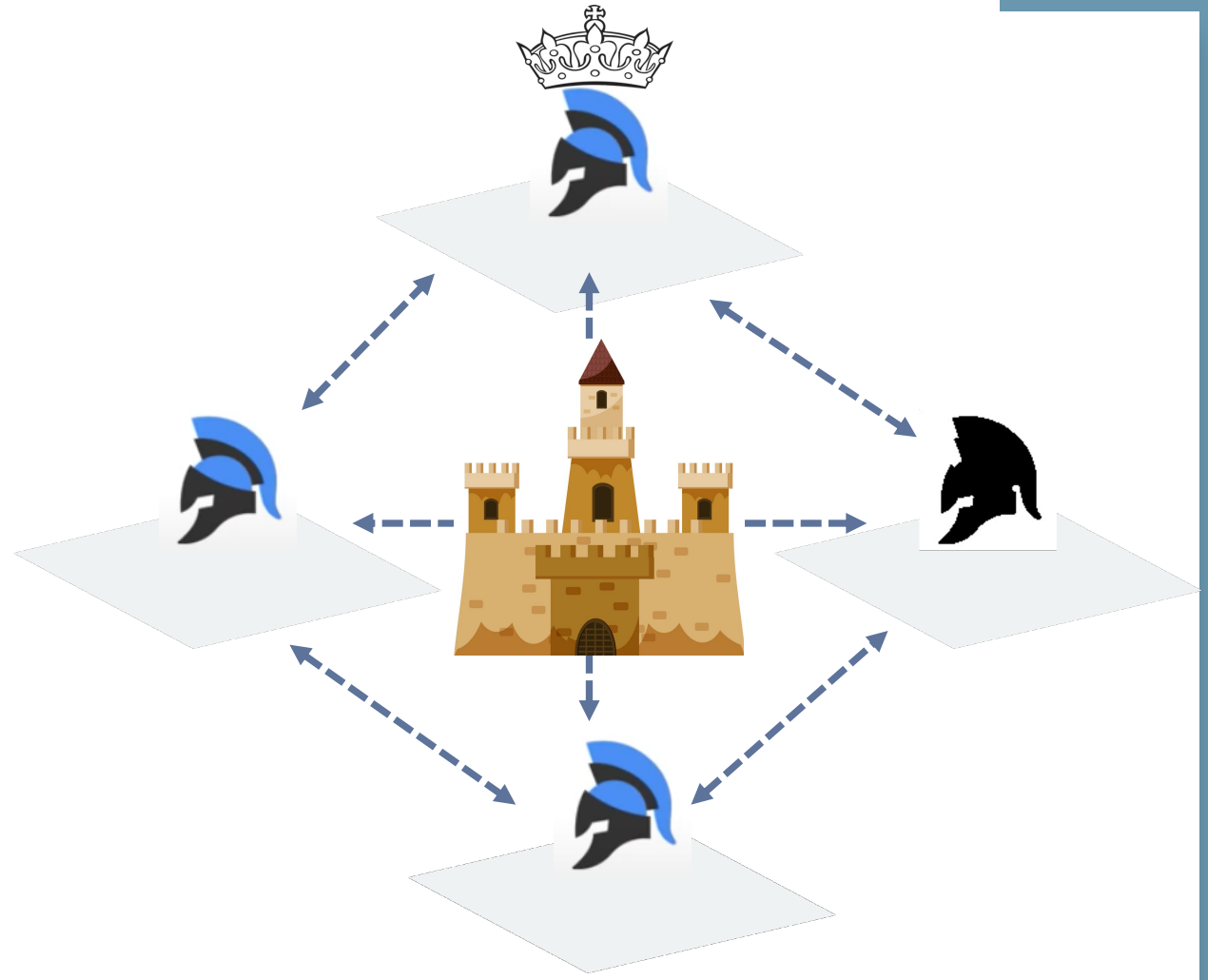
Generals must agree are they attacking or retreating.

Byzantine Fault Tolerance



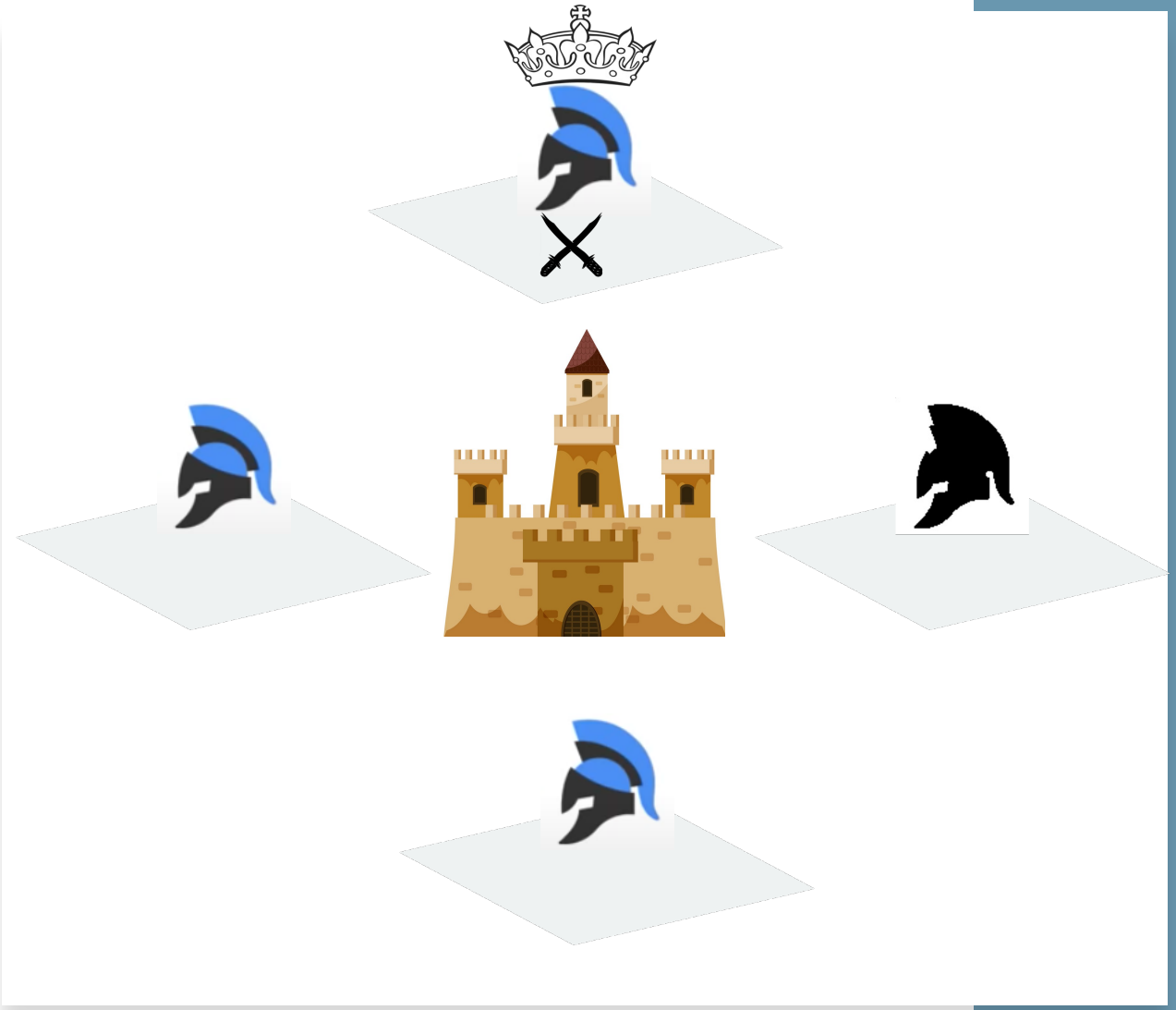
There is a main Commander and a traitor who is not known to others.

Byzantine Fault Tolerance

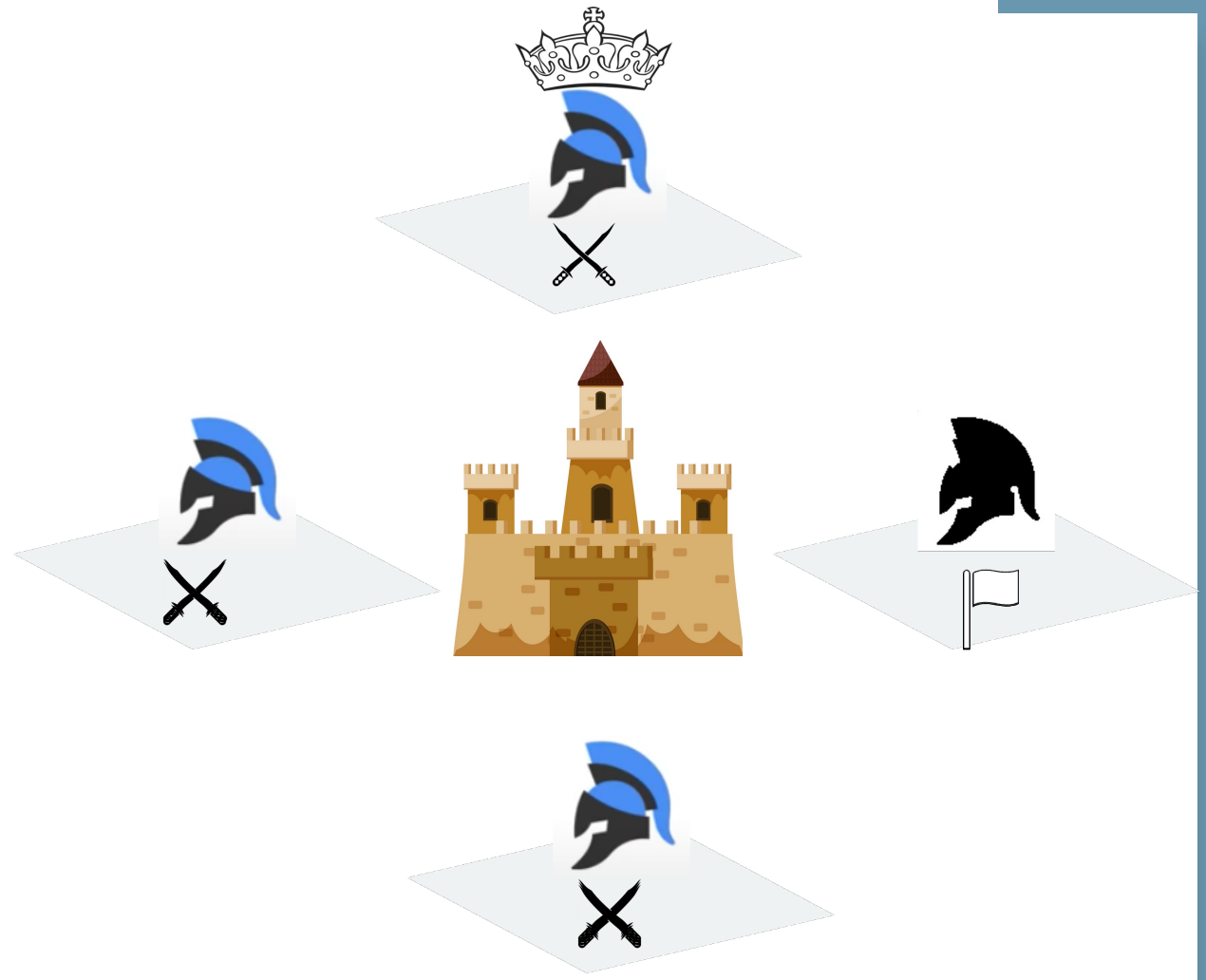


They all can communicate with each other.

Byzantine Fault Tolerance

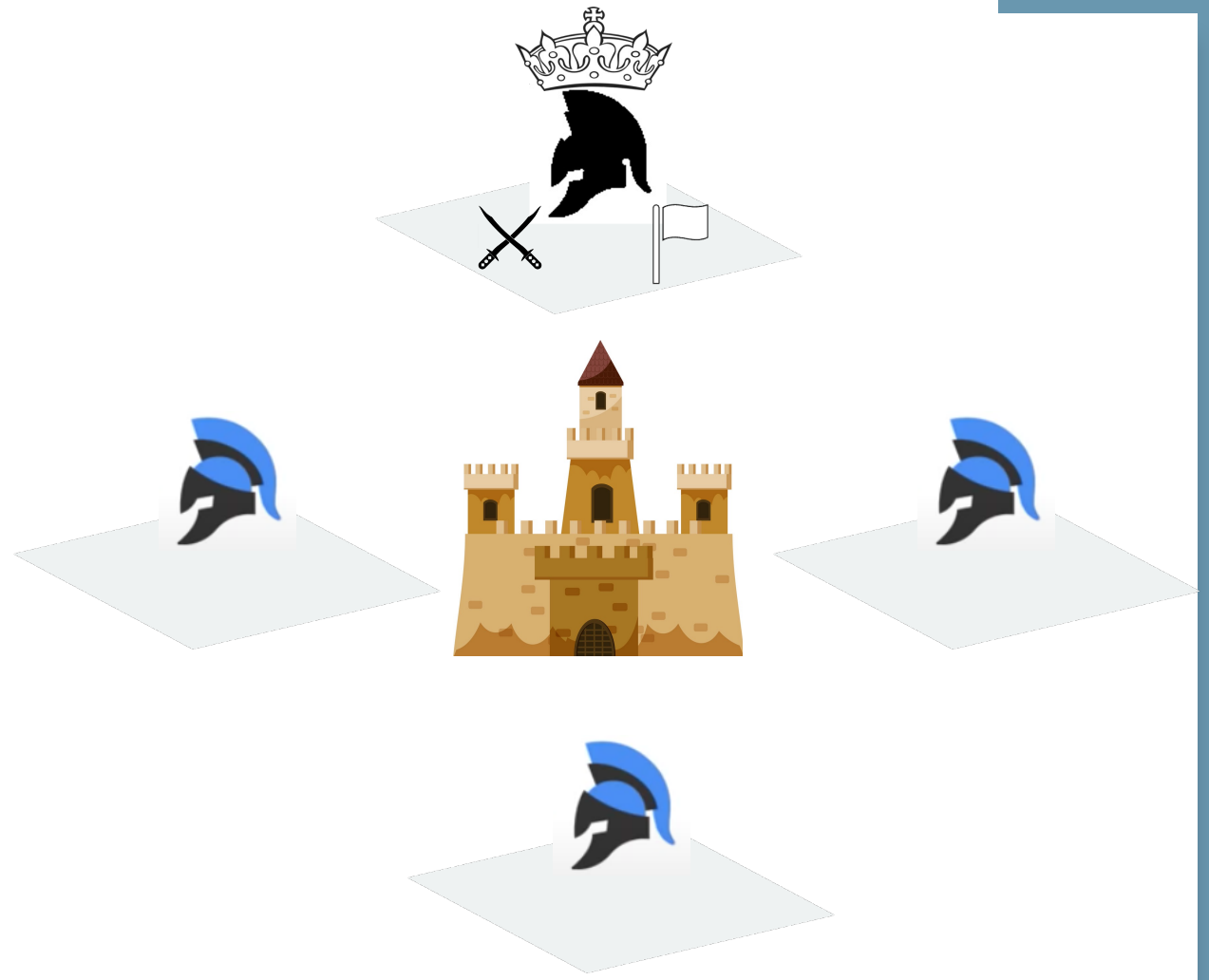


Byzantine Fault Tolerance



They came to the consensus to attack.

Byzantine Fault Tolerance

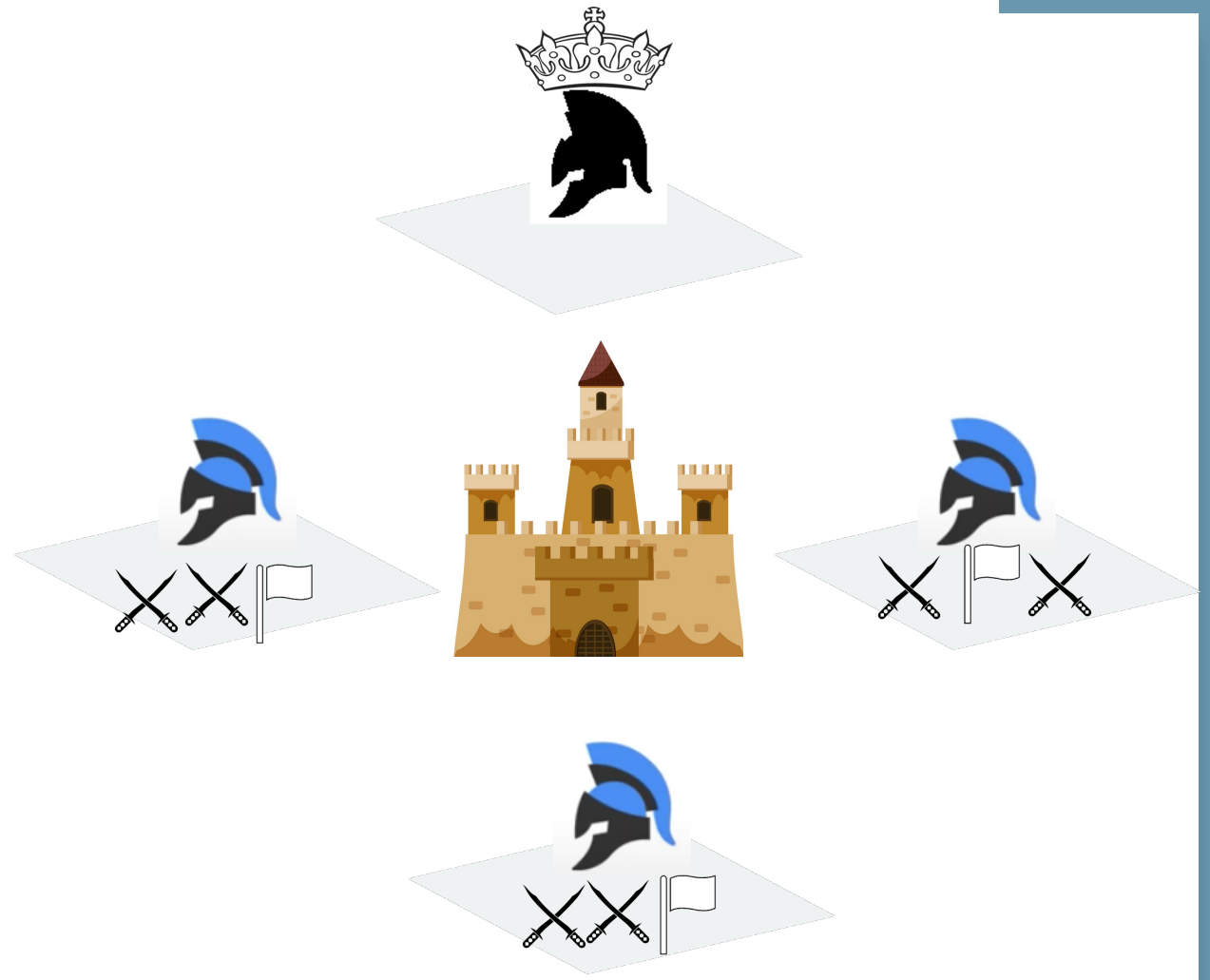


What happens if the commander be a traitor?

Byzantine Fault Tolerance

Question:
To what level the algorithm can tolerate?

The number of traitors should not exceed 33% of the total.



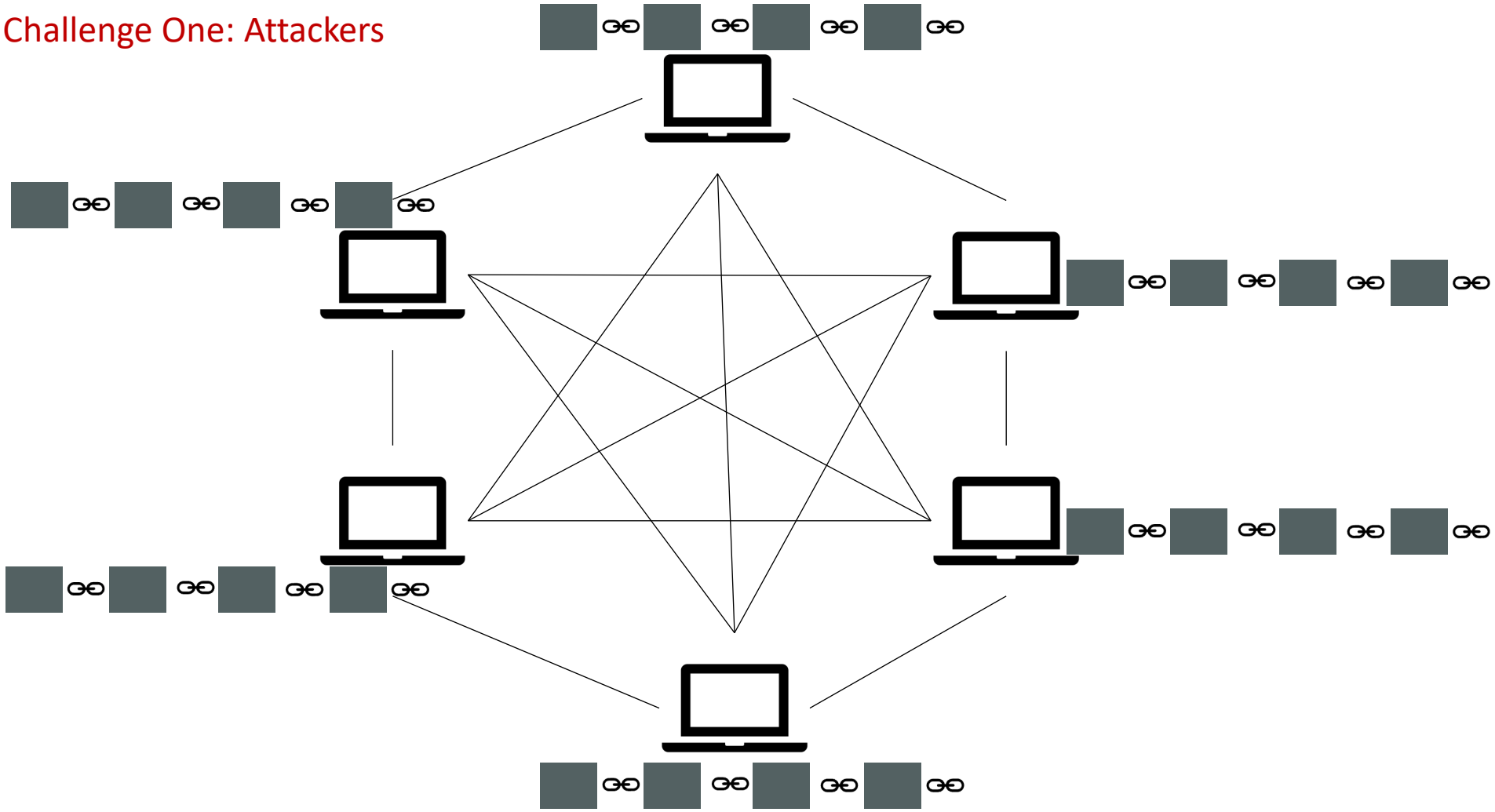
They came to the consensus to attack.

Consensus Protocol

A consensus protocol is a process through which all the peers of a Blockchain network reach a common agreement about the present state of the distributed ledger.

Consensus Protocol

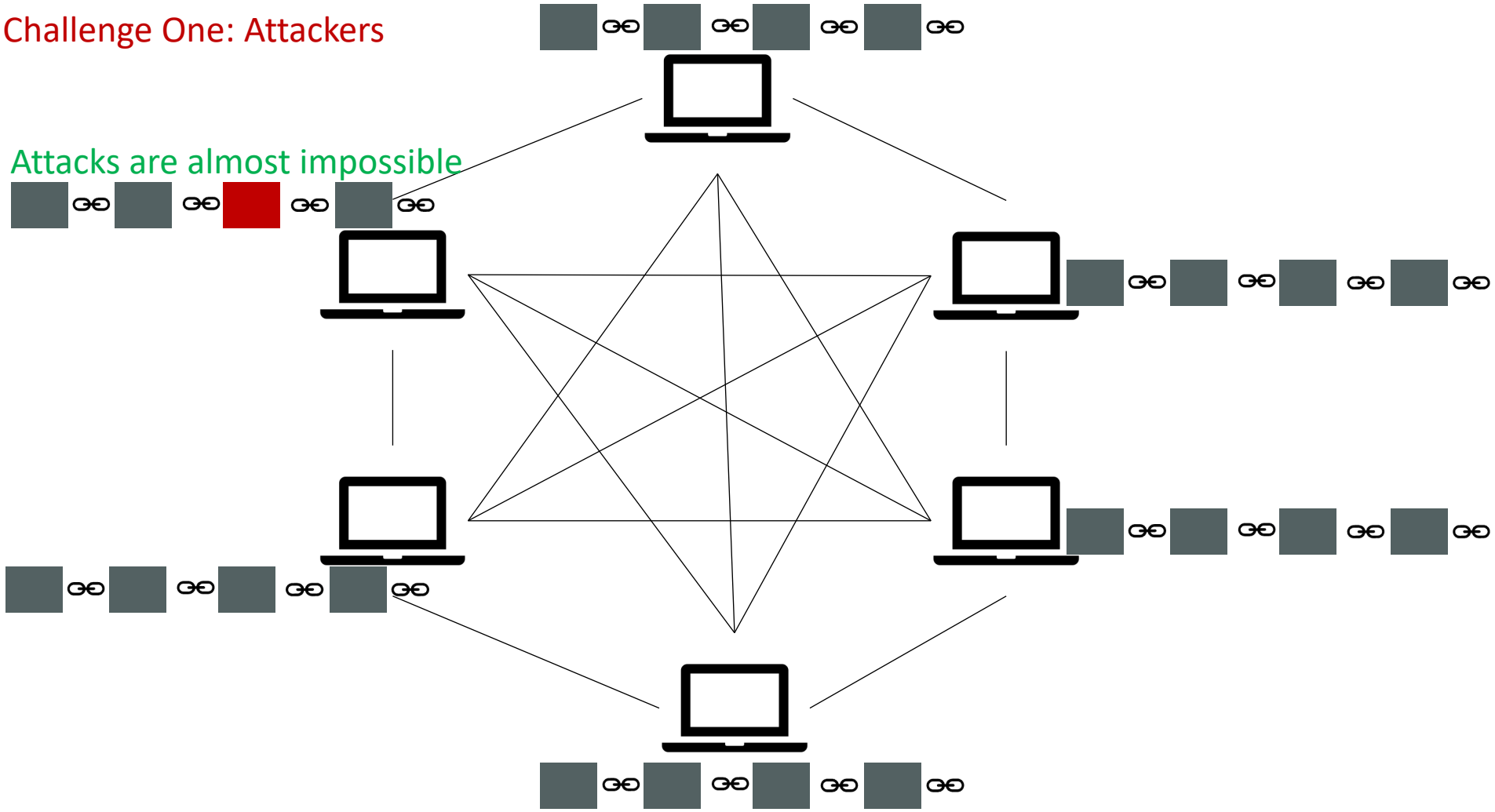
Challenge One: Attackers



Consensus Protocol

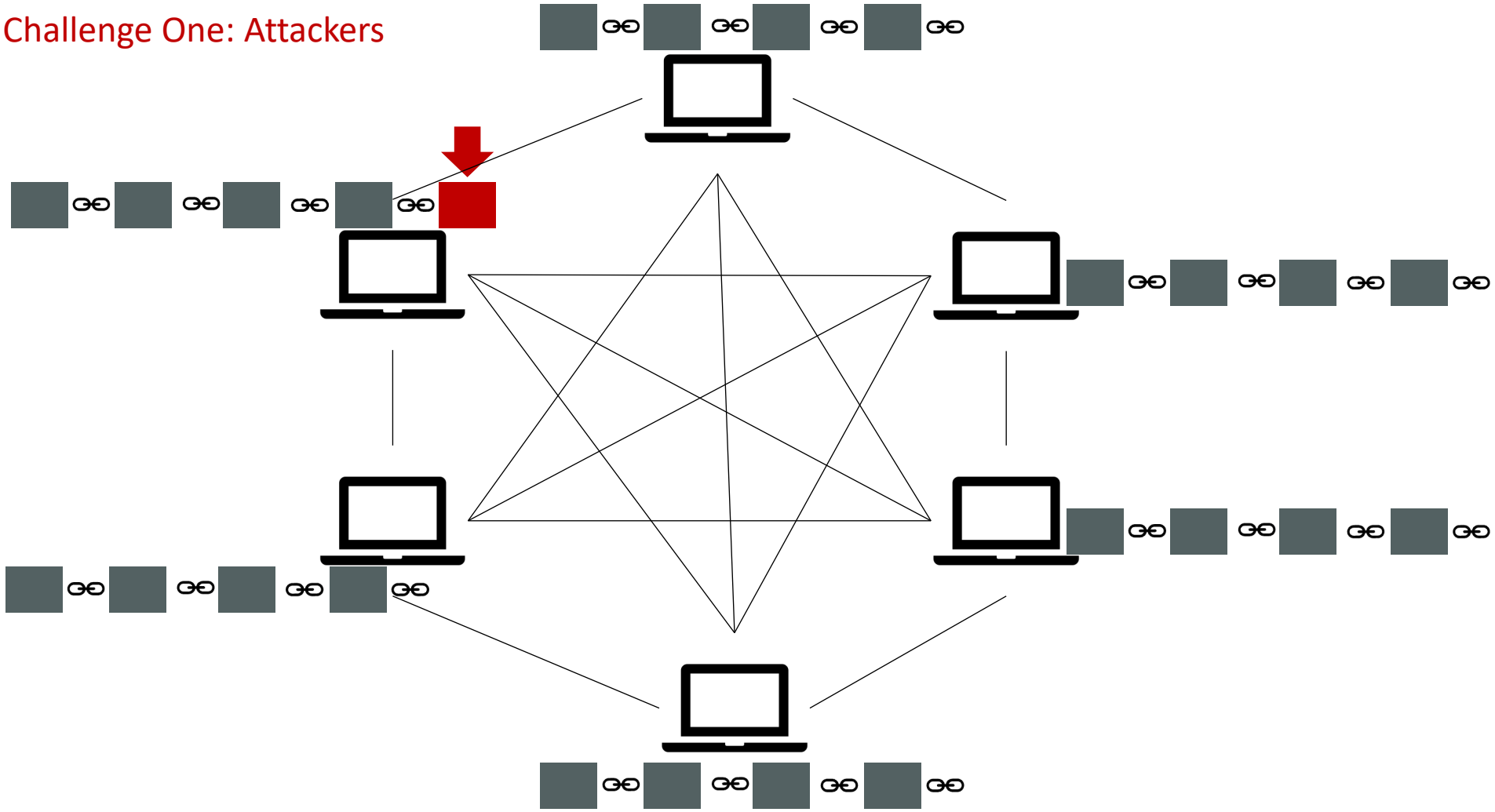
Challenge One: Attackers

Attacks are almost impossible



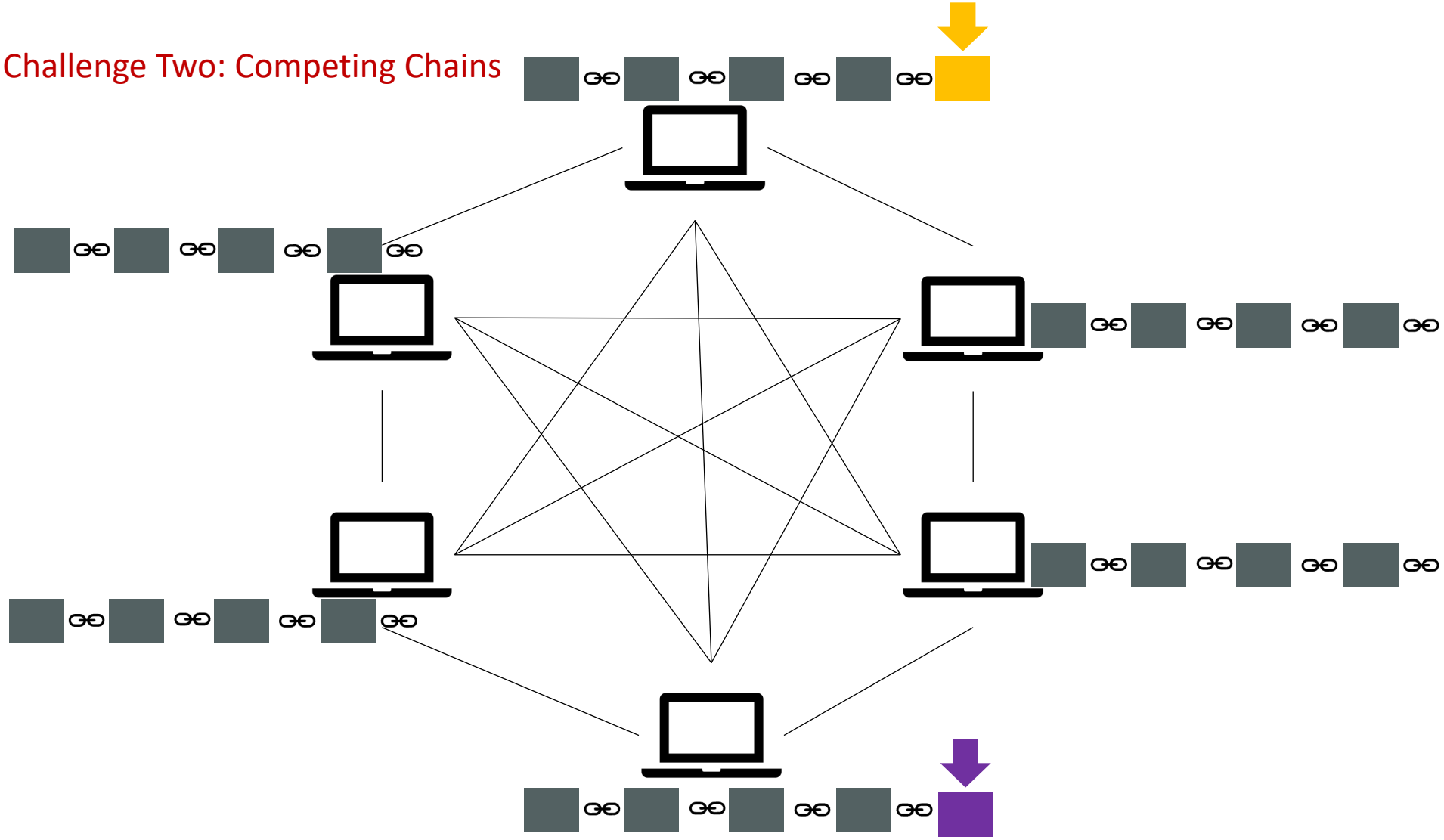
Consensus Protocol

Challenge One: Attackers



Consensus Protocol

Challenge Two: Competing Chains



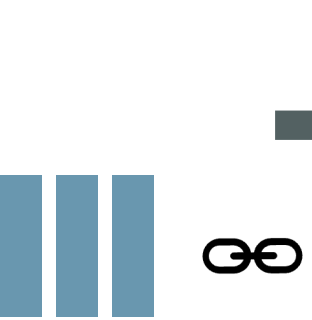
Consensus Protocol

- A consensus algorithm is a procedure through which all the peers of the Blockchain network reach a **common agreement** about the **present state of the distributed ledger**.

Main Consensus Protocols

- Proof-of-Work (PoW)
- Proof-of-Stack (PoS)
- Others(E.g. DPoS, PBFT, Ripple)

Consensus Protocol



Block #3

Nonce: 13200

Golden Nonce

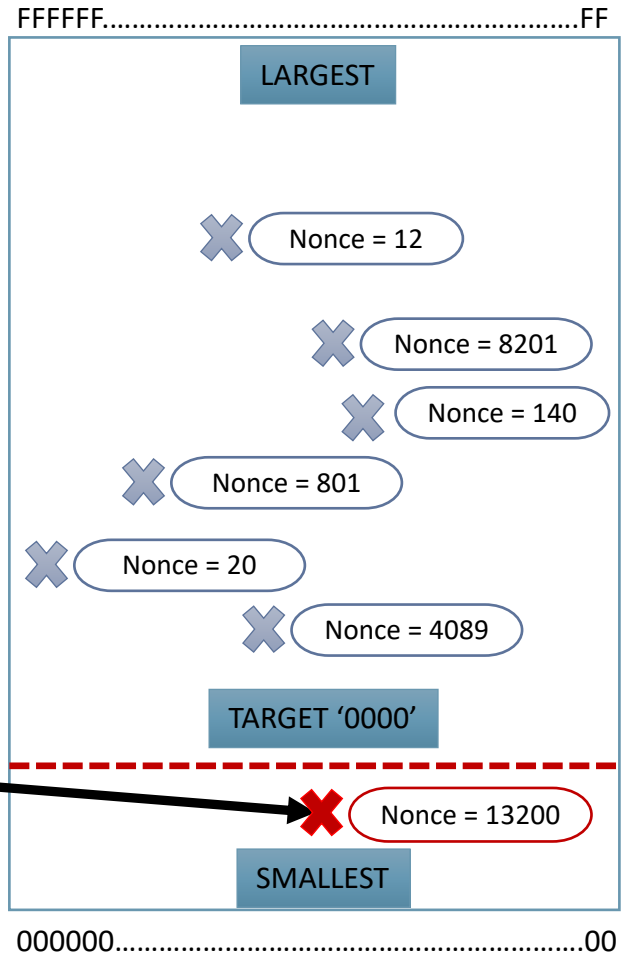
Data:
Sam -> Sarah 200 samcoins
Sam -> Dave 100 samcoins
Robert -> Joe 80 samcoins

Prev. Hash: 0000DF2E68FB432A

Hash: 00009C1F98E4730C

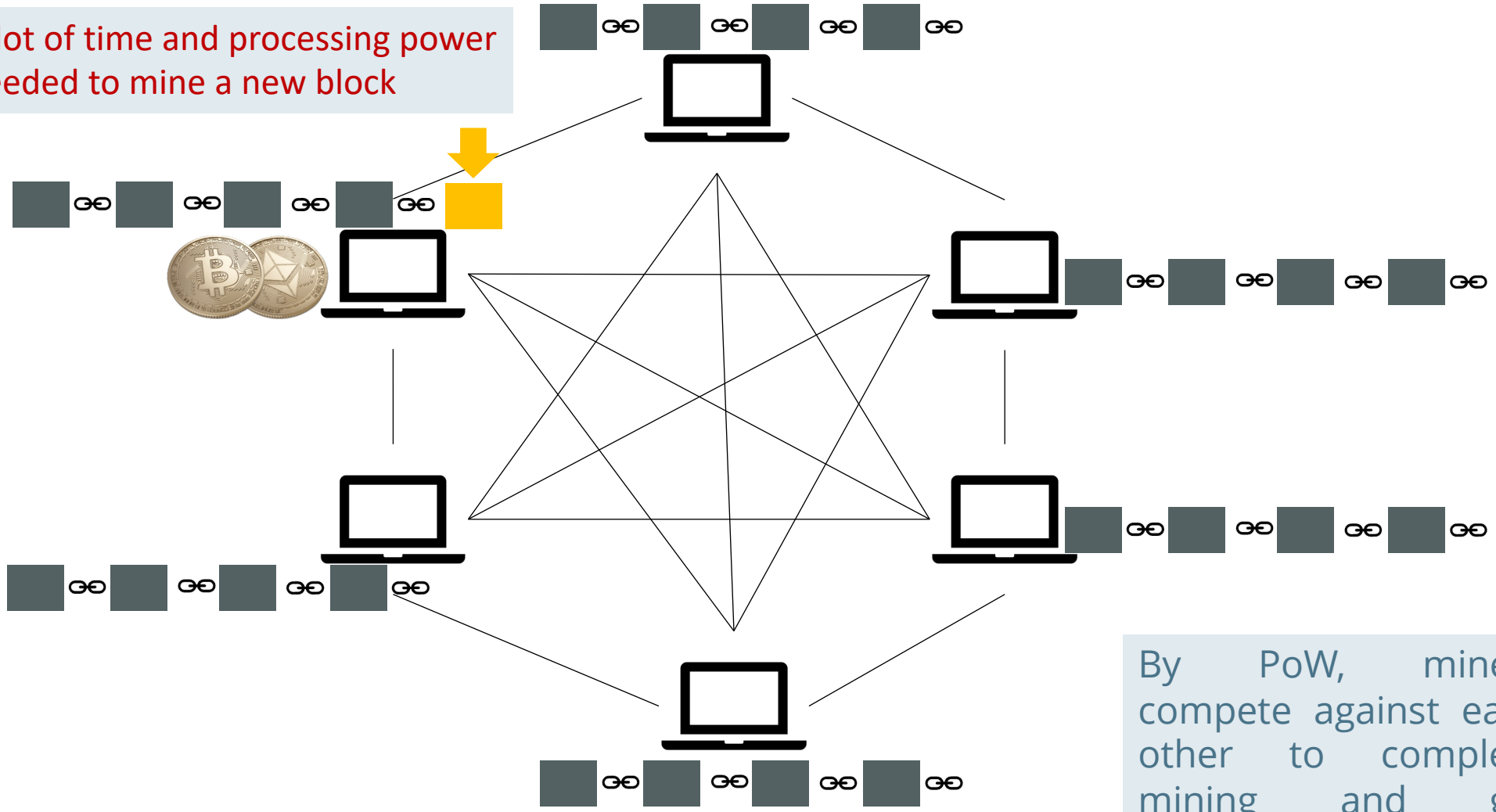
TARGET Hash leading zeros (e.g. '0000')

ALL POSSIBLE HASHES



Consensus Protocol

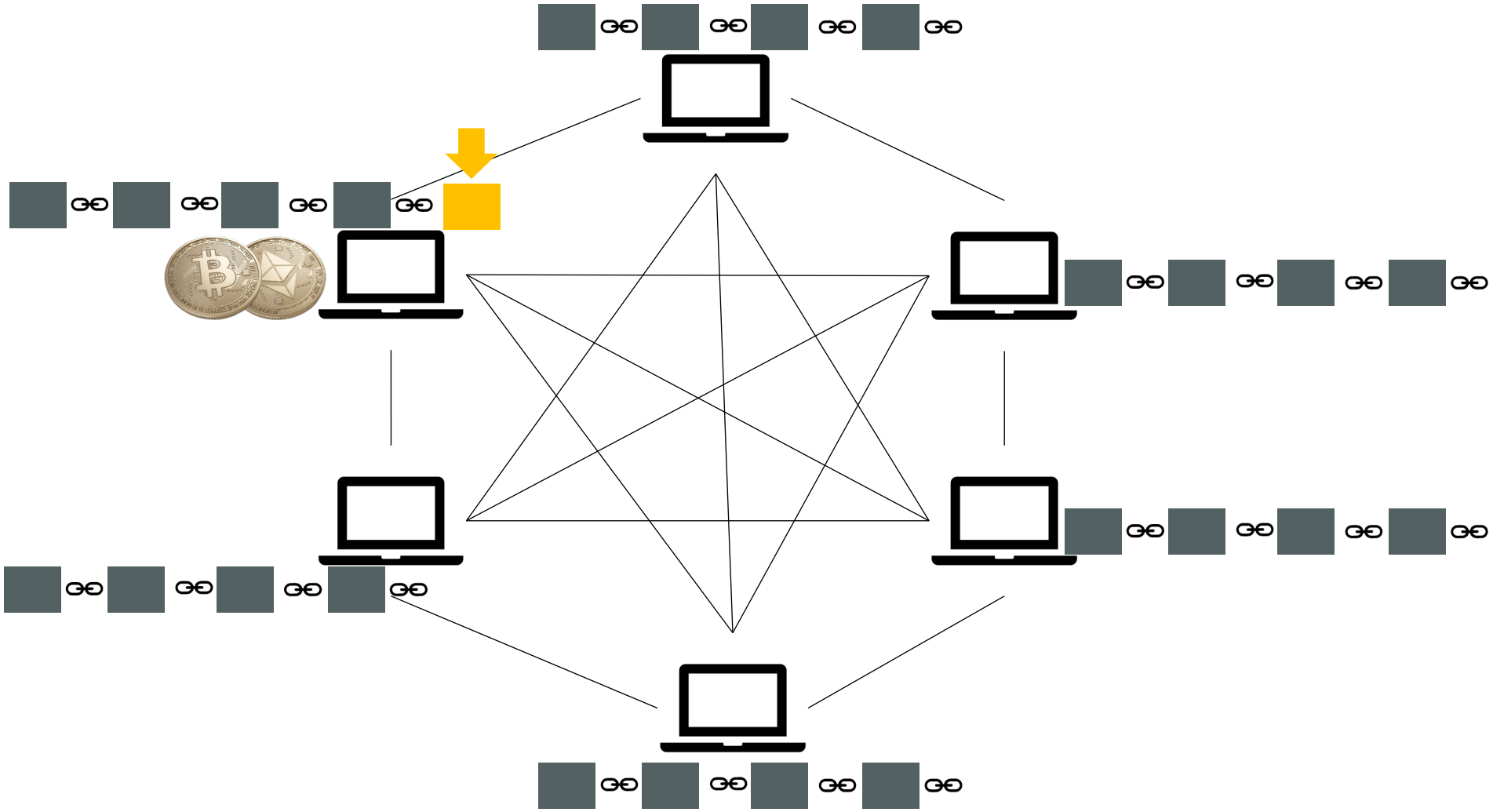
A lot of time and processing power needed to mine a new block



By PoW, miners compete against each other to complete mining and get rewarded.

Challenge 1
Attackers

Consensus Protocol



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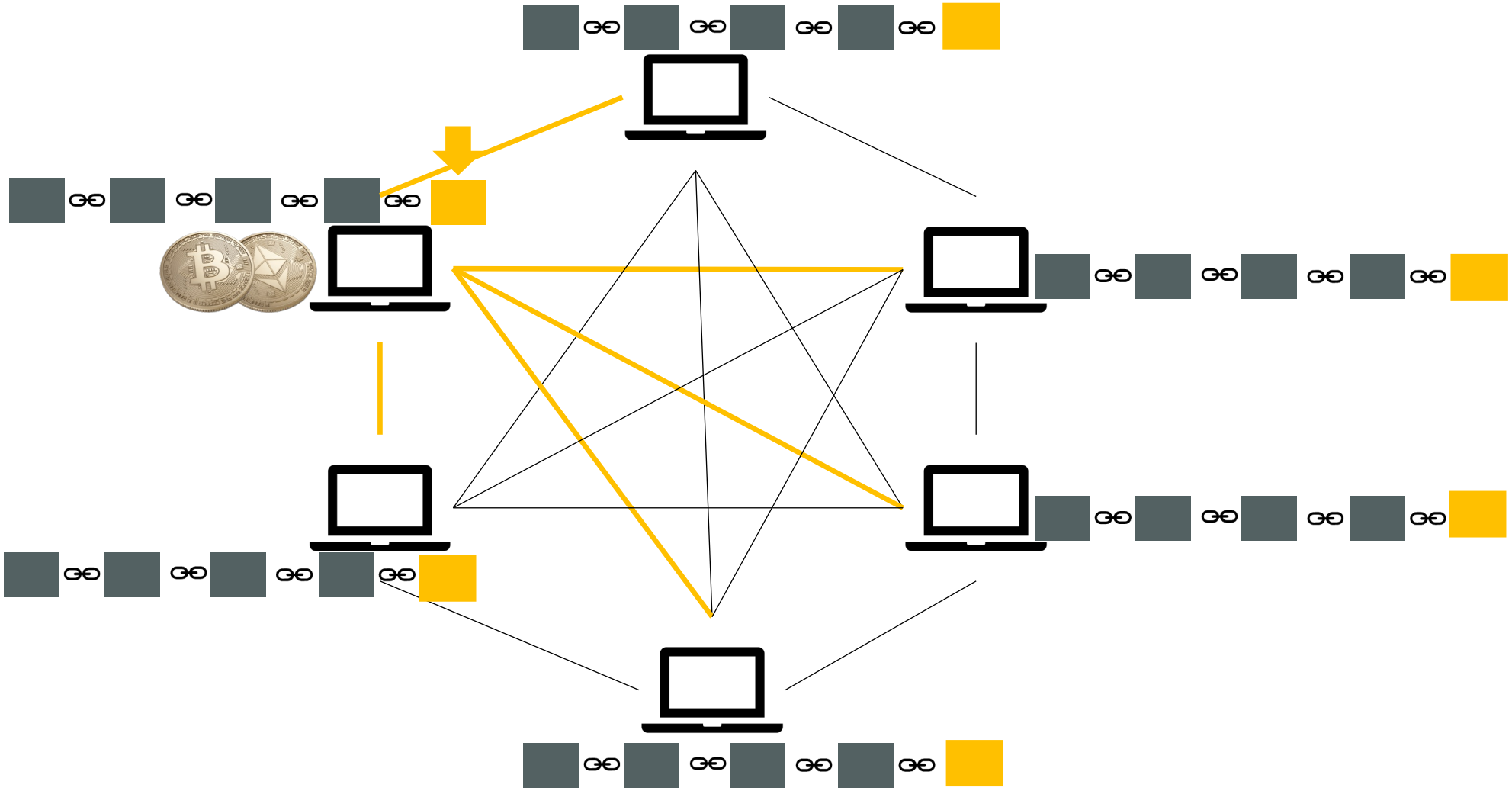
Attackers

Consensus Protocol



Challenge 1
Attackers

Consensus Protocol

1. Check syntactic correctness
2. Reject if duplicate of block we have in any of the three categories
3. Transaction list must be non-empty
4. Block hash must satisfy claimed *nBits* proof of work
5. Block timestamp must not be more than two hours in the future
6. First transaction must be coinbase (i.e. only 1 input, with hash=0, n=-1), the rest must not be
7. For each transaction, apply "tx" checks 2-4
8. For the coinbase (first) transaction, scriptSig length must be 2-100
9. Reject if sum of transaction sig opcounts > MAX_BLOCK_SIGOPS
10. Verify Merkle hash
11. Check if prev block (matching *prev* hash) is in main branch or side branches. If not, add this to orpha done with block
12. Check that *nBits* value matches the difficulty rules
13. Reject if timestamp is the median time of the last 11 blocks or before
14. For certain old blocks (i.e. on initial block download) check that hash matches known values
15. Add block into the tree. There are three cases: 1. block further extends the main branch; 2. block ext main branch; 3. block extends a side branch and makes it the new main branch.
16. For case 1, adding to main branch:
    1. For all but the coinbase transaction, apply the following:

https://en.bitcoin.it/wiki/Protocol_rules

Challenge 1
Attackers

Consensus Protocol

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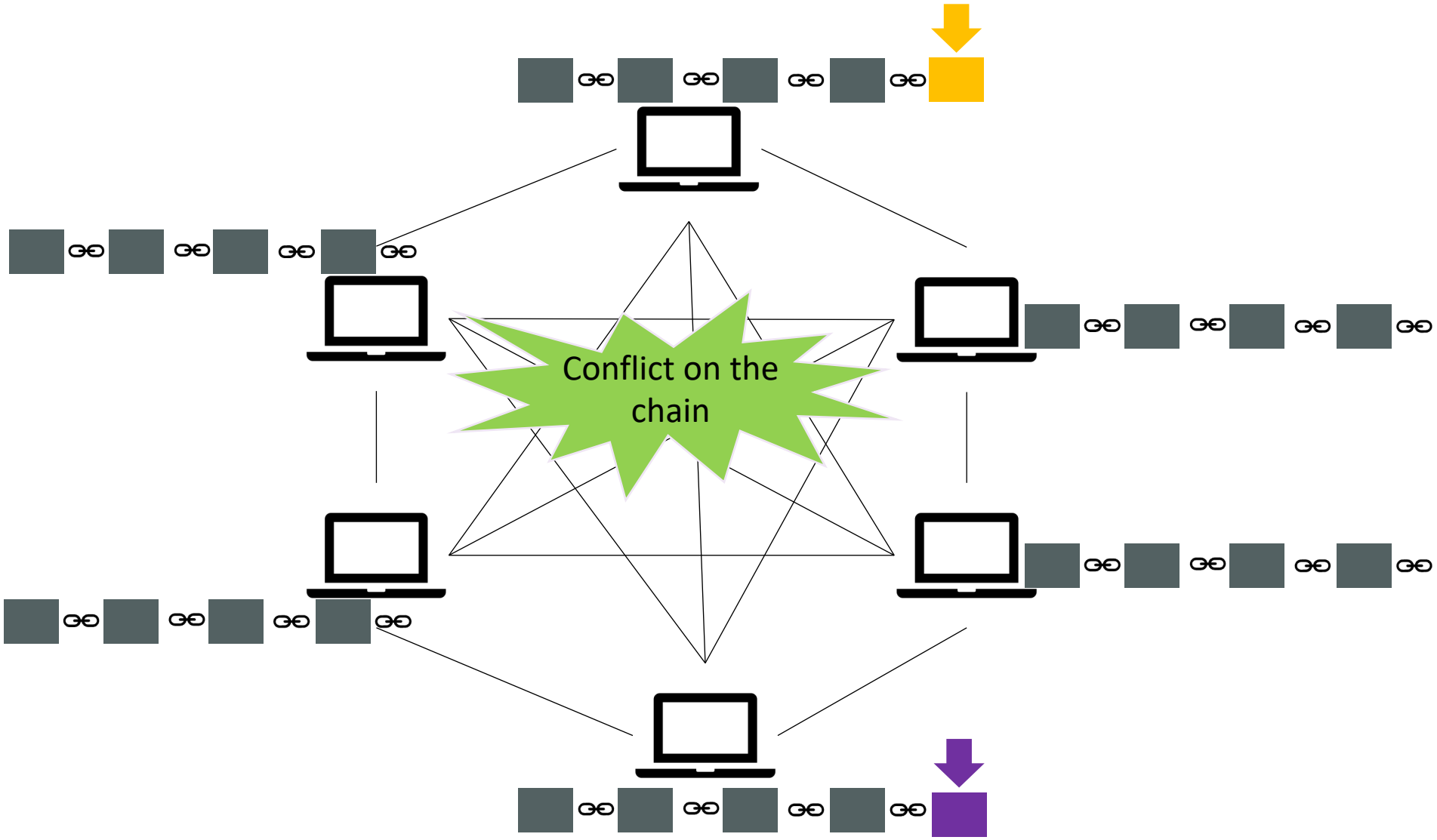
Cryptographic Puzzles: Hard to Solve – Easy to Verify

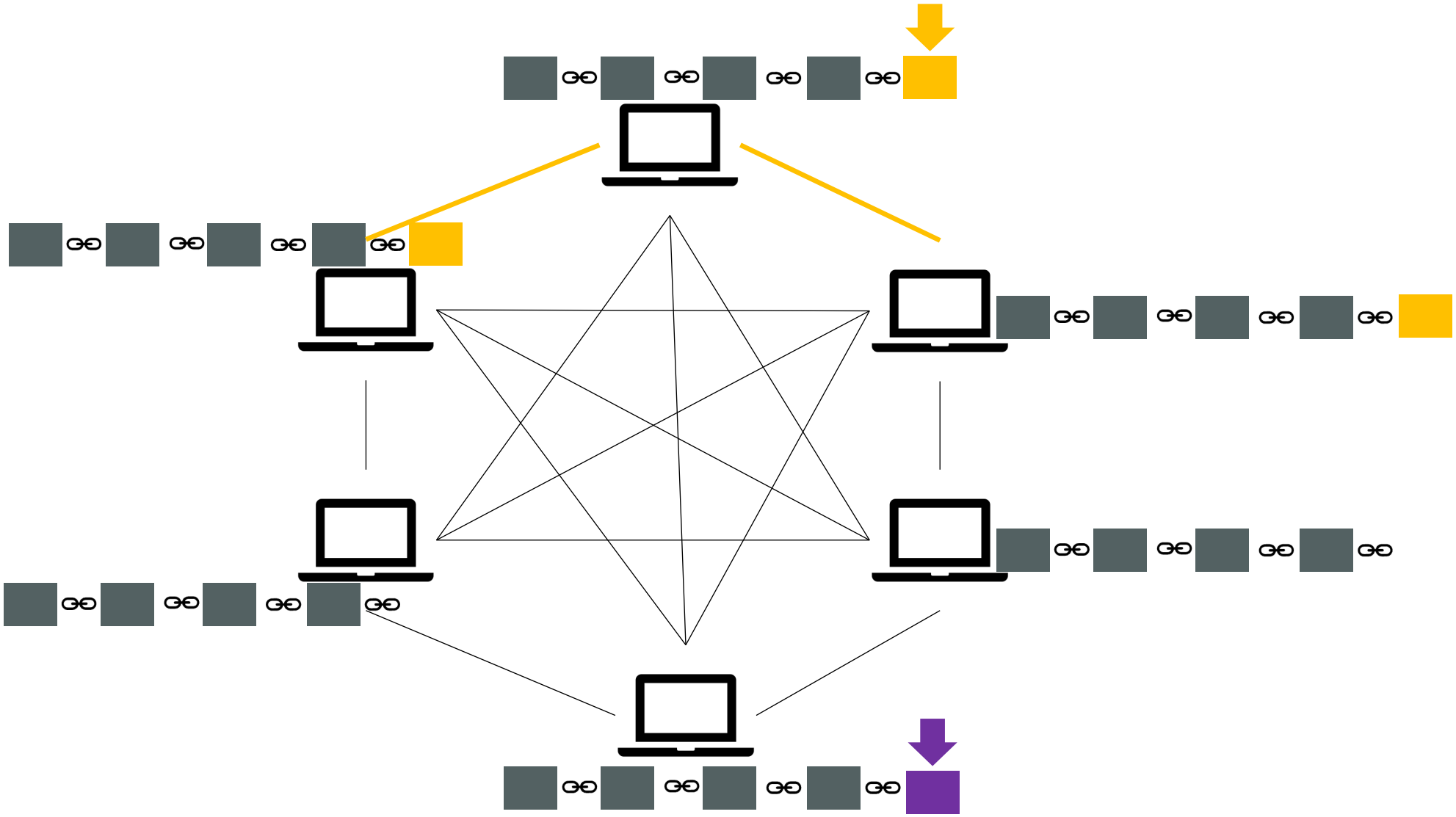
Challenge 1 Attackers

Consensus Protocol



Challenge 2
Competing Chains

Consensus Protocol



Challenge 2
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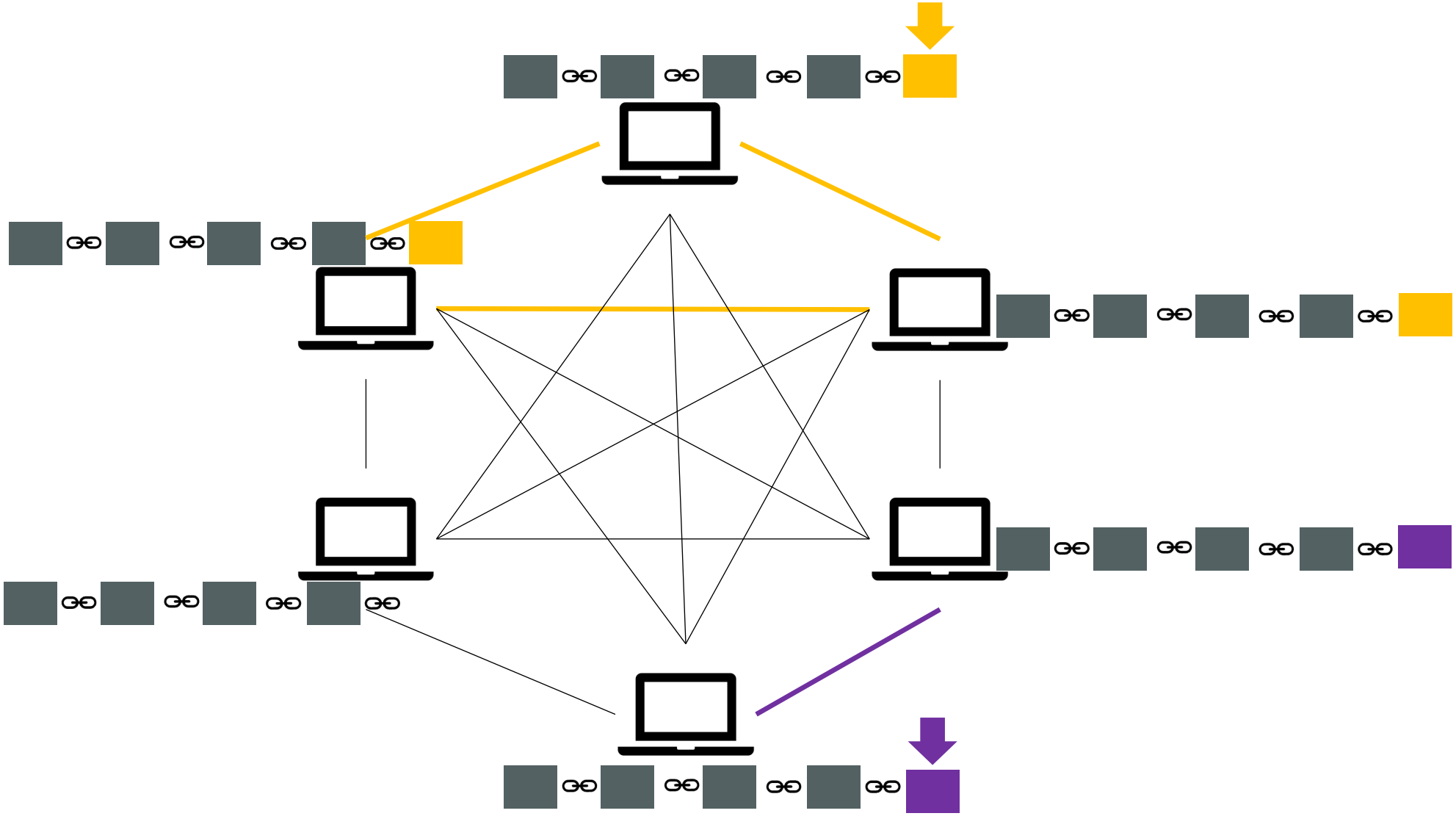

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Competing
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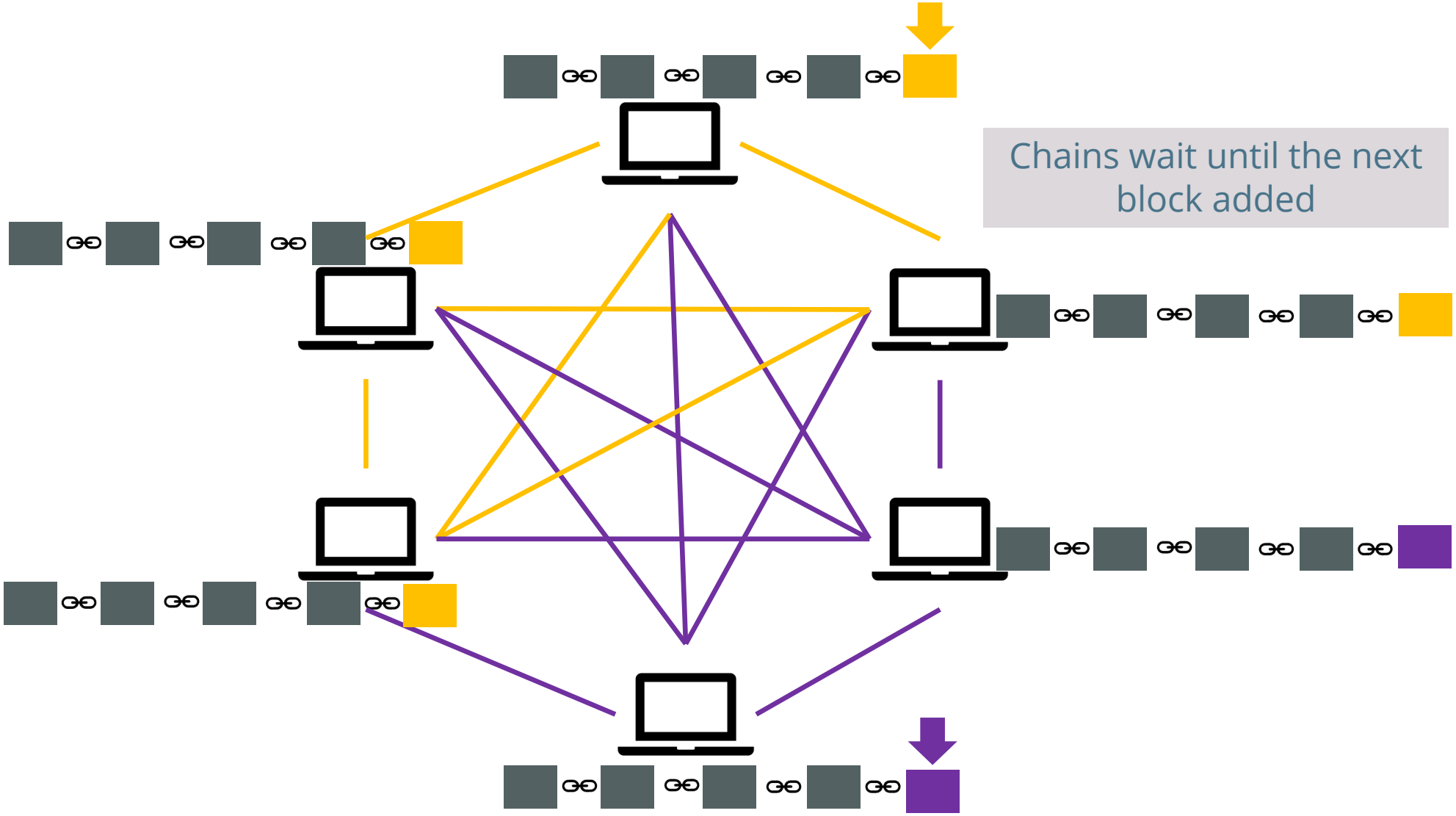
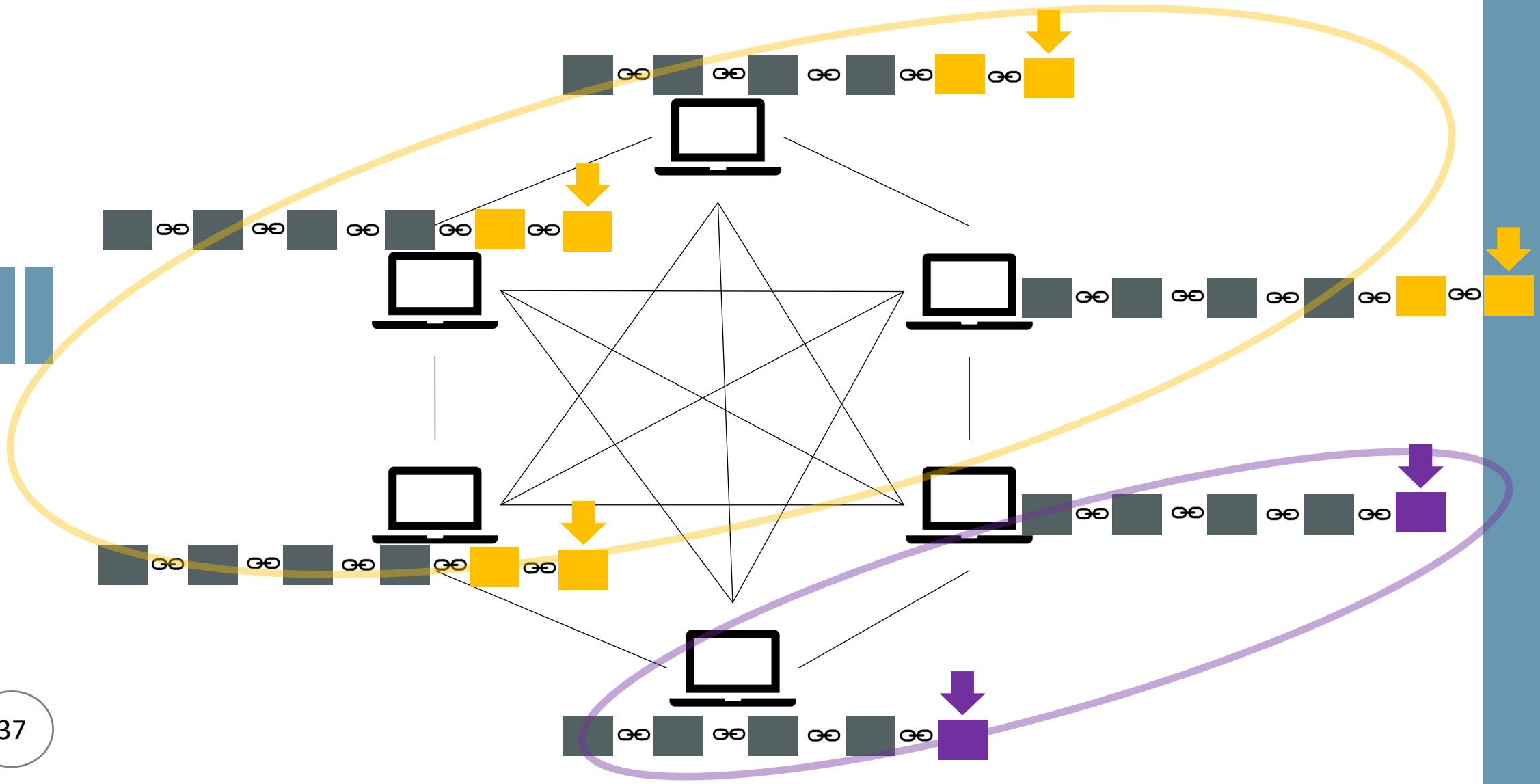


Chains wait until the next block added

Challenge 2
Competing Chains

Consensus Protocol



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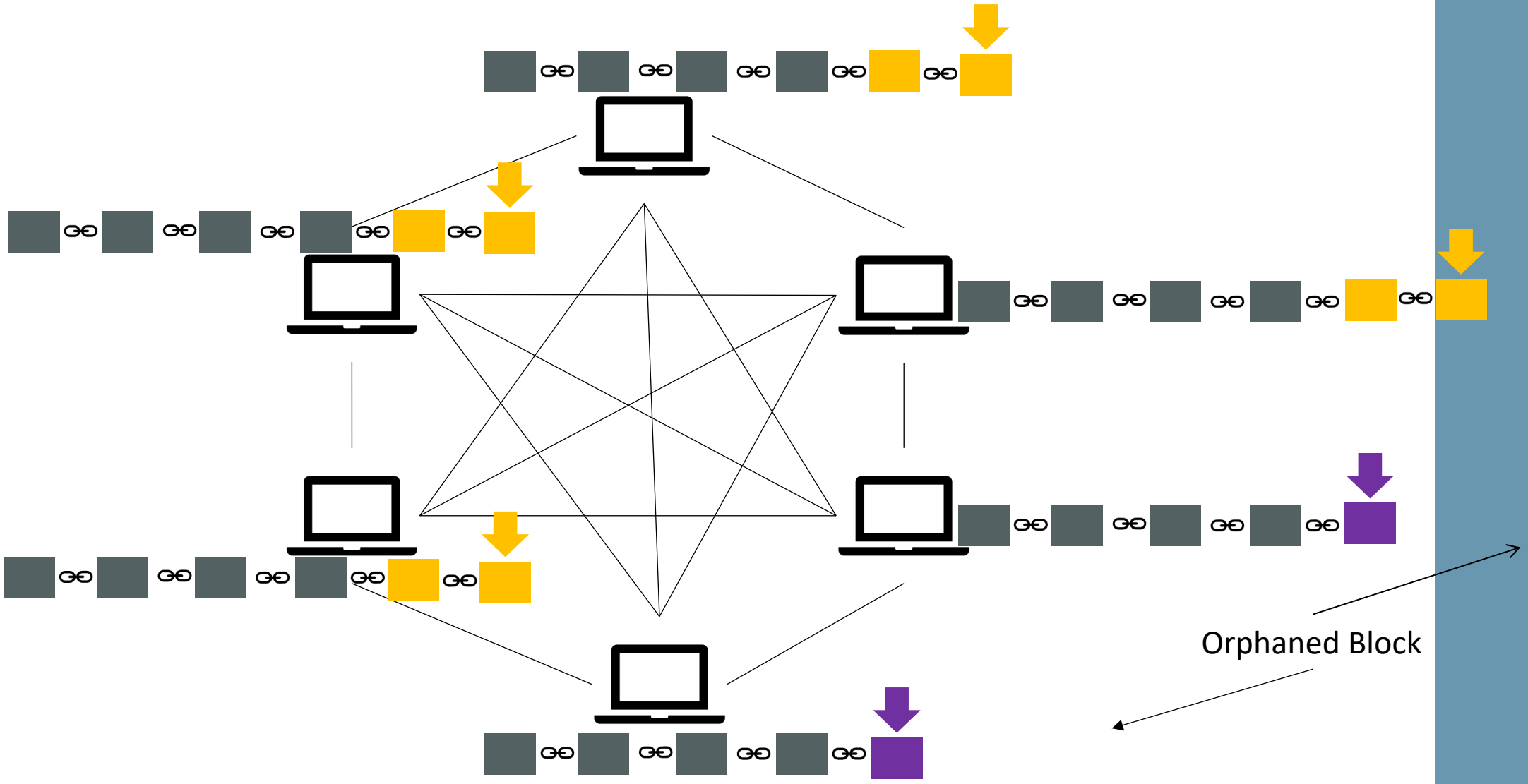

Blockchain Components

- Hash Cryptography
- Immutable Ledger
- Distributed P2P Network
- Mining
- Consensus Protocol

References

[1] Haber, Stuart, and W. Scott Stornetta. "How to time-stamp a digital document." Conference on the Theory and Application of Cryptography. Springer, Berlin, Heidelberg, 1990. https://www.anf.es/pdf/Haber_Stornetta.pdf

[2] Nakamoto, S. "Bitcoin: A P2P Electronic Cash System." (2009). https://bitcoin.org/bitcoin.pdf

[3] Wouter, Penard, and Tim V. Werkhoven. “On the Secure Hash Algorithm family” Chapter one of Cryptography in Context, 2008. https://webspace.science.uu.nl/~tel00101/liter/Books/CrypCont.pdf