Introduction to
Distributed Ledger Technologies
(the classy name of blockchains)

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What are we ?

What are we ?

Computers

What are we ?

What do we want ?

Computers

What are we ?

What do we want ?

Computers

Distributed data

What are we ?

What do we want ?

How we want it ?

Computers

Distributed data

What are we ?

What do we want ?

How we want it ?

Computers

Distributed data

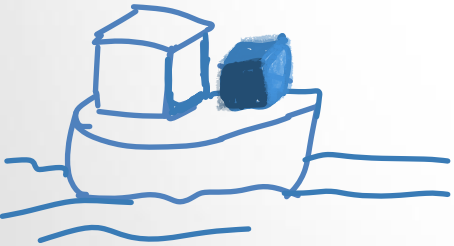
Consistent

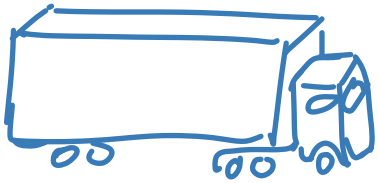
Efficient

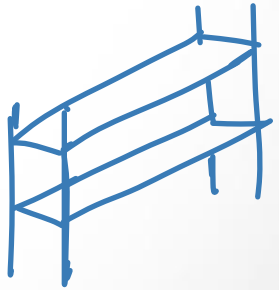
Secure

Scalable

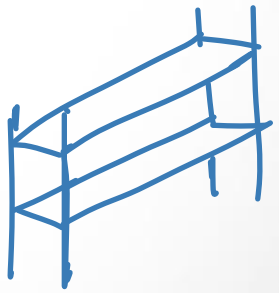
Blockchain







Blockchain



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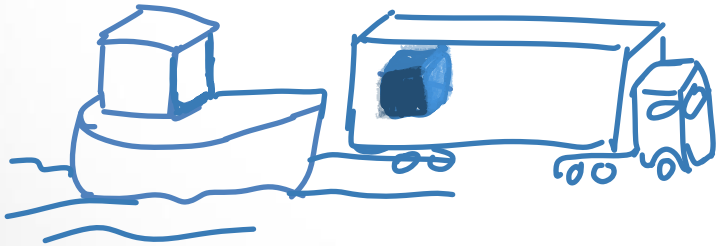
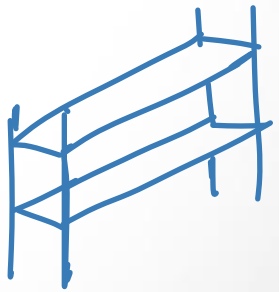
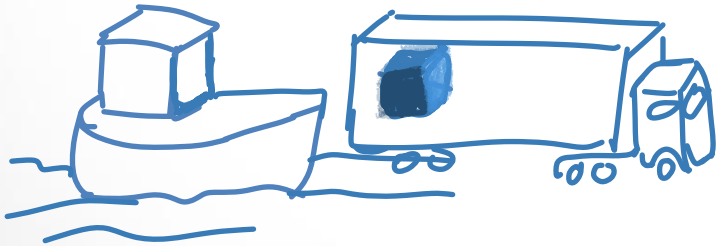
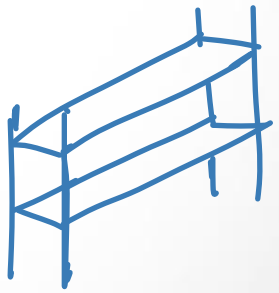




Blockchain

X is delivered
from A to B





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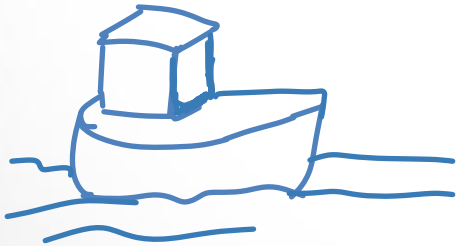

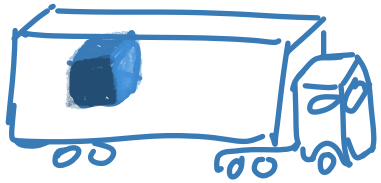

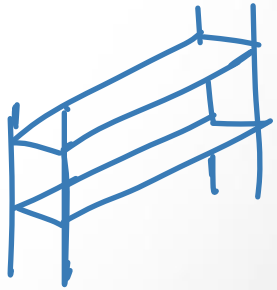

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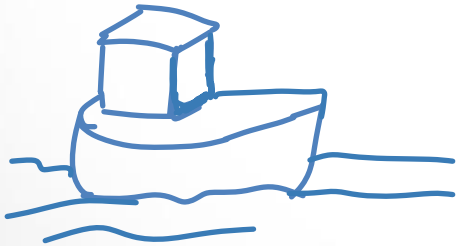
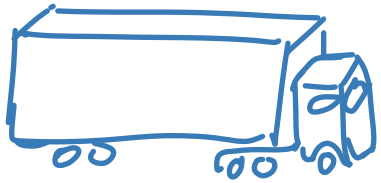
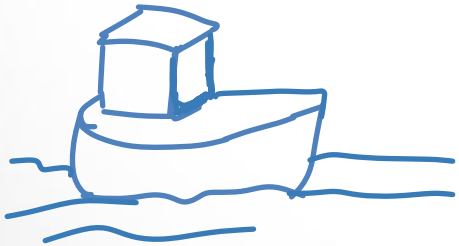


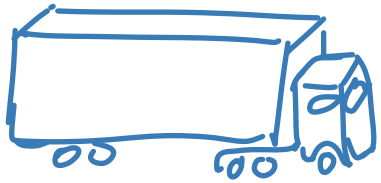


Blockchain

X is delivered
from A to B

X is delivered
from B to C



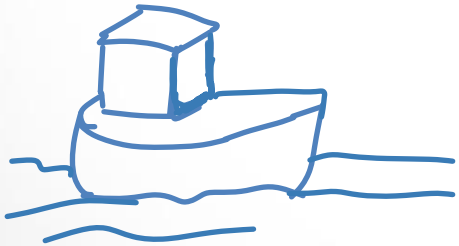


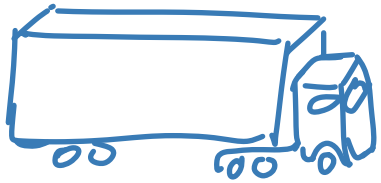
Blockchain

X is delivered from A to B

X is delivered from B to C

X is in the final product



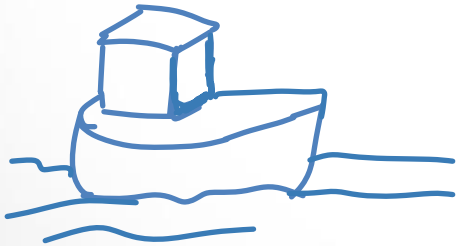


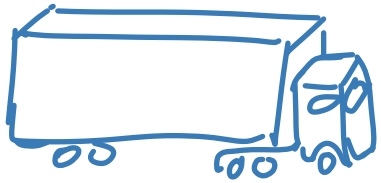
Blockchain

X is delivered from A to B

X is delivered from B to C

X is in the final product





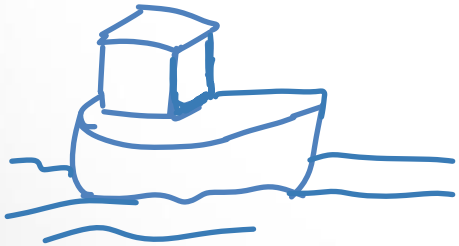
X is delivered from B to D

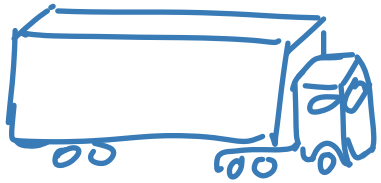
Blockchain

X is delivered from A to B

X is delivered from B to C

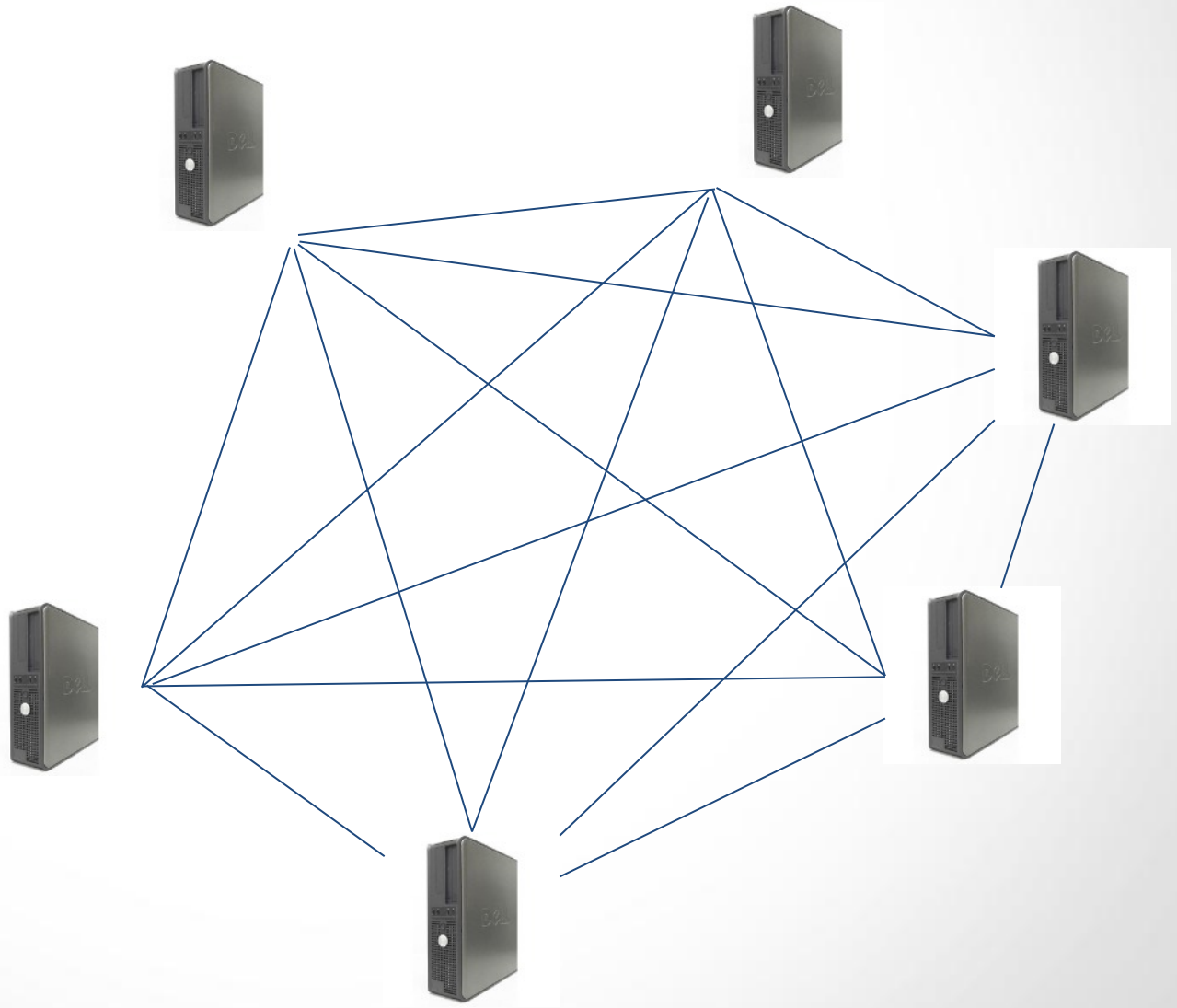
X is in the final product





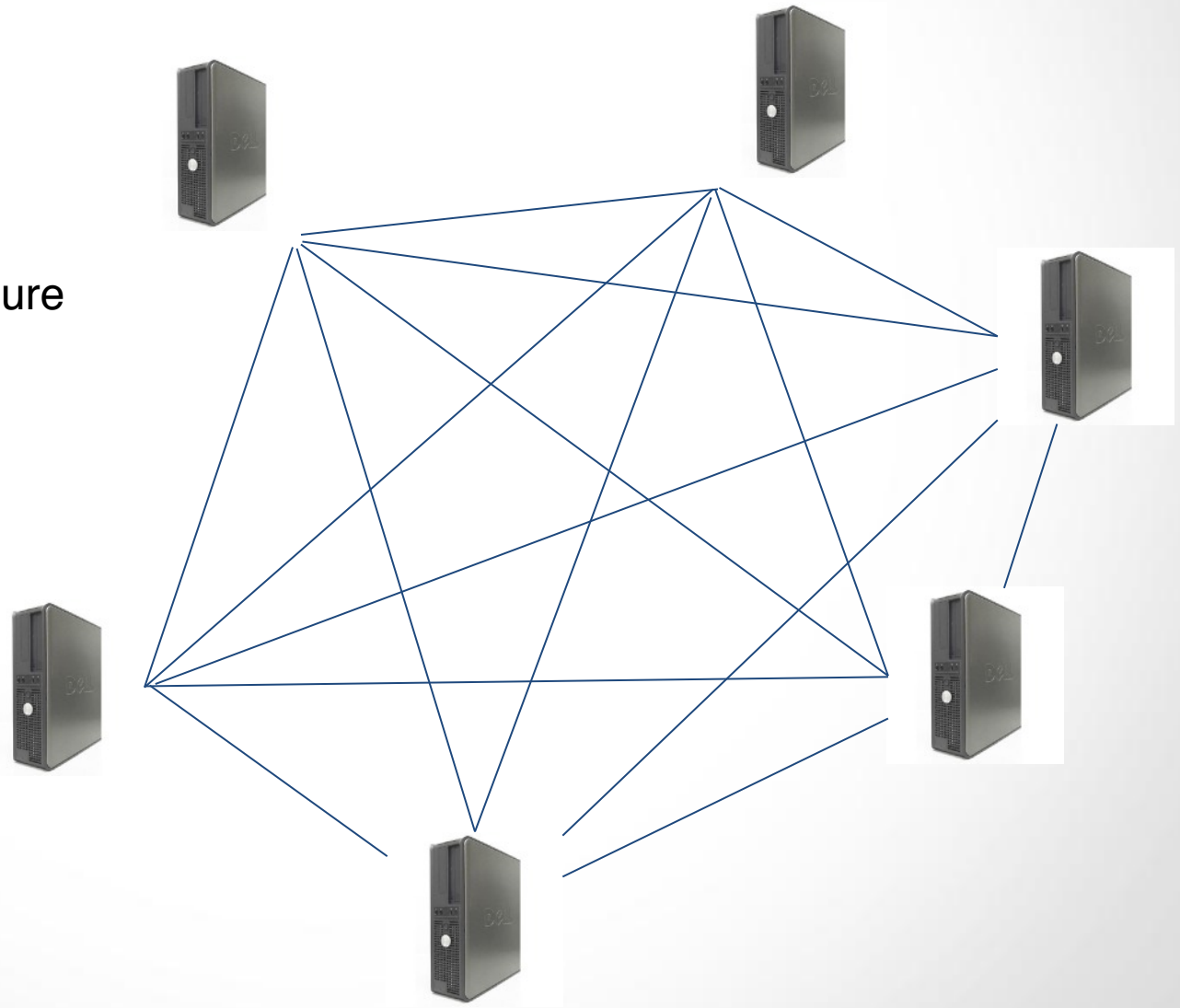
X is delivered from B to D

Data is distributed :



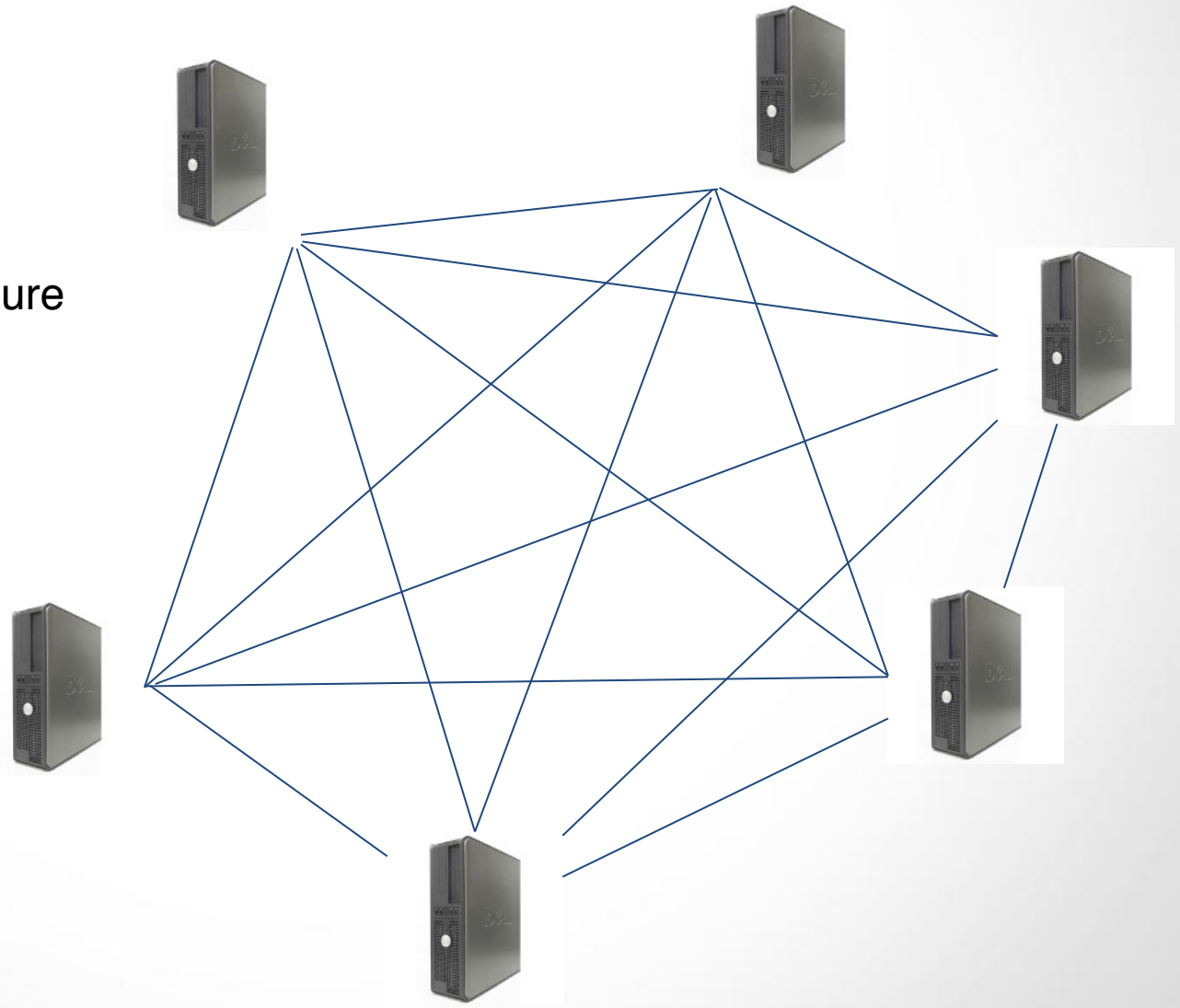
Data is distributed :

- no single point of failure



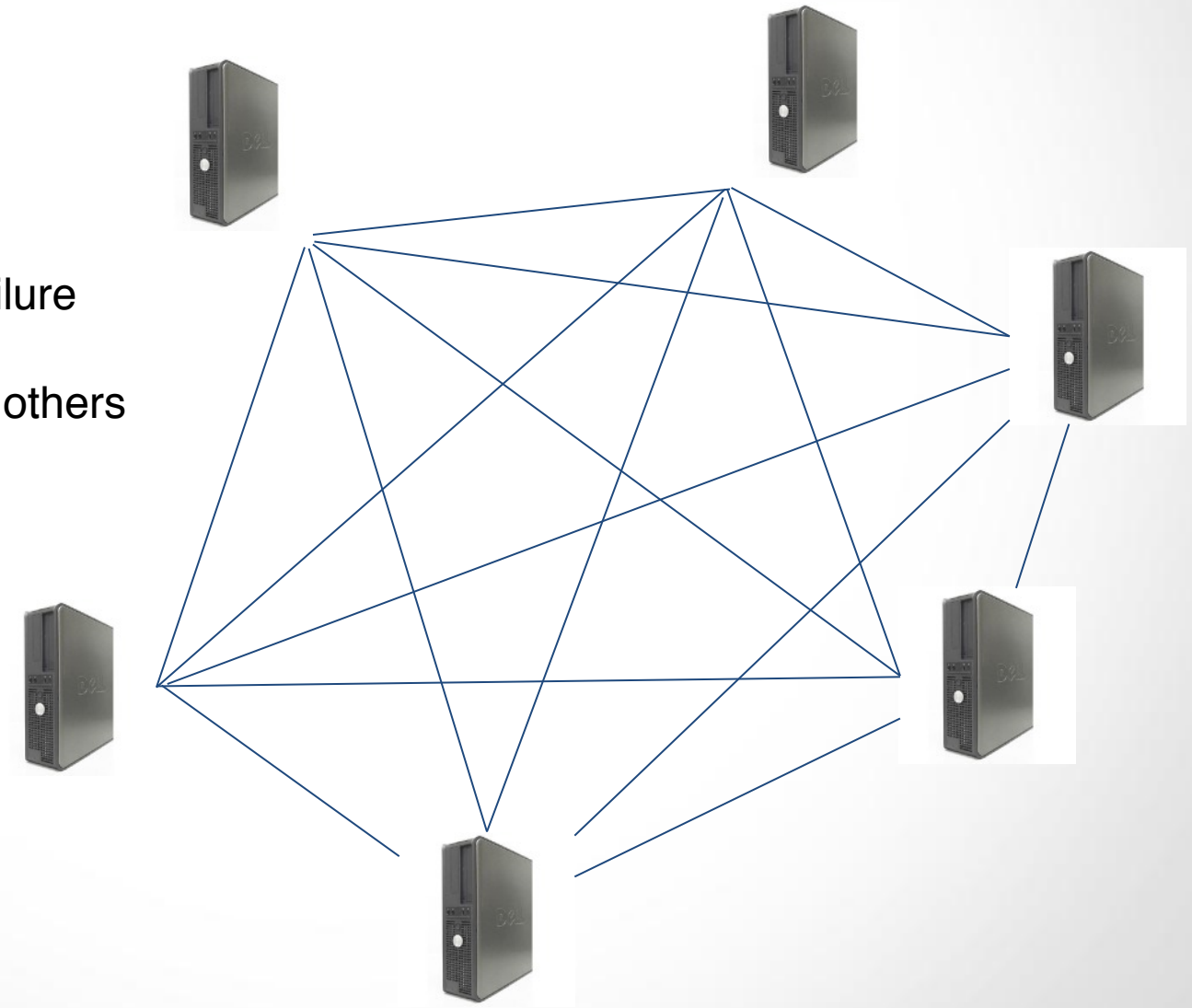
Data is distributed :

- no single point of failure
- no central Authority



Data is distributed :

- no single point of failure
- no central Authority
- no need to trust the others



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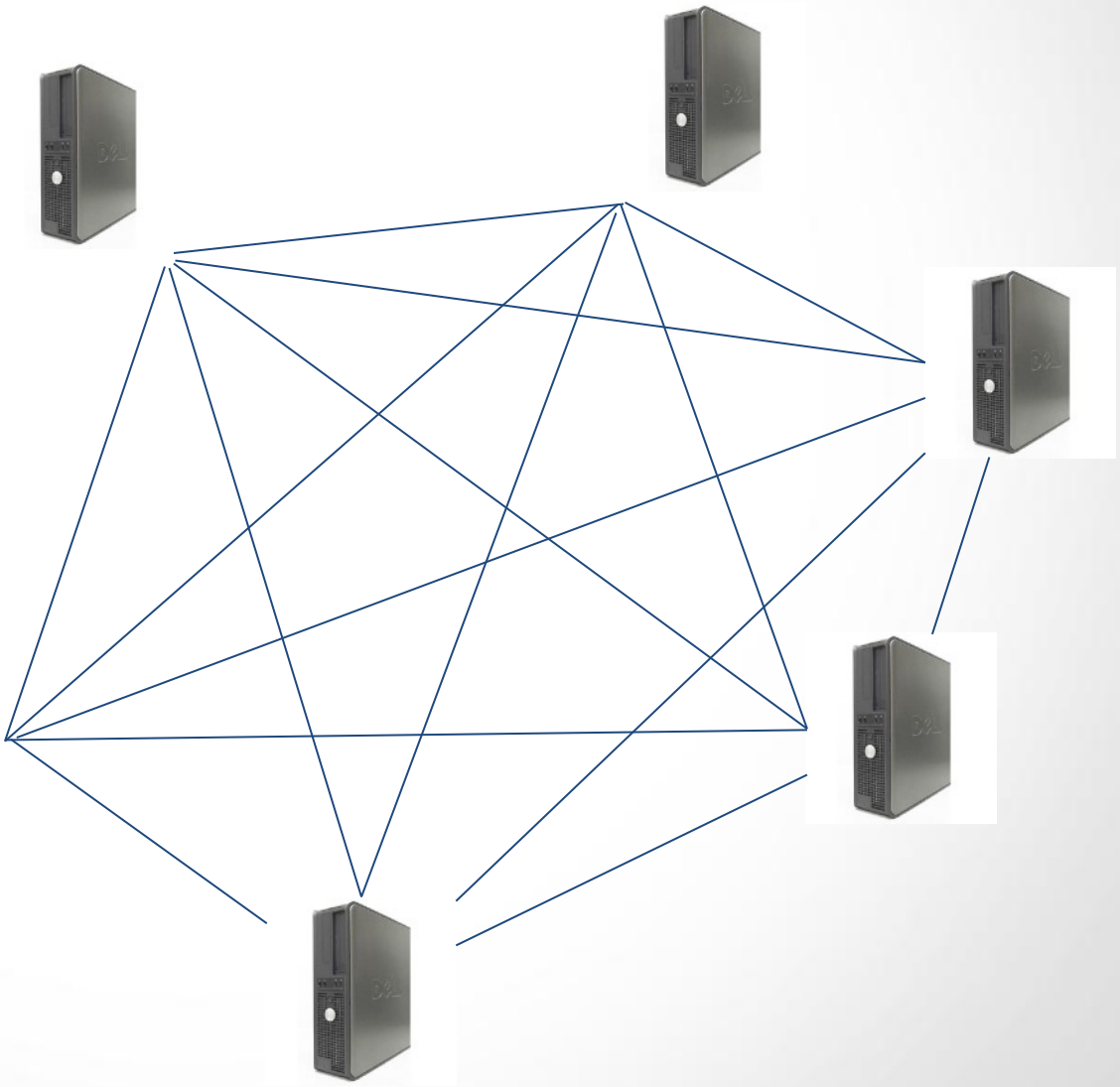
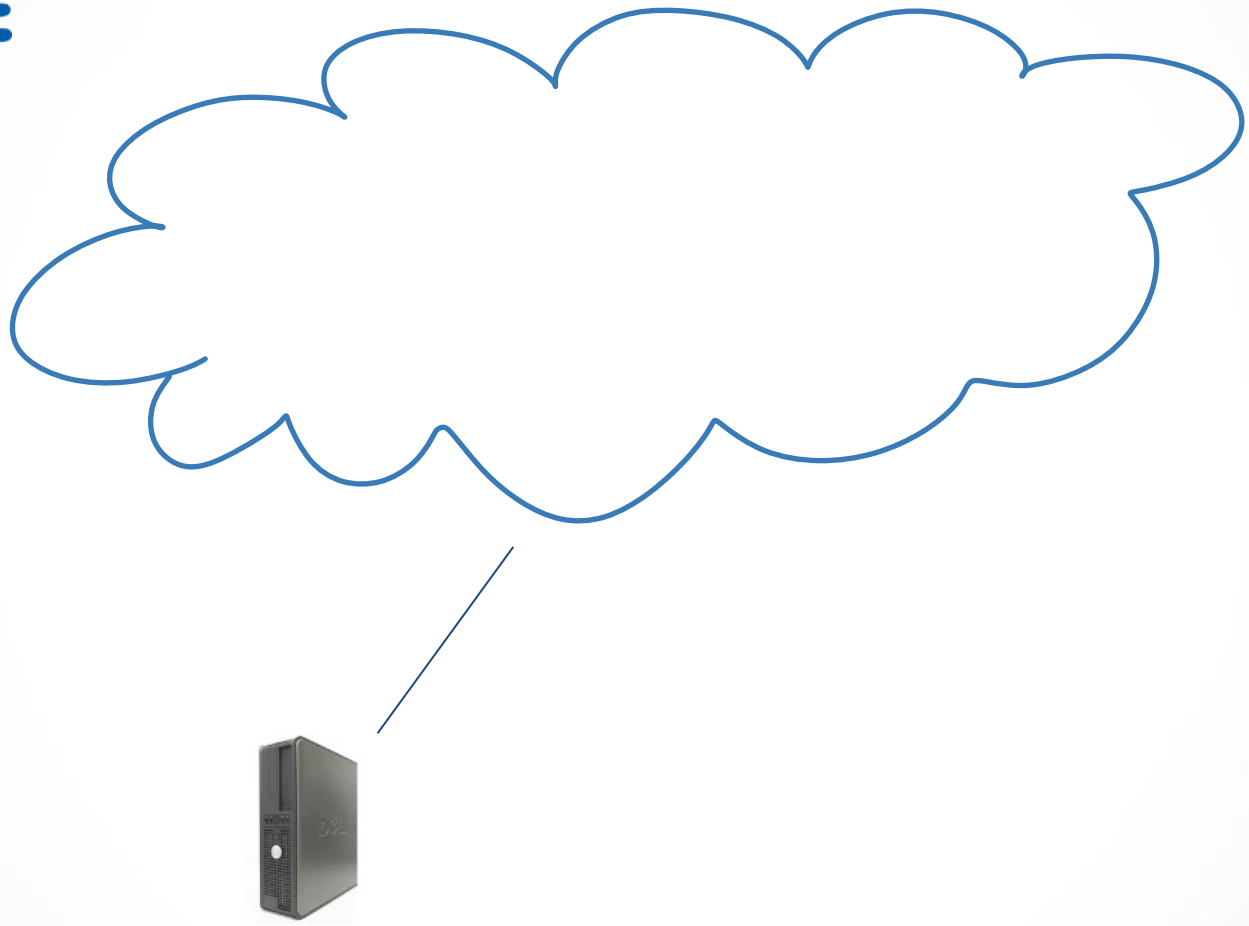
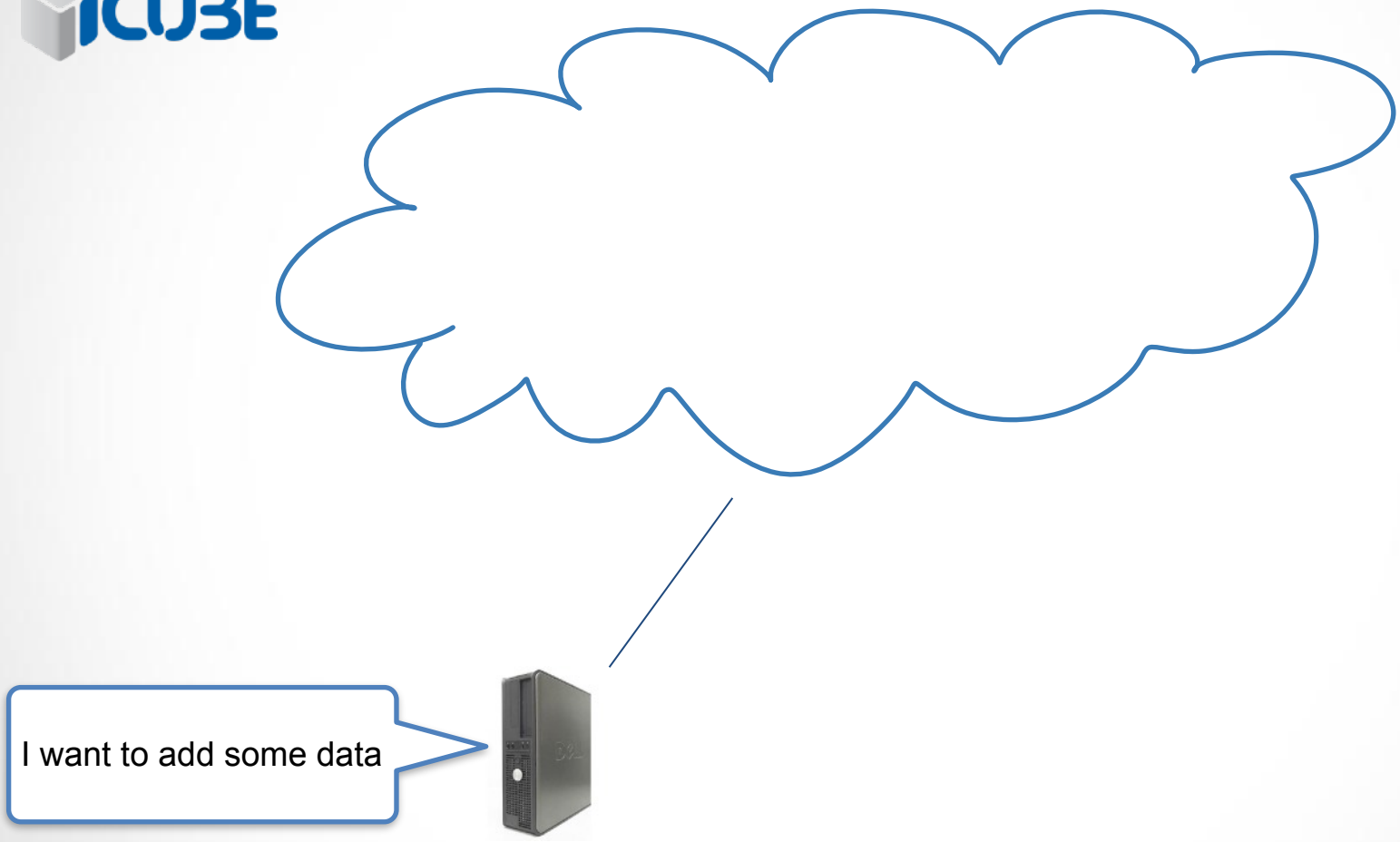
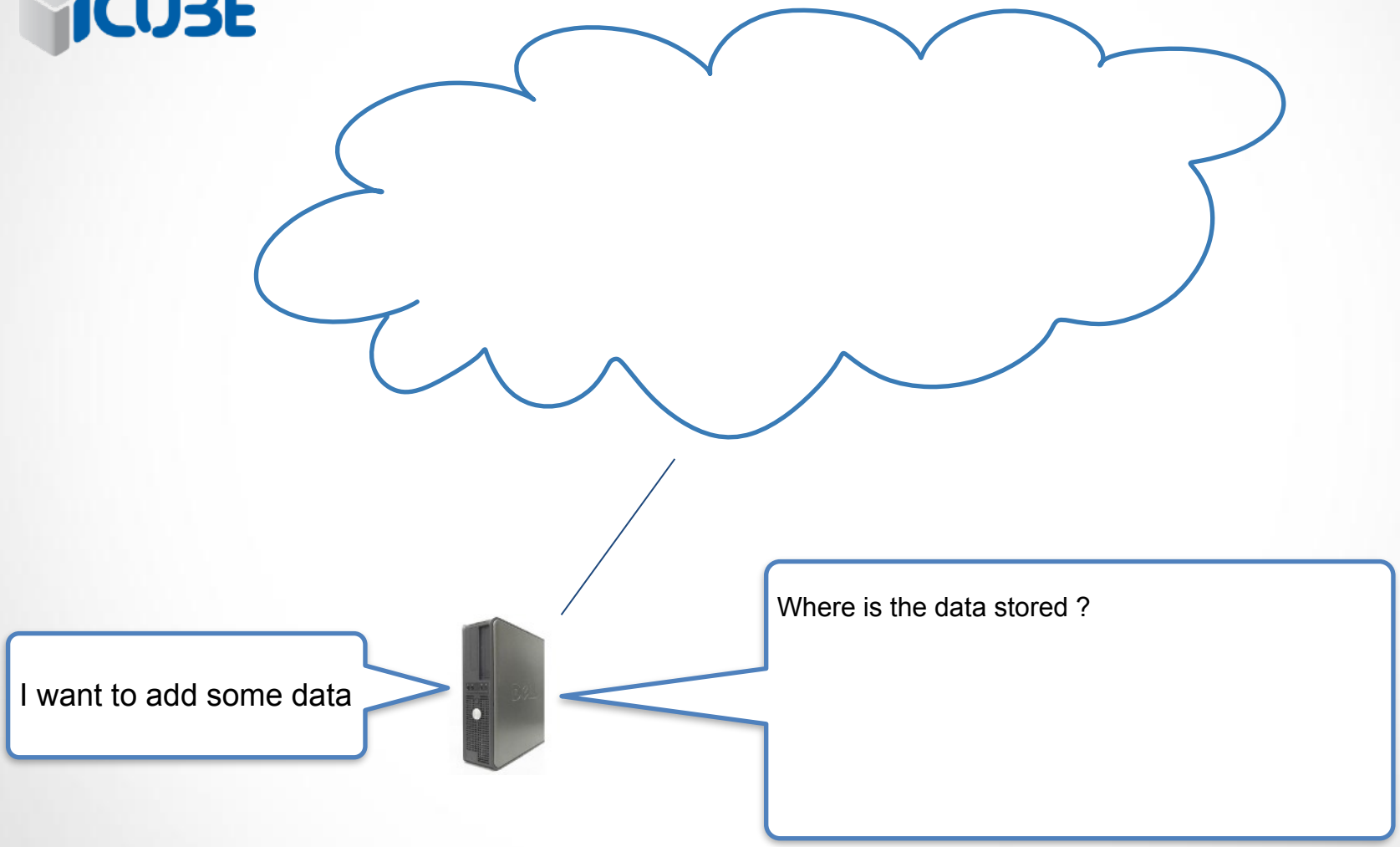
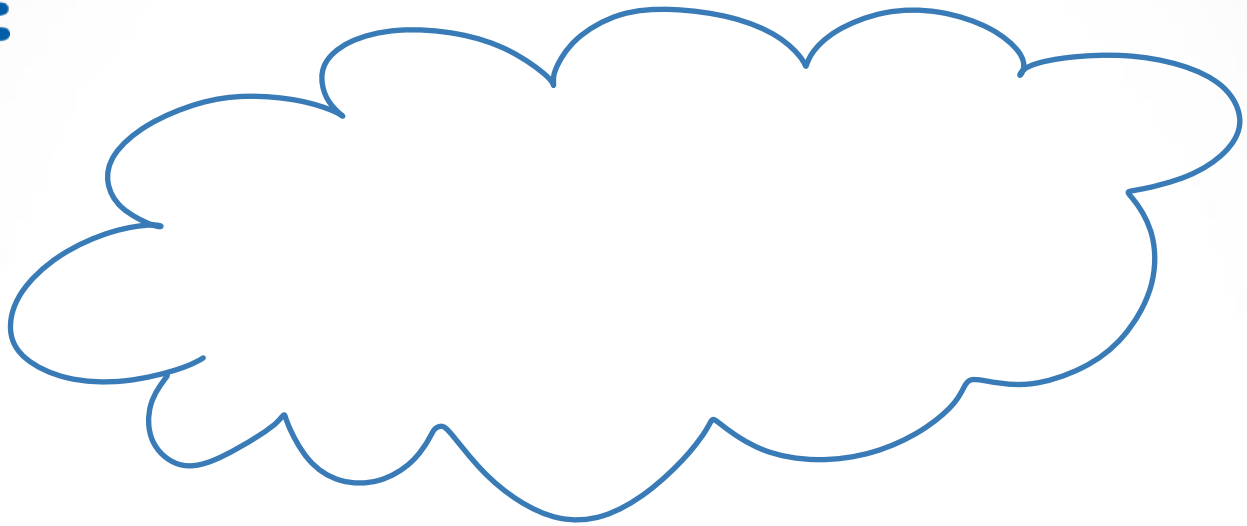




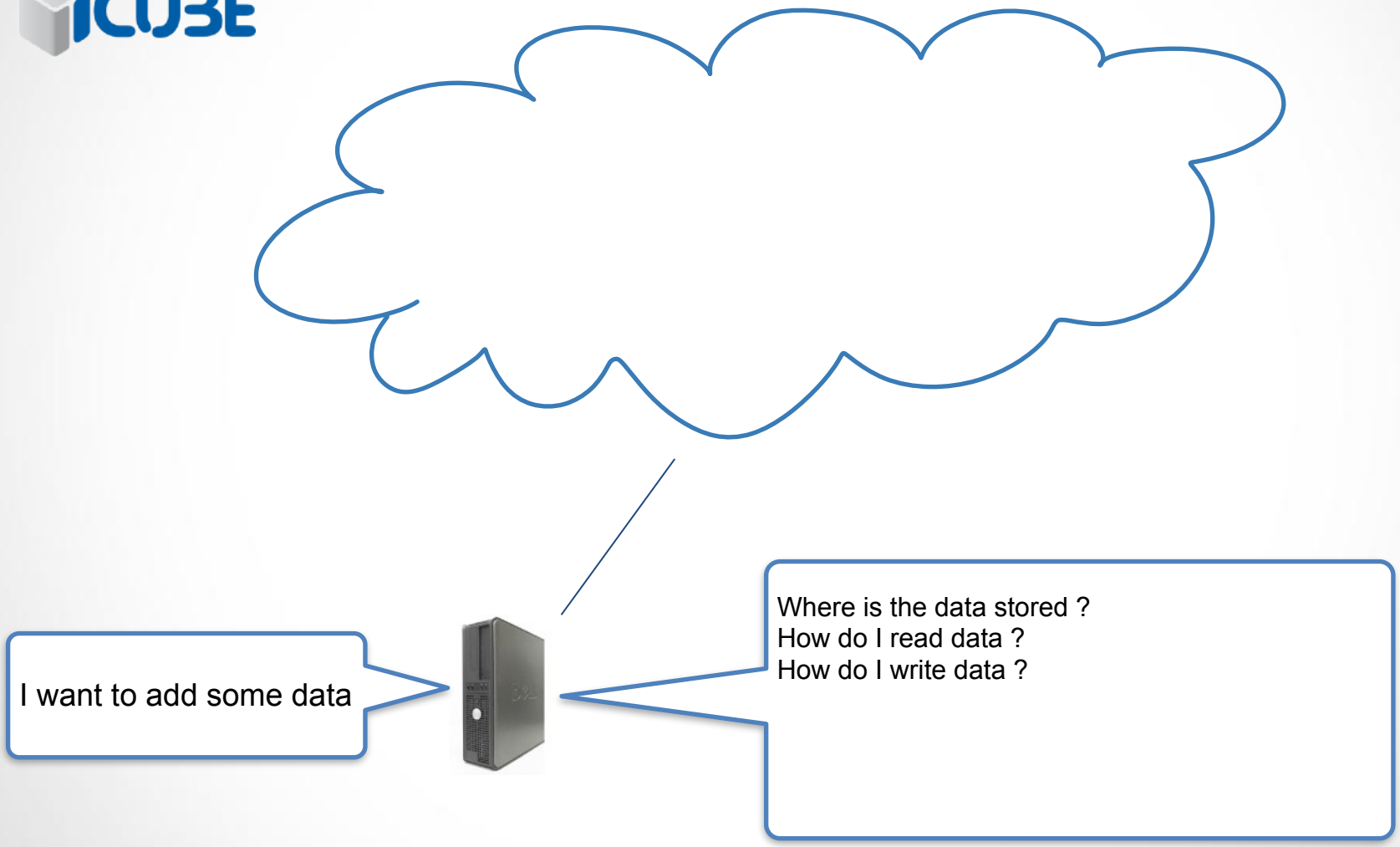

I want to add some data

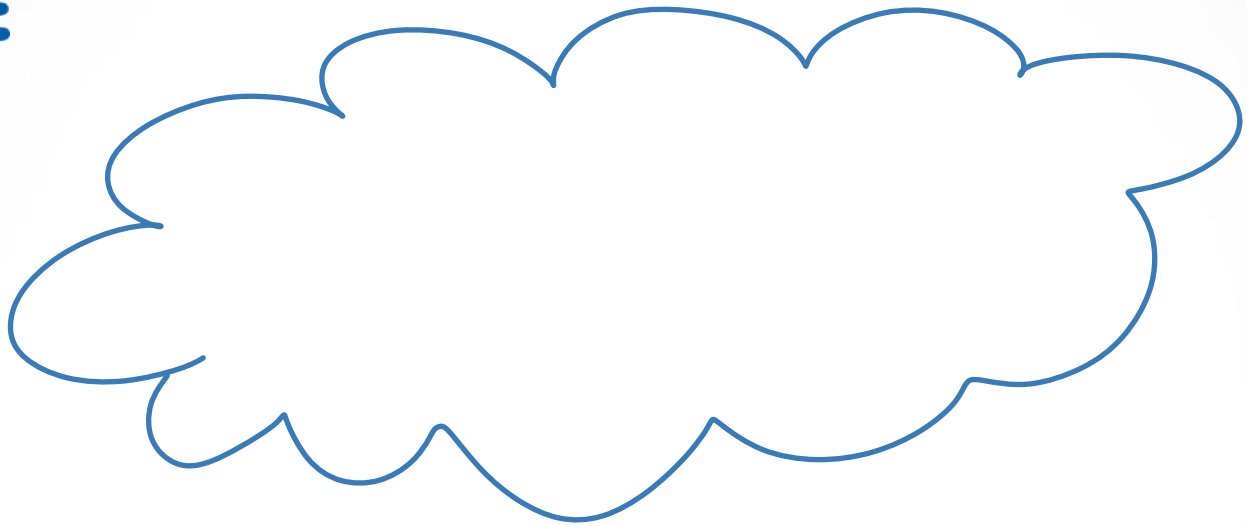

I want to add some data
Where is the data stored ?



I want to add some data

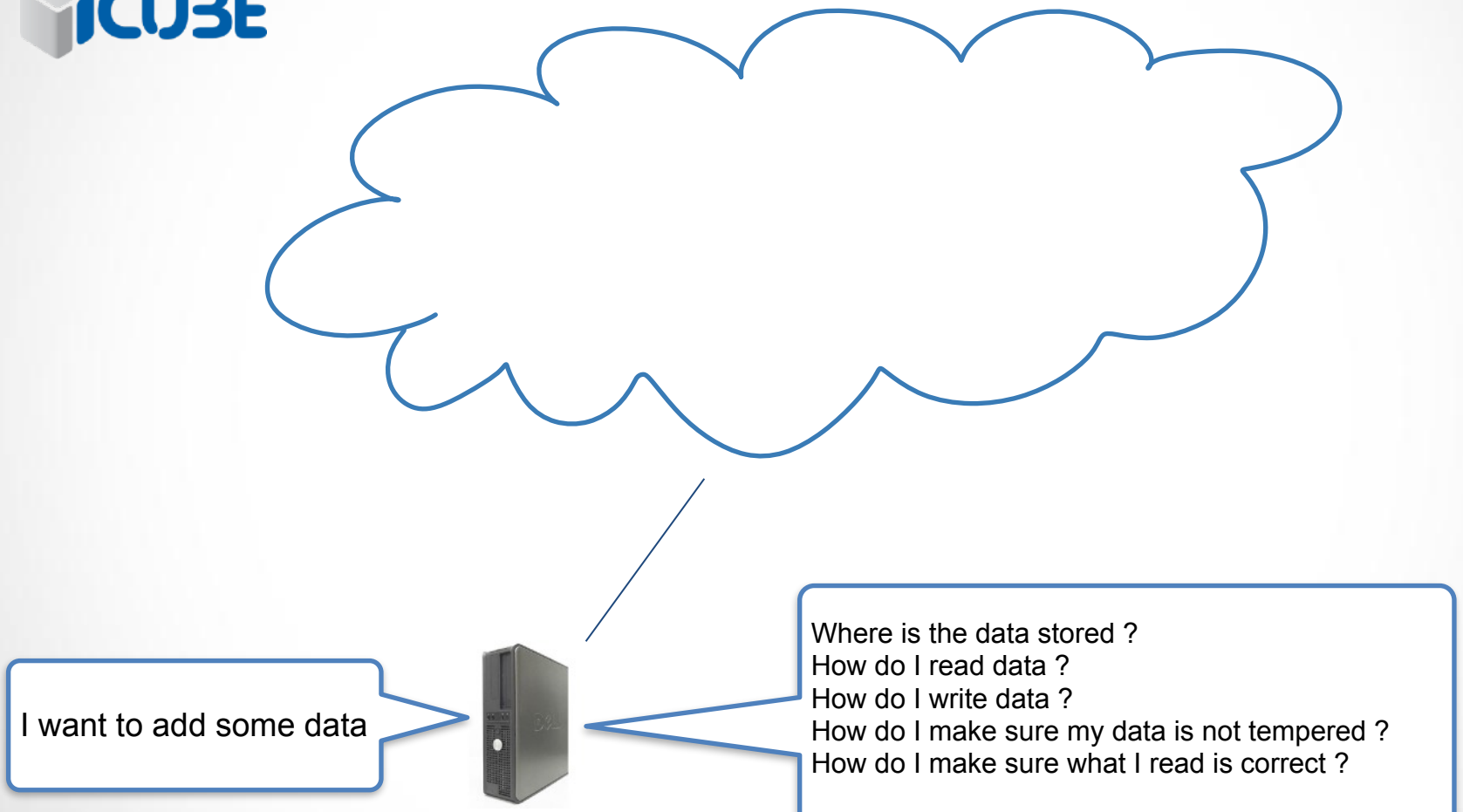
Where is the data stored ?
How do I read data ?

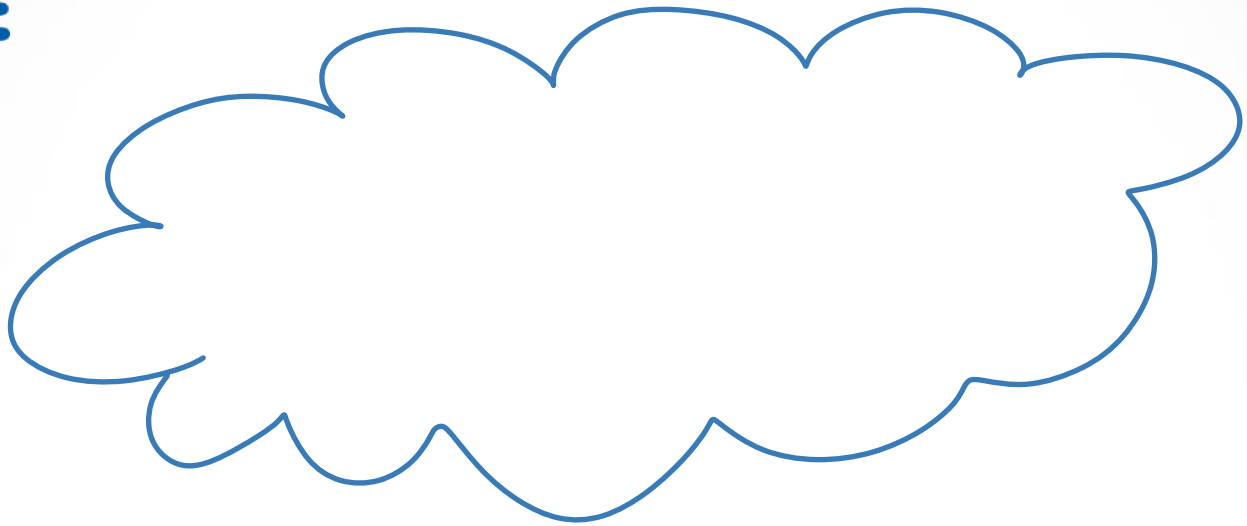

I want to add some data
Where is the data stored ?
How do I read data ?
How do I write data ?



I want to add some data

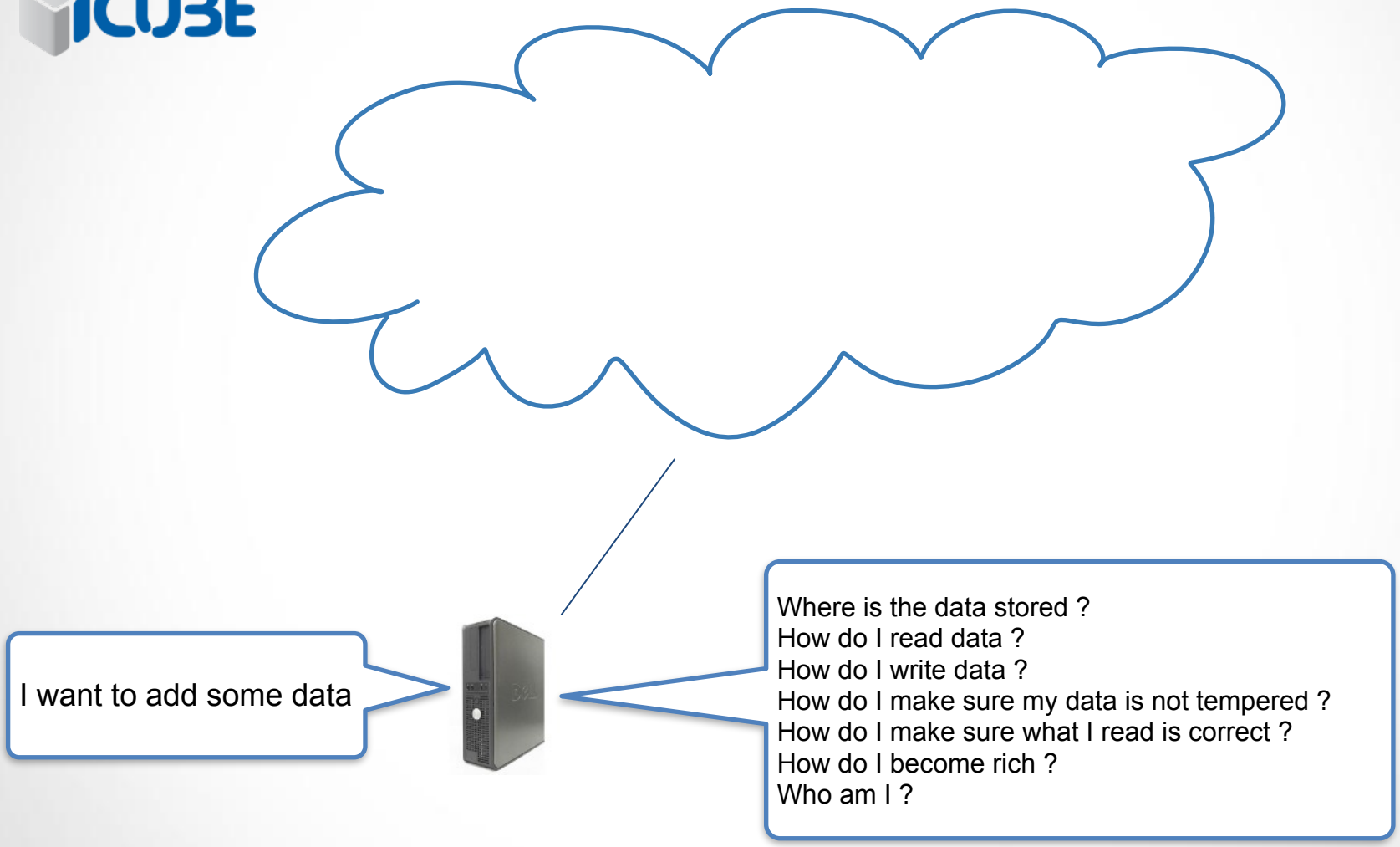
Where is the data stored ?
How do I read data ?
How do I write data ?
How do I make sure my data is not tempered ?


I want to add some data
Where is the data stored ?
How do I read data ?
How do I write data ?
How do I make sure my data is not tempered ?
How do I make sure what I read is correct ?

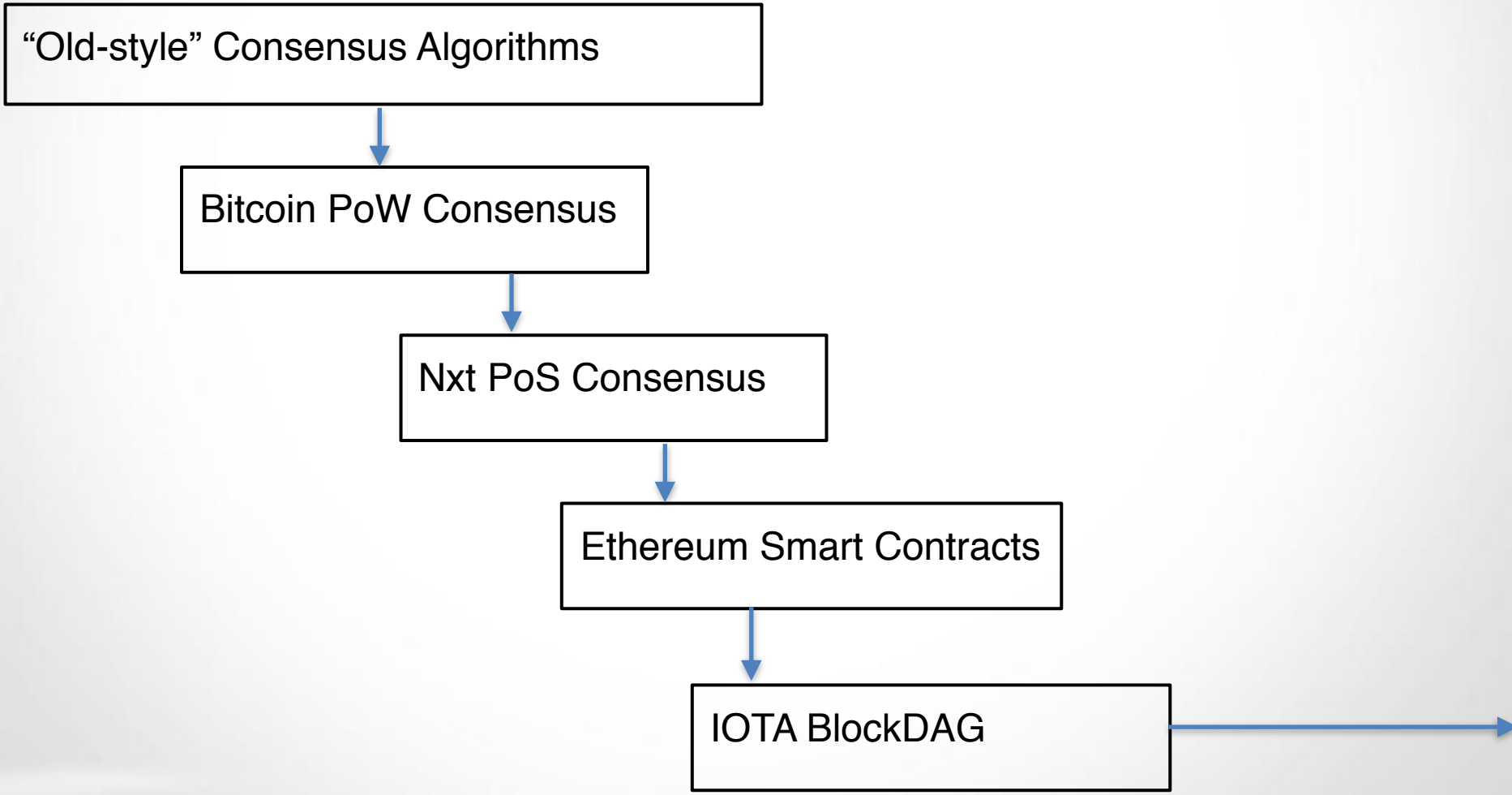


I want to add some data

Where is the data stored ?
How do I read data ?
How do I write data ?
How do I make sure my data is not tempered ?
How do I make sure what I read is correct ?
How do I become rich ?


I want to add some data
Where is the data stored ?
How do I read data ?
How do I write data ?
How do I make sure my data is not tempered ?
How do I make sure what I read is correct ?
How do I become rich ?
Who am I ?

Talk Chain


“Old-style” Consensus Algorithms
Bitcoin PoW Consensus
Nxt PoS Consensus
Ethereum Smart Contracts
IOTA BlockDAG

“Old-style” Consensus Algorithms → Bitcoin PoW Consensus

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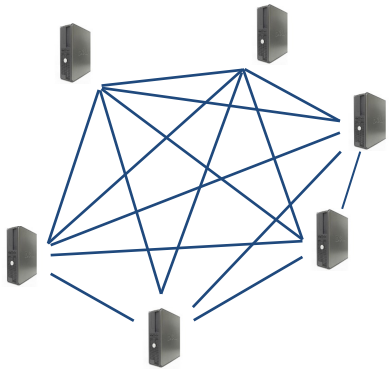
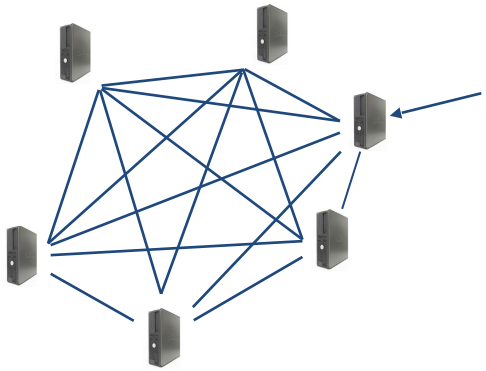
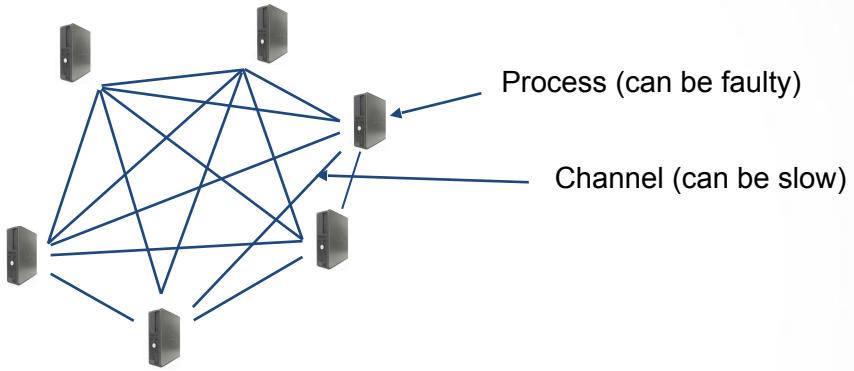
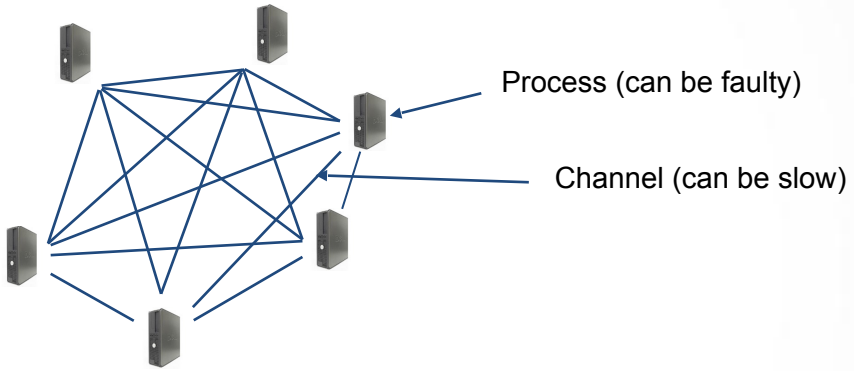


“Old-style” Consensus Algorithms → Bitcoin PoW Consensus



“Old-style” Consensus Algorithms → Bitcoin PoW Consensus

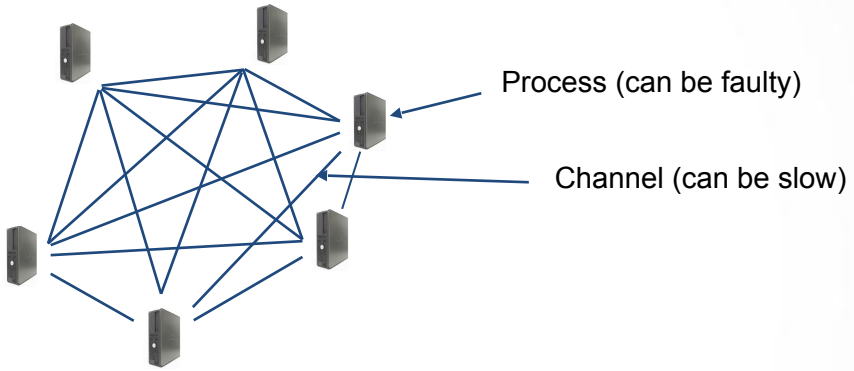




Definition of Consensus:

“Old-style” Consensus Algorithms

Bitcoin PoW Consensus

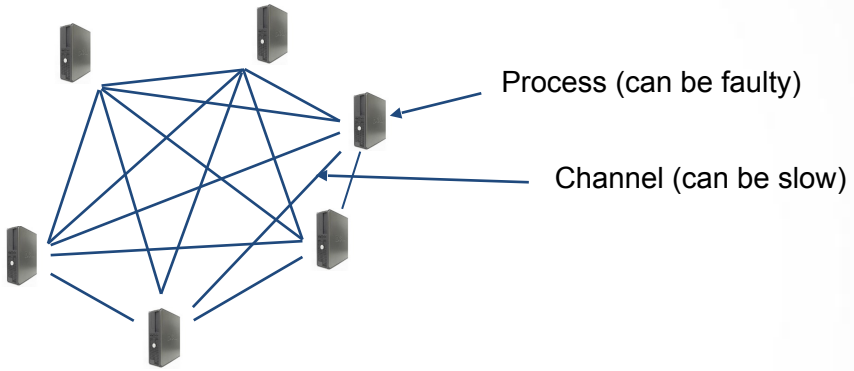


Definition of Consensus:

Each process starts with an input value

“Old-style” Consensus Algorithms

Bitcoin PoW Consensus



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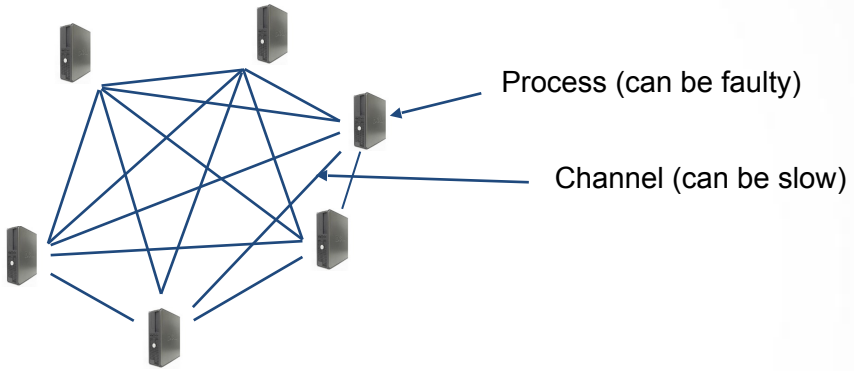


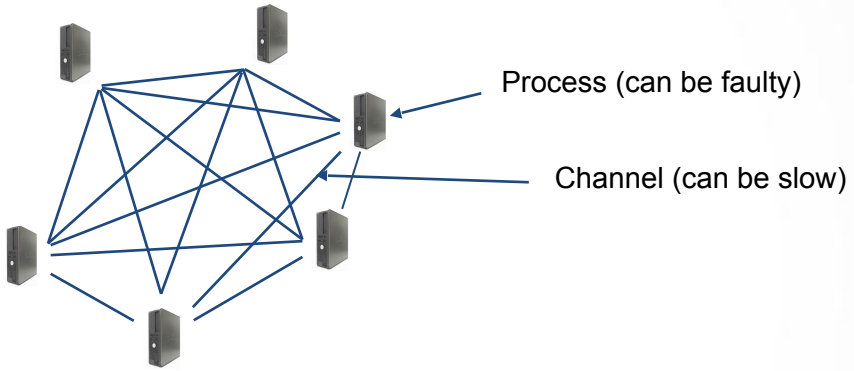
Definition of Consensus:

Each process starts with an input value

Agreement

“Old-style” Consensus Algorithms

→ Bitcoin PoW Consensus

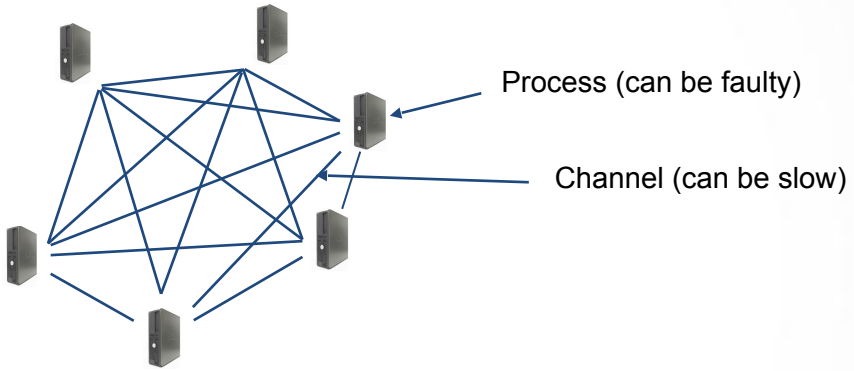


Definition of Consensus:

Each process starts with an input value

Agreement

Every correct process must agree on the same value.



Definition of Consensus:

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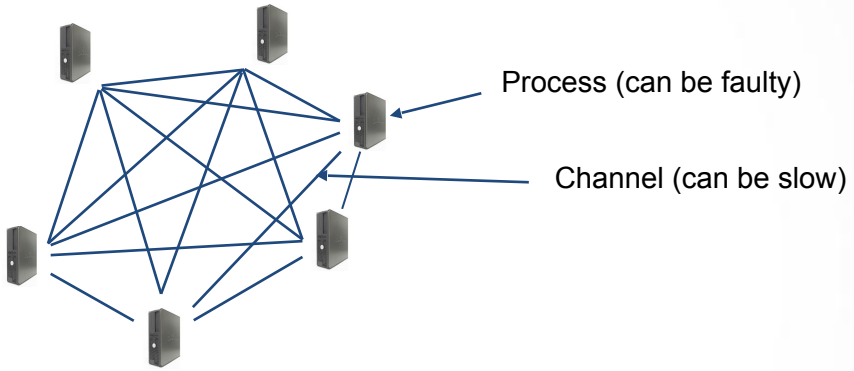
Validity



Definition of Consensus:

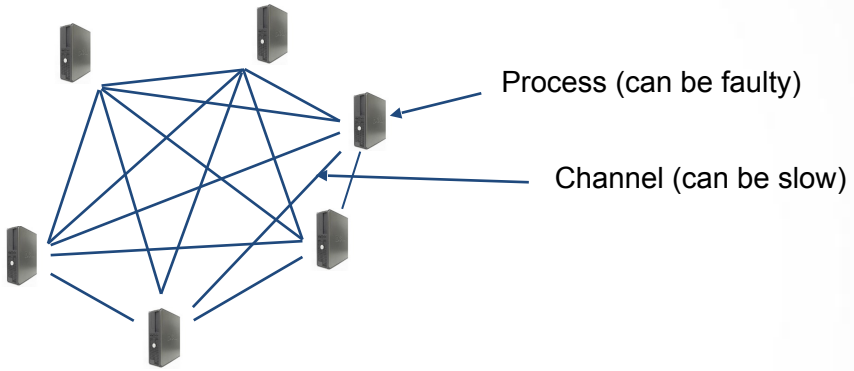
Each process starts with an input value

Agreement

Every correct process must agree on the same value.

Validity

If all processes propose the same value *v*, then all correct processes decide *v*.



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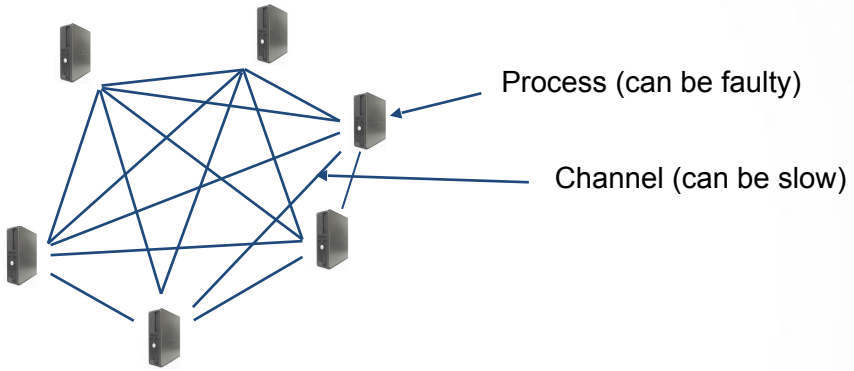
Termination



Definition of Consensus:

Each process starts with an input value

Agreement

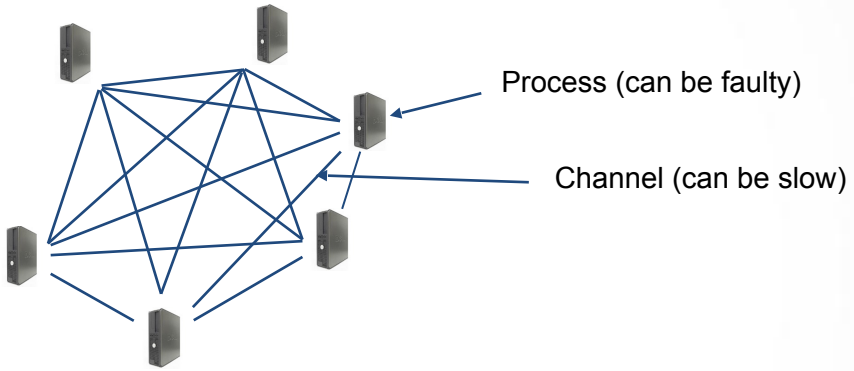
Every correct process must agree on the same value.

Validity

If all processes propose the same value *v*, then all correct processes decide *v*.

Termination

Every correct process decides some value.



Definition of Consensus:

Each process starts with an input value

Agreement

Every correct process must agree on the same value.

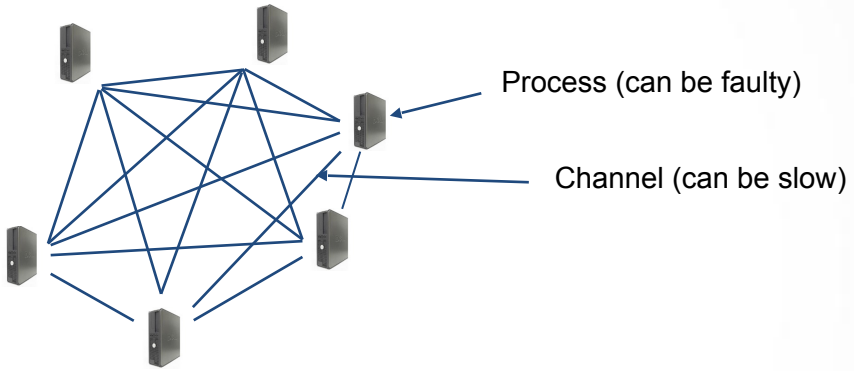
Validity

If all processes propose the same value *v*, then all correct processes decide *v*.

Termination

Every correct process decides some value.

Integrity



Definition of Consensus:

Each process starts with an input value

Agreement
Every correct process must agree on the same value.

Validity
If all processes propose the same value *v*, then all correct processes decide *v*.

Termination
Every correct process decides some value.

Integrity
Every correct process decides at most one value, and if it decides some value *v*, then *v* must have been proposed by some process.

Bitcoin PoW Consensus

Impossibility results

Impossibility results [FLP 1985] "Impossibility of distributed consensus with one faulty process"

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Costly algorithms

“Old-style” Consensus Algorithms → Bitcoin PoW Consensus

Impossibility results	[FLP 1985] "Impossibility of distributed consensus with one faulty process"
Costly algorithms	Every node should be connected to every node, broadcast everything, and waits for n/2 responses

“Old-style” Consensus Algorithms → Bitcoin PoW Consensus

Impossibility results	[FLP 1985] "Impossibility of distributed consensus with one faulty process"
Costly algorithms	Every node should be connected to every node, broadcast everything, and waits for n/2 responses
Still puzzle researchers’ minds	

“Old-style” Consensus Algorithms → Bitcoin PoW Consensus

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“Old-style” Consensus Algorithms → Bitcoin PoW Consensus

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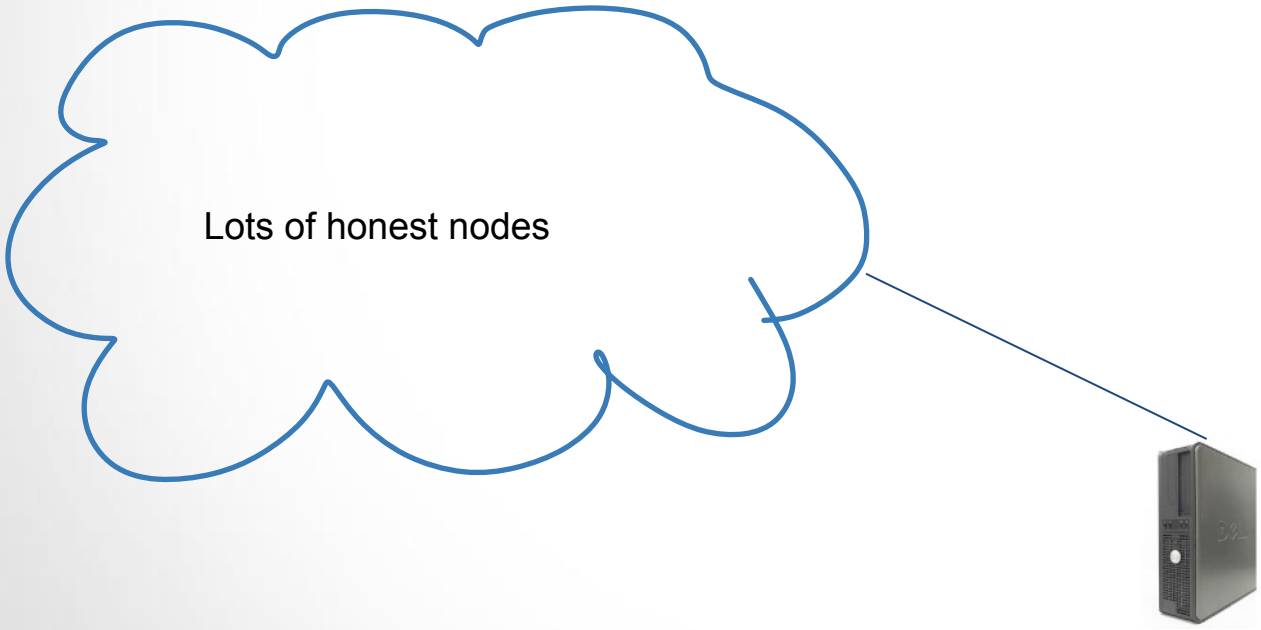
There exists consensus algorithms that tolerates up to n/3 Byzantins processes

So what’s the problem with an algorithm tolerating n/3 byzantin nodes ?



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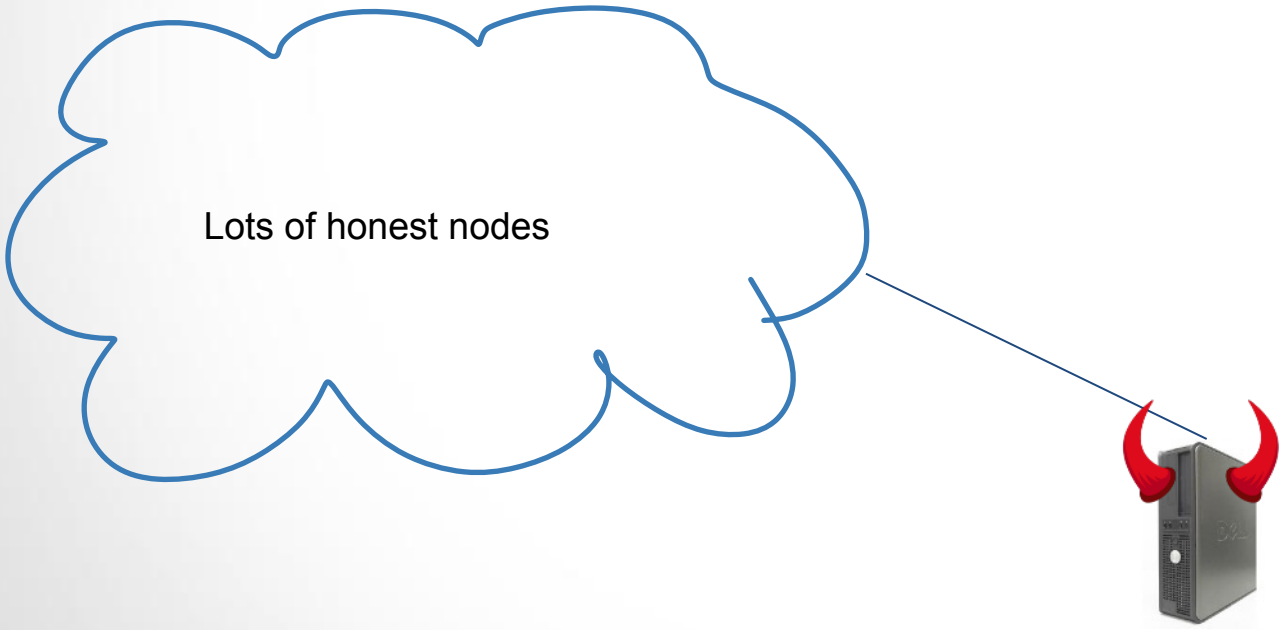

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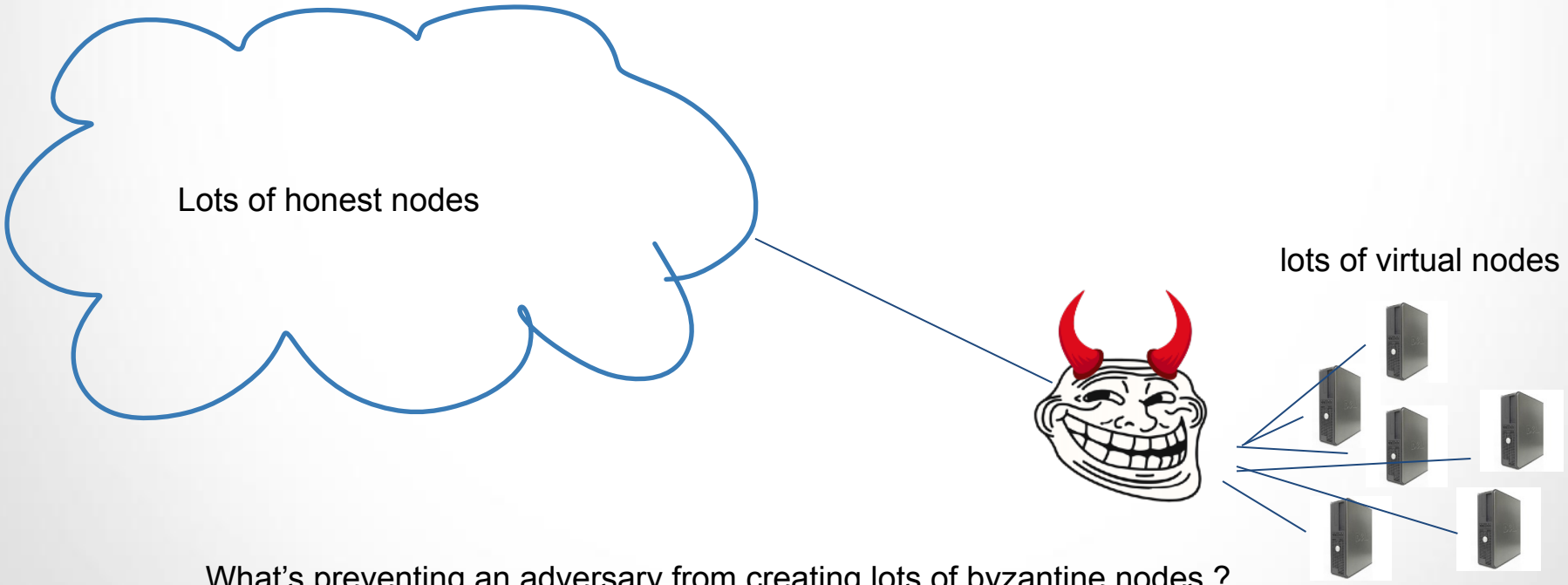

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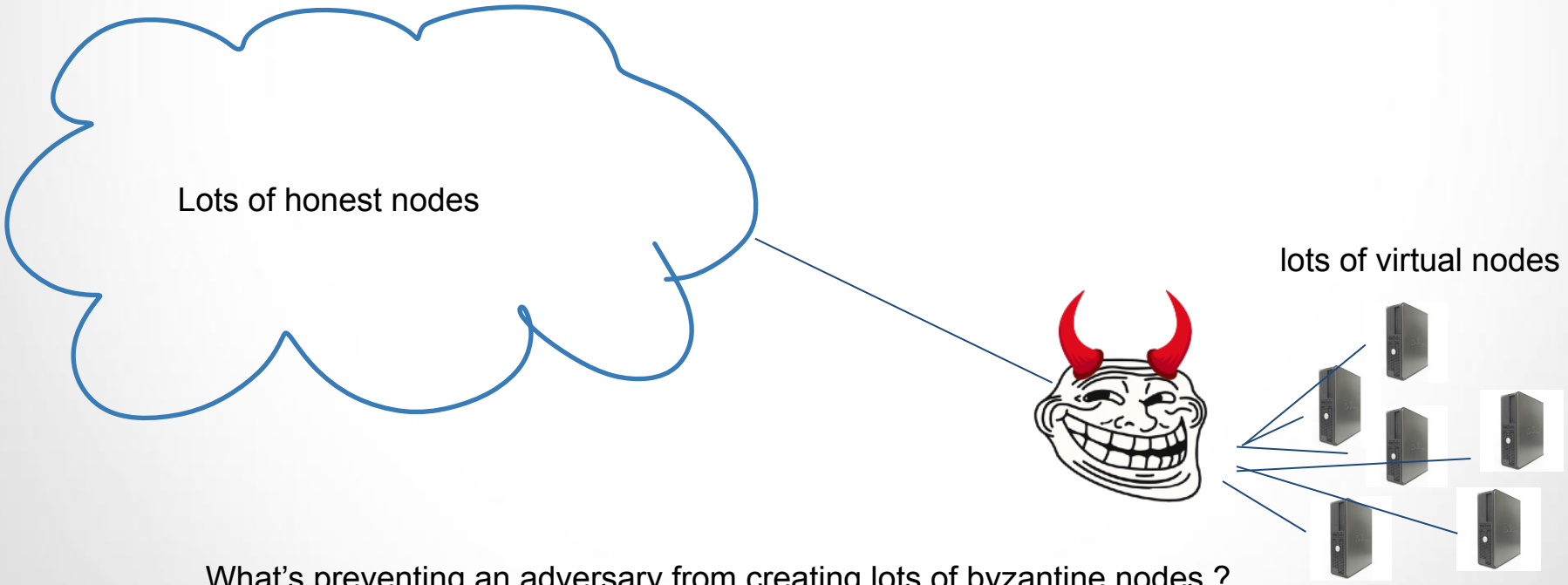
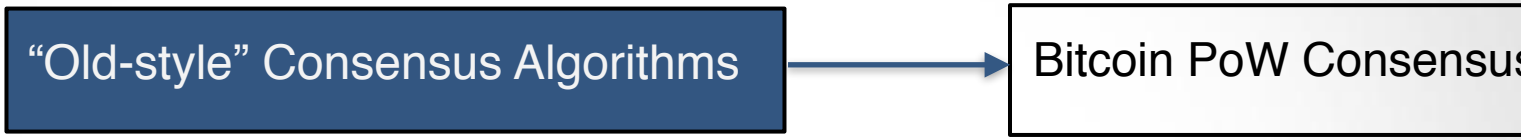


What’s preventing an adversary from creating lots of byzantine nodes ?

“old-style” consensus algorithms work well when the participants are known, and not too many (eg, Hashgraph blockchain, 39 known participants in the “council”)


“Old-style” Consensus Algorithms
Bitcoin PoW Consensus

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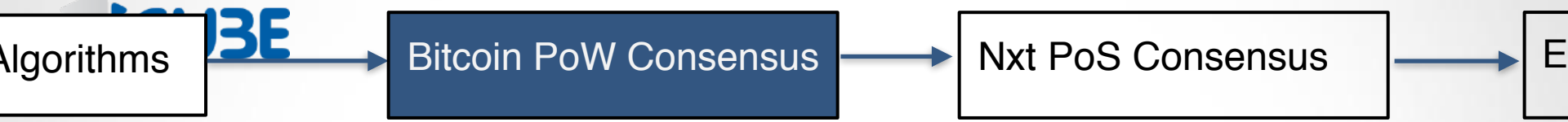
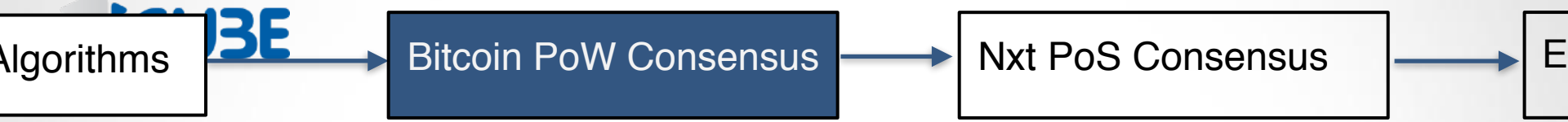


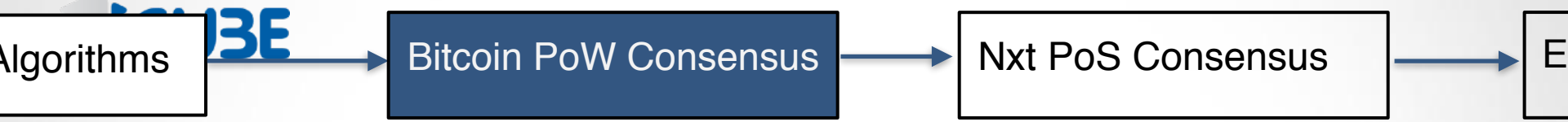
How much work can you do ?



How much work can you do ?

Your importance in the network depends on how many times you can execute a hash function.

(no interest in simulating many nodes, because your hashing power will remain the same)


Algorithms
Bitcoin PoW Consensus
Nxt PoS Consensus
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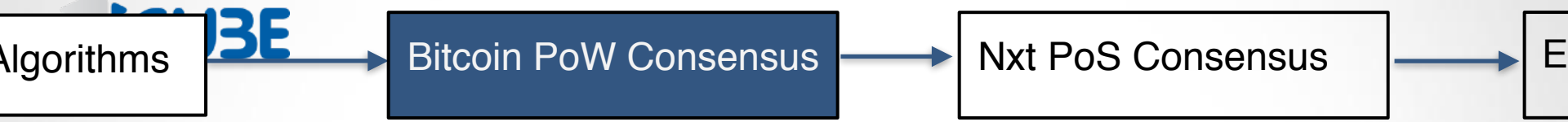

Basic principle of the Bitcoin Protocol :

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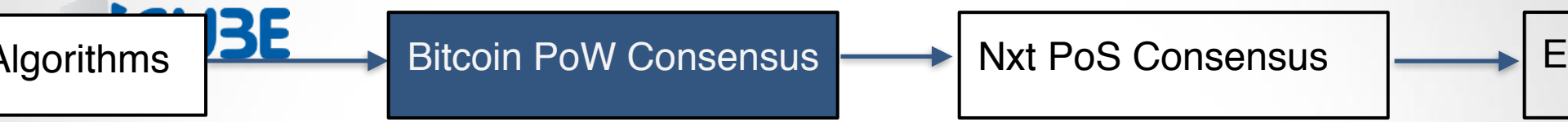

Basic principle of the Bitcoin Protocol :

- Choose randomly one node
- This node decides what to write in the database

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In more details

What is the database ?
The blockchain

In more details

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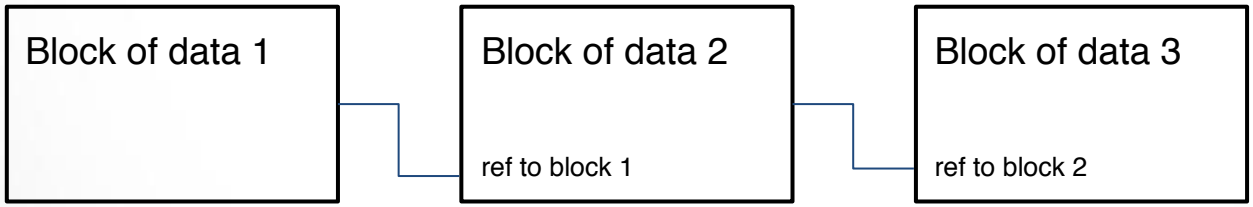
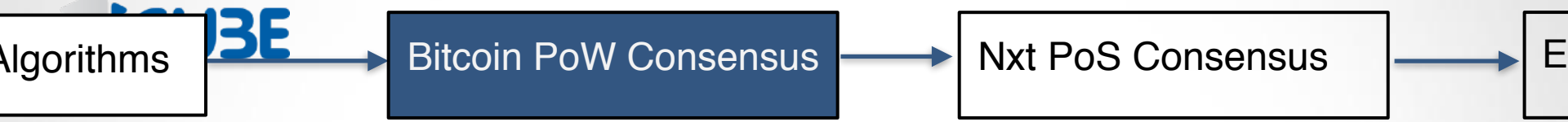


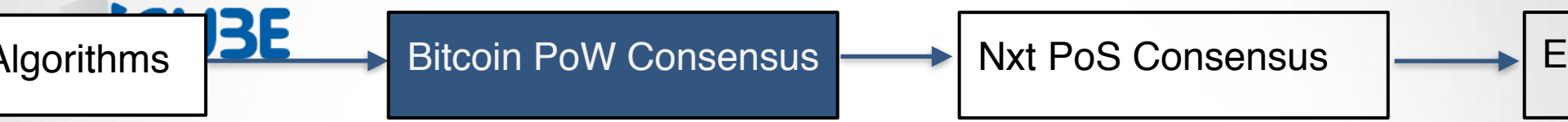
It's a data structure with one function: append(Block)

(you cannot remove a block, so to "remove" a data just overwrite it)



In more details

Who stores the data? Every nodes



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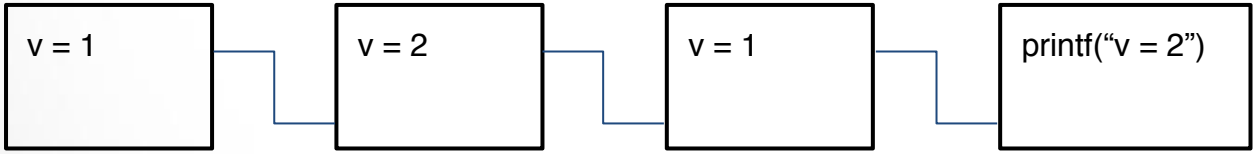

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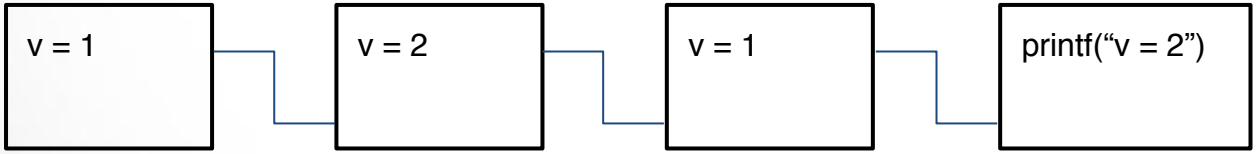
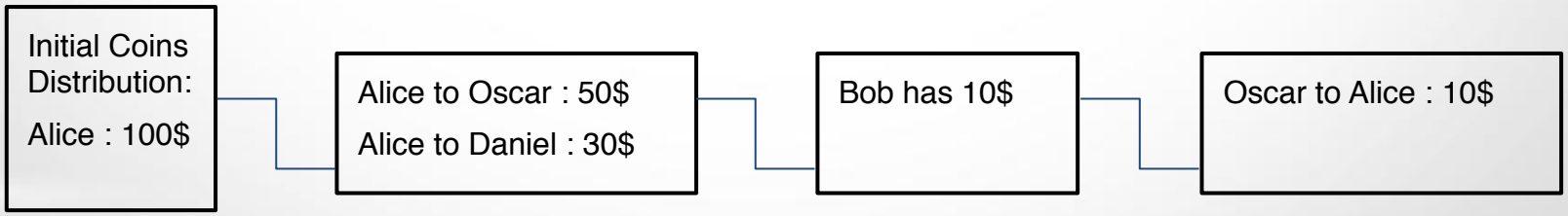


Exemple 2: How much does Alice have ? and Bob ?



In more details

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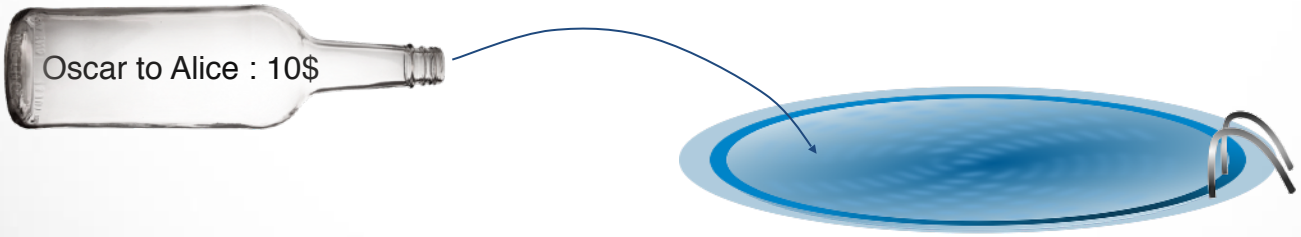

https://blockchain.info/unconfirmed-transactions

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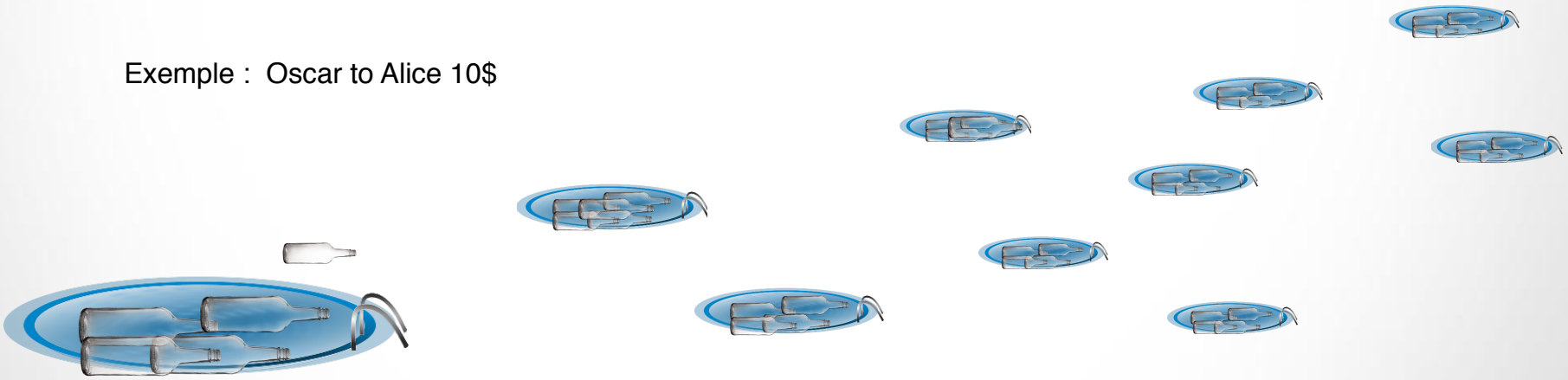

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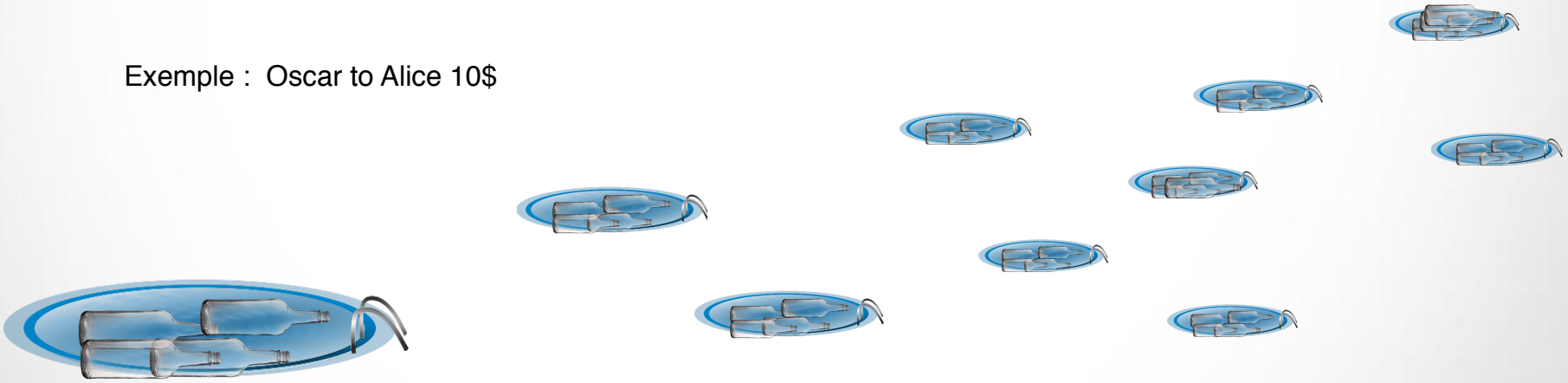

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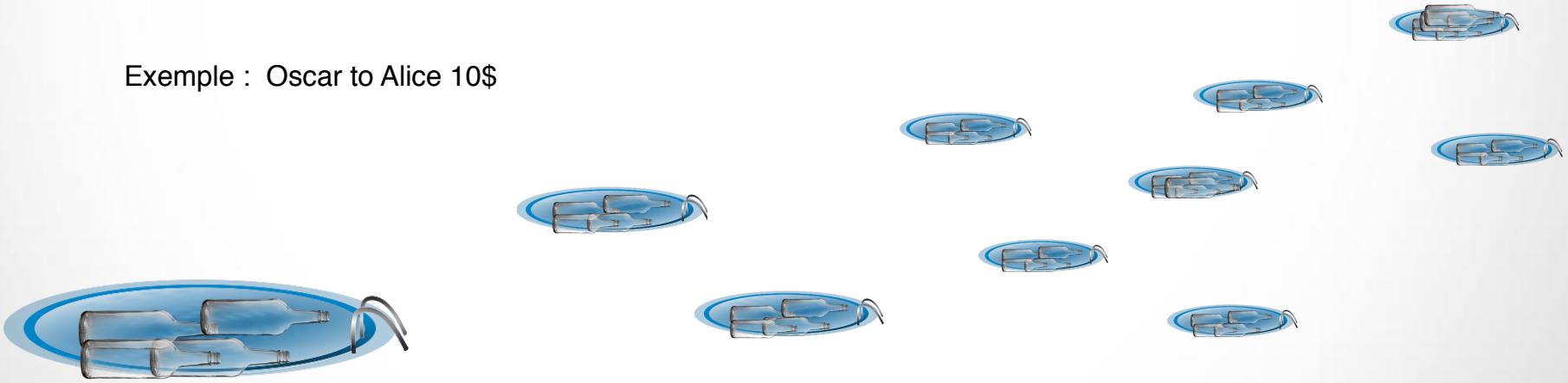

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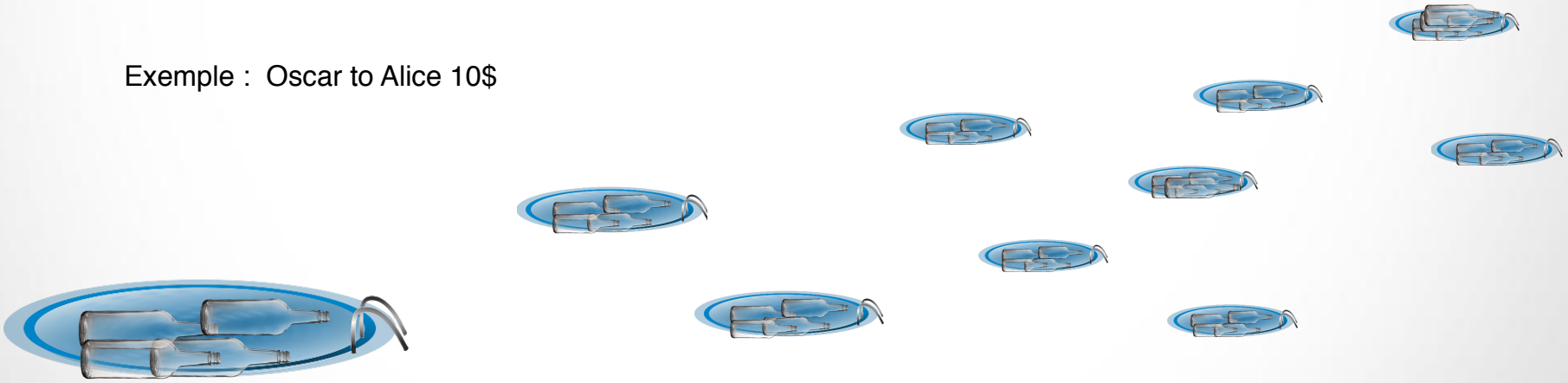

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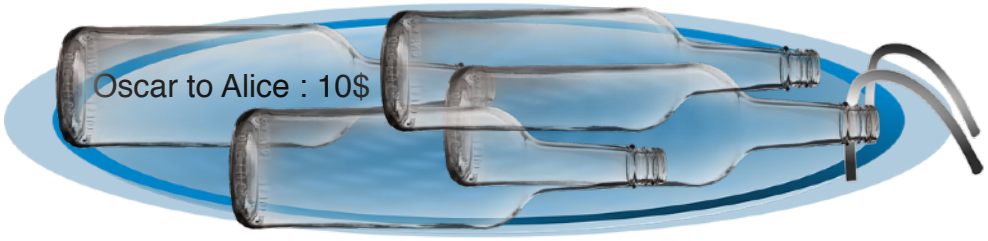

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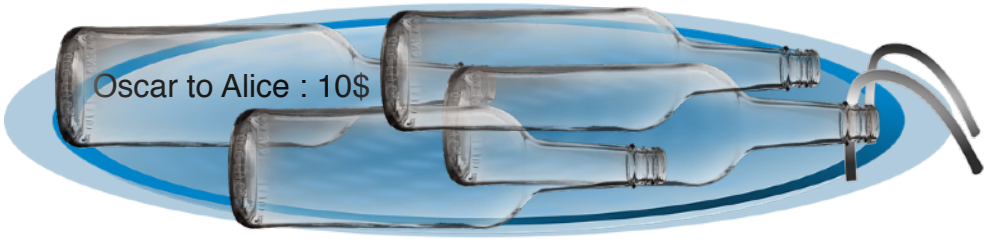

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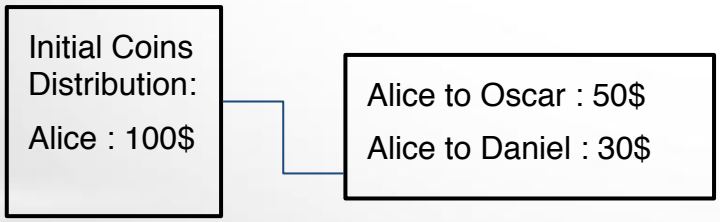

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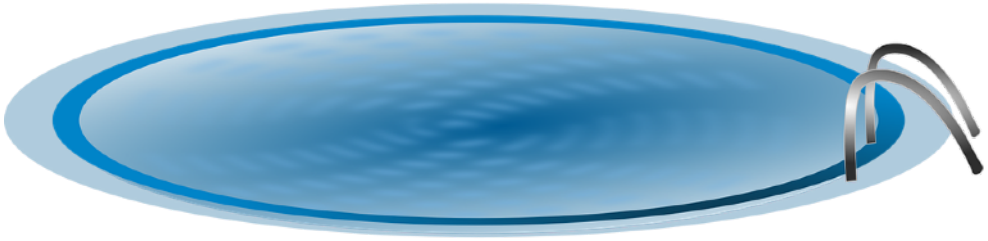

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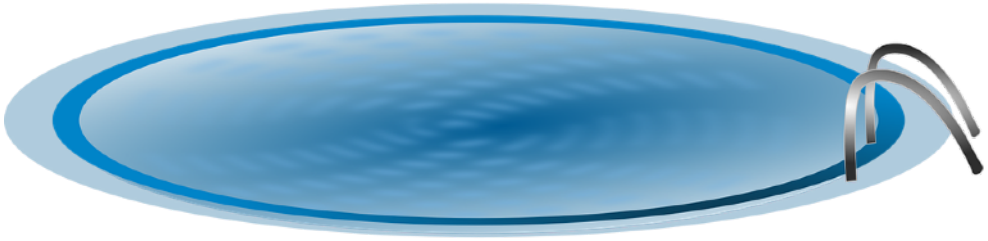

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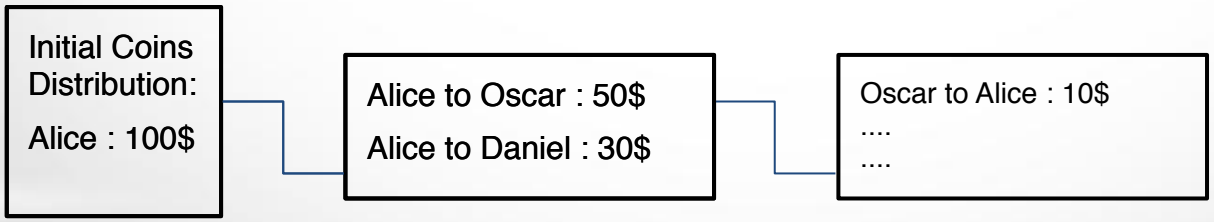

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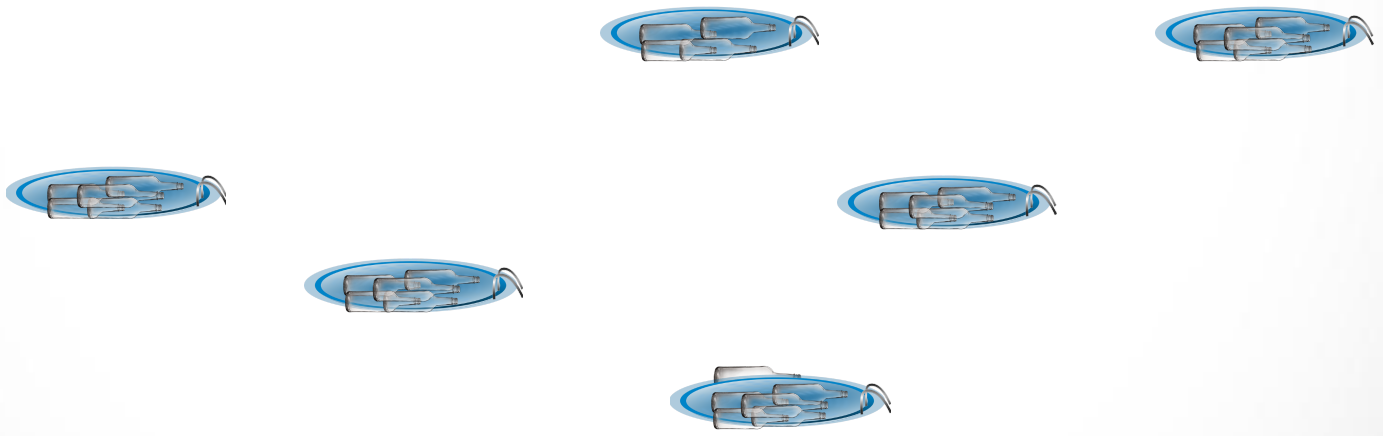

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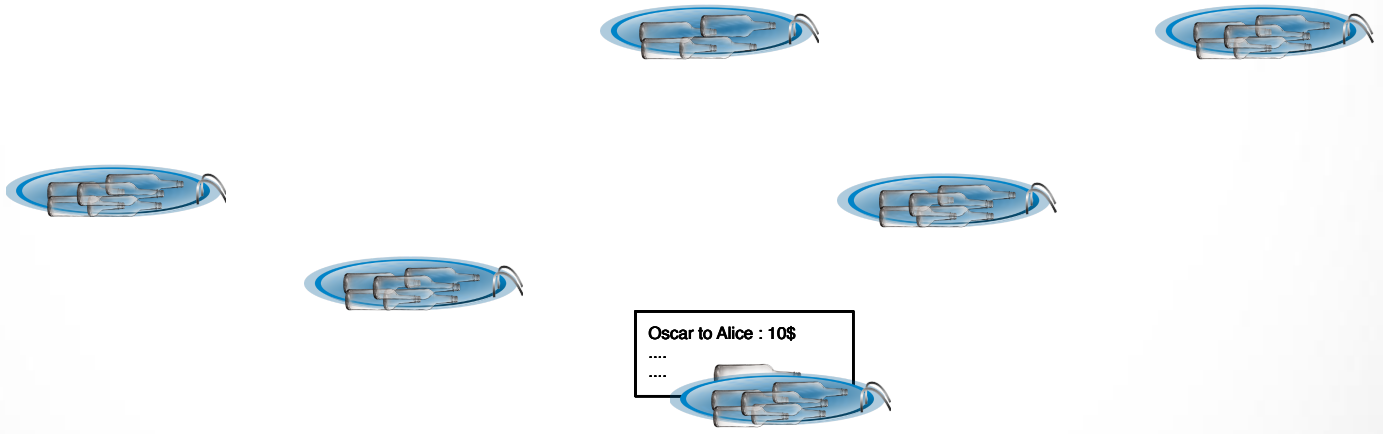

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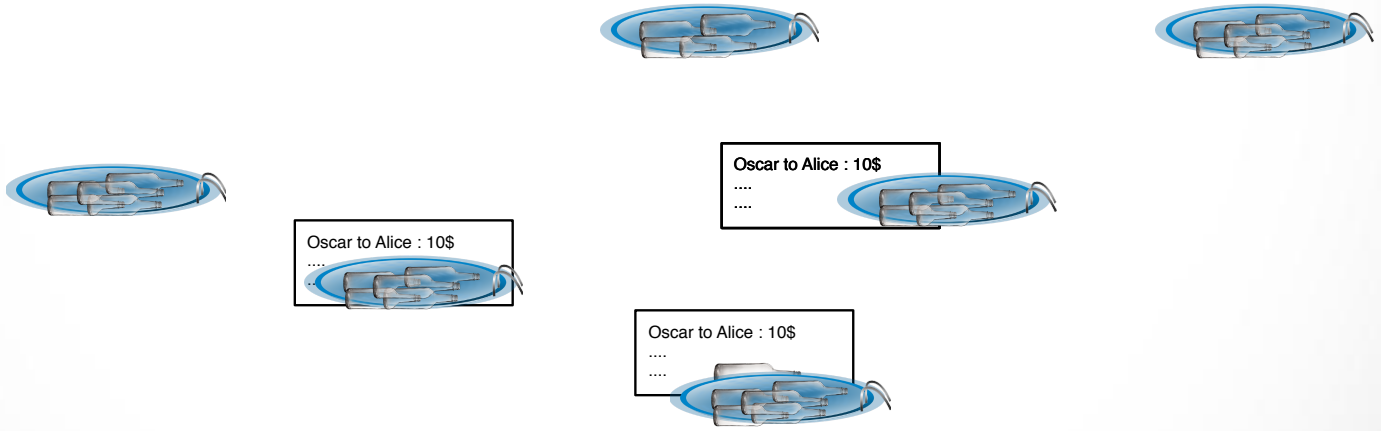

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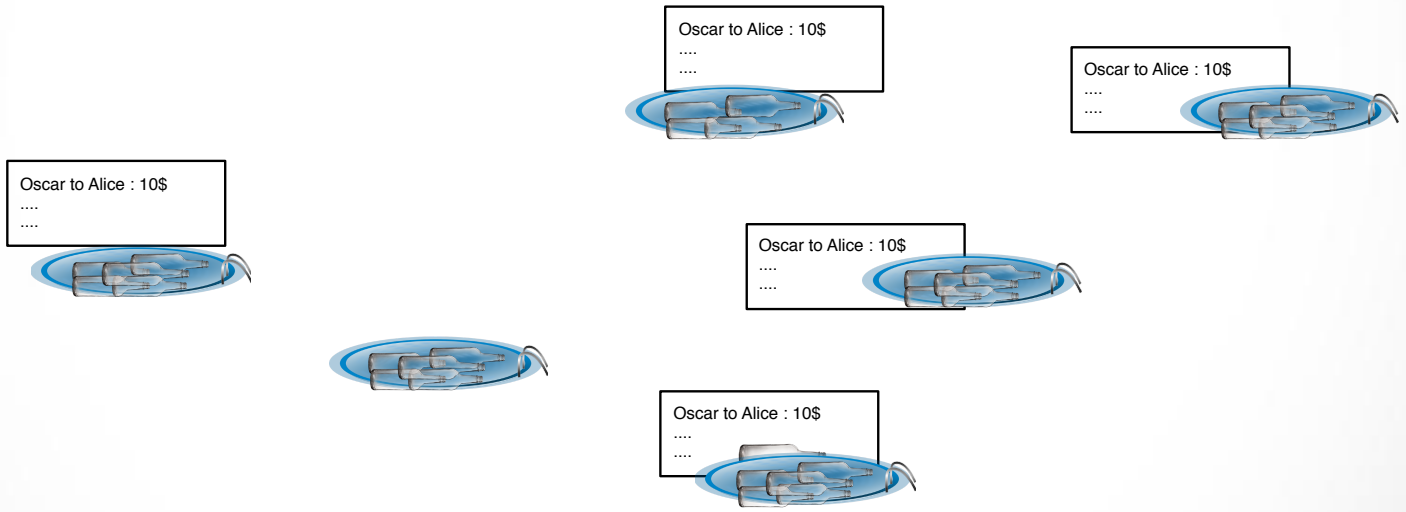

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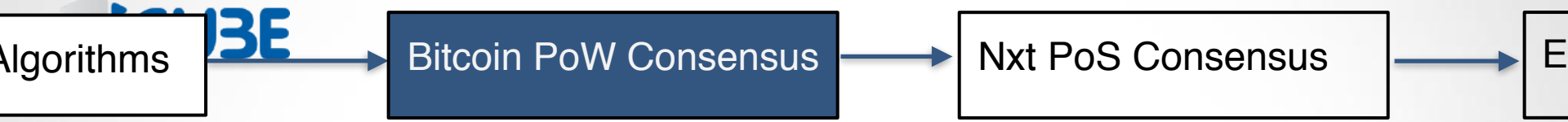
In more details

How to prevent anyone from appending a block?

How to make sure data is not removed?

https://anders.com/blockchain/

4080782: I worked hard for this presentation



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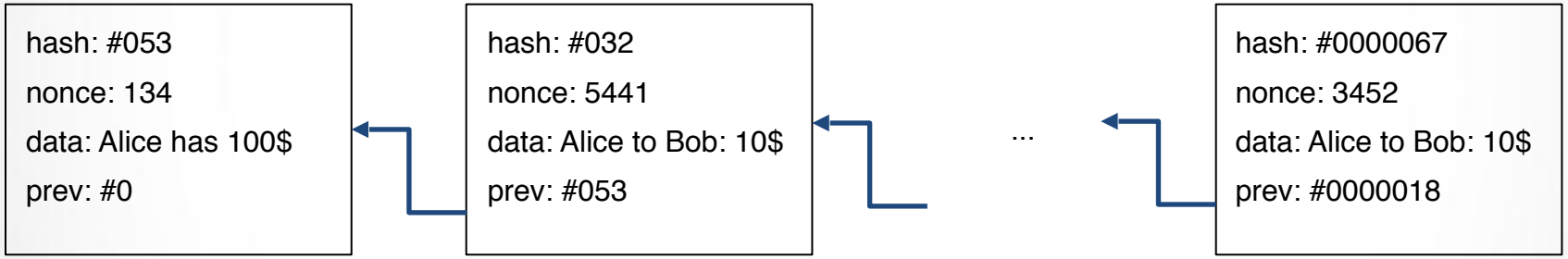

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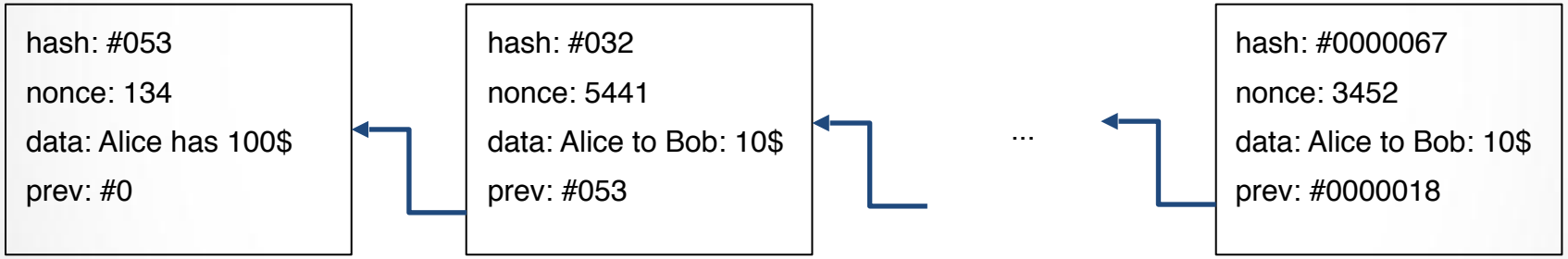

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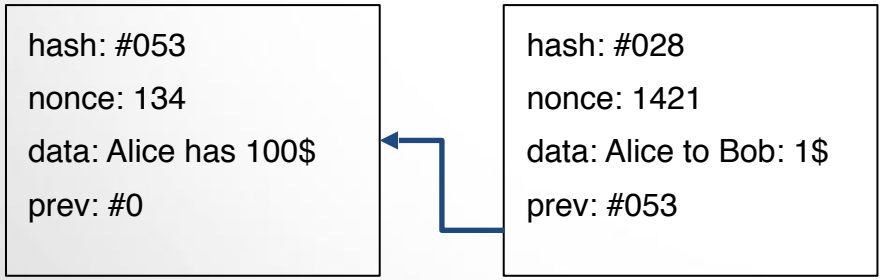

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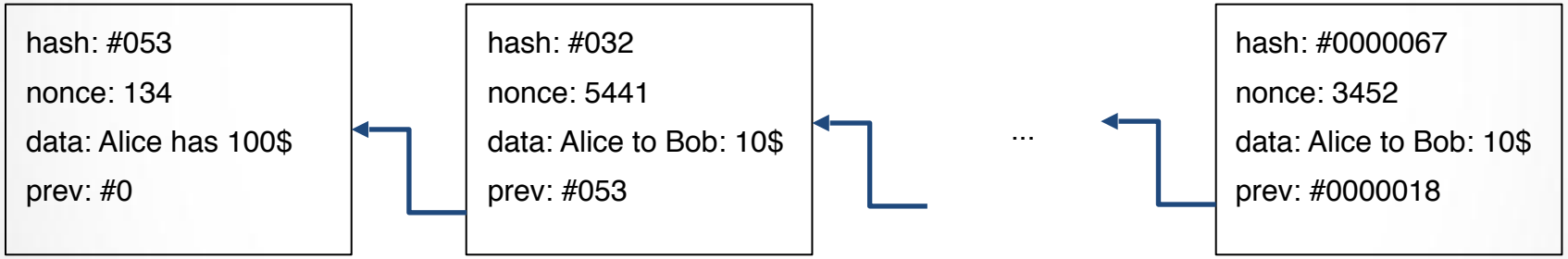

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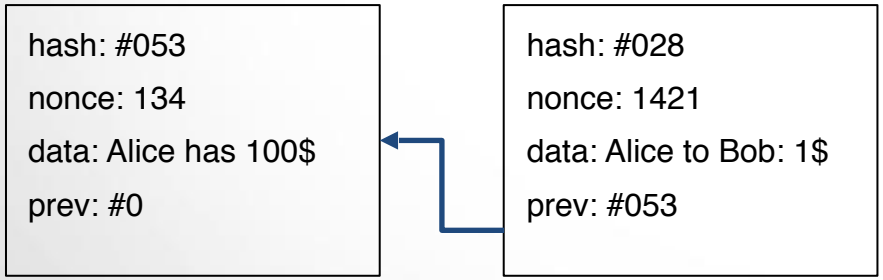
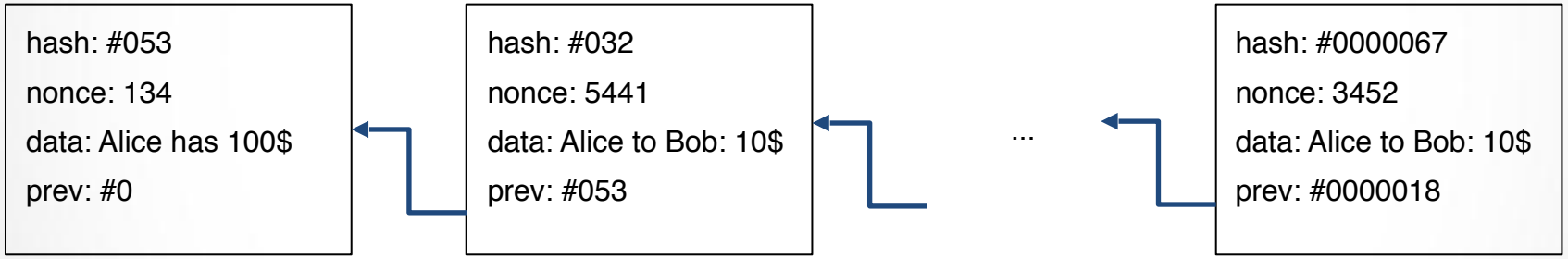


But the other nodes will prefer the longest blockchain

In more details



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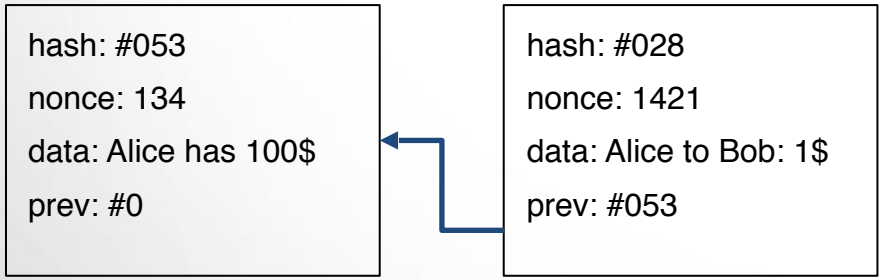
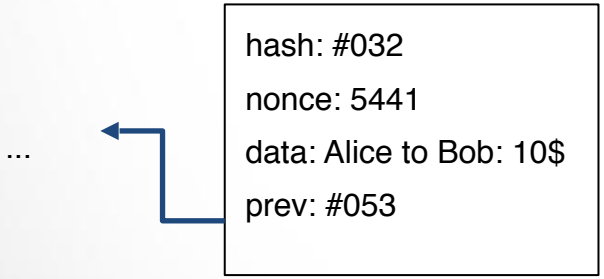


But the other nodes will prefer the longest blockchain

The deeper the block you modify, the harder it gets to generate a blockchain longer than the existing one

In more details

What if two nodes generates two different block at the same time ?



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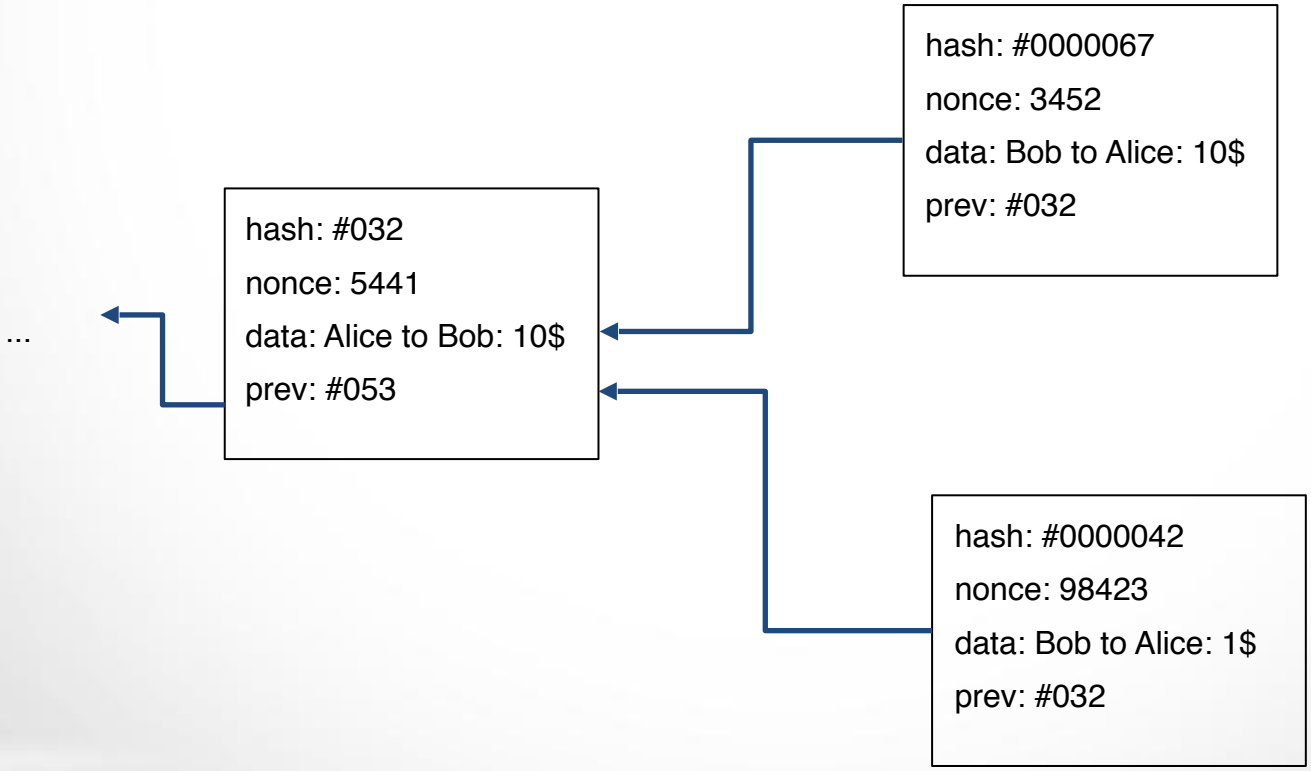

In more details

hash: #0000067
nonce: 3452
data: Bob to Alice: 10$
prev: #032

parts of the networks will receive this first and will try to append a block to this
(they don't want to change their choice when they receive the other one because that would mean that they wasted their computing power on this one)

hash: #0000042
nonce: 98423
data: Bob to Alice: 1$
prev: #032

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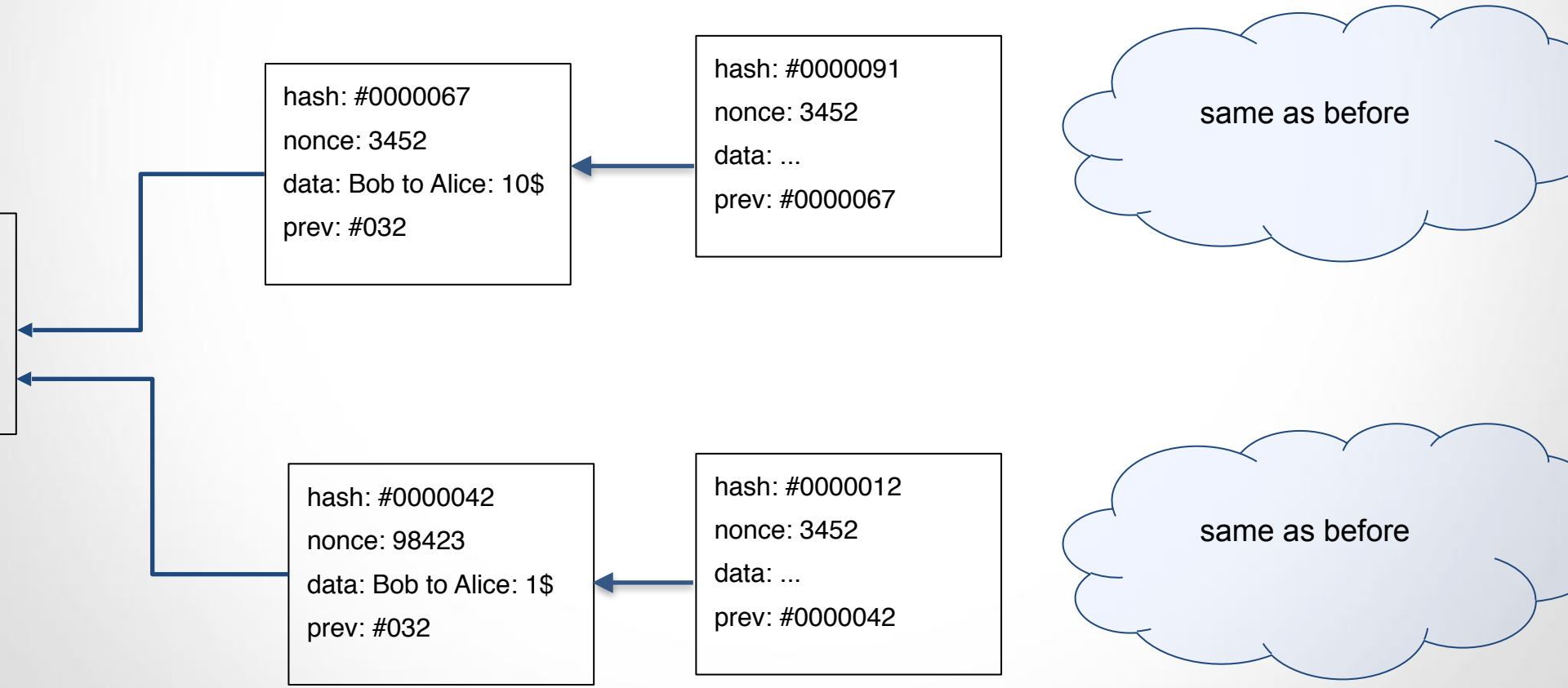
In more details



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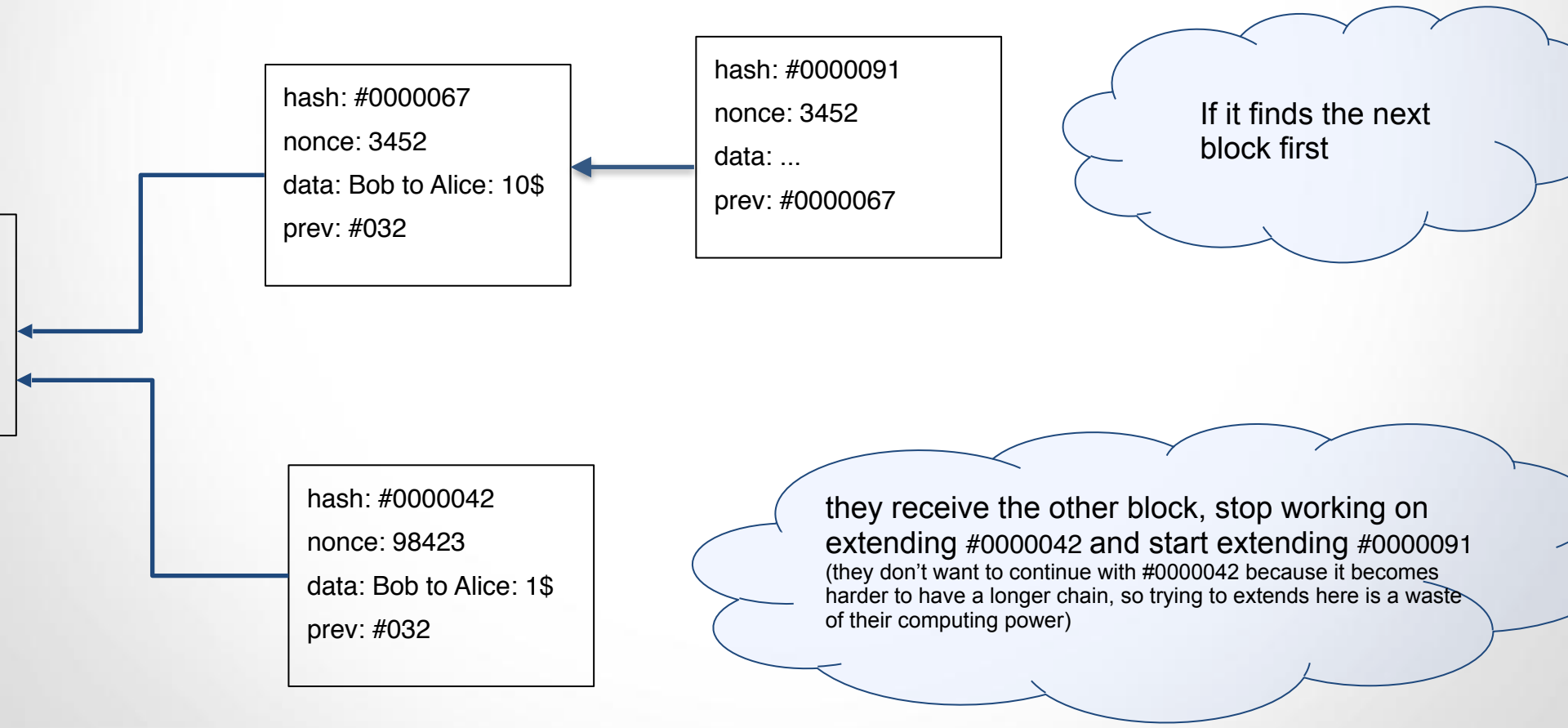

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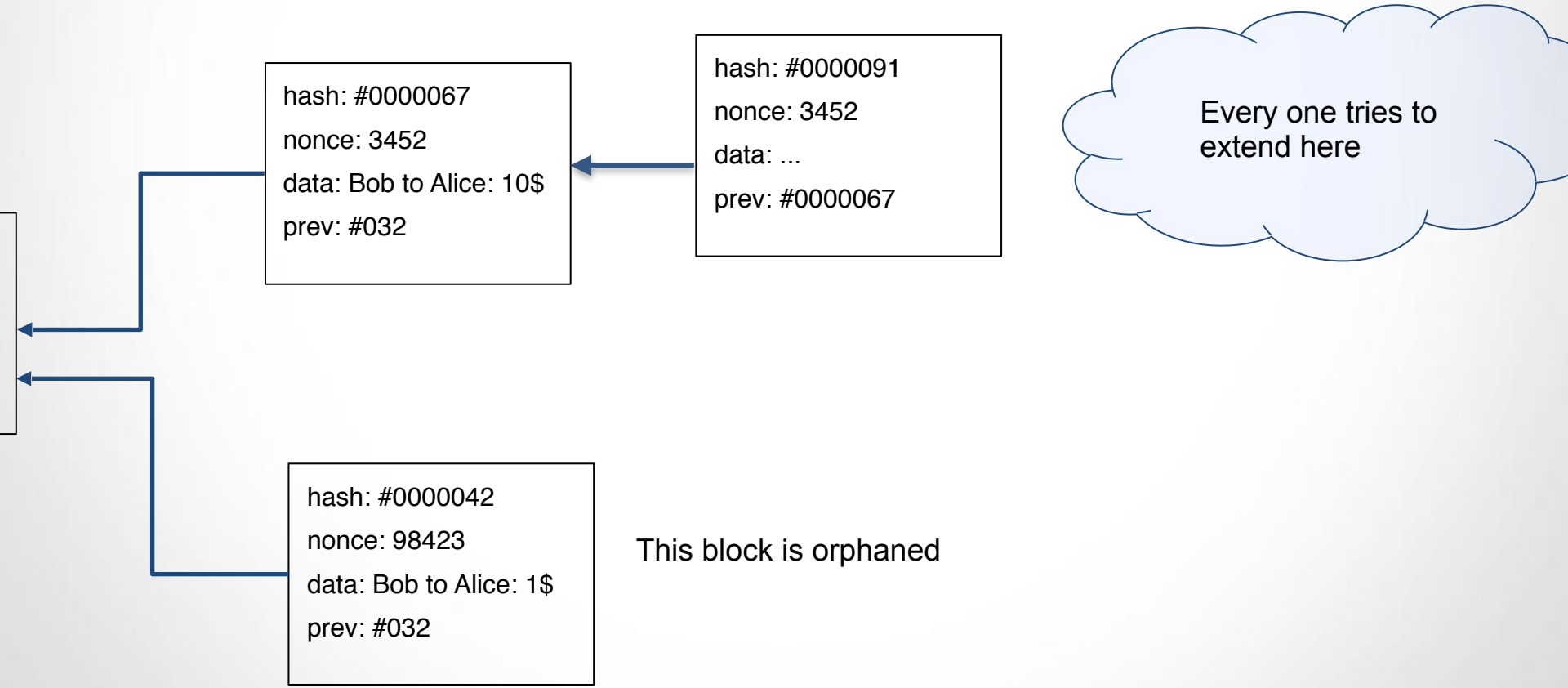

In more details

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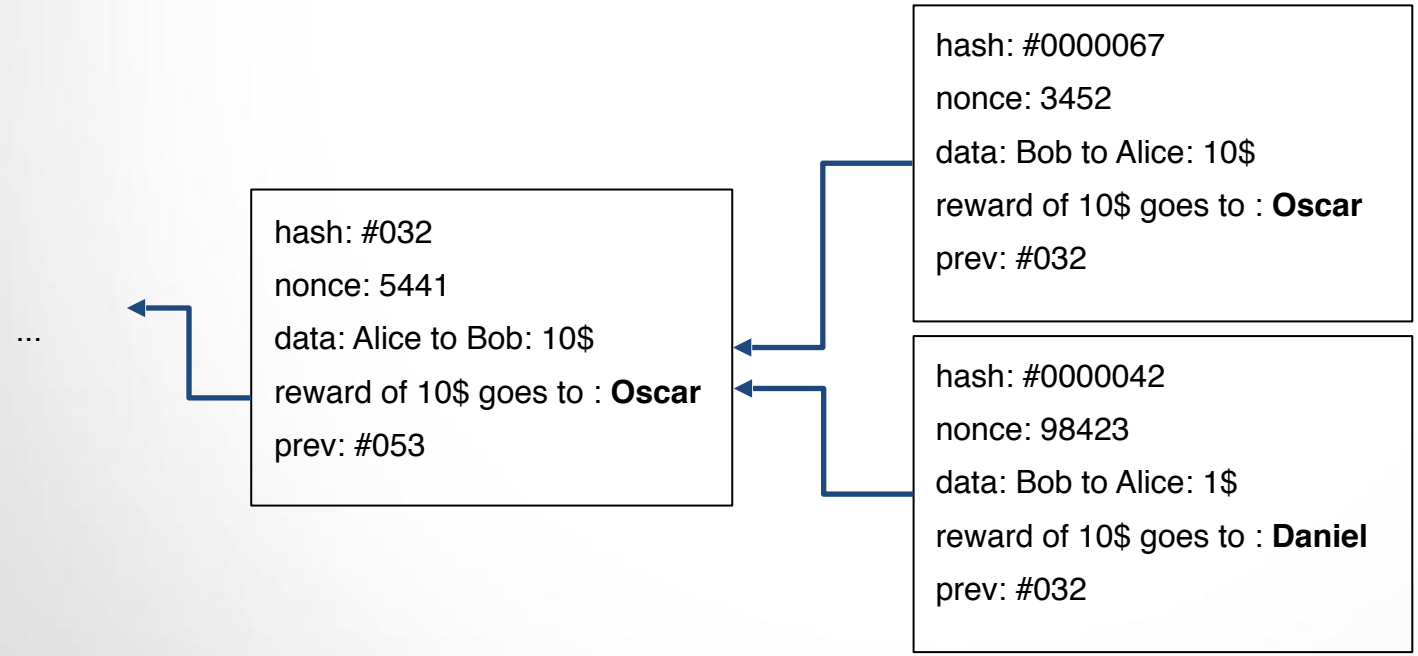

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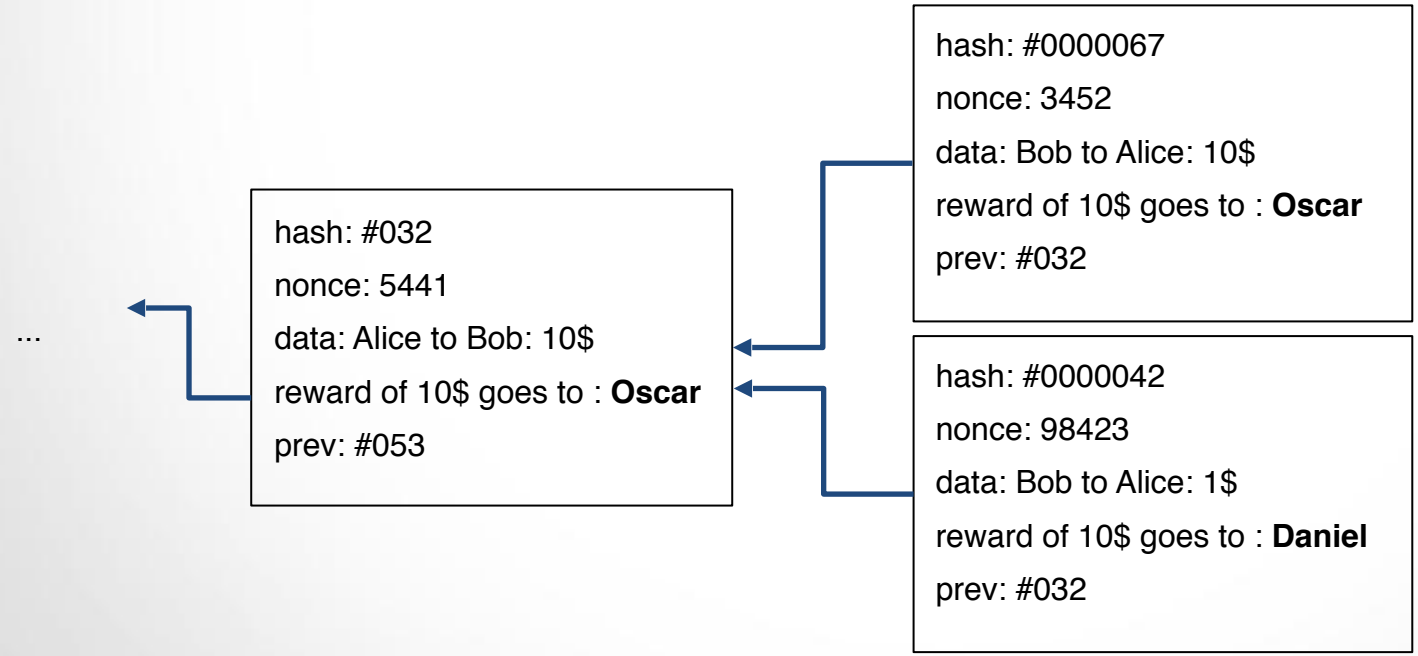

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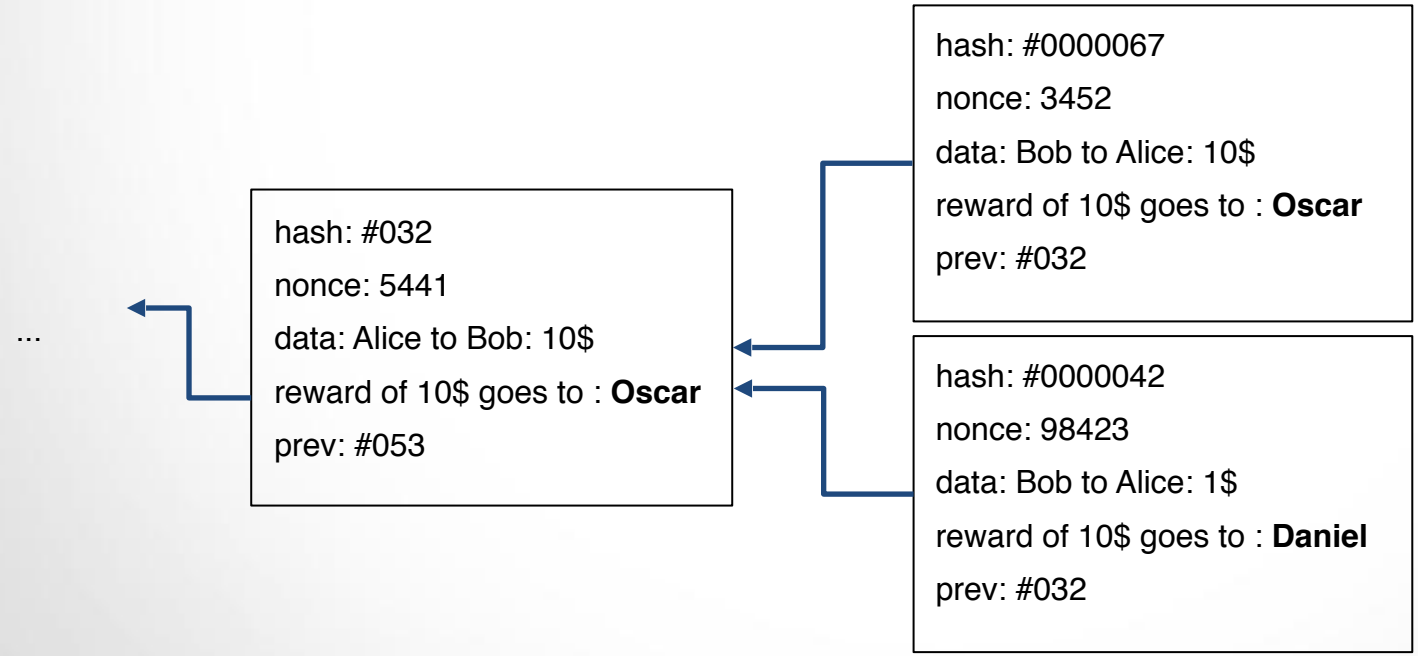

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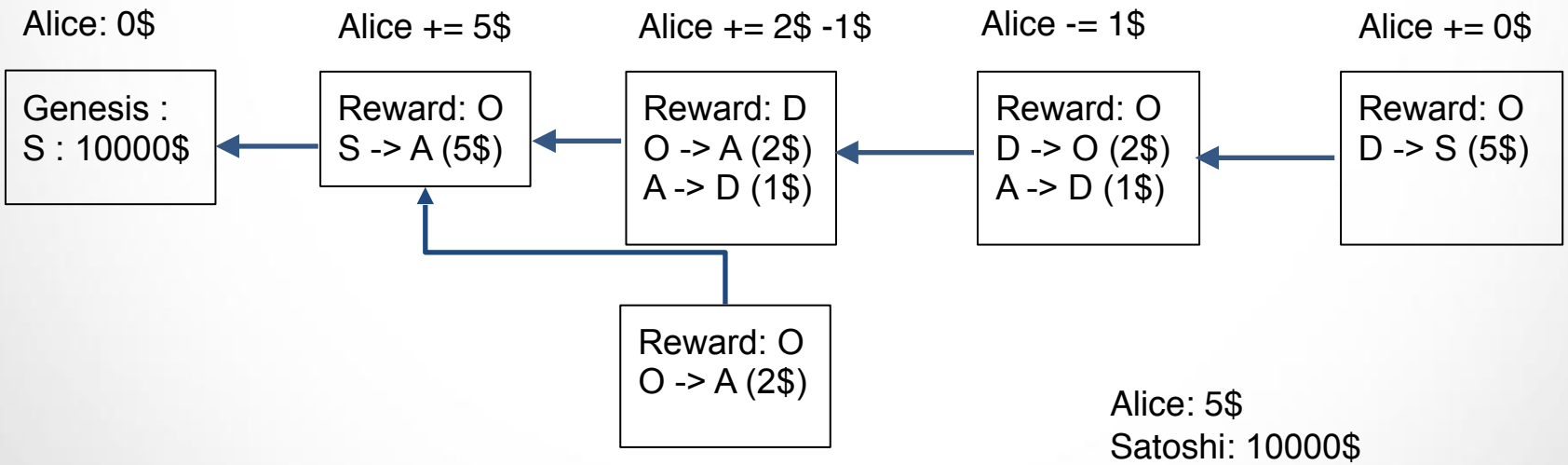
So the goal of the nodes, is to find a block first, and that this block is not orphaned.
This does not mean “extends only the version where I have the greatest balance” because you want to avoid wasting hashing power on a chain that has great chance to be orphaned

In more details

What is the balance of Alice ?

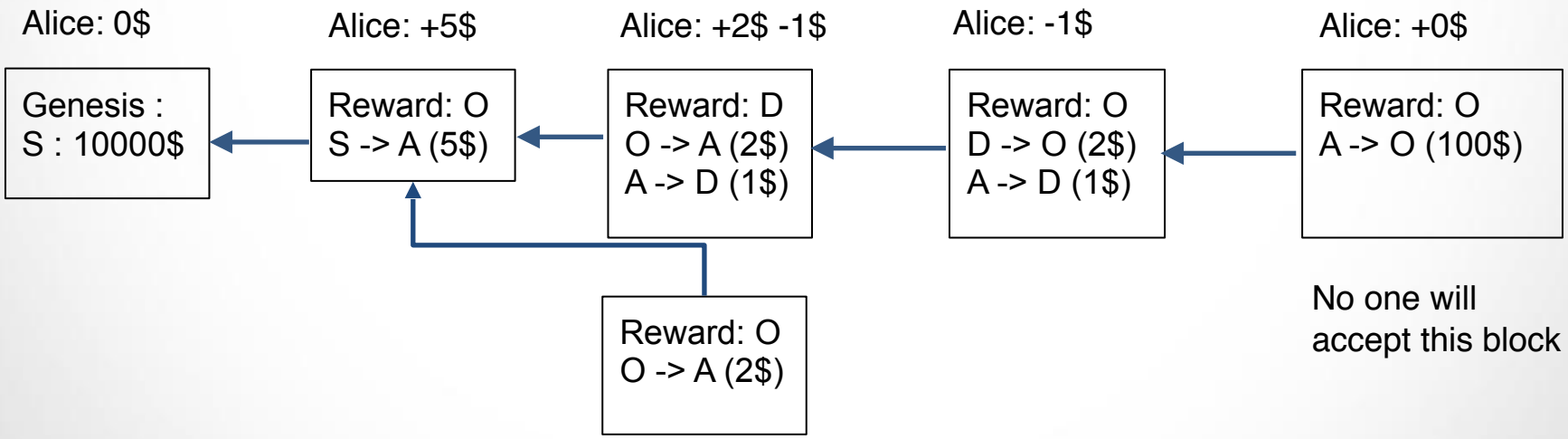


Alice: 5$
Satoshi: 10000$
Oscar: 30$
Daniel: 5$

Sum: 10000 + 4x10

In more details

Block Validation



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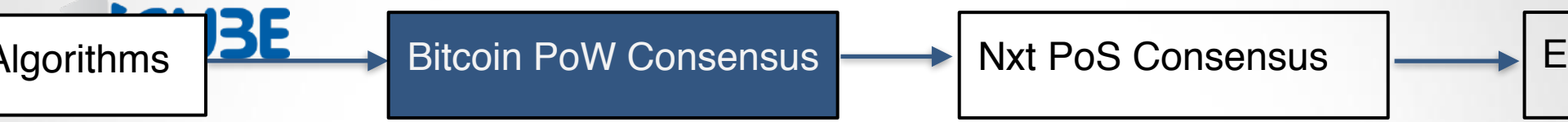

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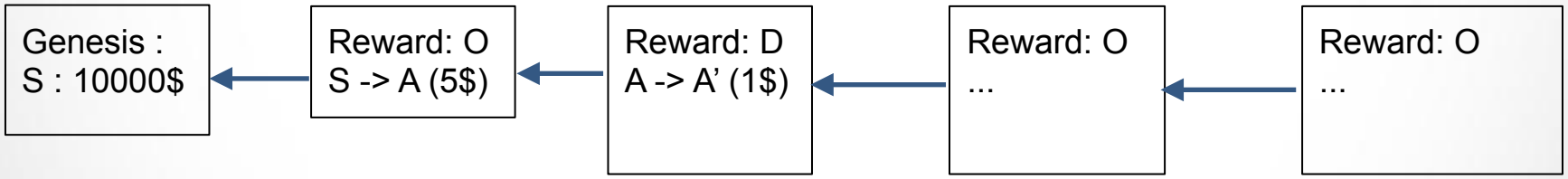

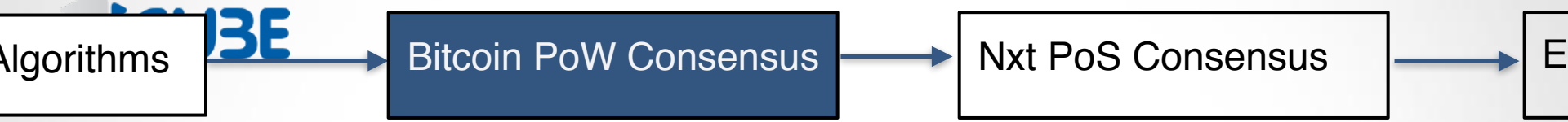

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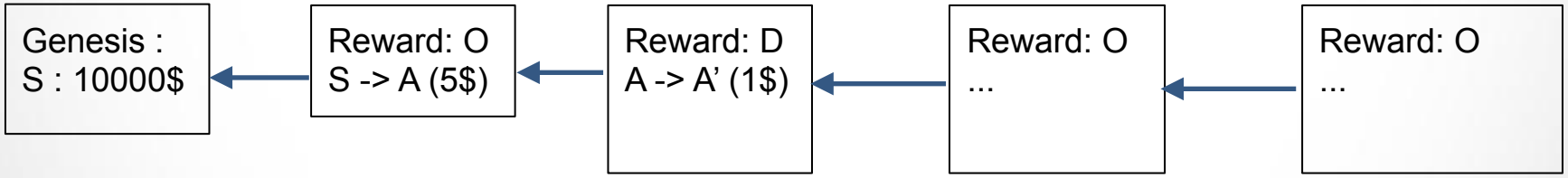

Now, no one will ever include
A -> B (1$) transaction because it's in
conflict with A -> A' (5$)

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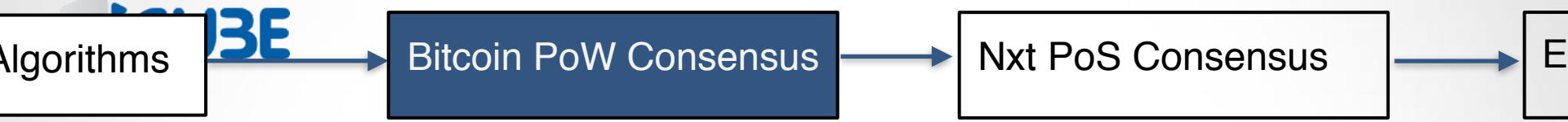
Bob waits to see this transaction in a block before giving the sandwich



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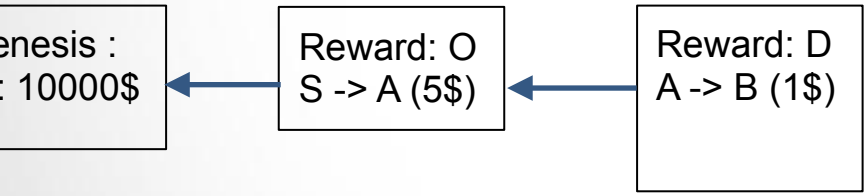

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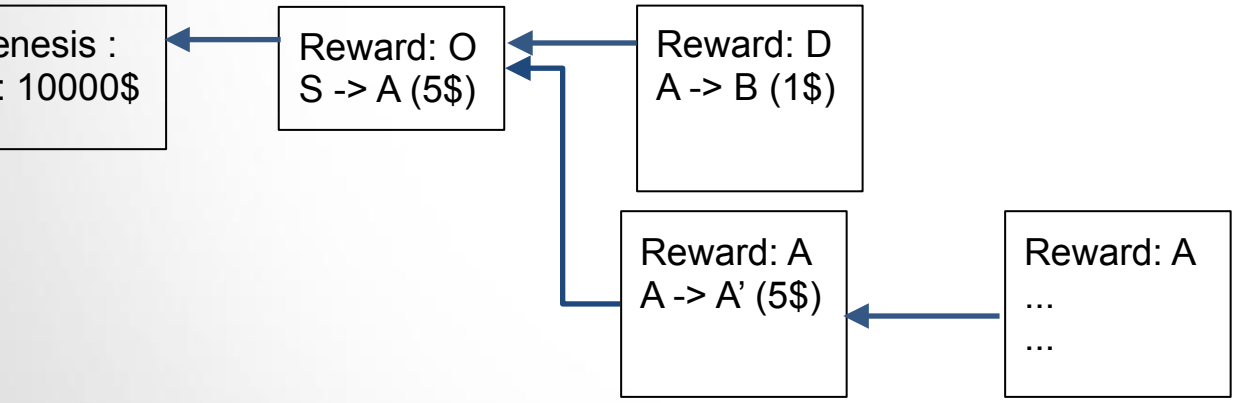

Alice also sign A -> A' (5$) and use a lots of power to extends this chain faster than the other

In this chain, B never received the coins and A -> B (1$) cannot be included anymore

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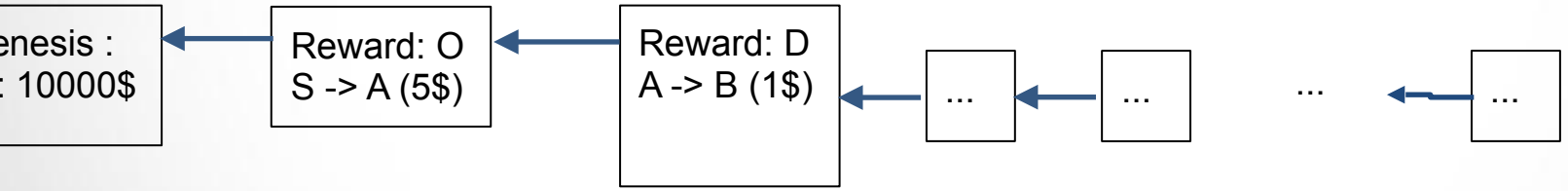

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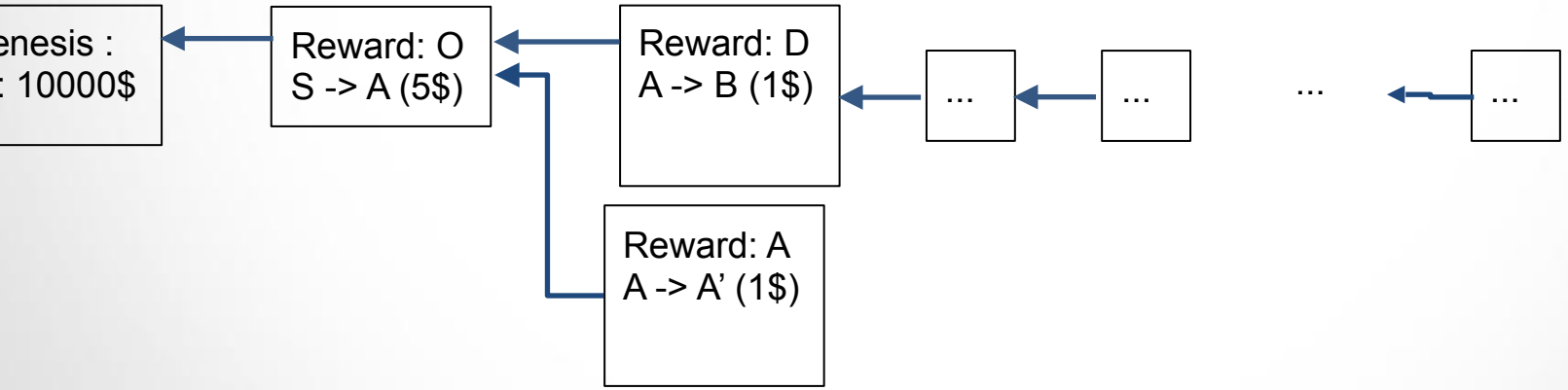
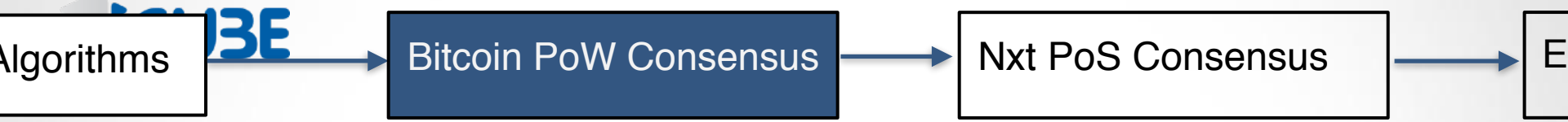


It's too expensive for Alice to generate 10 blocks on her own



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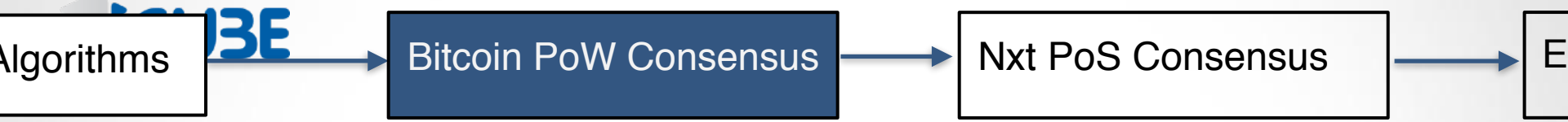
- Bitcoin protocol :
  - new blocks should arrive in average every 10 minutes
  - reward : 12.5BTC (divided by two every 4 years)



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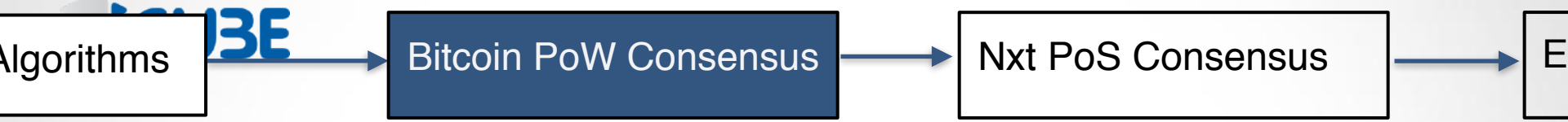
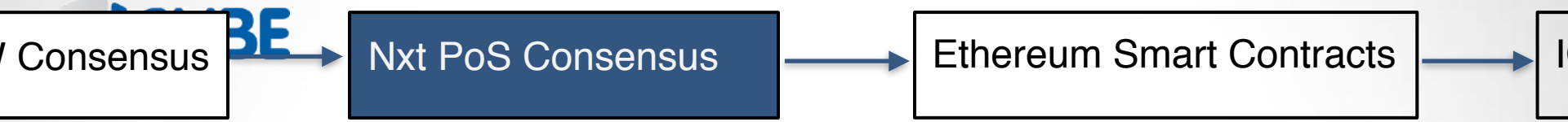
  https://digiconomist.net/bitcoin-energy-consumption



How to avoid wasting energy for leader election ?



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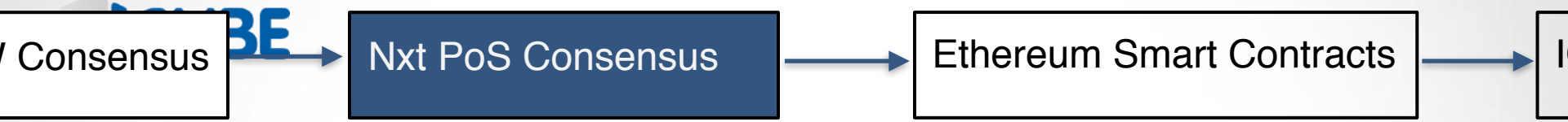

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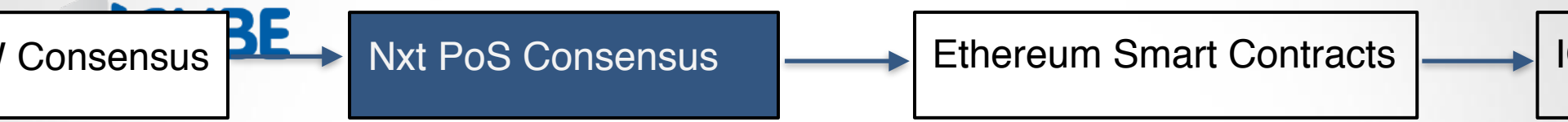

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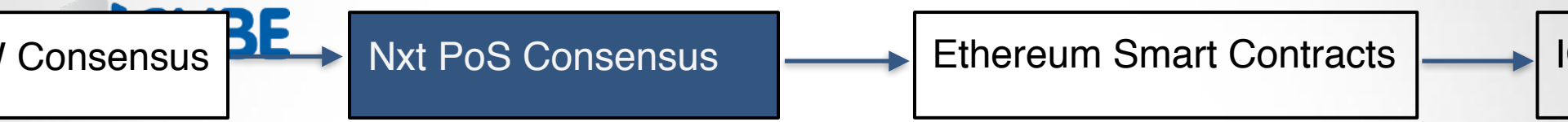

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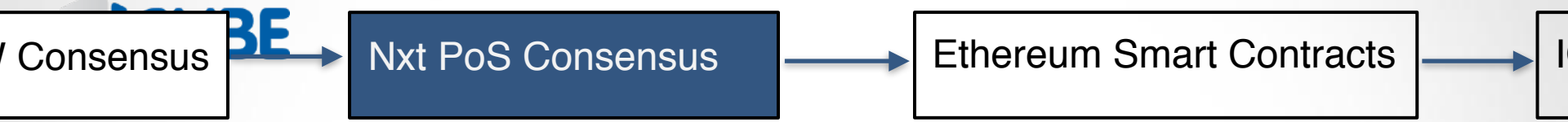

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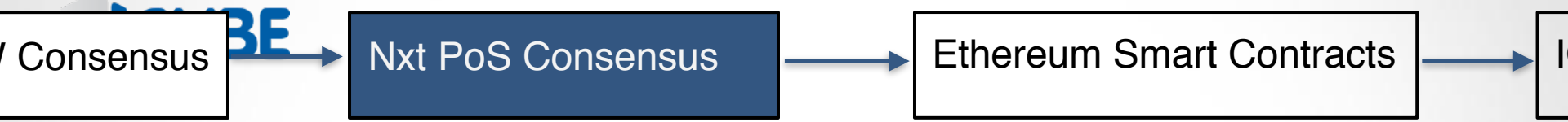

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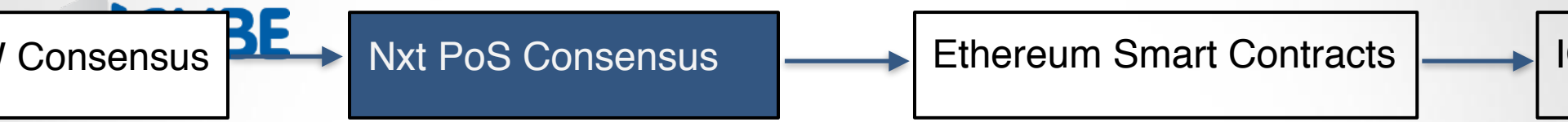

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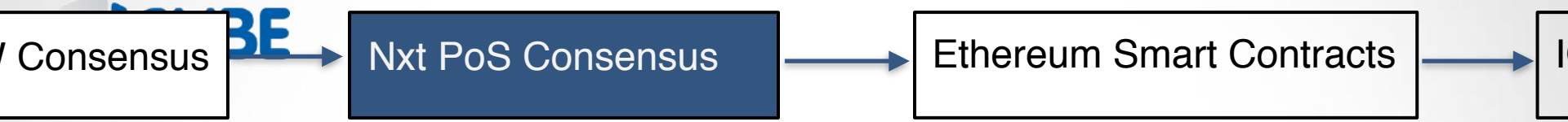
- The address with the smallest *t* is elected.



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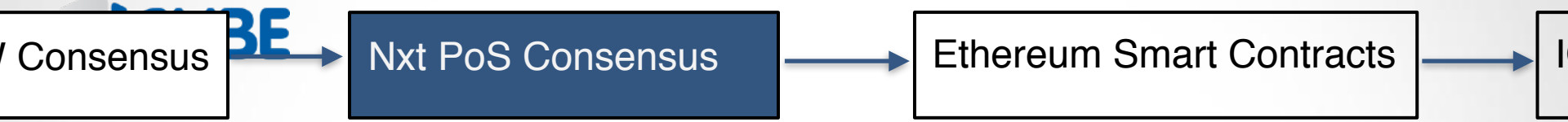

Using “old-style” Consensus algorithm

- Elects n validators (with PoS for instance)
- The validators use “old-style” Consensus algorithm to agree on the next blocks


onsensus
Ethereum Smart Contracts
IOTA BlockDAG

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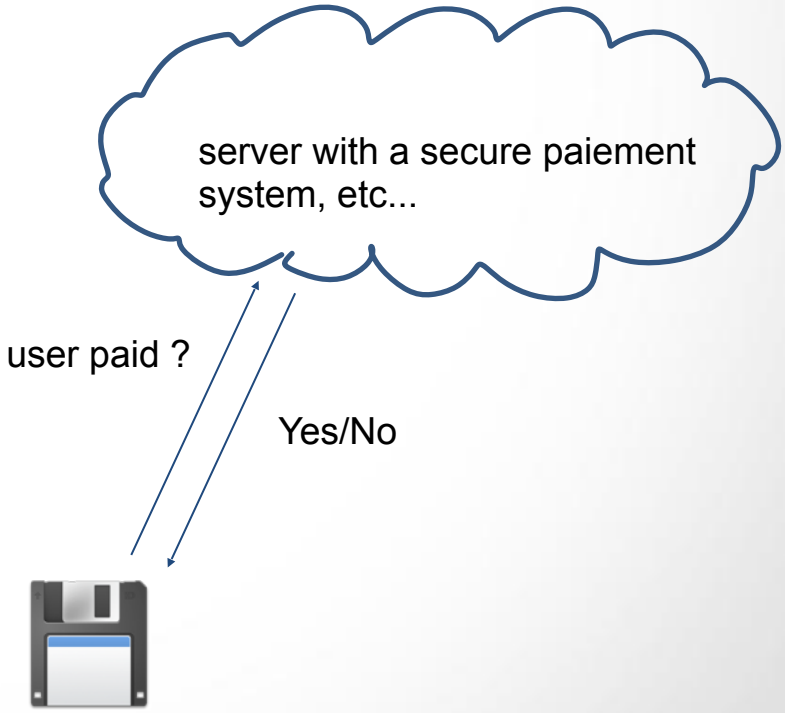

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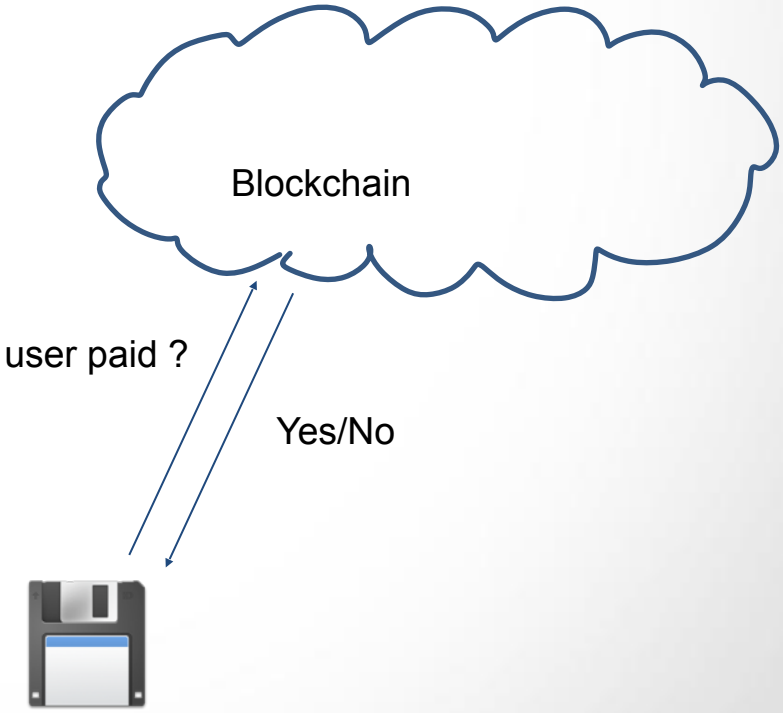

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“

var usersWhoOwnTheGame: Set

If an address *adr* sent to Alice 10$ and add “buyTheGame()” in the data of a block **then**
usersWhoOwnTheGame.insert(*adr*)

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Then in addition to remember the balance of each address, each nodes remember the value of *usersWhoOwnTheGame* and updates it after each block if the condition is met.

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Should be understood by every nodes in the same way

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Alice add this to a block:

```
pragma solidity ^0.4.18;
contract AliceGame {
  mapping(address => bool) public usersWhoOwnTheGame;

  function buy() public payable {
    if(msg.value >= 10)
    {
      usersWhoOwnTheGame[msg.sender] = true;
    }
  }
}
```

test here: http://remix.ethereum.org/

-> gets translated to EVM instructions


```
PUSH1 0x80
PUSH1 0x40
MSTORE CALLVALUE
DUP1
ISZERO
PUSH2 0x10
JUMPI
PUSH1 0x0
DUP1
REVERT
JUMPDEST
POP
PUSH2 0x166
DUP1
PUSH2 0x20
PUSH1 0x0
CODECOPY
PUSH1 0x0
RETURN
STOP
PUSH1 0x80
PUSH1 0x40
MSTORE
PUSH1 0x4
CALLDATASIZE
LT
```

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A client can ask a node “what’s the value of this variable *@AliceGame.usersWhoOwnTheGame[playerAdr]*”

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When calling a contracts you declare

- The called function
- How much gas at most the miner will spend executing it
- How much Ether you're willing to pay per Gas spent

Fun fact

Fun fact

You can buy this crypto cat for 150 ETH (10000$)

Better Fact

https://www.dash.org/network/#section-governance

So what's the problem?

So what's the problem?

It does not scale

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Bitcoin : 4 transactions / seconds

So what's the problem?

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Bitcoin : 4 transactions / seconds

Visa: 2 000 transactions / seconds

Solutions

Solutions

Sharding (each node own a fraction of the database)

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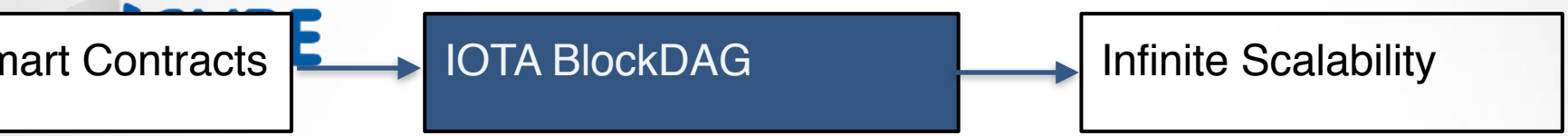
Side-chains

Solutions

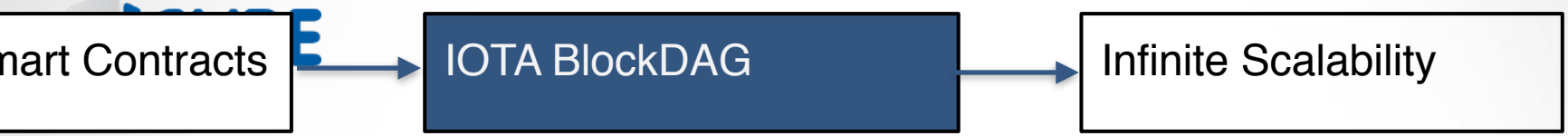
Sharding (each node own a fraction of the database)

Side-chains

DAG instead of Chain



The Tangle (IOTA)



The Tangle (IOTA)

Each transaction is a small block that reference two previous ones

mart Contracts → IOTA BlockDAG → Infinite Scalability

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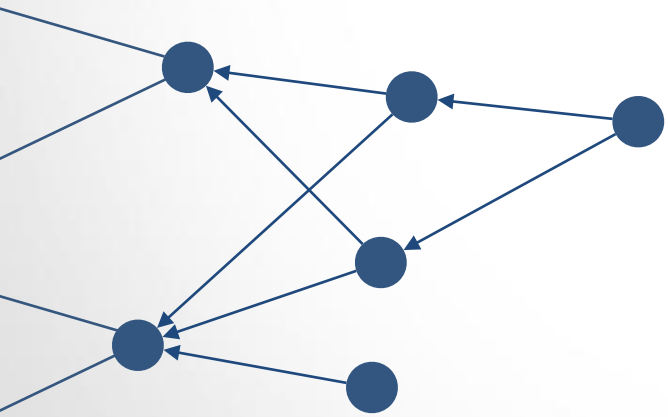

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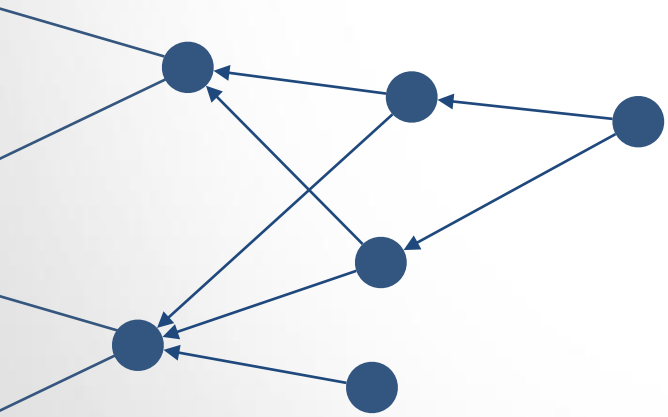

You come up with a DAG
(Directed Acyclic Graph)

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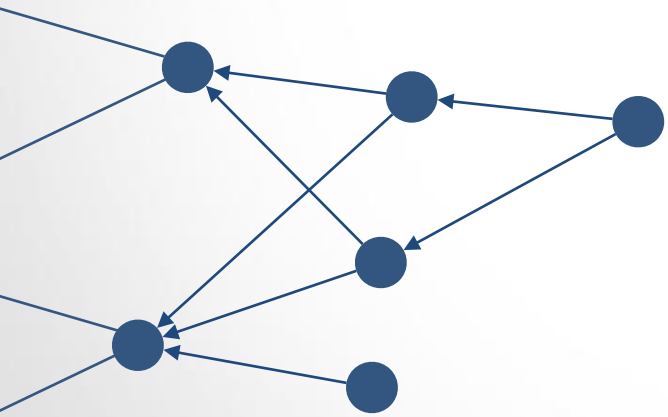

You come up with a DAG
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You're only limited by bandwidth and storage

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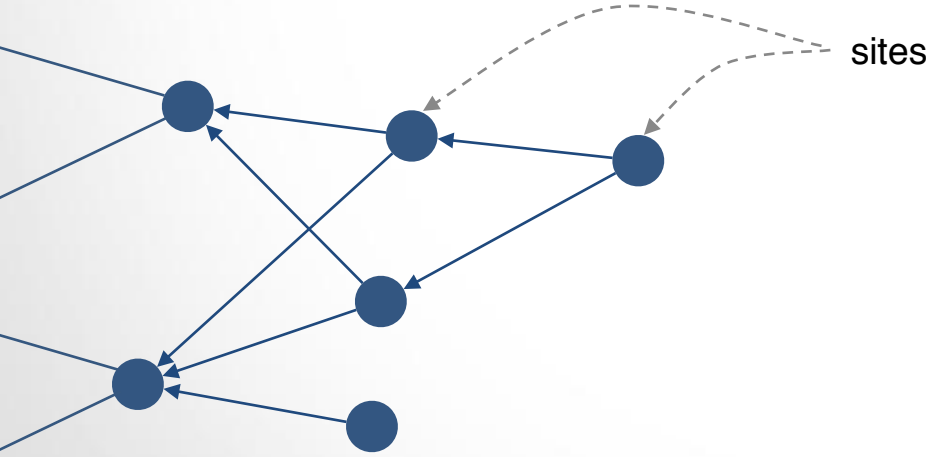

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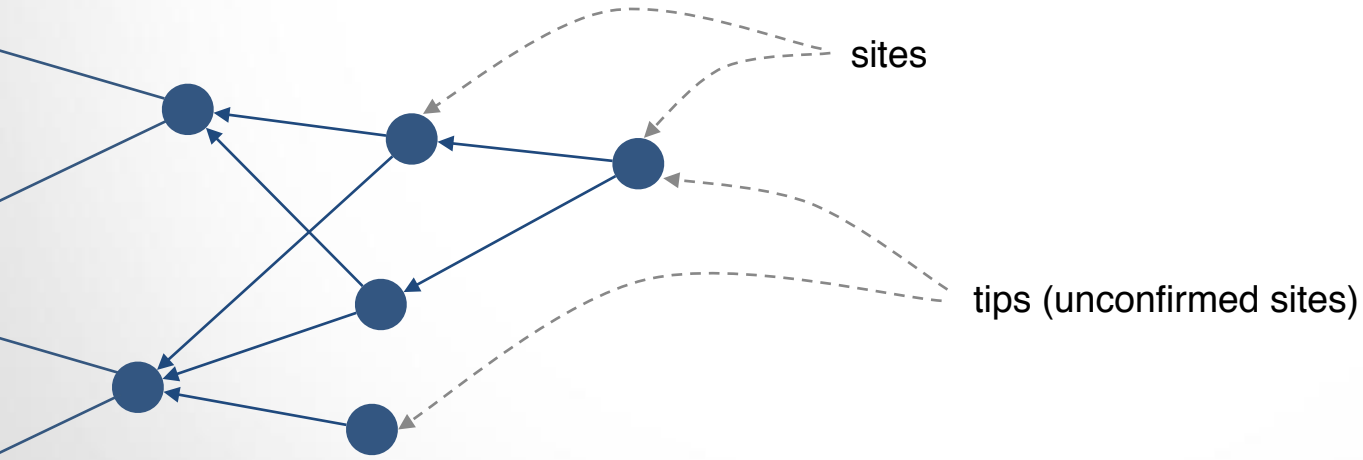

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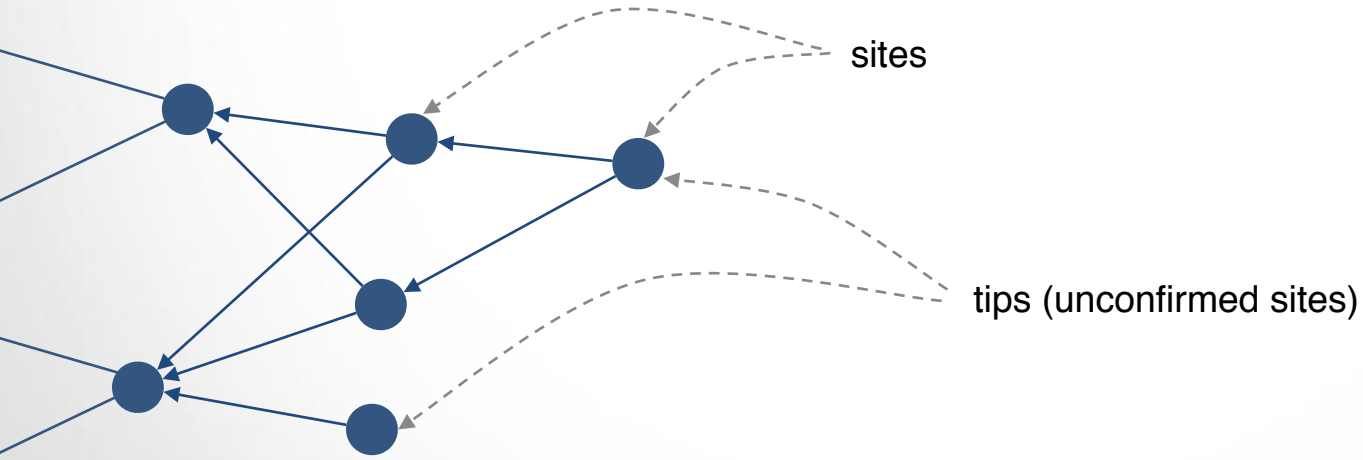
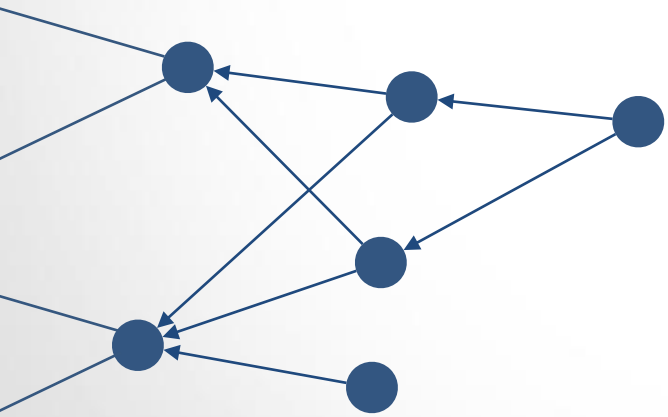


A new site and its parents should not create conflicts.

mart Contracts → IOTA BlockDAG → Infinite Scalability

The Tangle (IOTA)

How to read a value?



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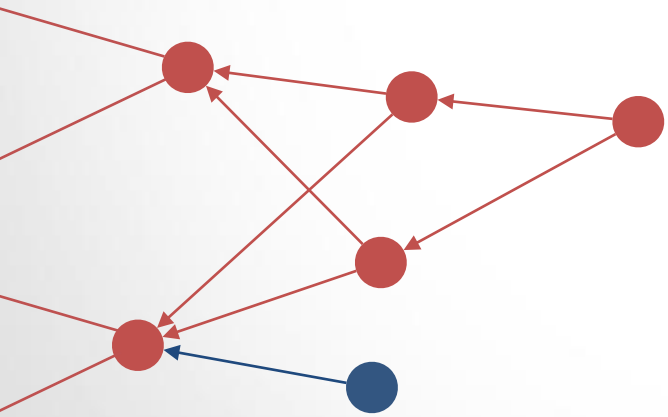


How to read a value?

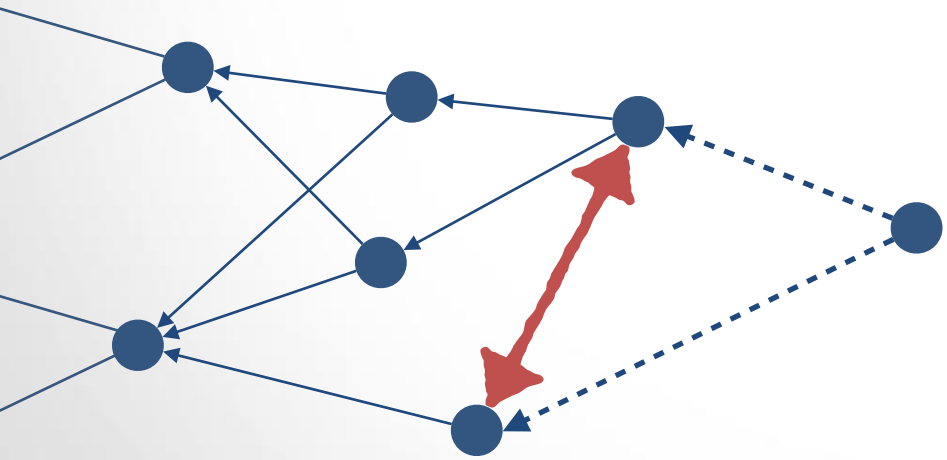
If you take a tip, you can order transactions and do the same as in a blockchain

mart Contracts → IOTA BlockDAG → Infinite Scalability

The Tangle (IOTA)

How to read a value?

What if tips are conflicting?



A new site cannot confirm conflicting sites

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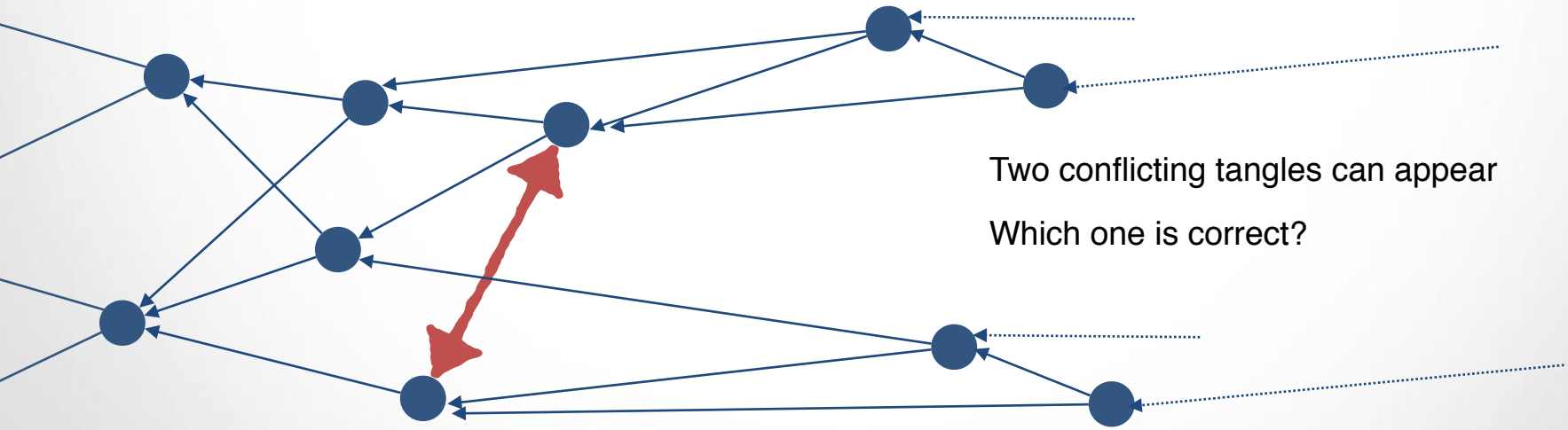

Two conflicting tangles can appear

Which one is correct?

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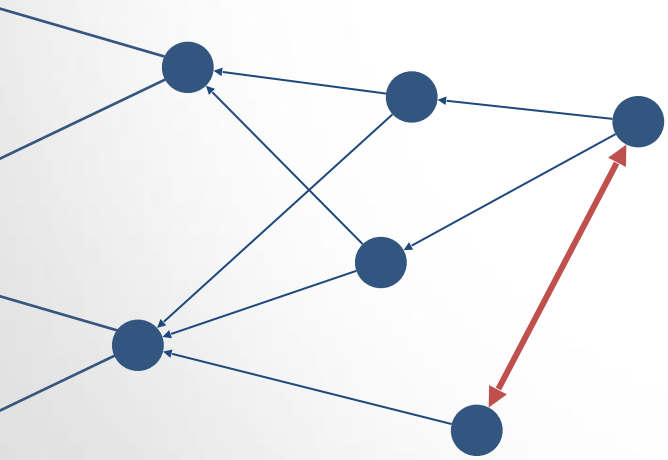
The Tangle (IOTA)



Tip Selection Algorithm (TSA):

- so we know how to read values
- so we know where to extend the Tangle

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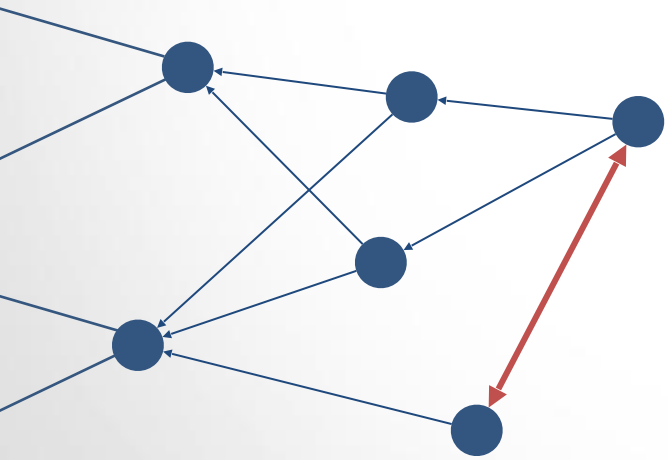
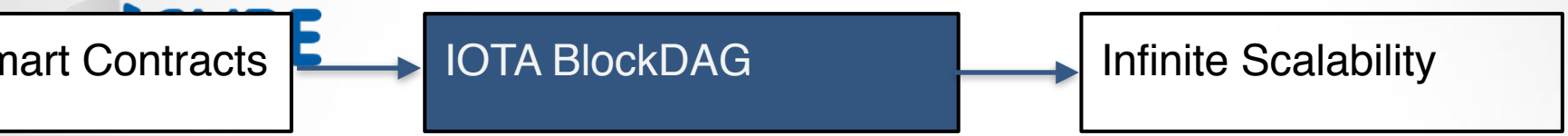


Tip Selection Algorithm (TSA):

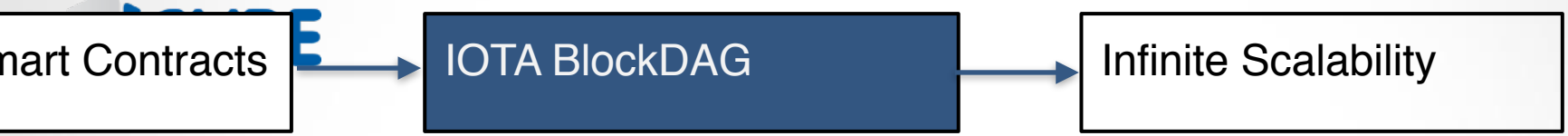
- so we know how to read values
- so we know where to extend the Tangle

In Bitcoin, we read values from, and we try to extend, the longest chain. If you don't follow this, you'll lose money.



The Tangle (IOTA)

In the Tangle, forks are ok if not conflicting



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But conflicting forks are worst in this case

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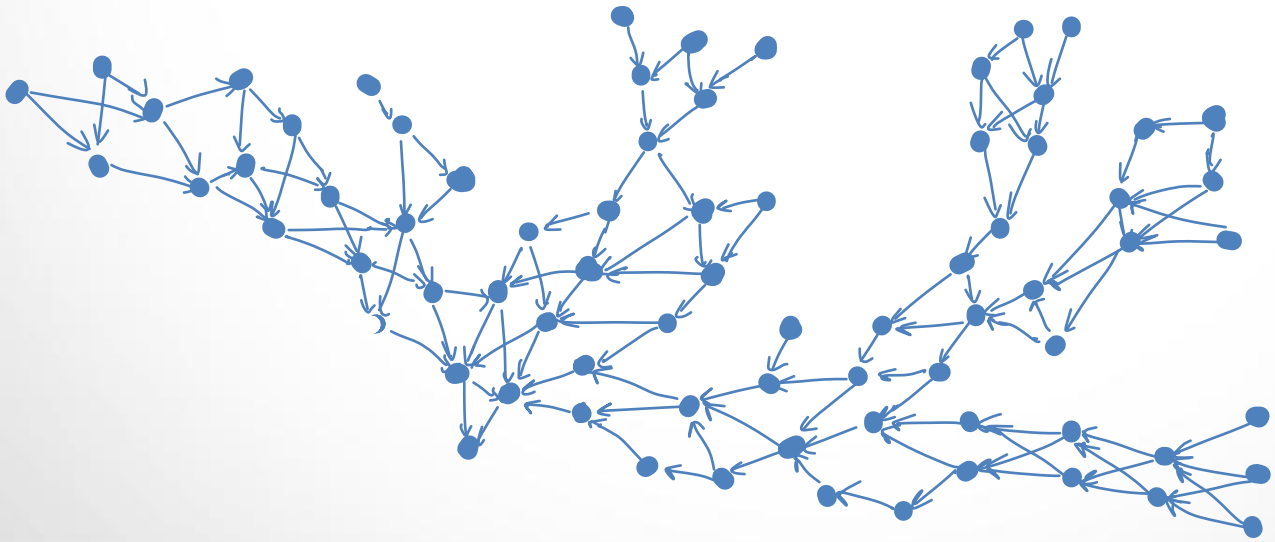

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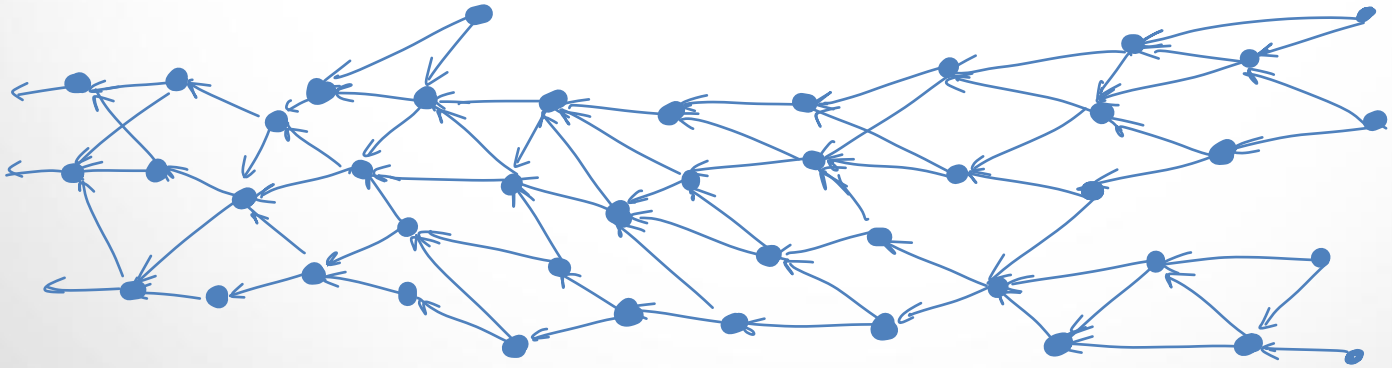
The Tangle (IOTA)

In the Tangle, forks are ok if not conflicting

So its better to have something like this



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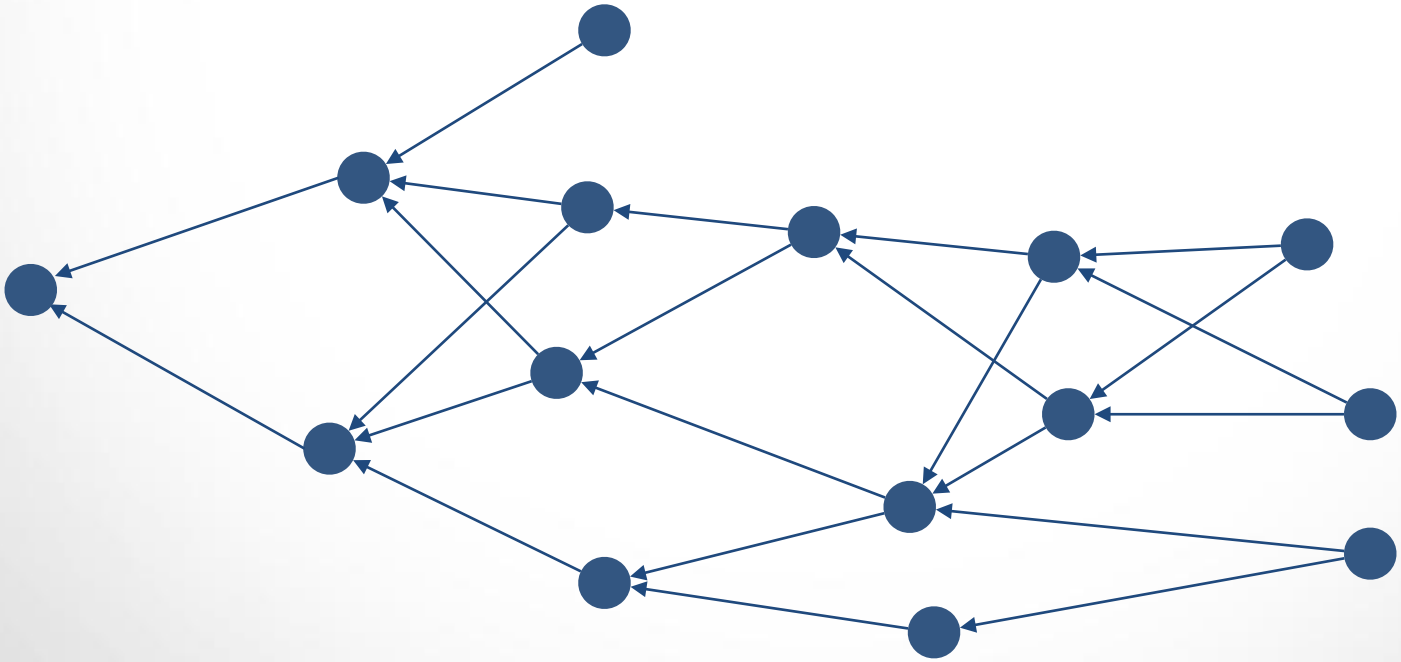

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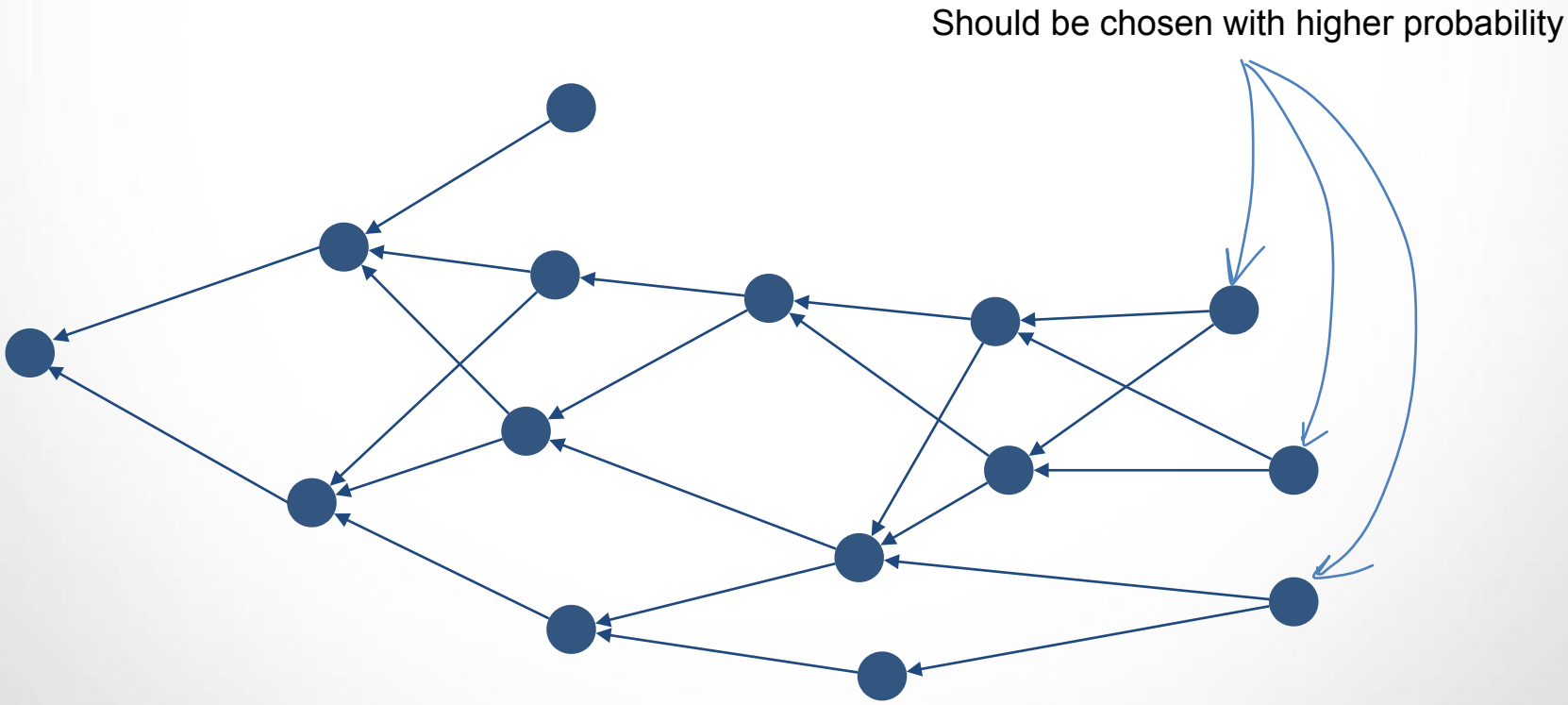

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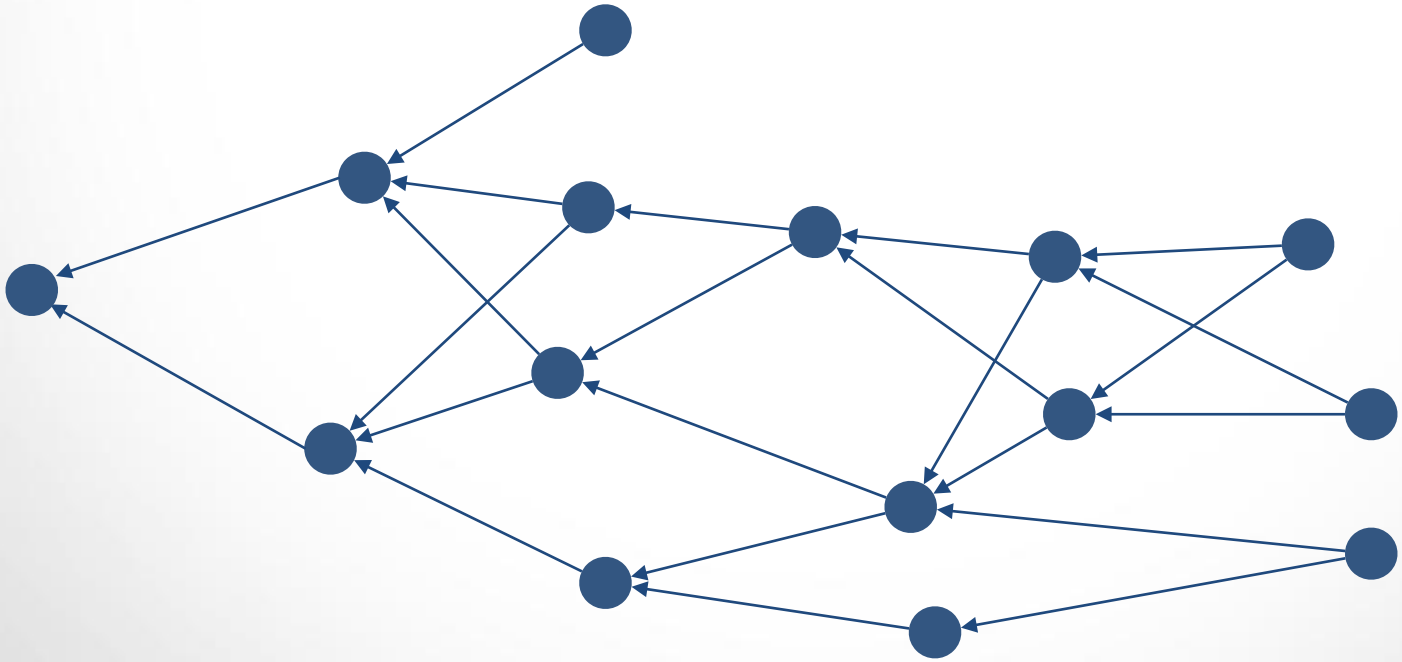
The Tangle (IOTA)

Compute cumulative weight to each site



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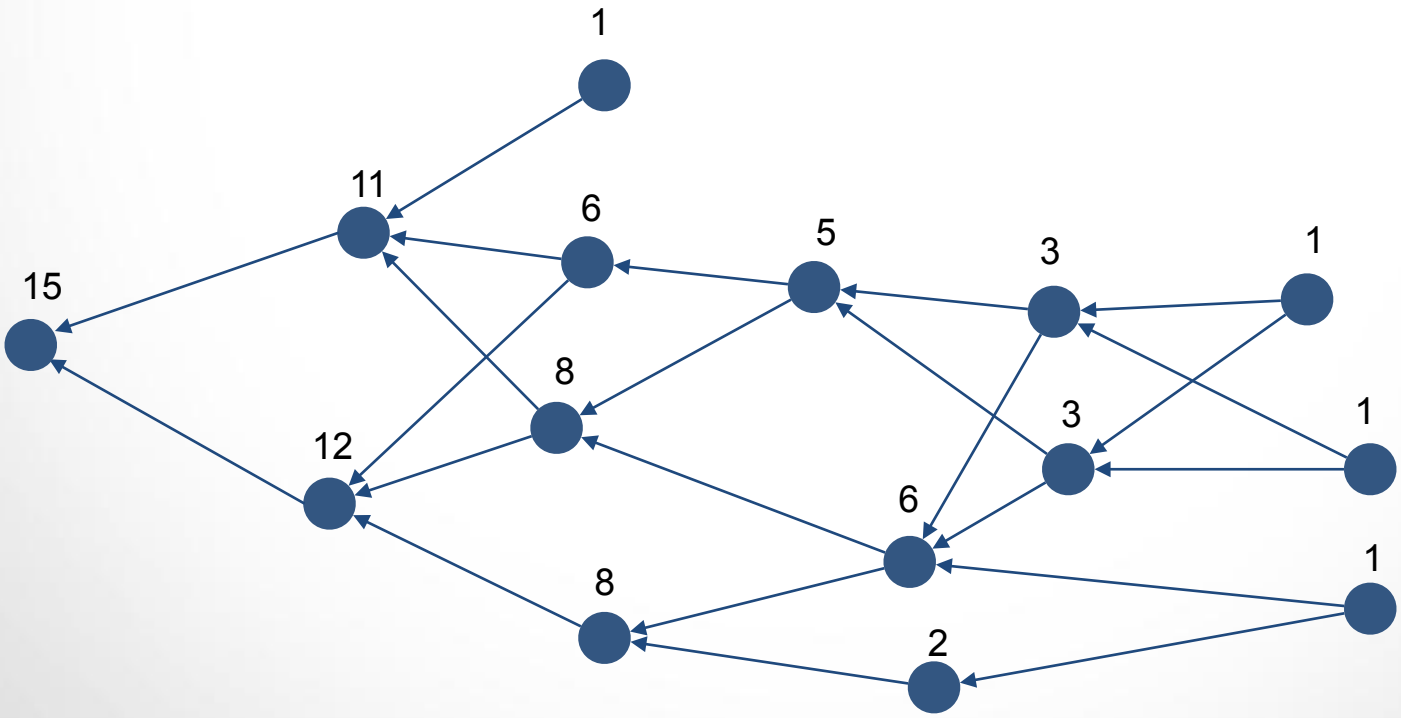

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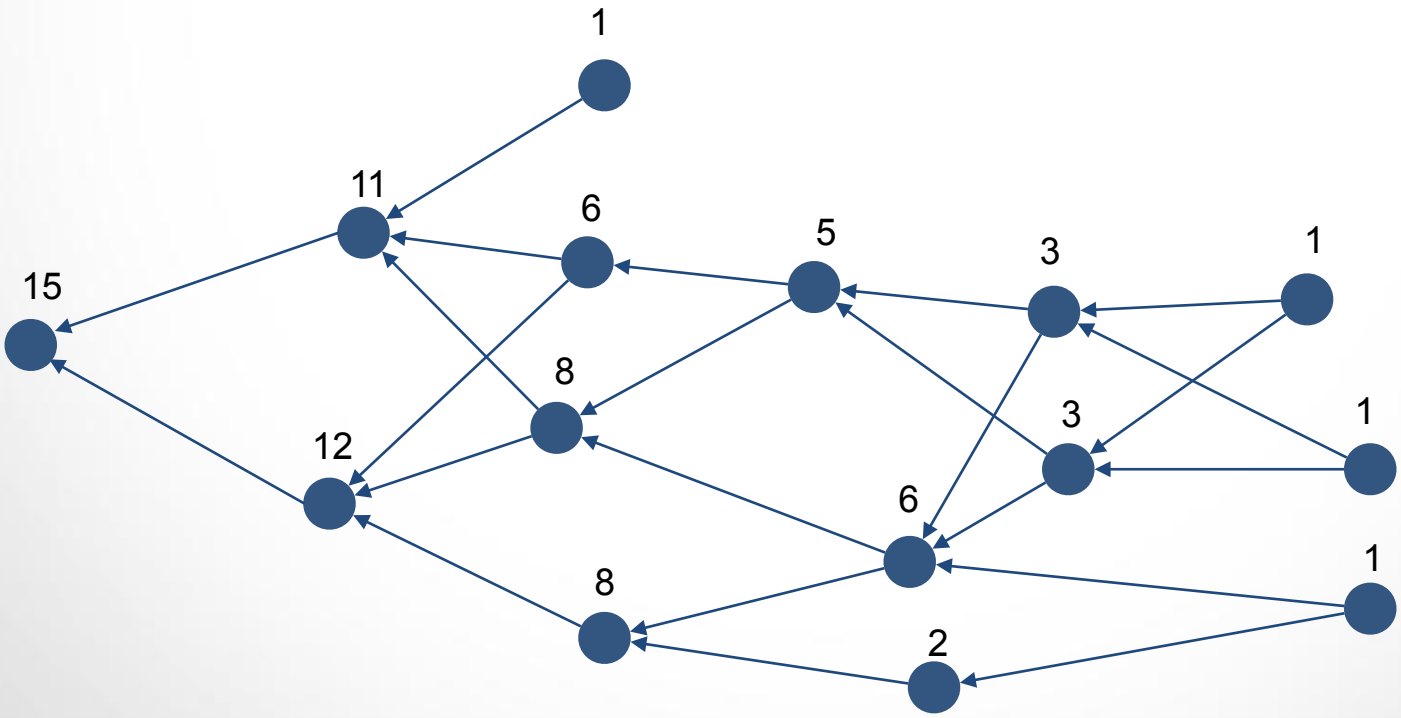

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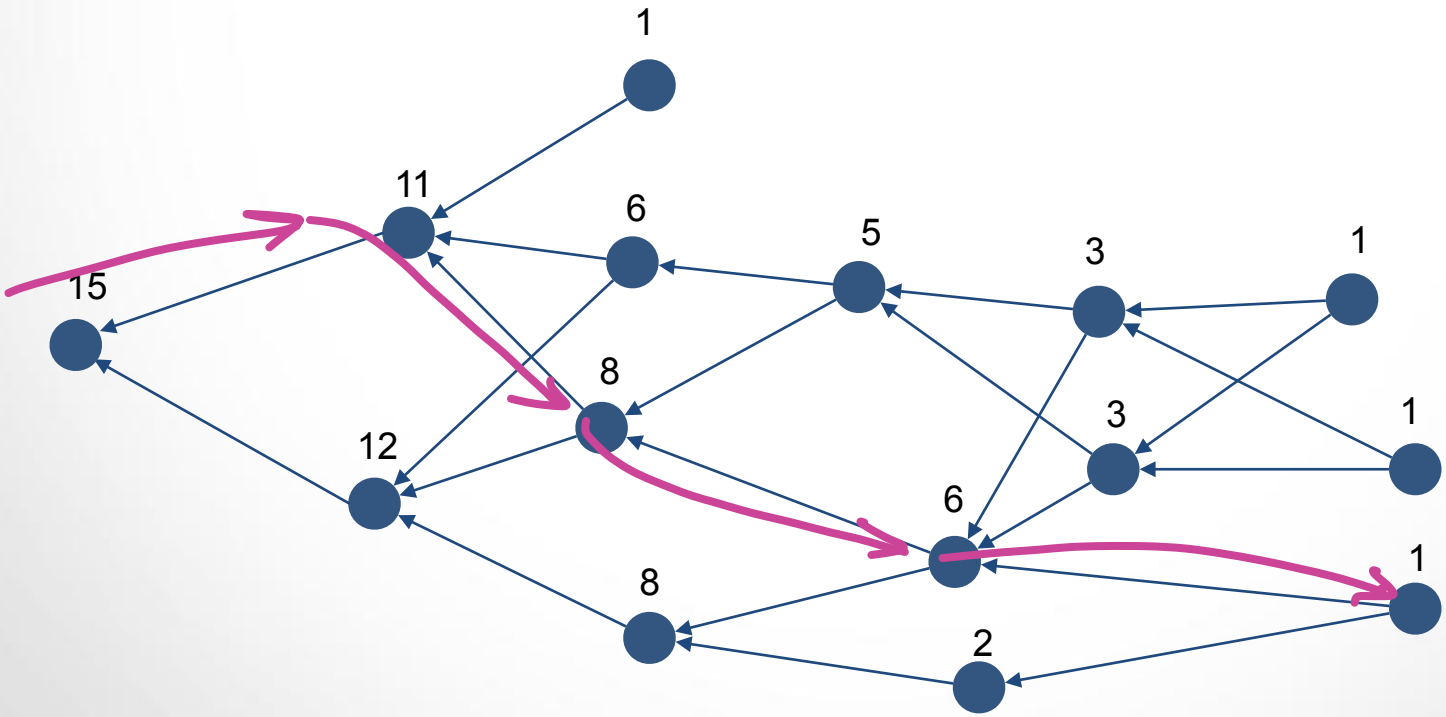

mart Contracts → IOTA BlockDAG → Infinite Scalability

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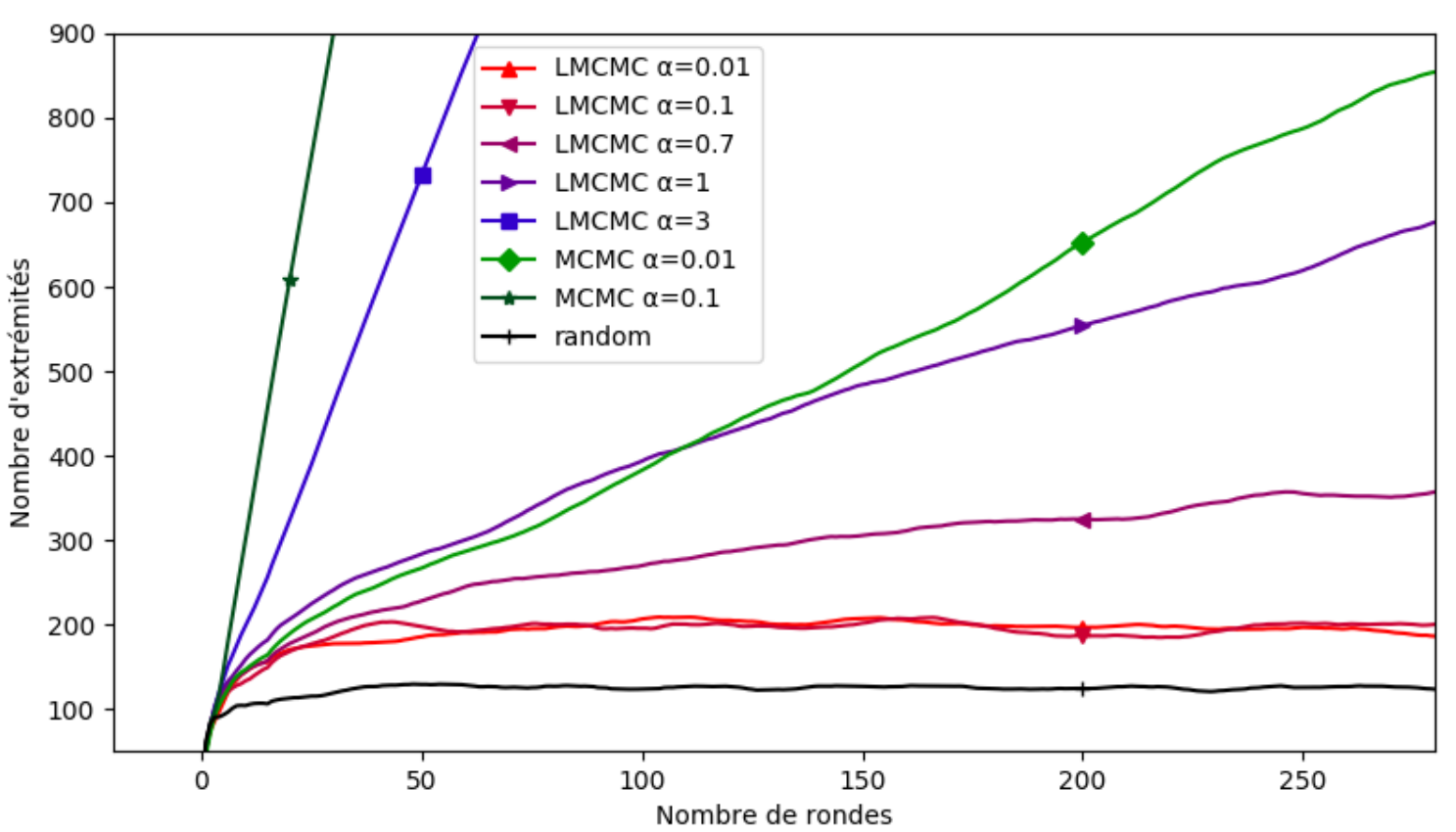
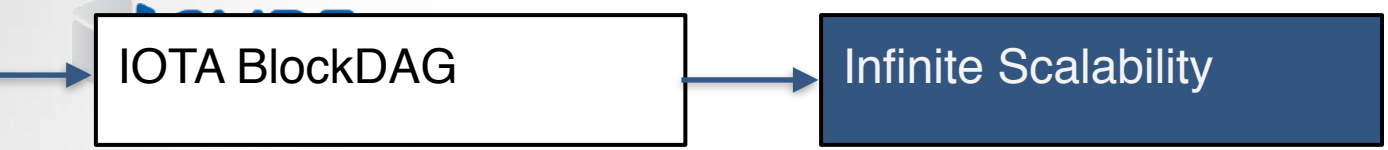
How many tips are left behind ?




IOTA BlockDAG
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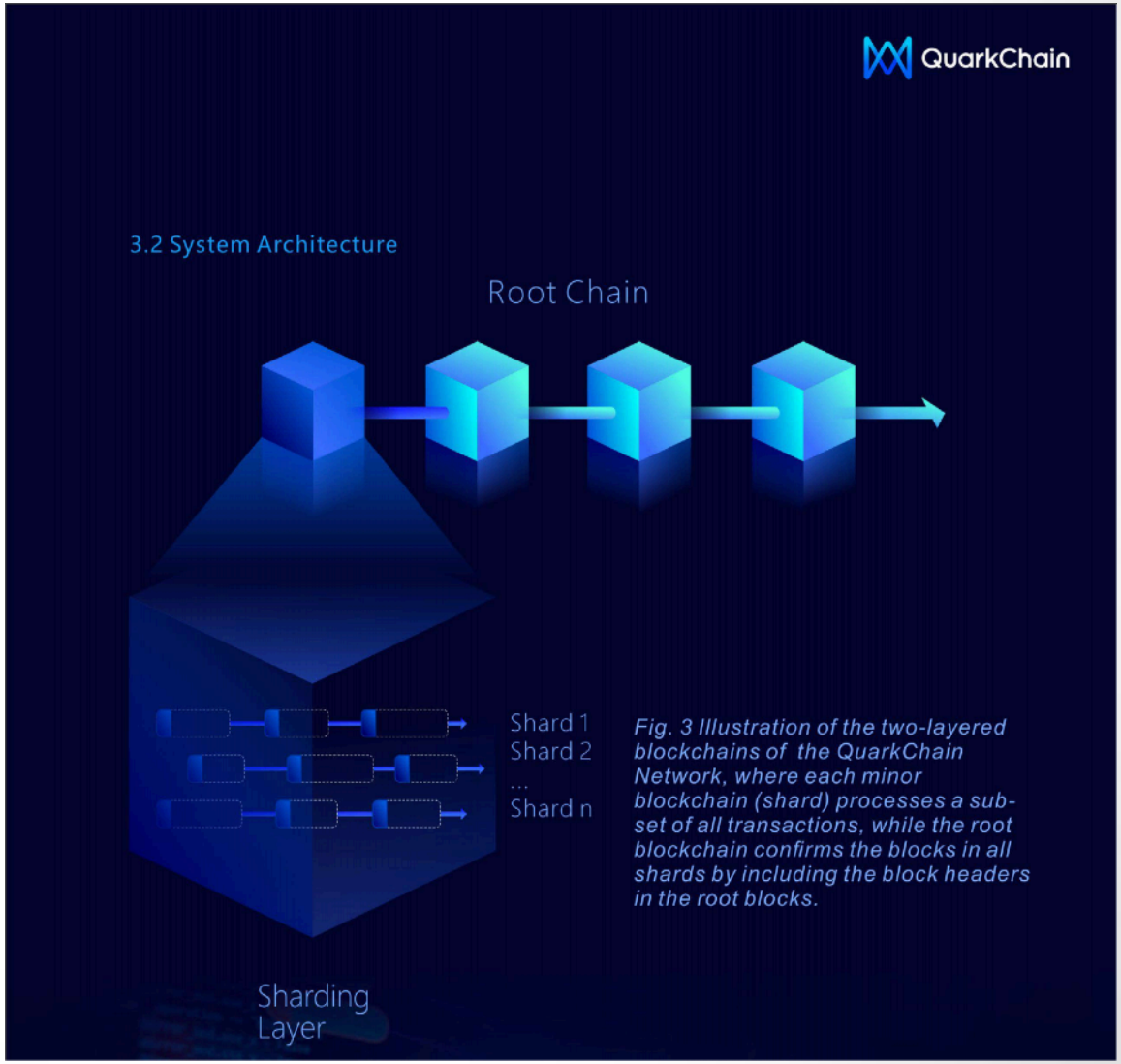
QuarkChain white paper :

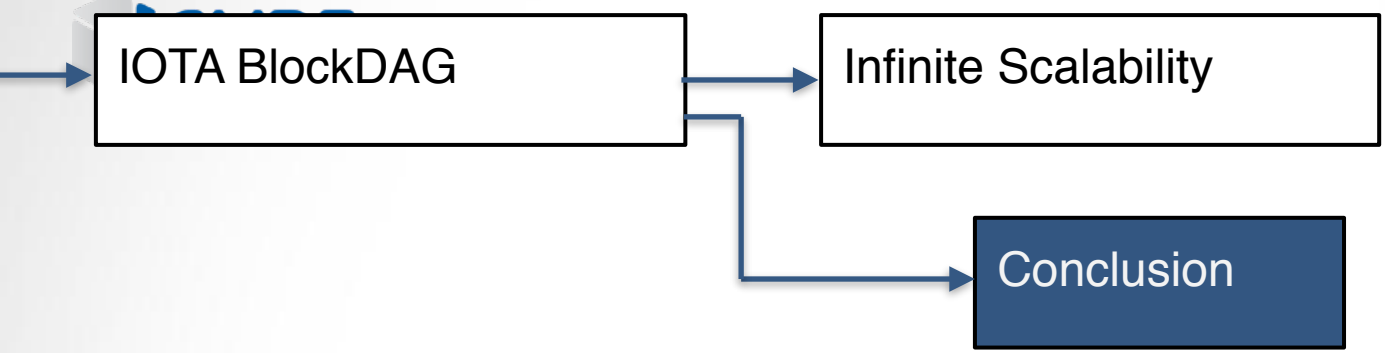


https://quarkchain.io/QUARK%20CHAIN%20Public%20Version%200.3.4.pdf

QuarkChain white paper :

The QuarkChain Network is helping move blockchain into the next generation by increasing the current TPS capacity several-thousand fold of what it is now, to a projected about 100,000 TPS. The network being built is project to be free of congestion, making it affordable for all usage scenarios that demand speed and volume. We envision such a network applied to industries that demand higher TPS. Ultimately, the QuarkChain Network aims to build a high-throughput network to support applications such asdistributed social media, high frequency trading, Internet of Things (IoT), gaming, and payment.

https://quarkchain.io/QUARK%20CHAIN%20Public%20Version%200.3.4.pdf


IOTA BlockDAG
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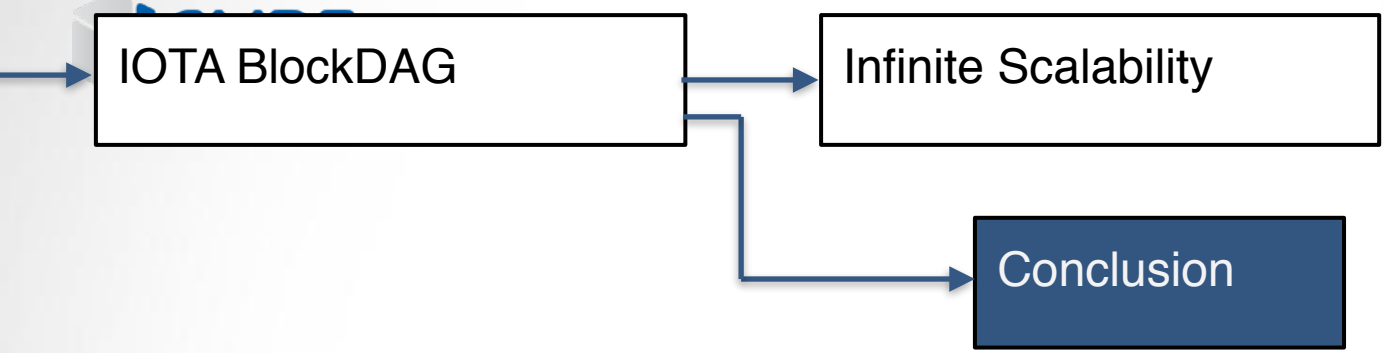
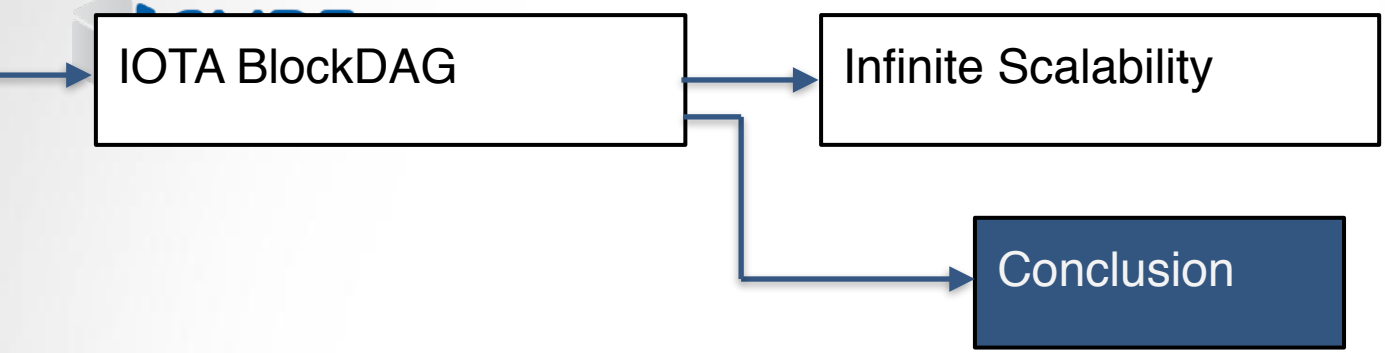
Conclusion

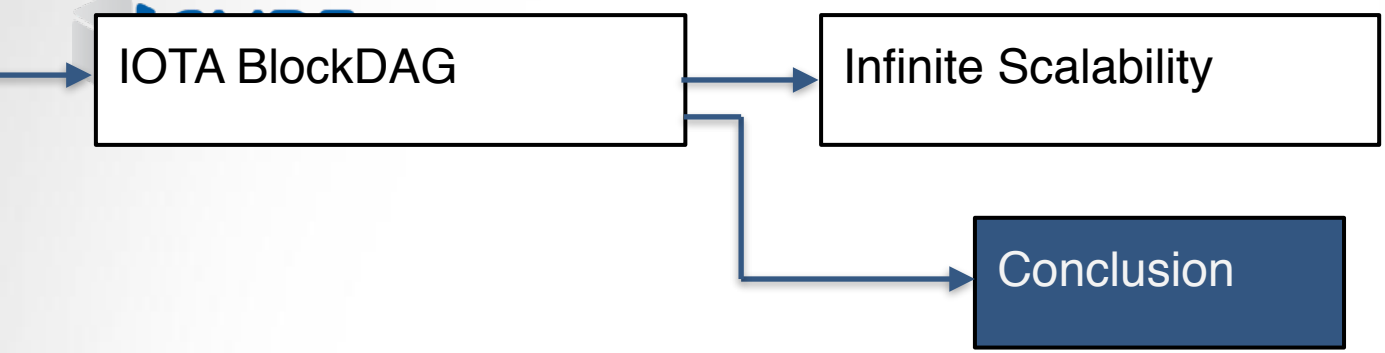


Take Away



Take Away

$$\text{quality of a protocol} = \frac{1}{\text{graphic quality of the white paper}}$$



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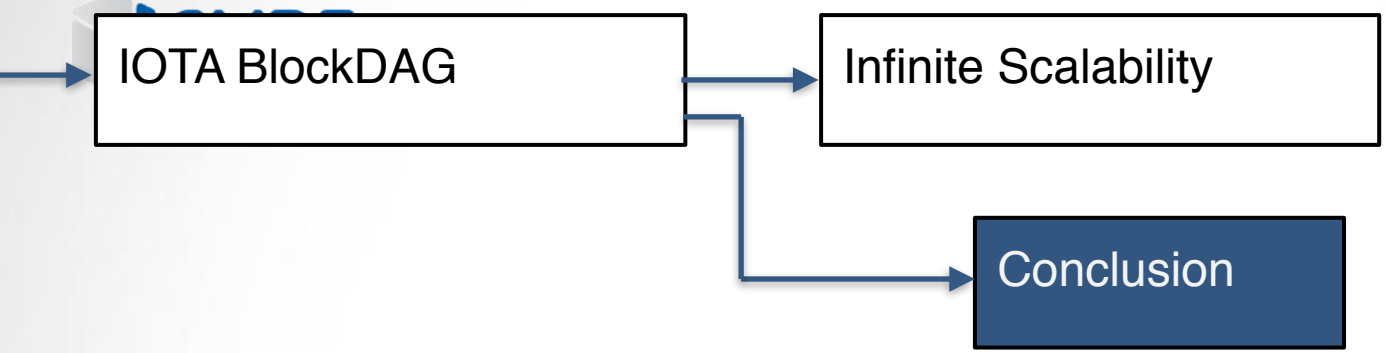
Ethereum Smart contracts are smart



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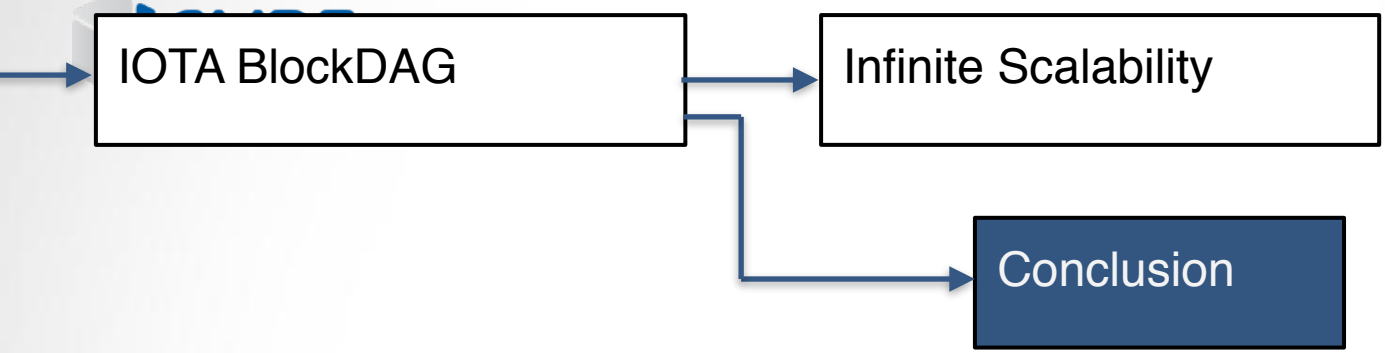
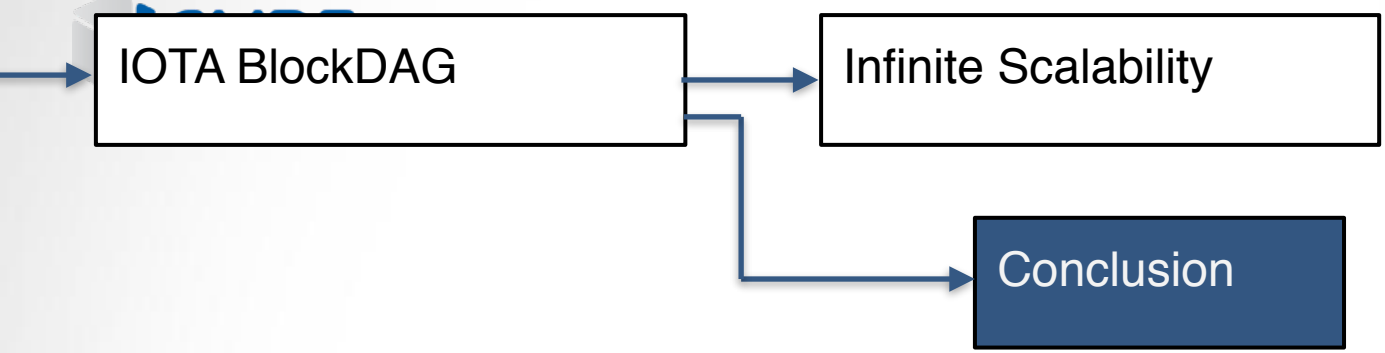
IOTA tangle is tangled



Perspectives



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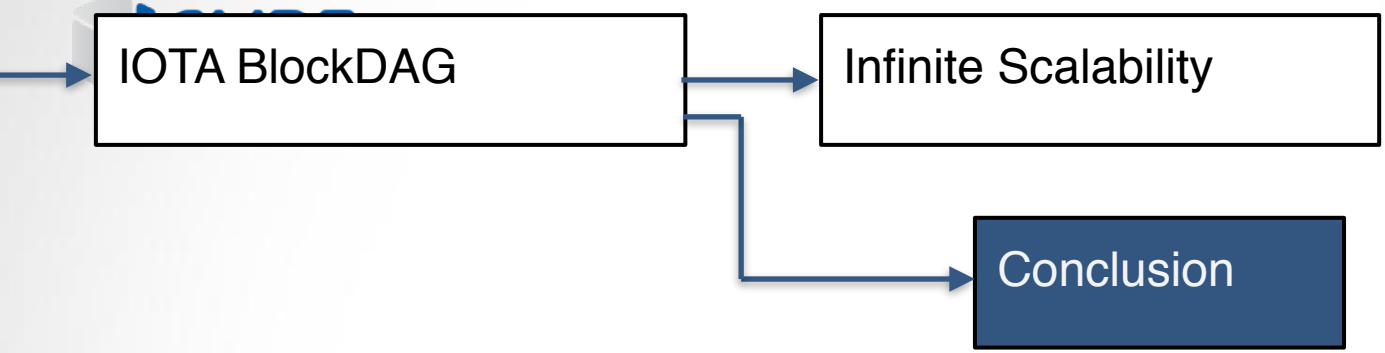

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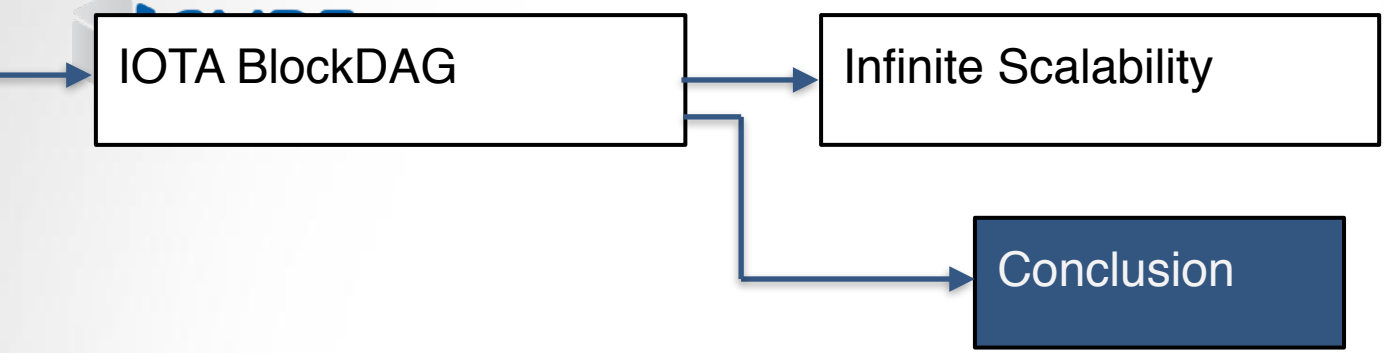

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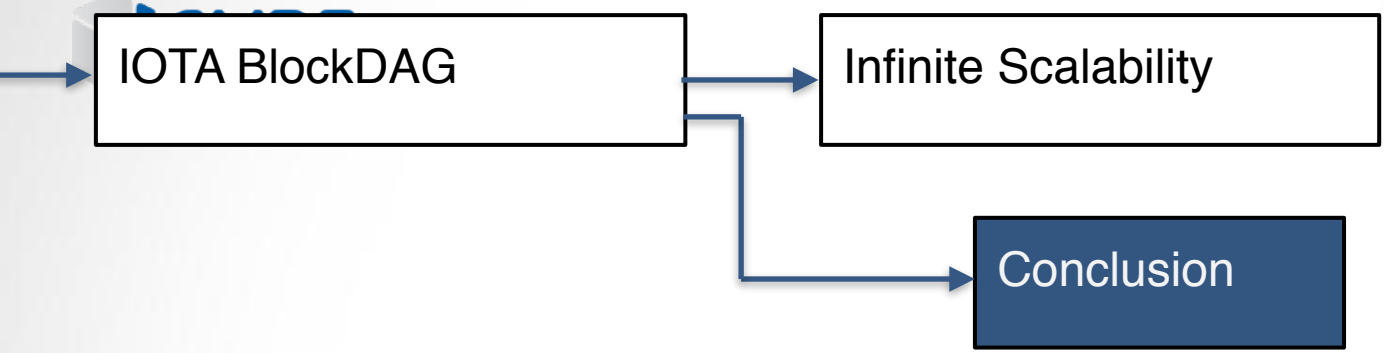

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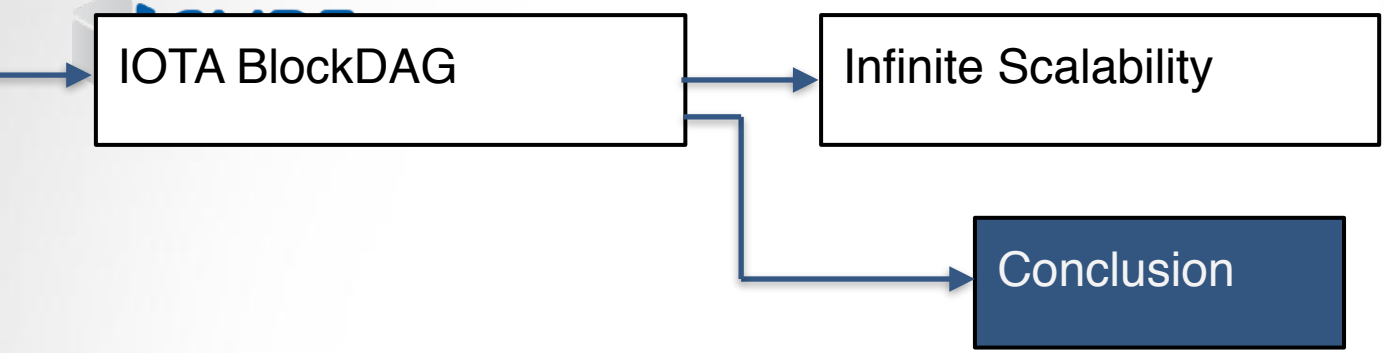

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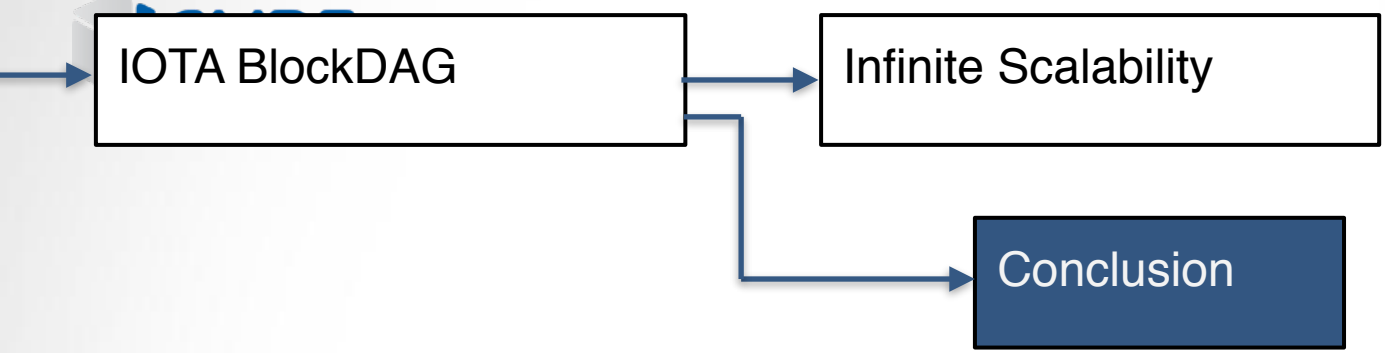

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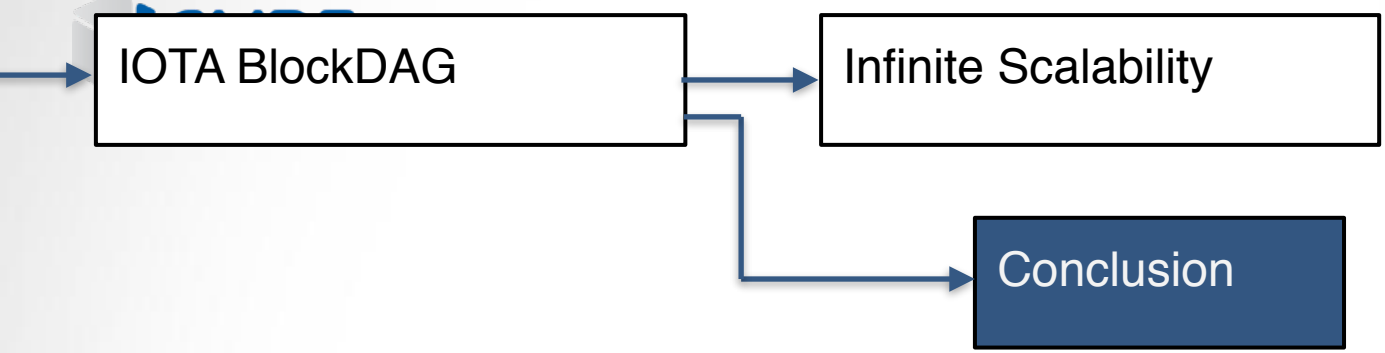

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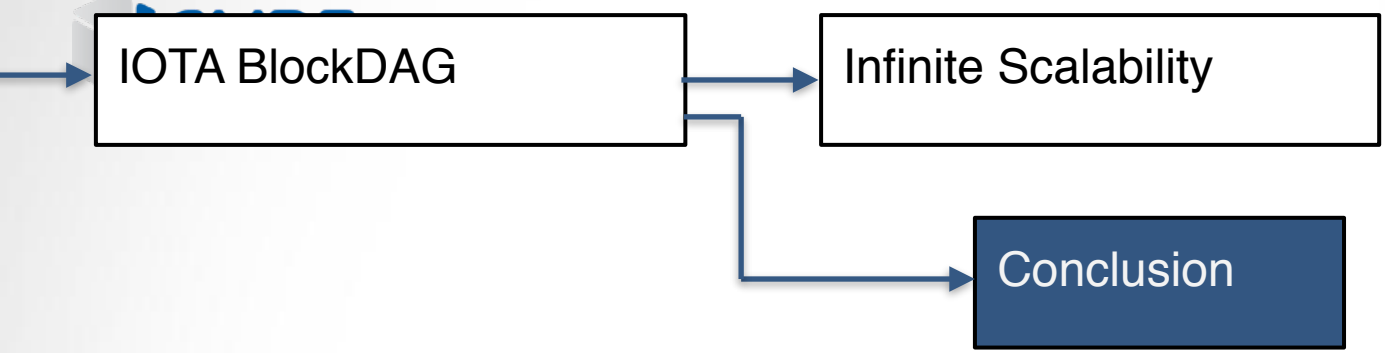

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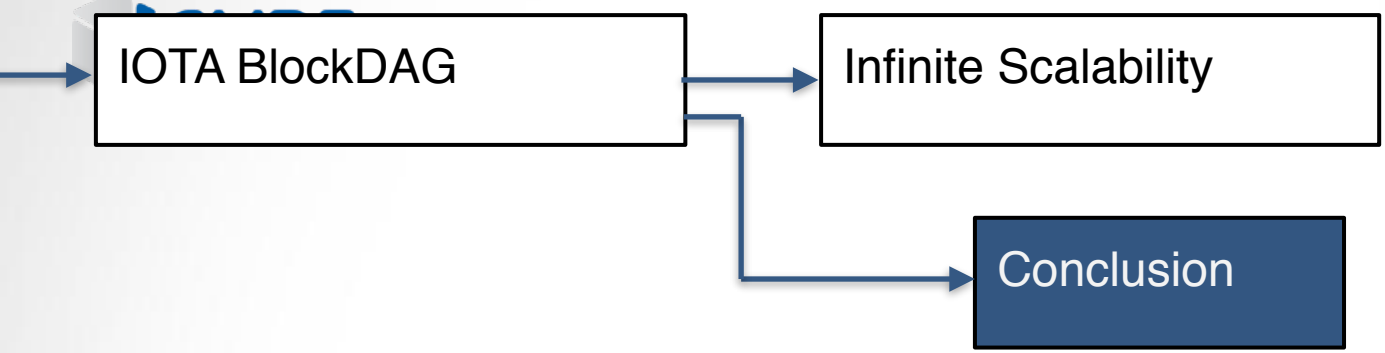

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And also :

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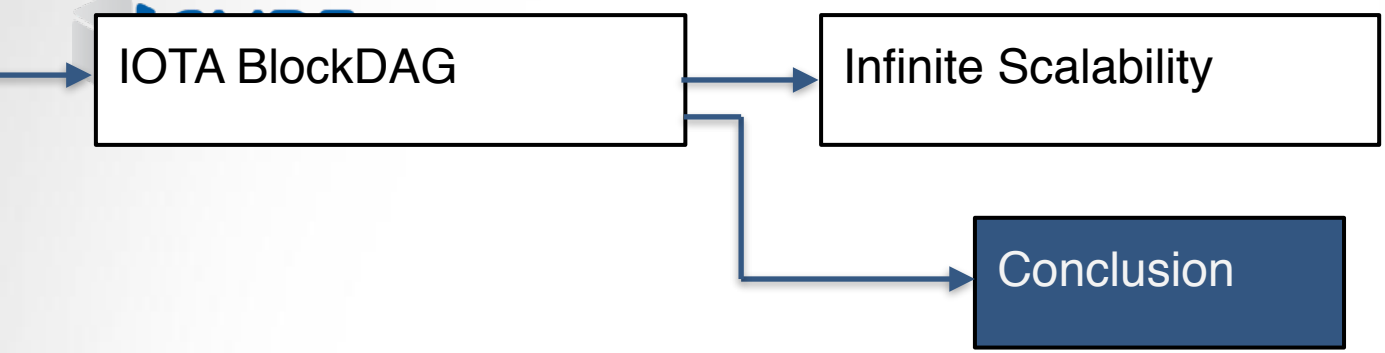

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And also :

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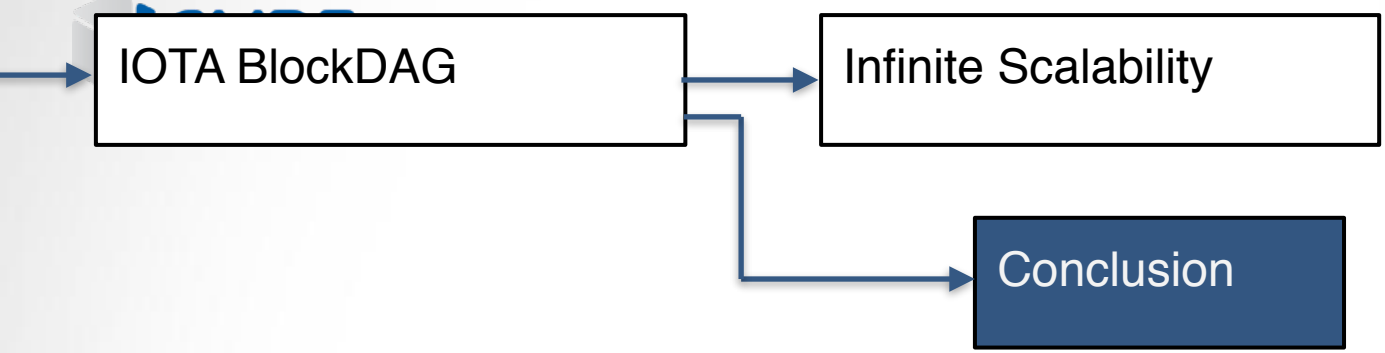
- How to analyze blockchain history to predict …



Perspectives

Lots of interesting open problems about :

- Network impacts on blockchain security
- Properly defining the attacks
- How to defend against them

Also :

- How to store efficiently blockchain data
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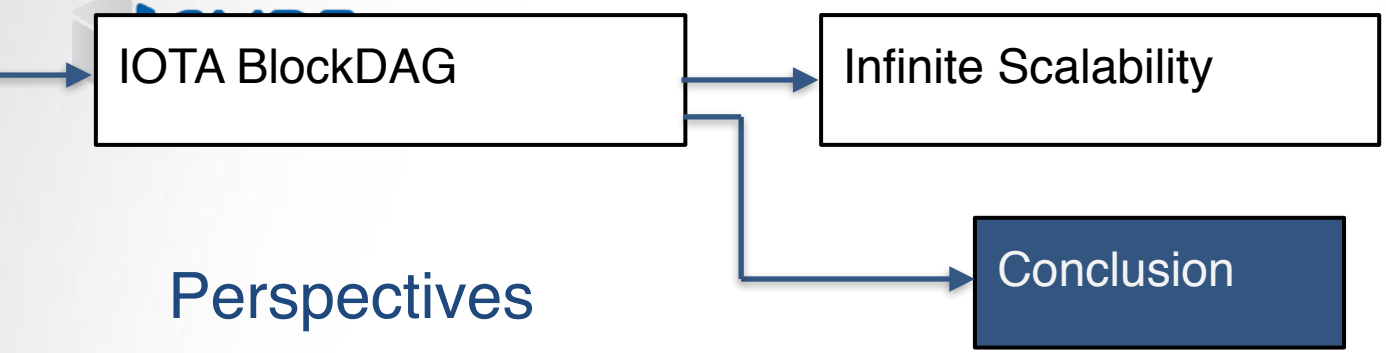

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Thank you for your attention !

Quentin Bramas. The Stability and the Security of the Tangle. 2018. 〈hal-01716111v2〉