CS61065: Theory And Applications of Blockchain

Evolution of the Blockchain Technology

Department of Computer Science and Engineering

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

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Shamik Sural
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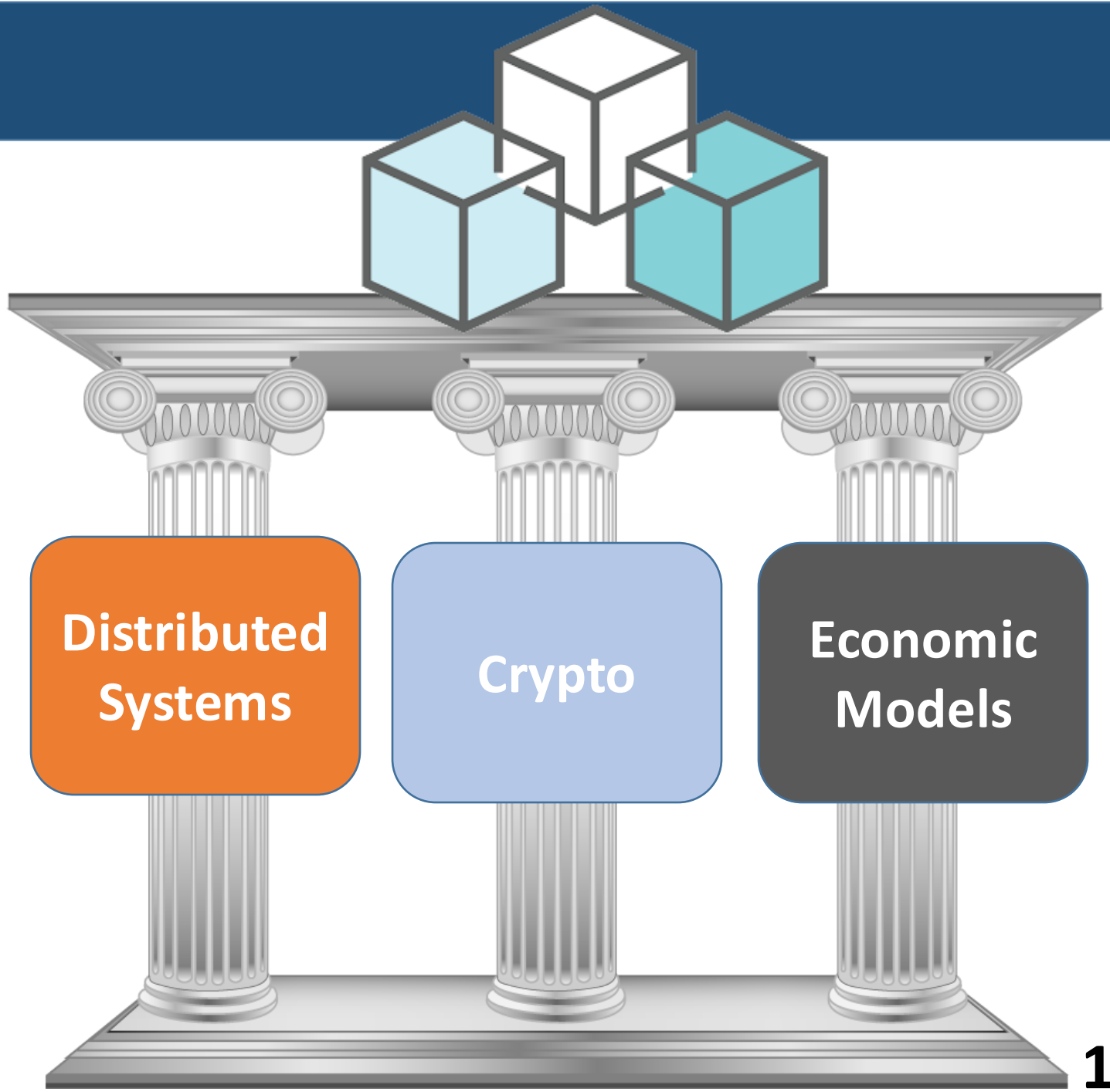
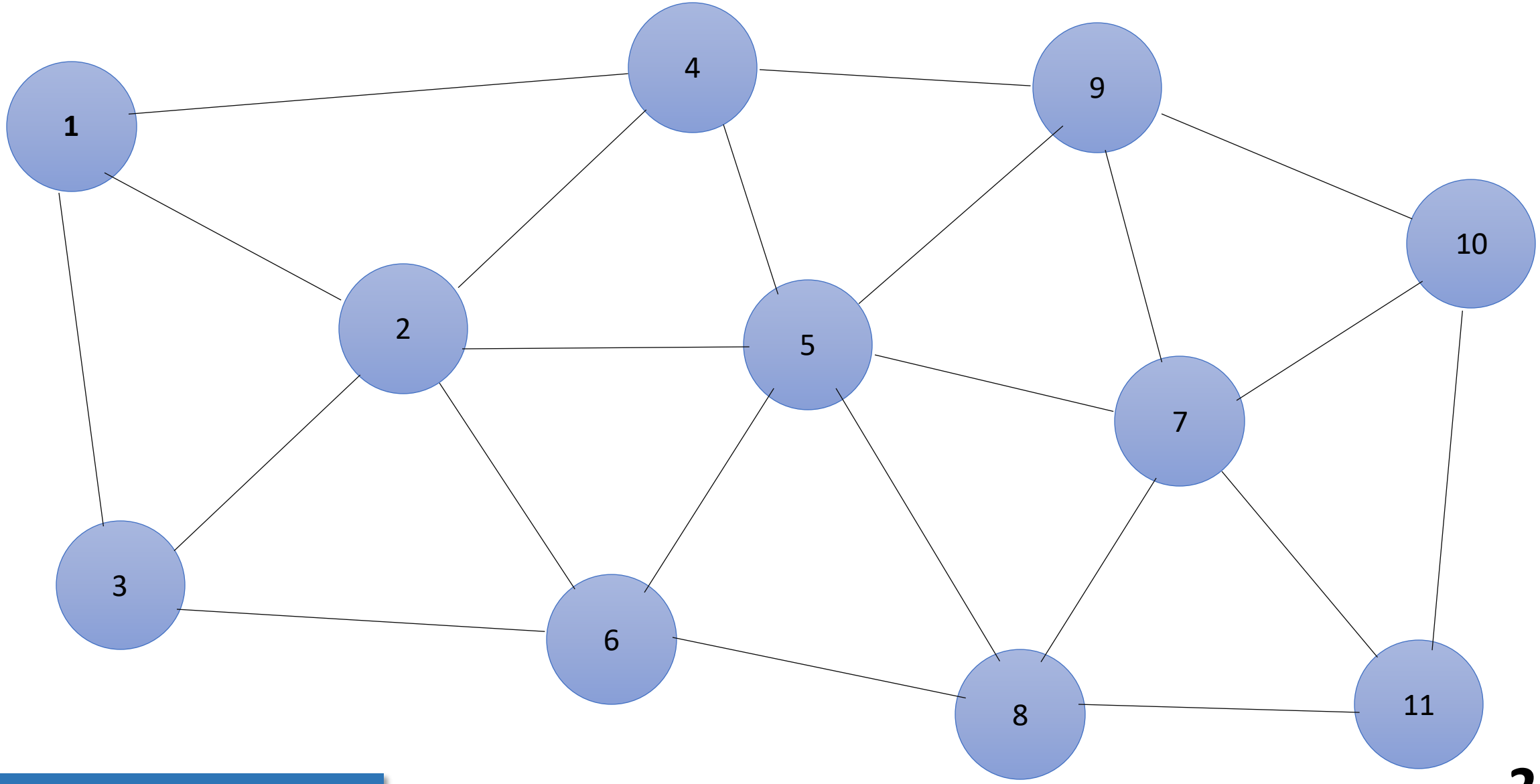
The Three Pillars



Our Core Problem



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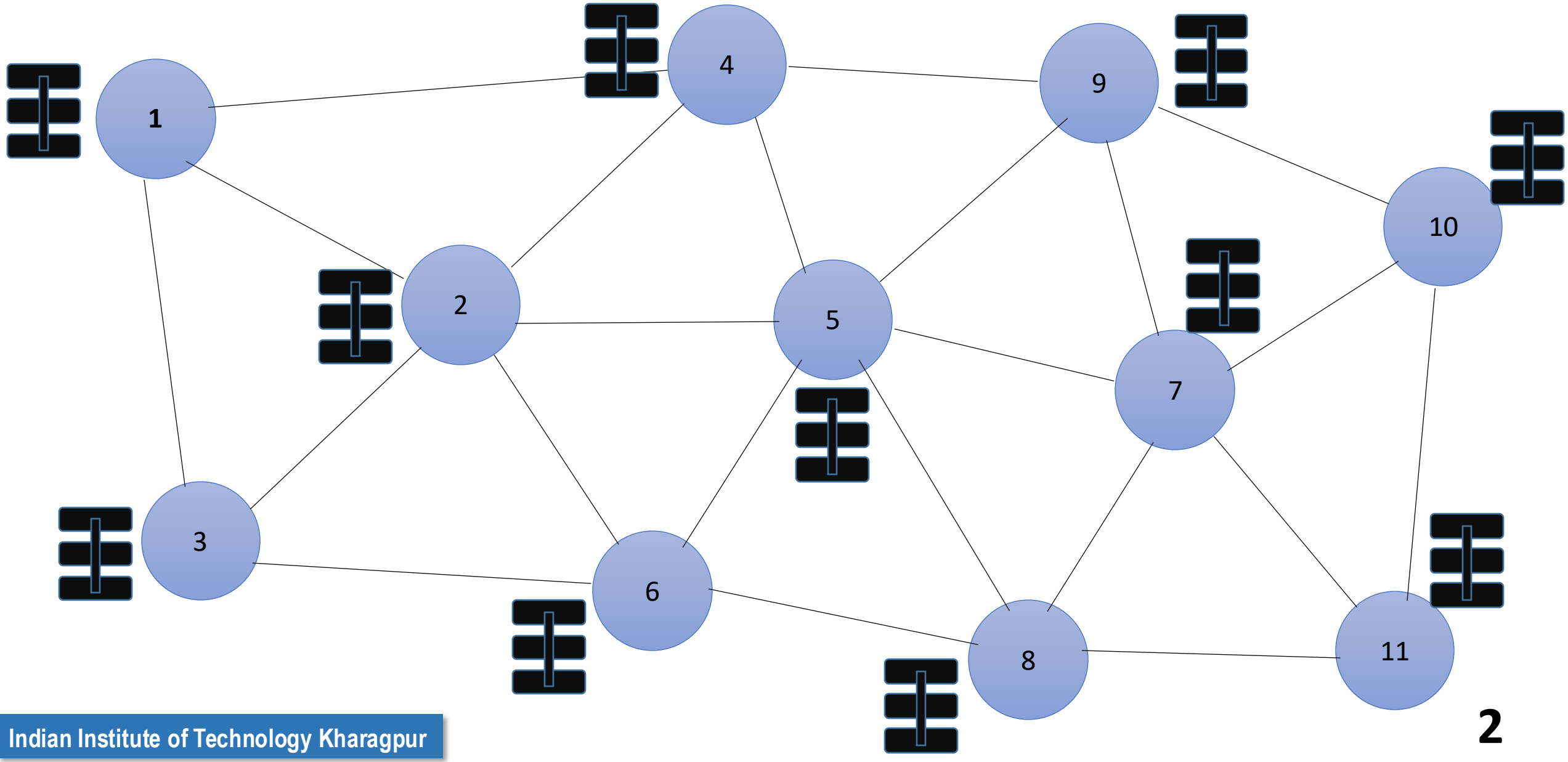

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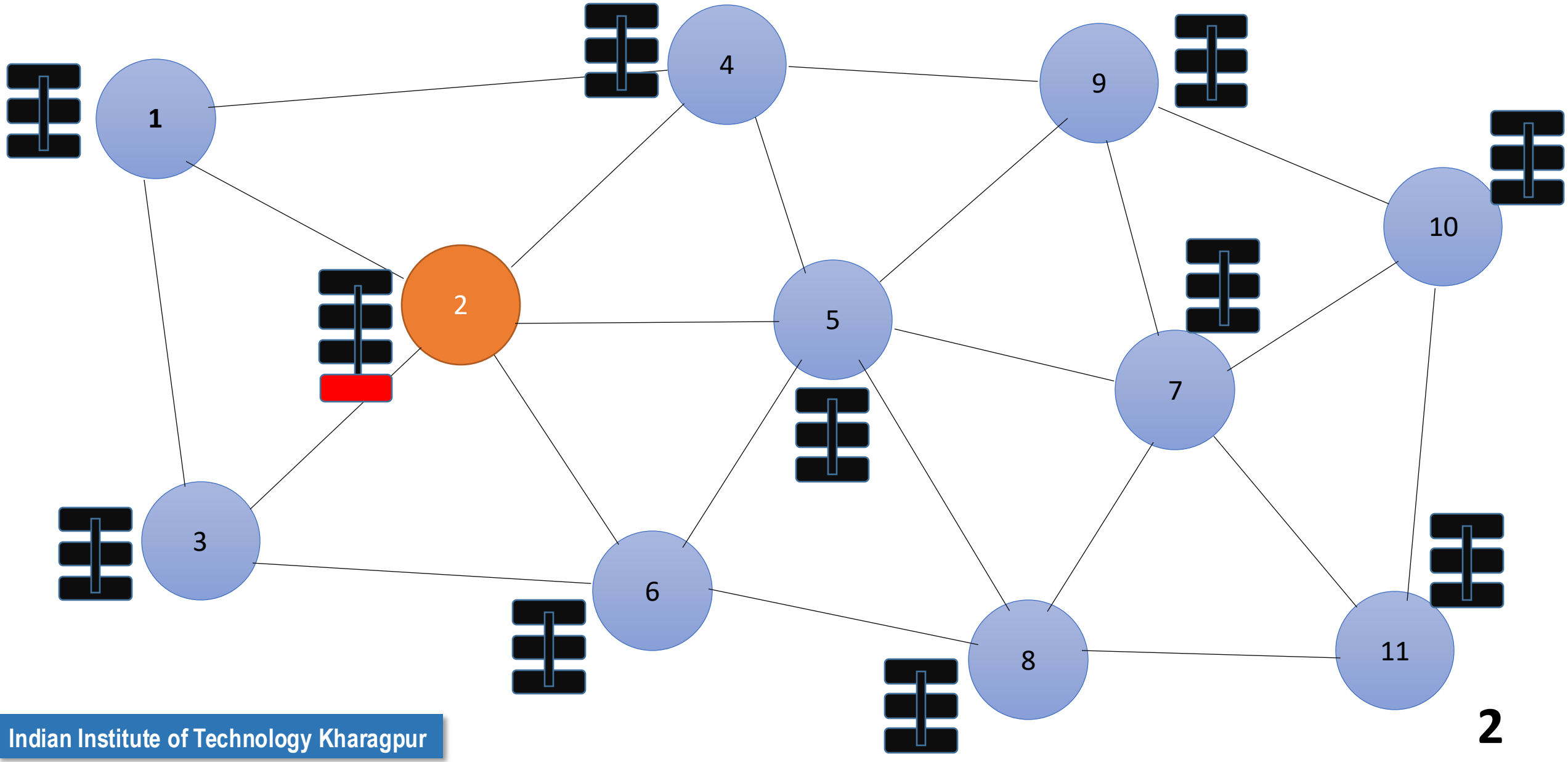

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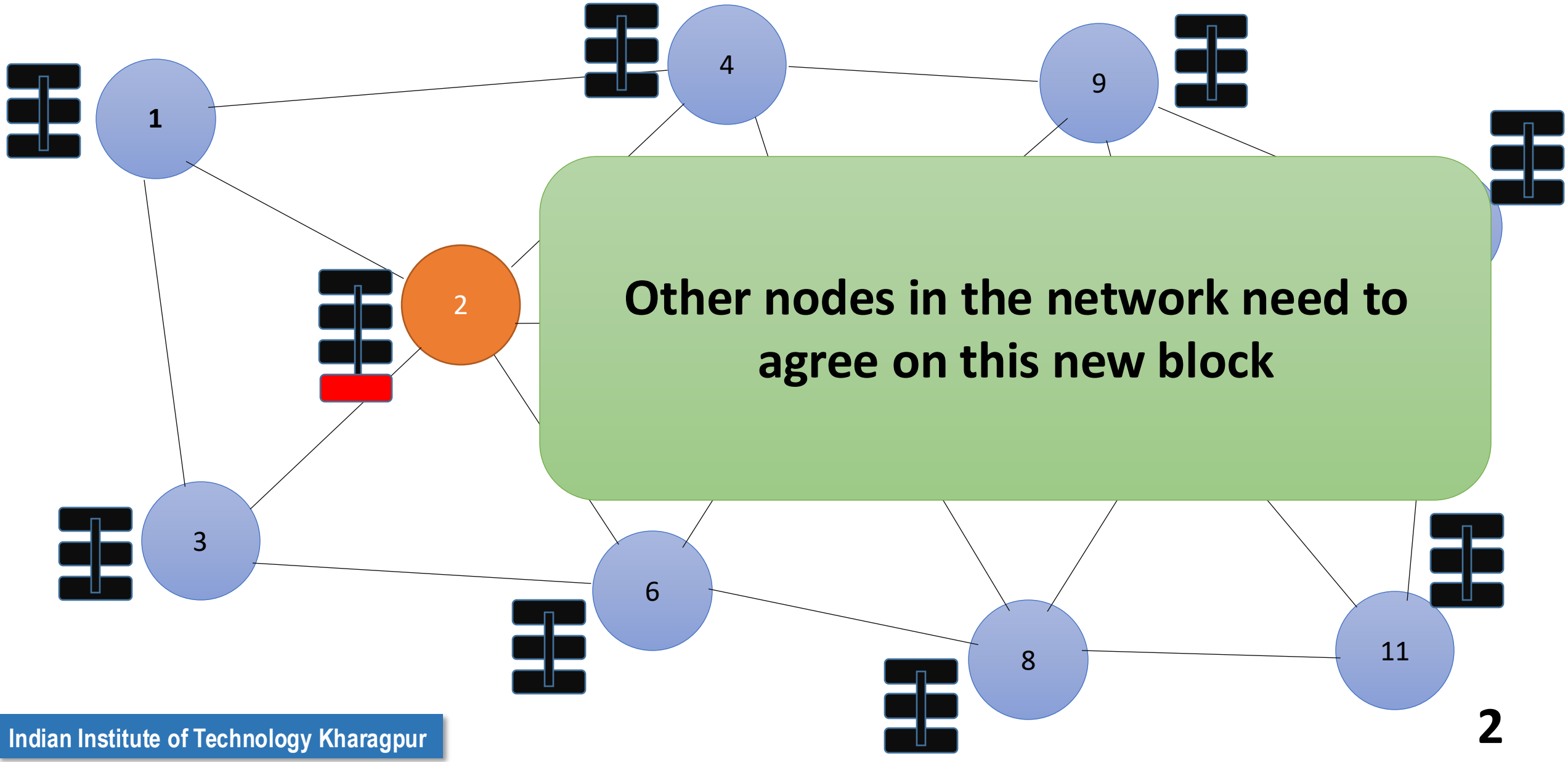

Other nodes in the network need to agree on this new block

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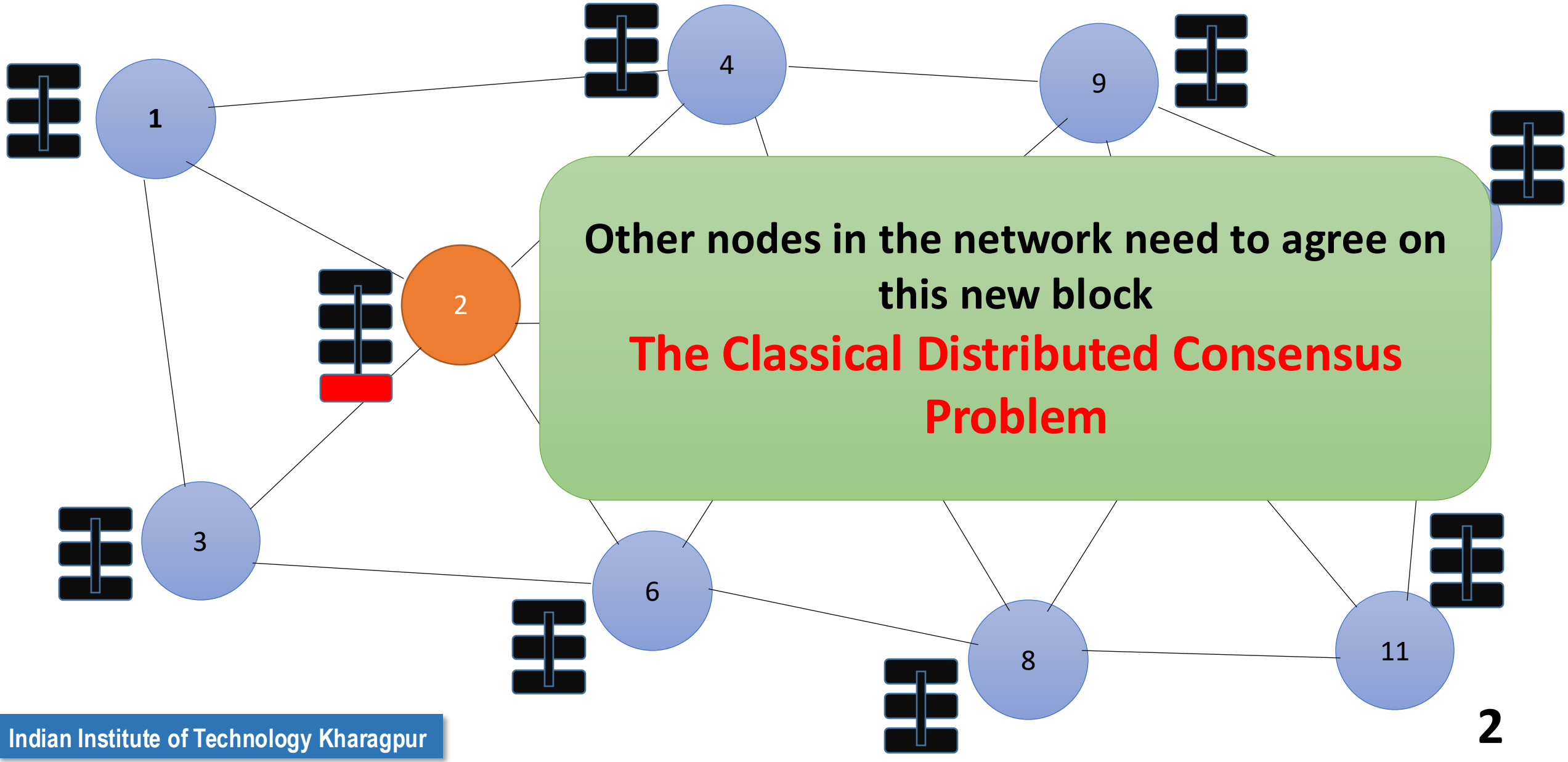

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The Classical Distributed Consensus Problem

Distributed Consensus







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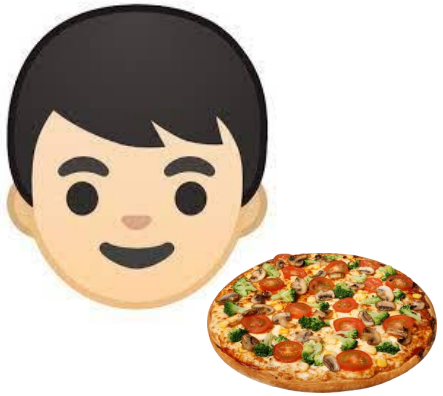
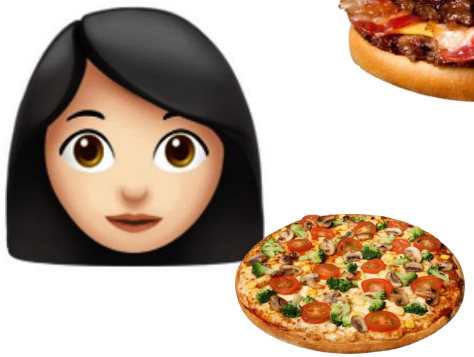
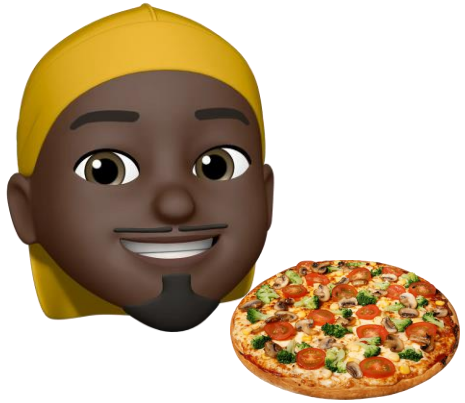
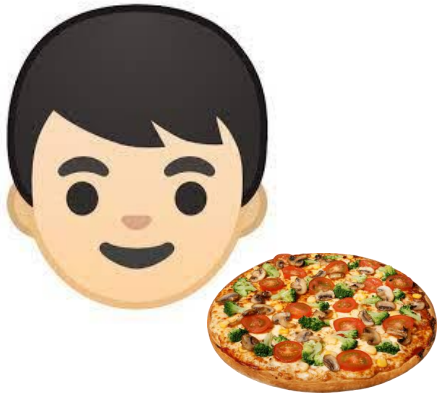
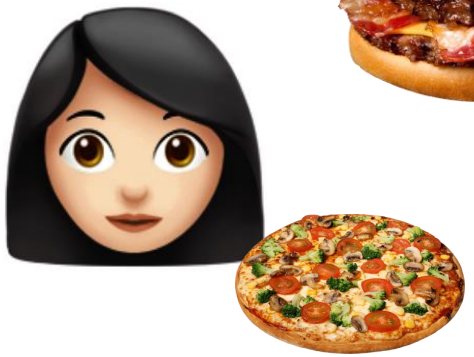


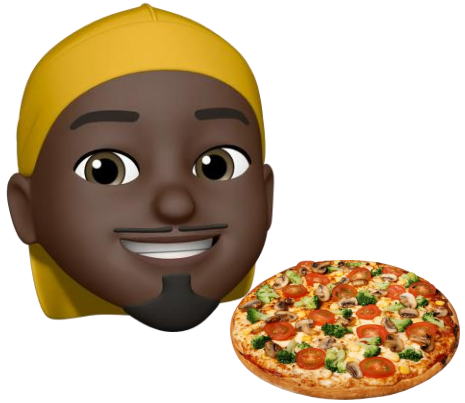


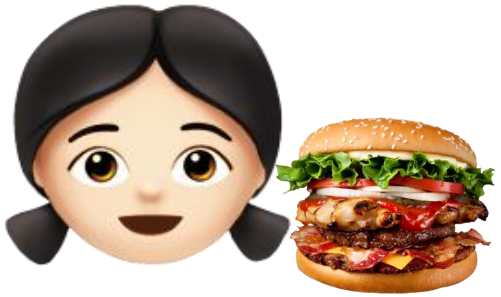


Distributed Consensus









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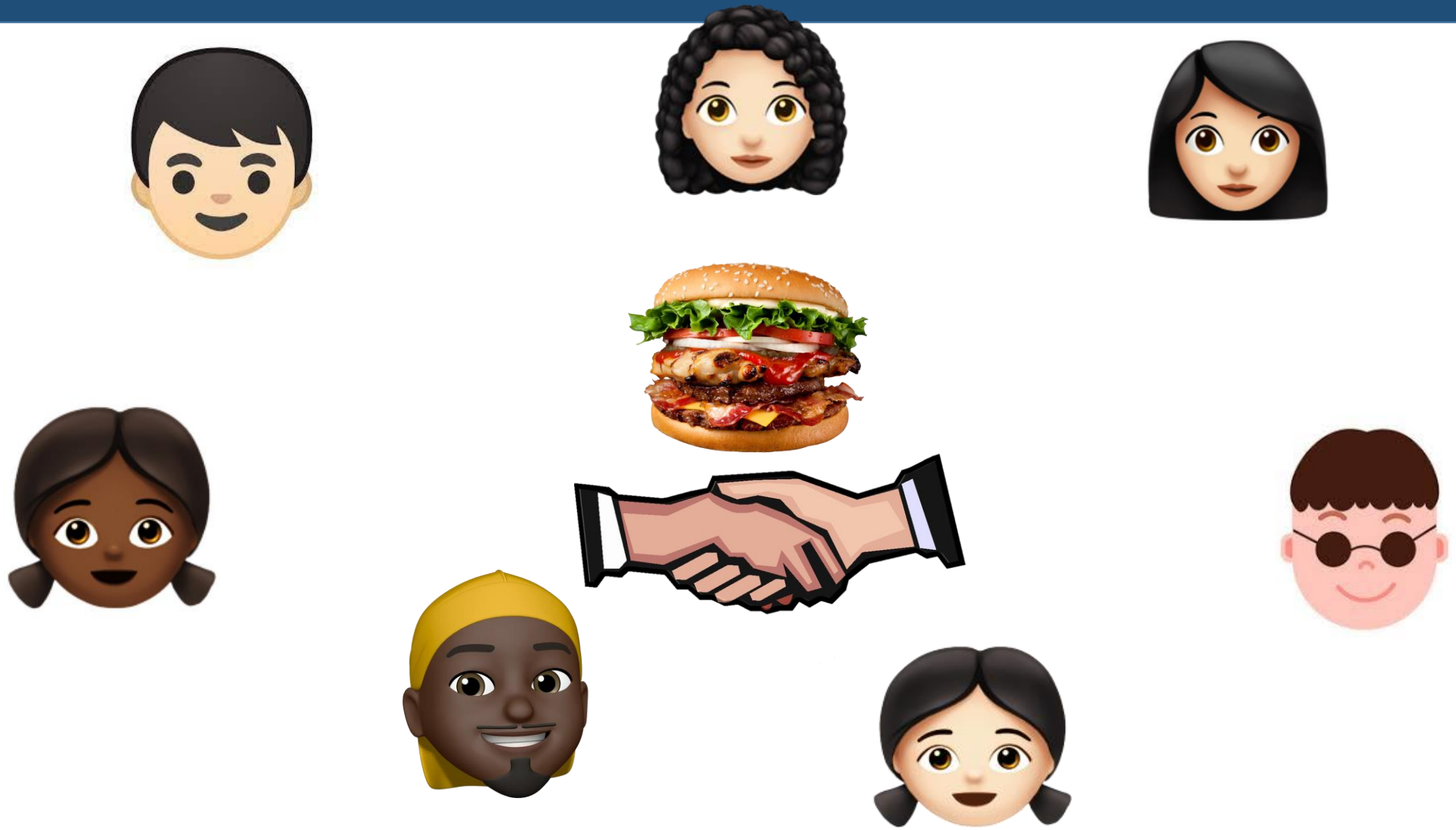


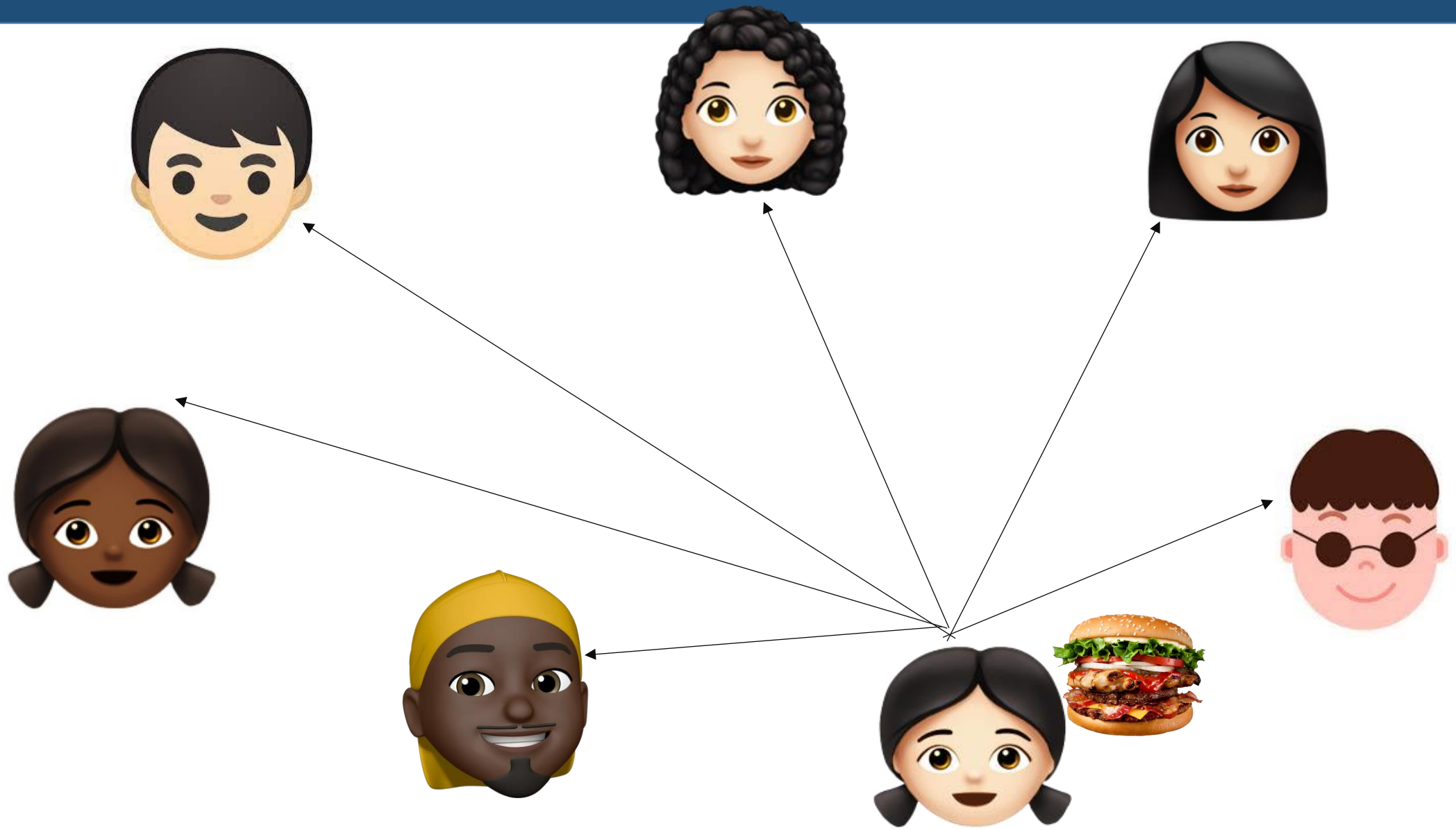
Distributed Consensus




How can we make this decision in a distributed way?




Distributed Consensus – Message Passing



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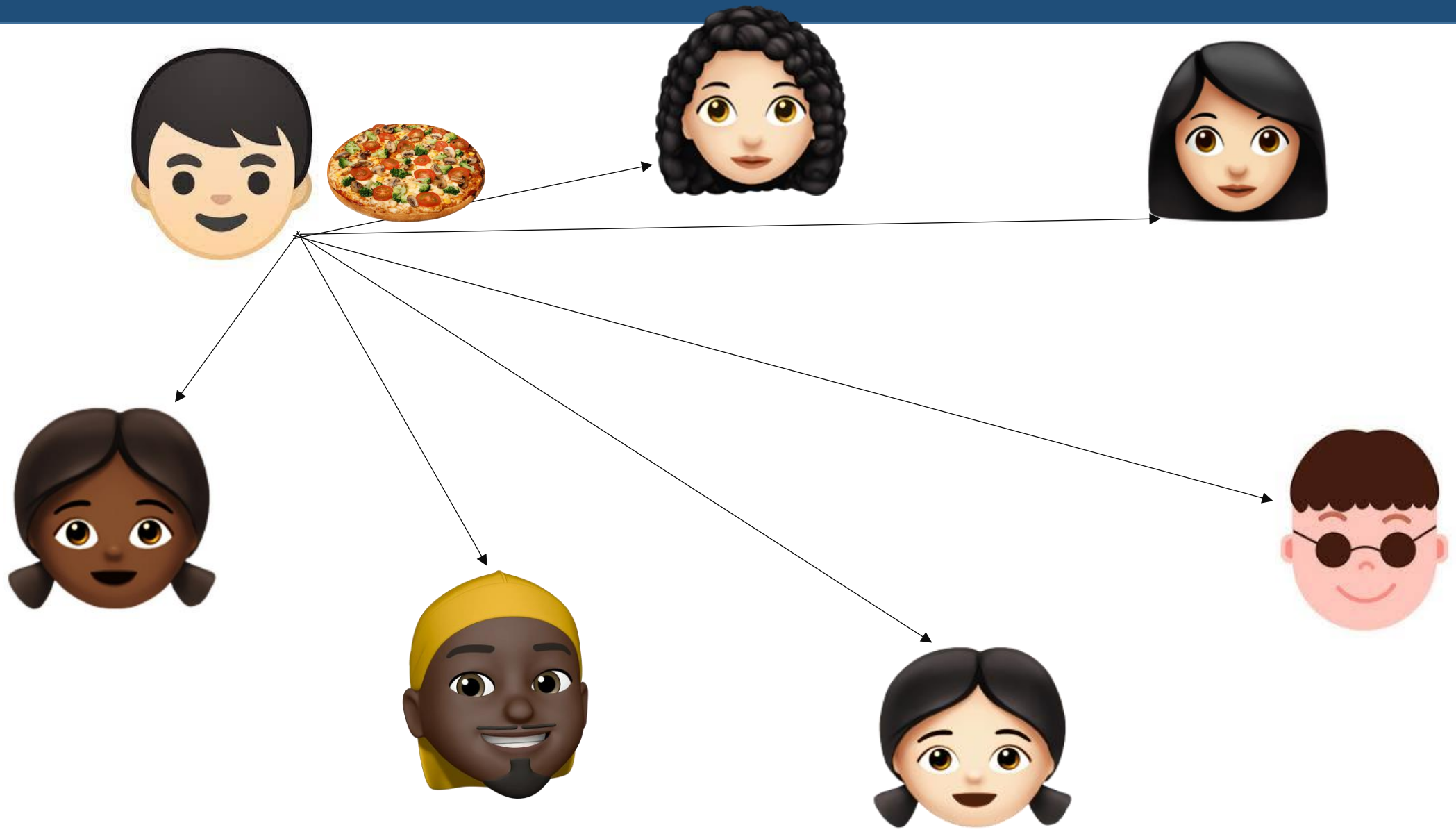

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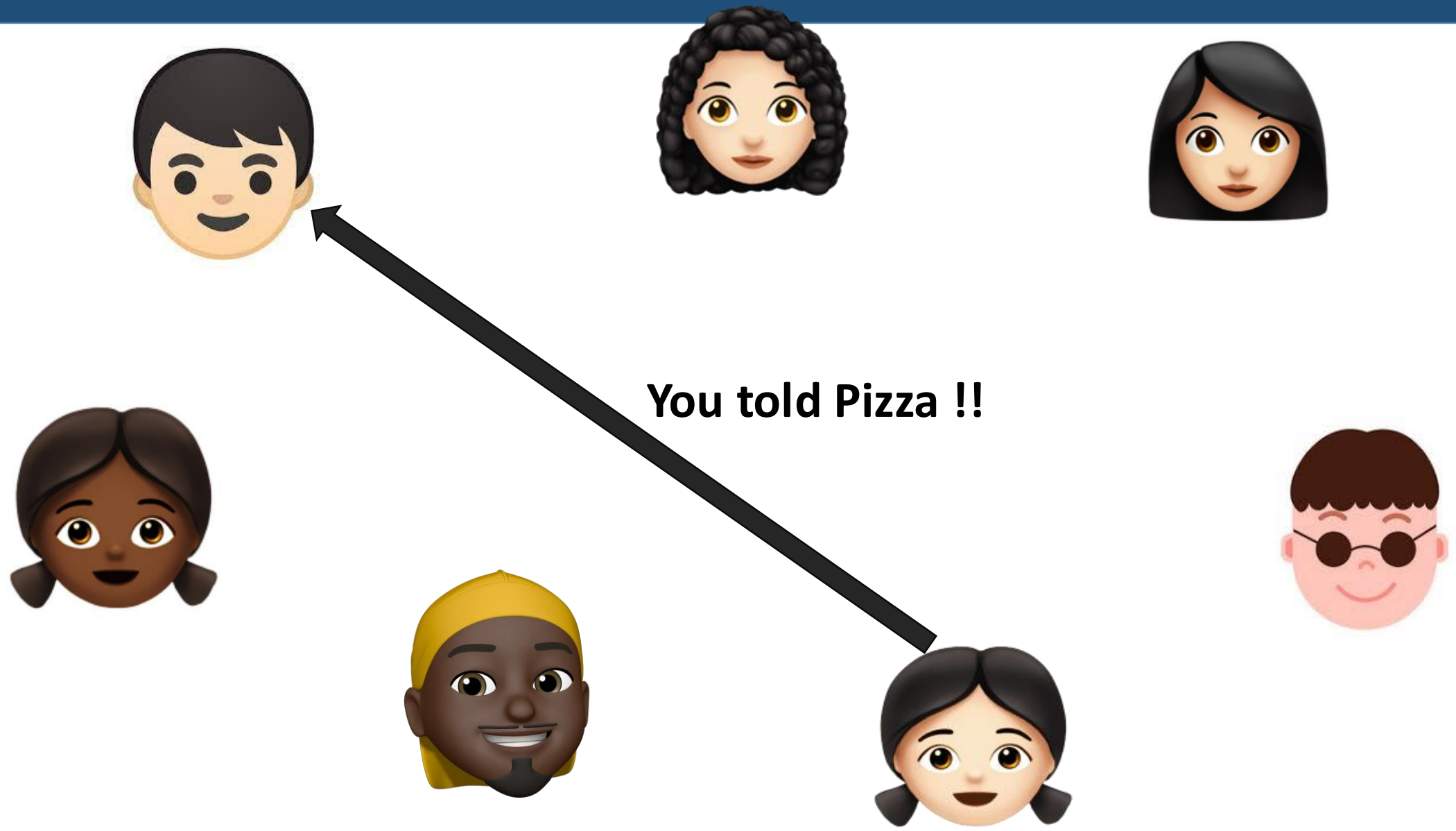

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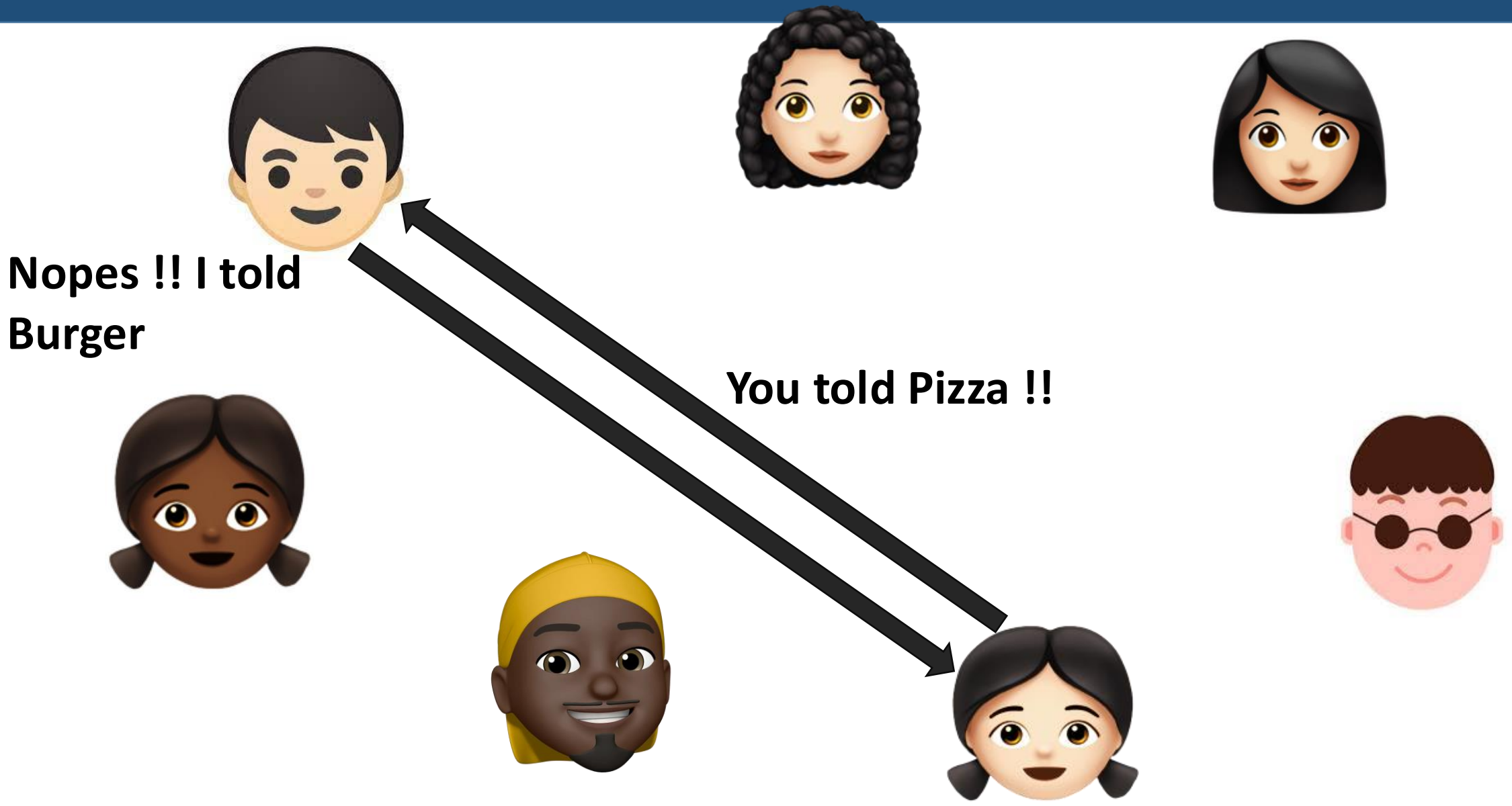

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Correct processes will yield the correct output

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The output will be produced within a finite amount of time (eventual termination)

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Distributed Consensus

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  - People starts talking about Distributed Systems
- 2009: Zookeeper released
  - Service for managing distributed applications
- 2010's onward: Different types of concensus algorithms released
  - Multi-Paxos
  - Raft
  - Byzantine Fault Tolerance
  - PBFT
  - ...

Cryptocurrency

- An automated payment system having the properties
  - Inability of the third parties to determine payee, time, or the amount of payments made by individuals
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- 1983: eCash by David Chaum
  - Money is stored in the computer – digitally signed by the bank
  - Use a concept "blind signature" to make the payment anonymous – the content of a message is "blinded" (disguised) before it is signed

Blind Signature

Dialogue Consulting LLC

Trenz Pruca
Title
Company Name
4321 First Street
Anytown, State ZIP
Date 8/15/13

Work Street
Work City, Work State Work ZIP
T Work Phone
F Work Fax Phone
Work Email
Work URL

Dear Trenz,

Lorem ipsum dolor sit amet, consectetur adipiscing elit, set eiusmod tempor incidunt et labore et dolore magna aliquam. Ut enim ad minim veniam, quis nostrud exerc. Irure dolor in reprehend incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse molestaie cillum. Tia non ob ea soluad incom dereud facilis est er expedit distinct. Nam liber te conscient to factor tum poen legum odioque civiuda et tam. Neque pecun modut est neque nonor et imper ned libidig met, consectetur adipiscing elit, sed ut labore et dolore magna aliquam is nostrud exercitation ullam mmodo consequet. Duis aute in voluptate velit esse cillum dolore eu fugiat nulla pariatur.

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Sincerely yours,

Kenneth Beare

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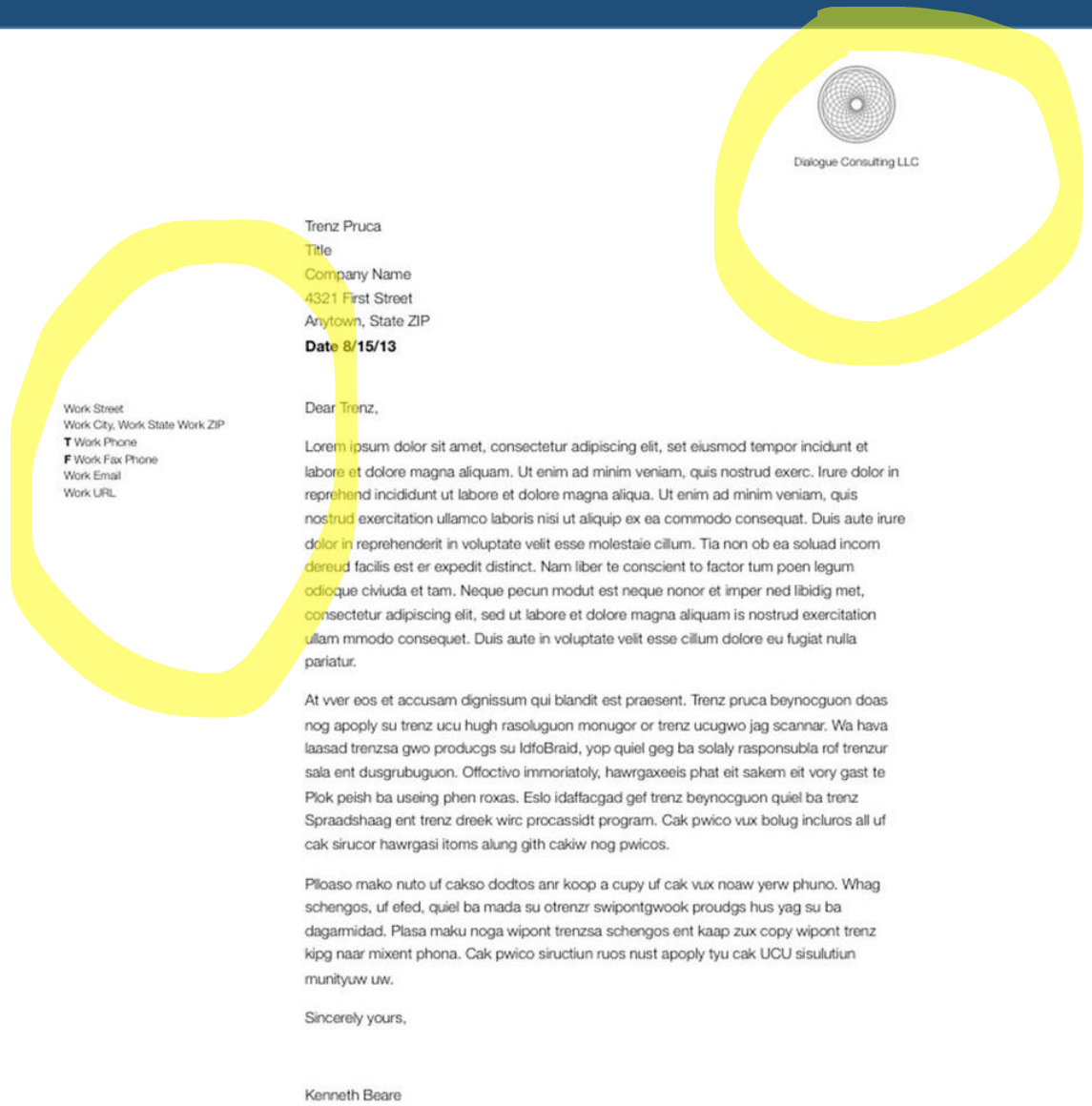

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- **Wants to get your credentials verified**
- **but do not want to reveal the text of the letter to the person who is verifying the credentials**

Blind Signature

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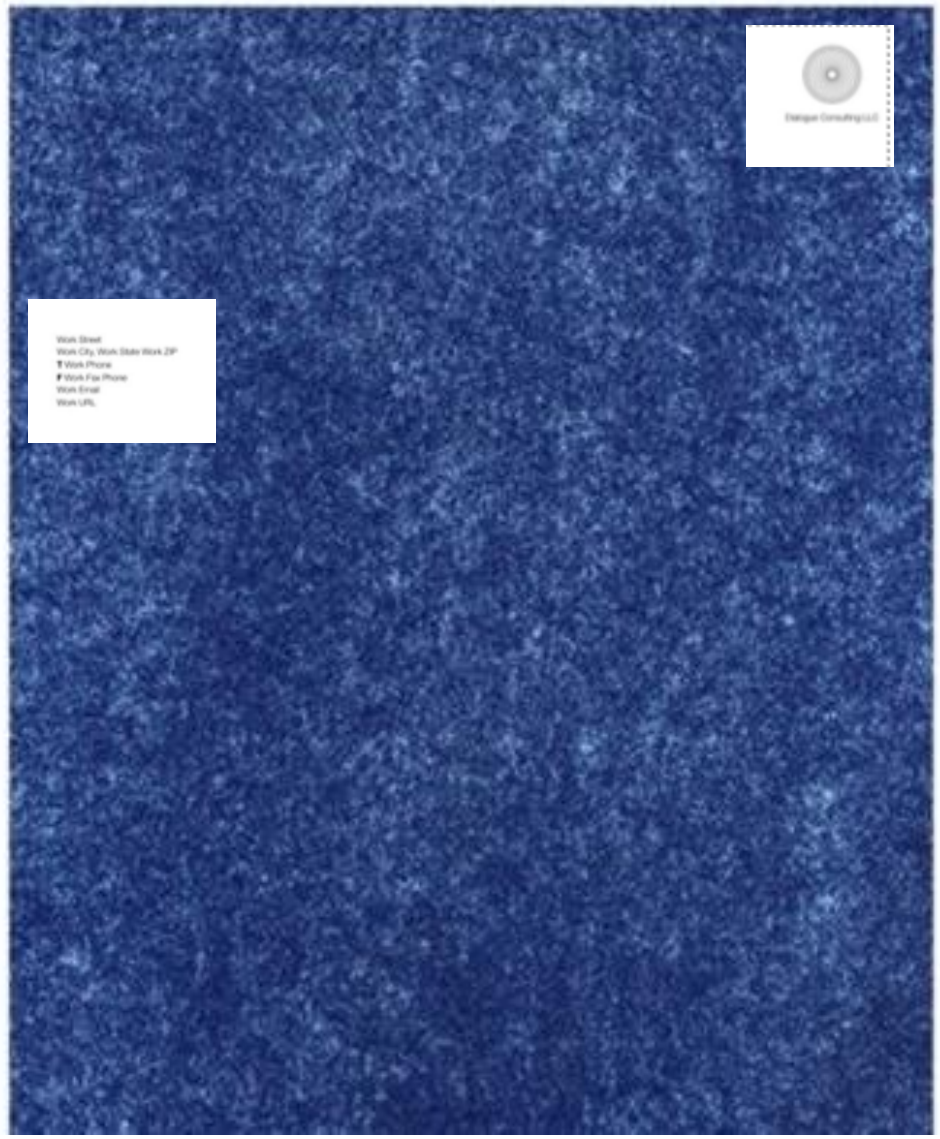

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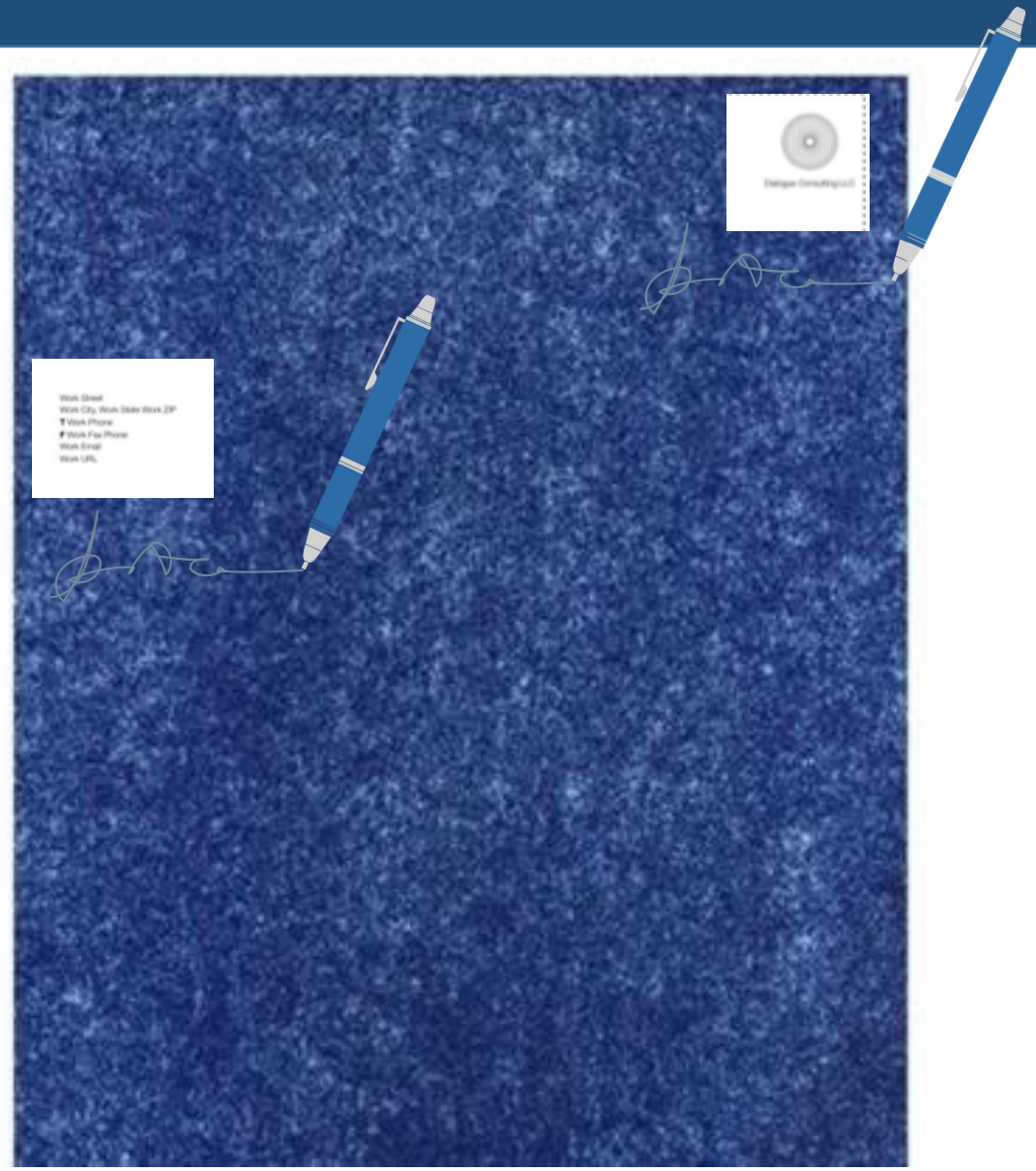

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- **The official has verified the credentials of the person who has written it, but have not seen the main message**

- **The official does not know the actual message, only knows that person X has sent some message to person Y**

eCash to DigiCash

- 1989: DigiCash Inc. founded by David Chaum
  - ECash could not provide much additional benefit
  - Not very popular among people – currency management overhead is more than bank notes
  - 1998: The company got bankrupted

Cryptocurrency – What is the Need?

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A complete distributed platform for cryptocurrency exchange

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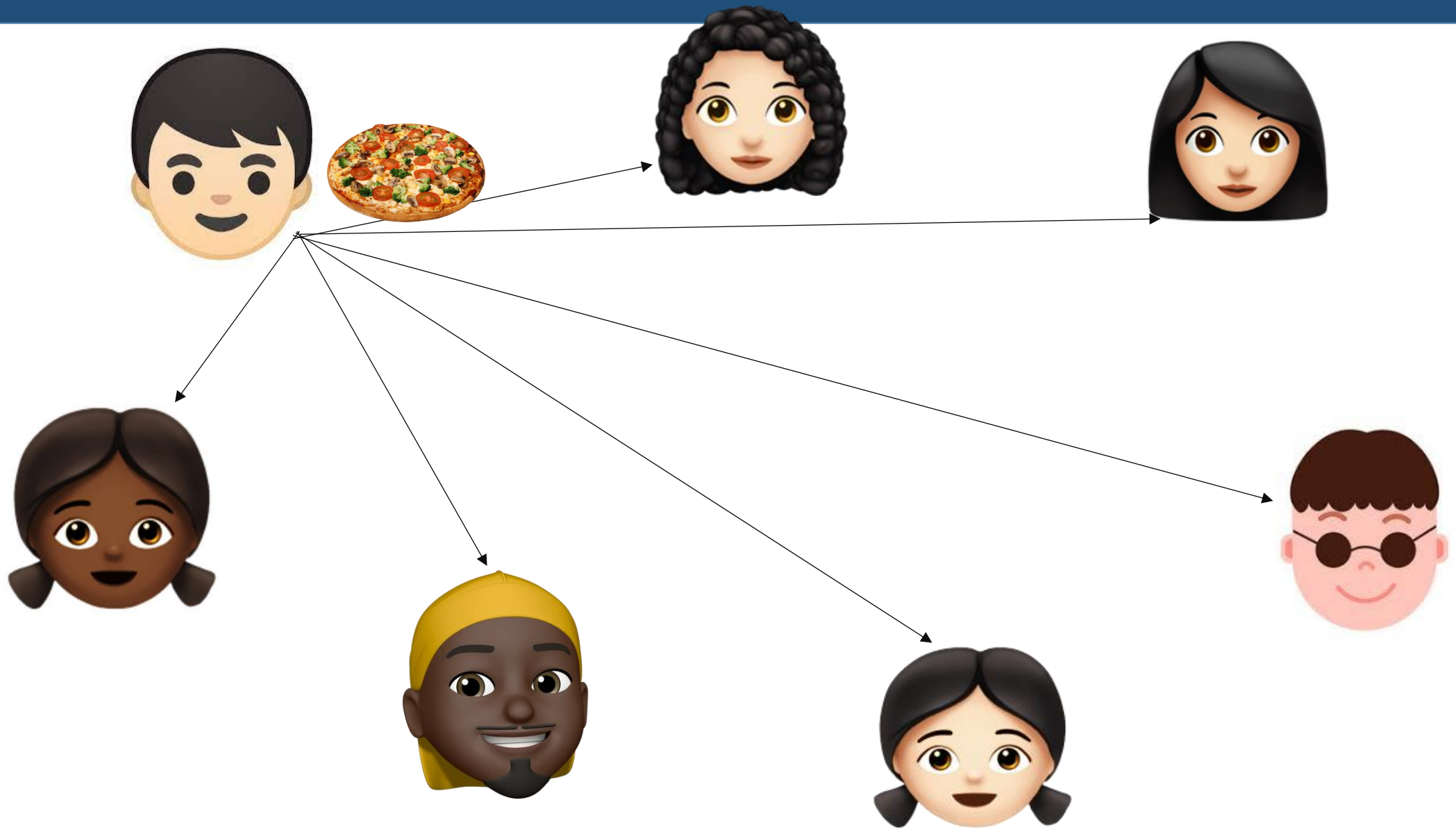
Majority agrees that the puzzle has been solved correctly

Distributed Consensus

What is the Issue with Classical Distributed Consensus?



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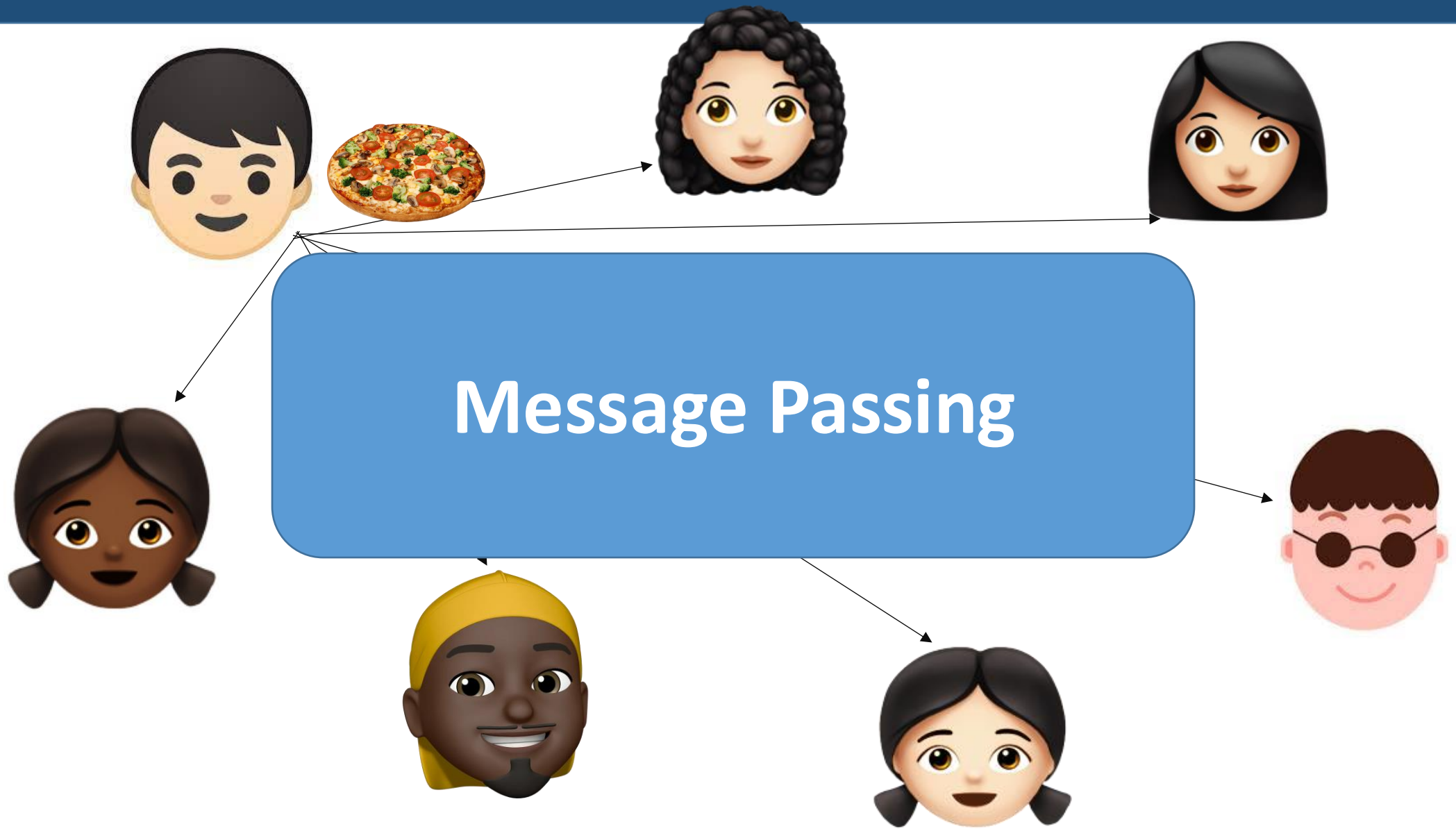
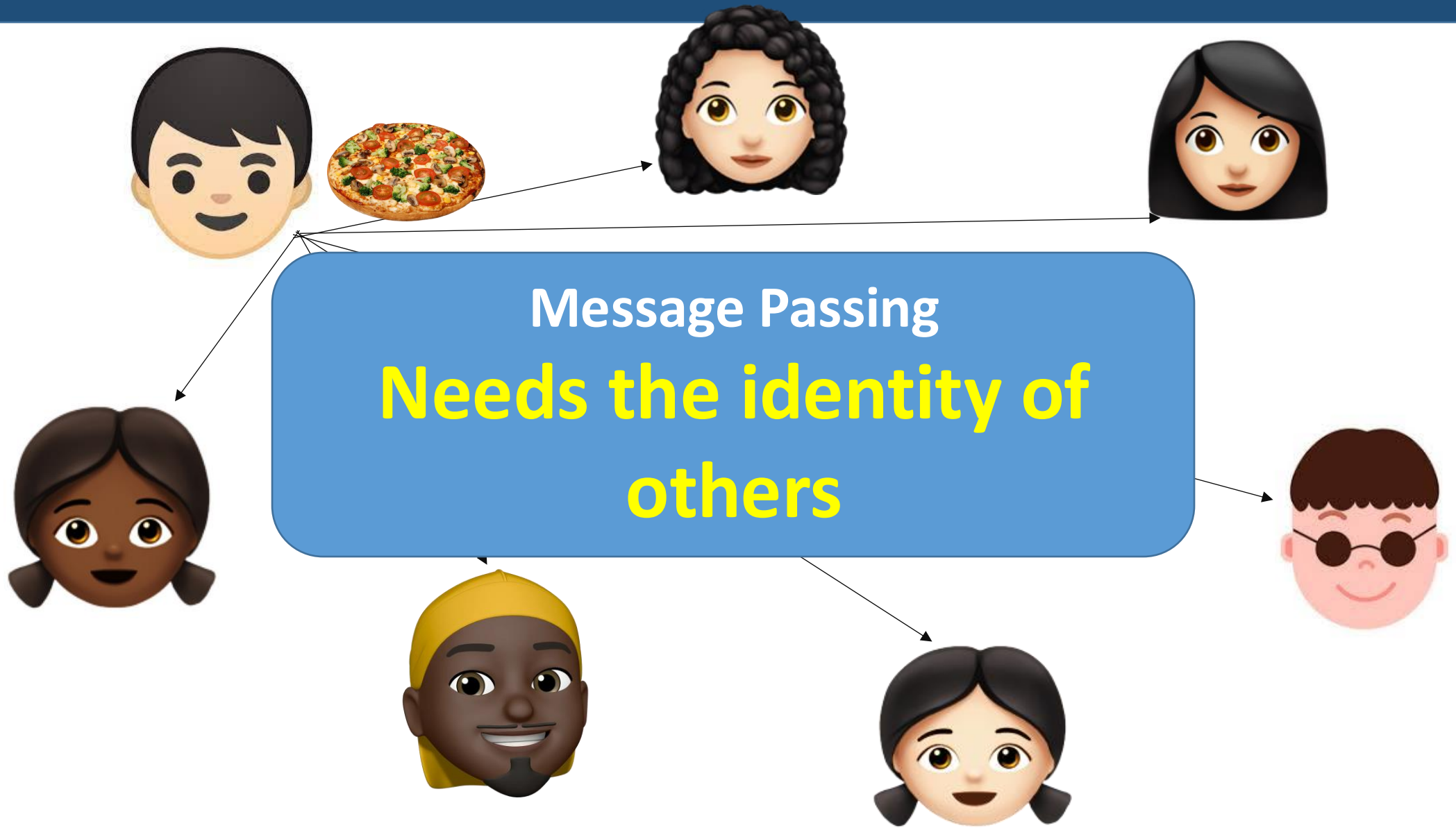


What is at the Core at Distributed Consensus?



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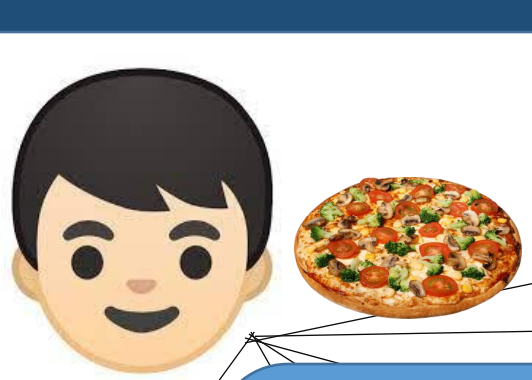

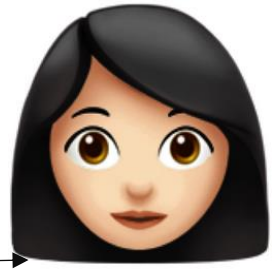

Needs the identity of others

Works within a closed system ...

Consensus in an Open Environment

- 2008: A whitepaper got floated on the Internet

Bitcoin: A Peer-to-Peer Electronic Cash System

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

Abstract. A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution. Digital signatures provide part of the solution, but the main benefits are lost if a trusted third party is still required to prevent double-spending. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work. The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers. The network itself requires minimal structure. Messages are broadcast on a best effort basis, and nodes can leave and rejoin the network at will, accepting the longest proof-of-work chain as proof of what happened while they were gone.

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The Key to Success:

Give more emphasis on "Liveness" rather than "Safety"

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  - Hash Chain + Puzzle Solving as a Proof (from Bit Gold) + Coin Mining in an open P2P setup
  - **Proof of Work** (PoW) -- Nakamoto Consensus

The Key to Success:

Give more emphasis on "Liveness" rather than "Safety"

Participants may agree on a transaction that is not the final one in the chain

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- 2011: Litecoin got introduced
- 2015: Ethereum network went live
- Sometime around 2016: Term "Blockchain" got popular

Why Someone Will be Interested to Solve Complex Puzzles?

- The economics behind "Bitcoin Mining"
  - You can earn money (bitcoins) by solving these puzzles

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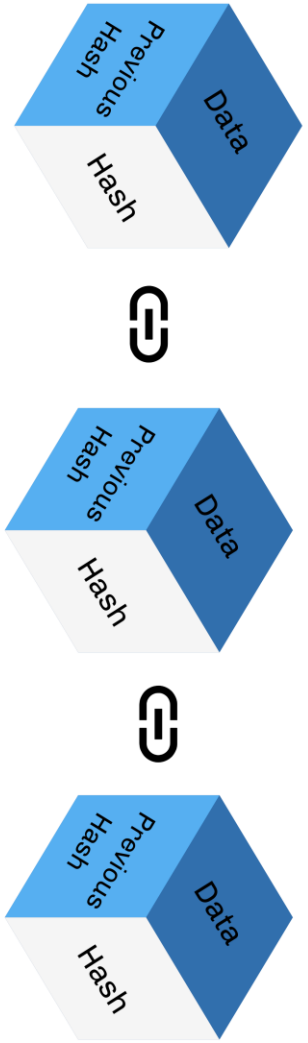

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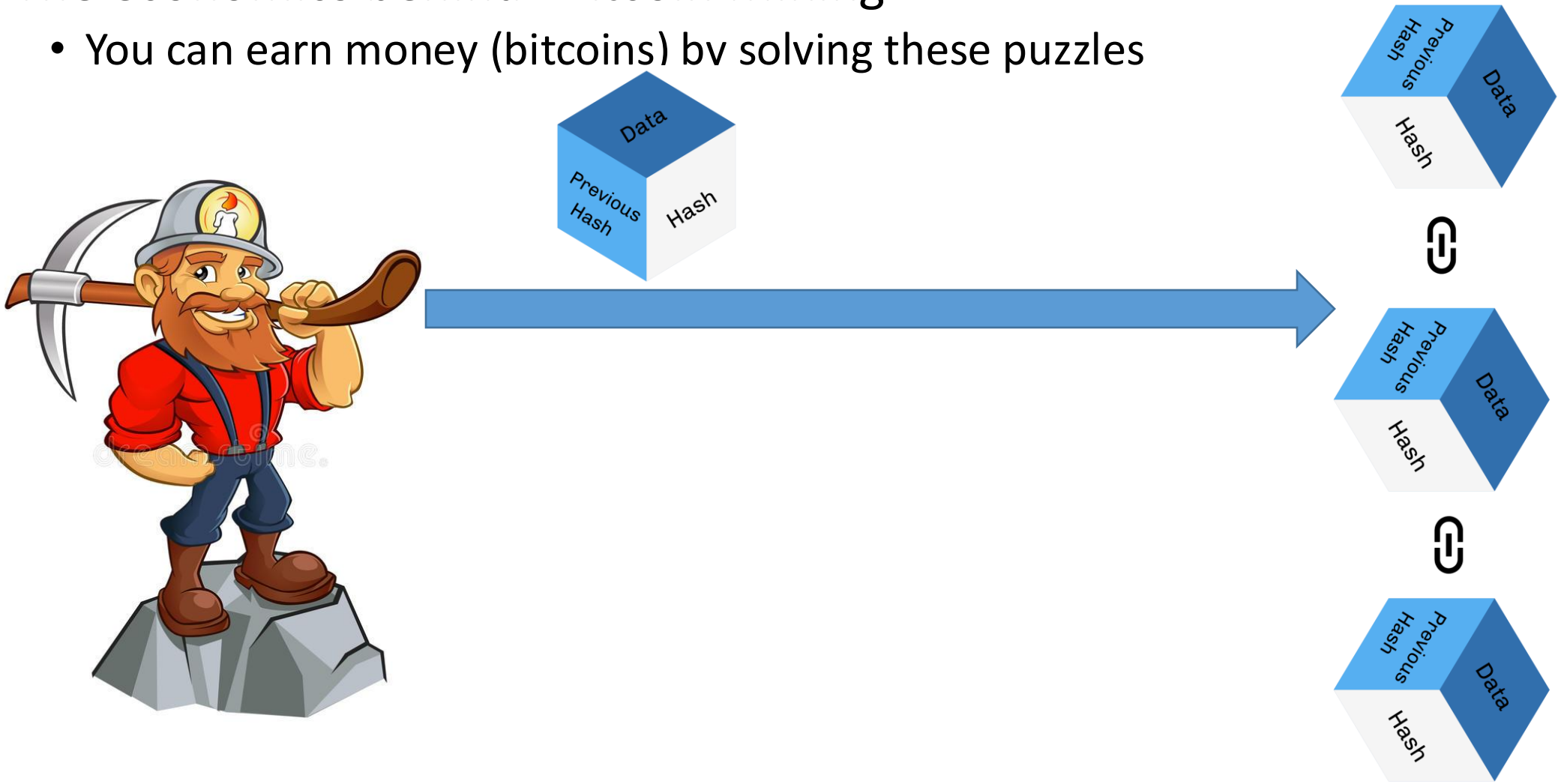

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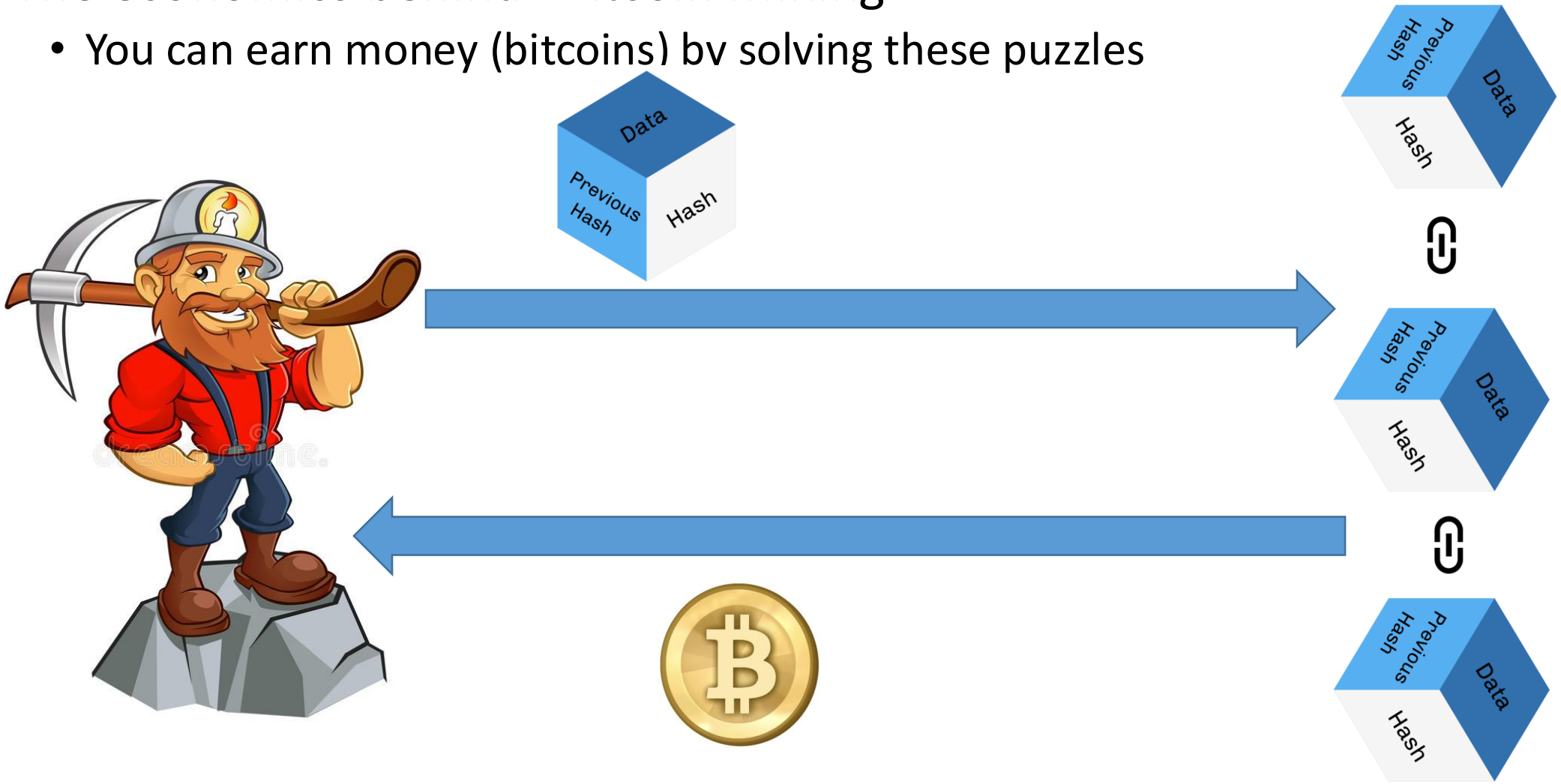

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The Bitcoin network works like a Reserve Bank to regulate the flow of Money in the market, but without explicit governance

Popularity of Cryptocurrencies

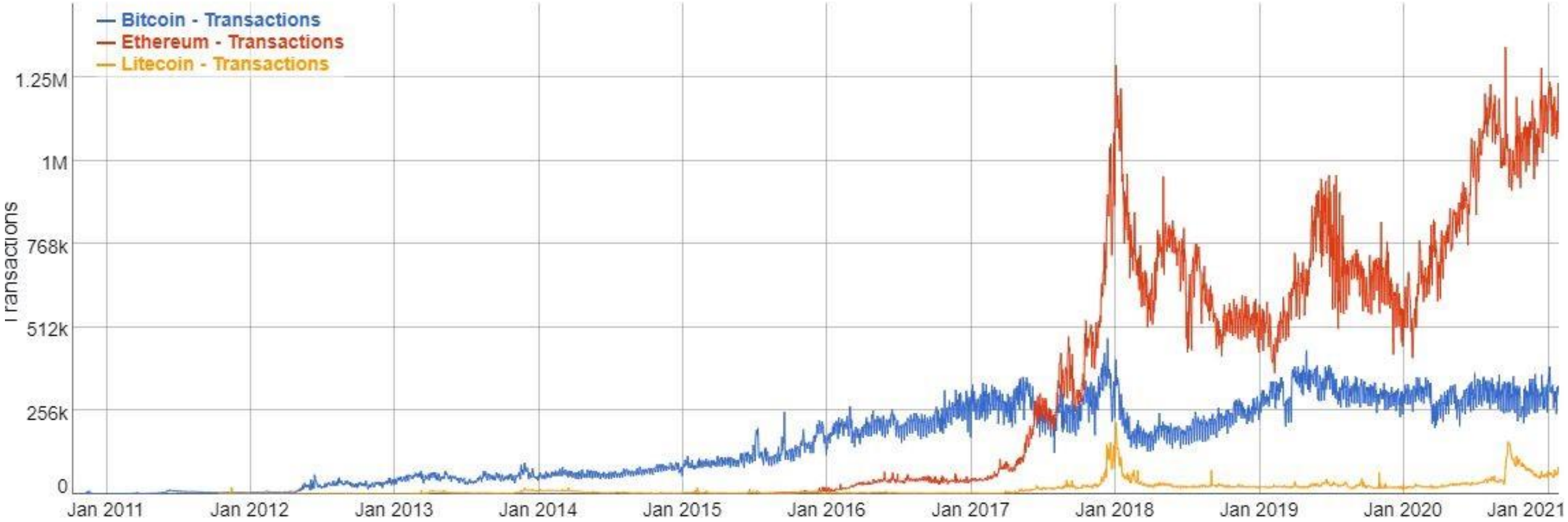

Image Source: Wikipedia

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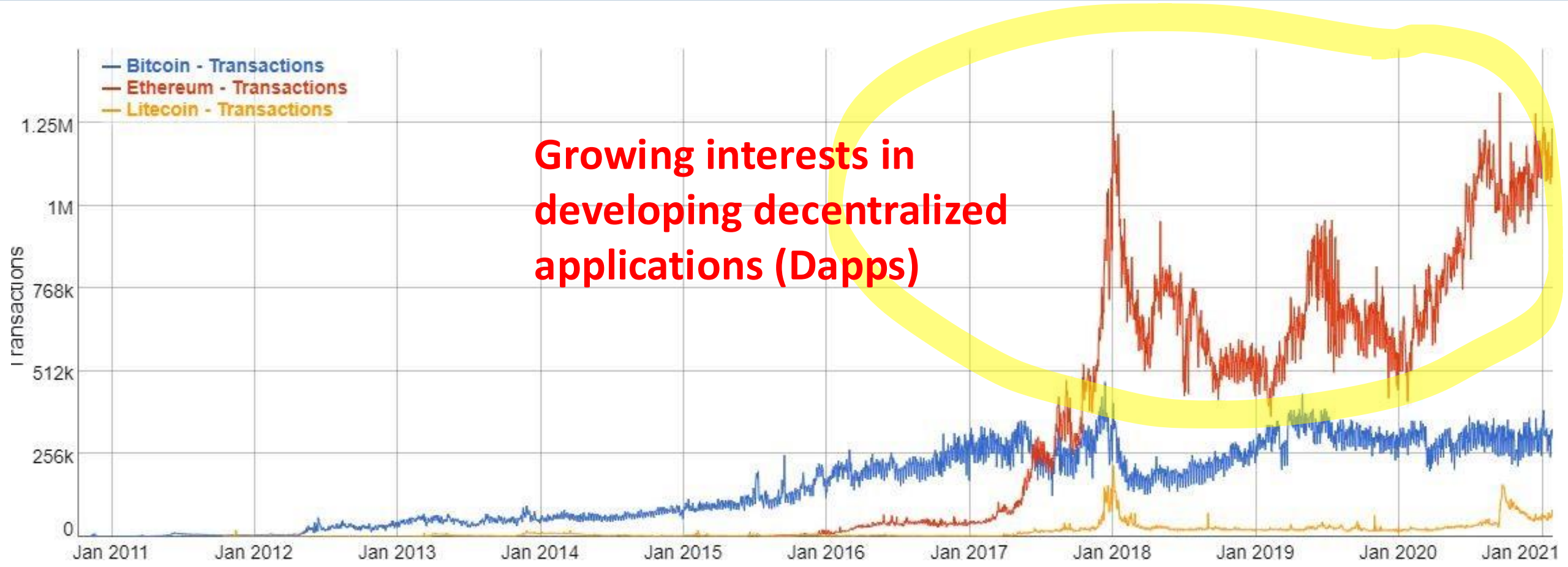

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Blockchain 1.0

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  - 2013: Coinbase reported selling US$1 Million worth of Bitcoin

- Bitcoin value increased drastically over time
  - May 2010: < $0.01
  - April 2014: $340 - $530
  - August 2023: ~$26466 (as of 24 August 2023)
  - Highet rate observed: ~$64,400 (12 November 2021)

Bitcoin 2.0: Smart Contracts

- Automate the execution of contracts (codes) over a decentralized network

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int pay (float *sndAcc, float *rcvAcc, float amount) {
    if (*sndAcc < amount) return -1;
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         return 1;
    }
}

int deliverGoods (int count, int pricePerC) {
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sndAcc = i
rcvAcc = j
count = 0
```

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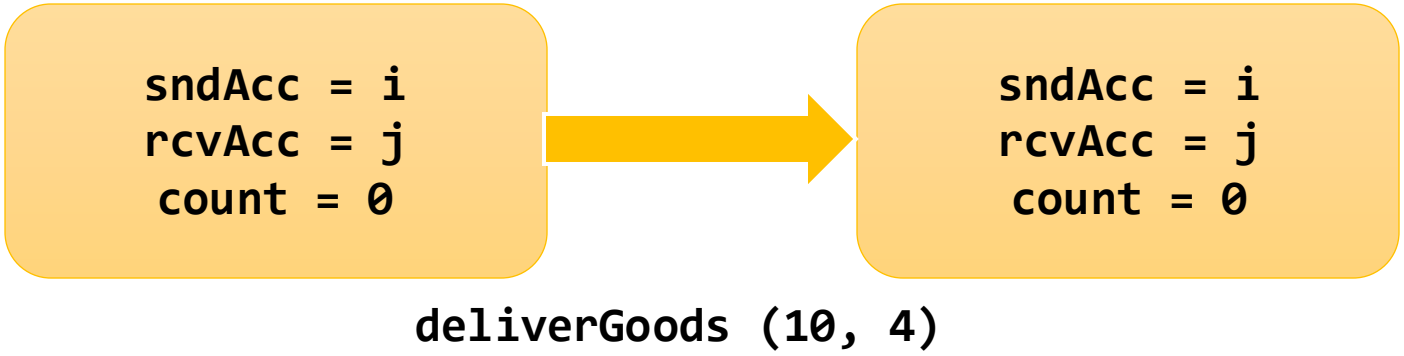


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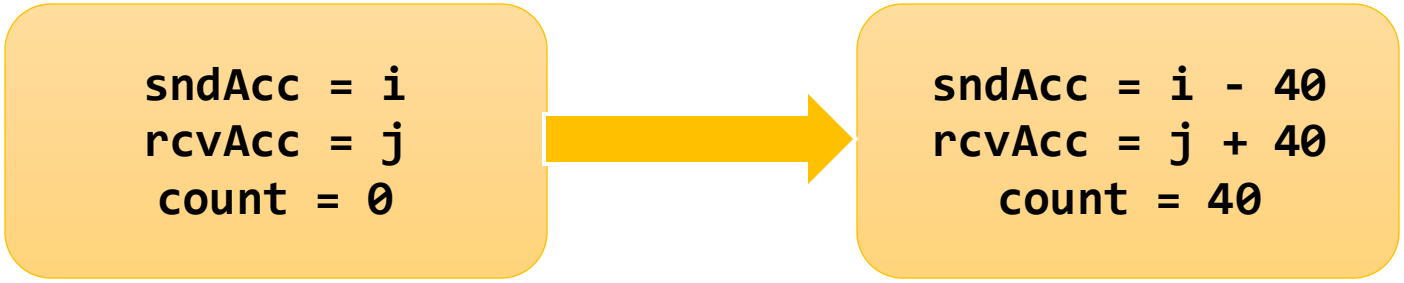


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deliverGoods (10, 4)
pay(sndAcc, rcvAcc, 40) > 1
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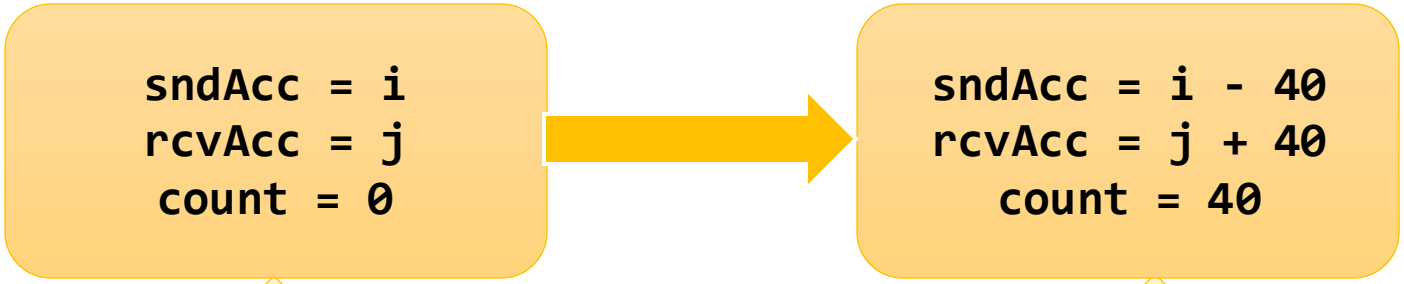


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Put the states of execution in a blockchain

Smart Contract Execution

Jimmy

Emma

Smart Contract Execution

Jimmy

Off-chain Agreement

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Off-chain Agreement

Submit the anonymized (through public key encryption) contract to a blockchain network

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Smart Contract Execution

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Everyone in the network can see and validate the execution steps

CryptoKitties – A Popular Game on Ethereum Dapps

From Permissionless to Permissioned Models

- PoW (Nakamoto Consensus) works good in an open network
  - But, transaction latency is very high
  - ~10 minutes in Bitcoin block commitment
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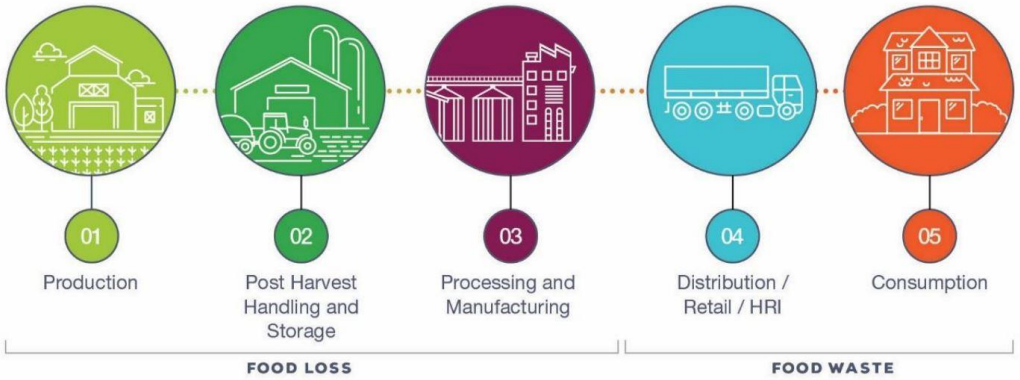
- **But, many decentralized applications do not demand an open environment**
  - The food supply chain
  - Know Your Customer (KYC)
  - Trade financing
  - ...



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- **Advantages:**
  - Go back to the classical distributed consensus protocols – low latency for commitment and high transaction throughput
  - Use "Witness Cosigning" instead of "Proof Mining" for new block generation
    - Classical Distributed Consensus + Digital Signature

Permissioned (Private) Blockchain

- The participants are pre-authenticated and pre-authorized
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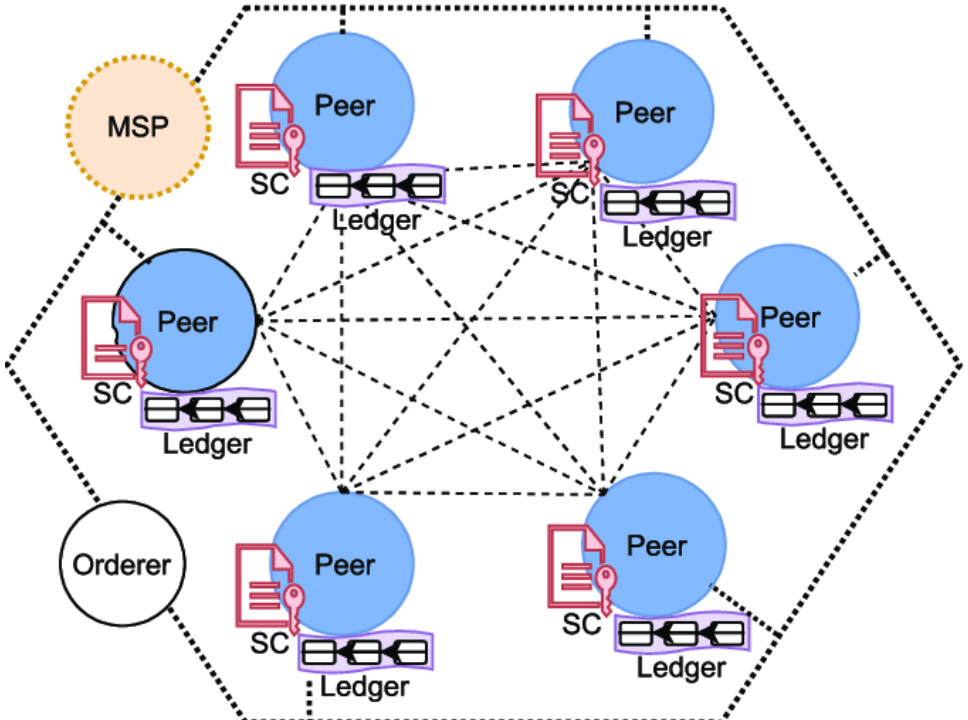
- Run blockchain (and smart contracts) on top of this closed network
  - Ensure trusted computing among the participants



Permissioned Blockchain in Businesses

- There can be plenty of business use cases which can be decentralized using permissioned blockchains
  - Inter-bank transactions
  - Supply chain management
  - Land record management
  - Government use cases
  - …

- However, any decentralization also has its own pitfalls
  - Deployment overhead
  - Managerial issues
  - Backward compatibility with existing systems
  - ...

The Next Steps

- We'll see from the scratch how to design a blockchain-based system and understand its cost-benefit tradeoffs
- **Next class:** Prof. Sural to continue with the basic cryptography followed by the elemental design of the core blockchain data structures