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Emerging Networking Technologies

Prof. Ling Li | Dr. Nadith Pathirage | Lecture 11

Semester 1, 2021

Emerging Networking Technologies

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- Serverless Computing
- Edge Computing
- **Internet Of Things (IoT)**
- **Software Defined Networking**
- **Blockchain**
  - Bitcoin
  - Other application examples

Internet of Things (IoT)

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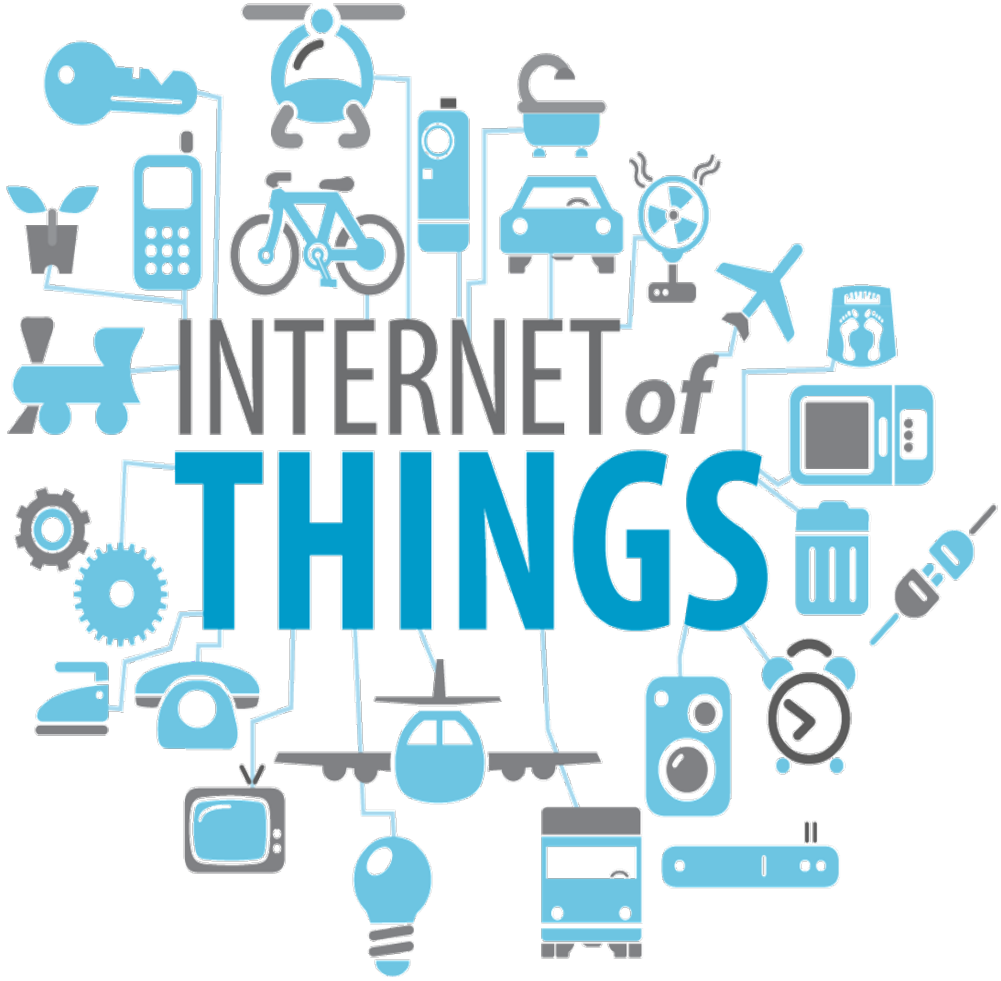
- The Internet of Things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.
- These devices range from ordinary household objects to sophisticated industrial tools.



Internet of what Things

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IoT Server

Internet

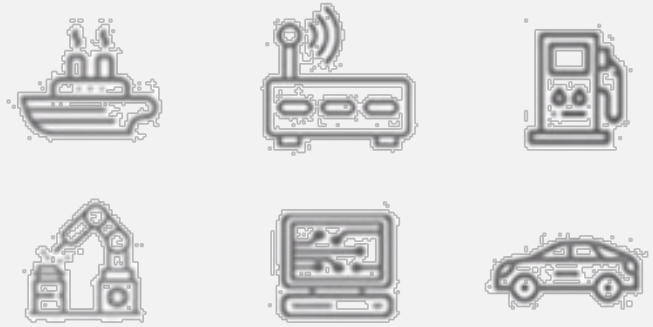
Gateway
Large/Complex Data Model

Radio Freq.

Wire

Big Things

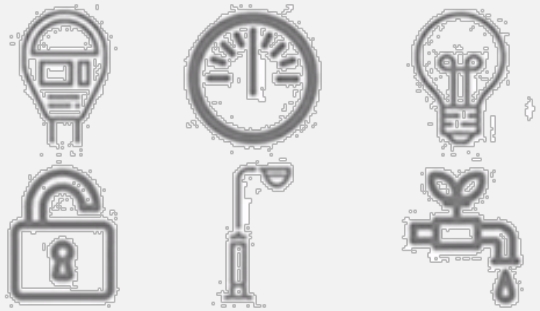
Large/Complex Data Model



- Big in complexity
- No problem with power
- Always connected
- Thousands of parameters to control

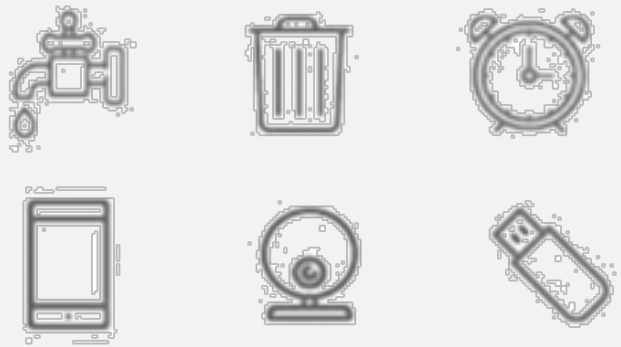
Non-IP Things

Simple Data Model
Constrained on BW/PWR/MEM
No internet connectivity



Small Things

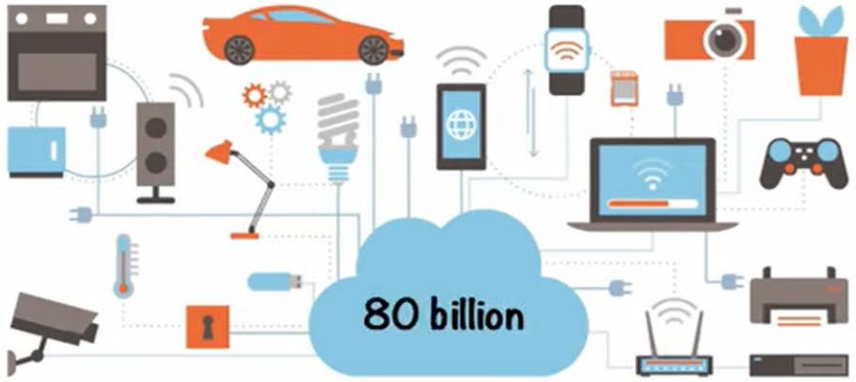
Simple Data Model
Constrained on BW/PWR/MEM

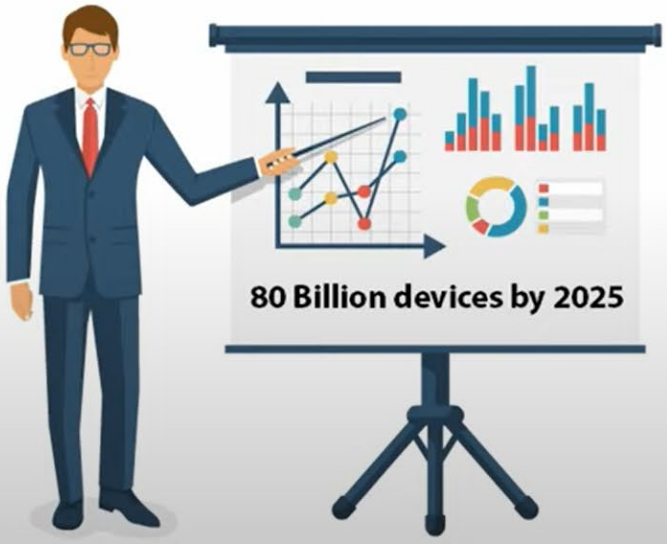


- Most connected with sim card
- Operate on battery
- Less parameters to control

In 2025:

20.4 billion by the end of 2020





Area	IoT Applications
Consumer Applications	Smart home technology, health and fitness apps, smart appliances, wearable tech
Medicine	Emergency alert systems, smart devices like hearing aids, smart bed management, remote health monitoring
Agriculture	Environmental sensors for farmland information
Manufacturing	Smart control of manufacturing systems, plant optimization
Energy	Remote control of heating systems, smart grid for balance energy usage
Infrastructure Management	Monitoring traffic, wind farms, railway track and bridges
Environmental protection	Checking pollution levels, soil health, and earthquake early-warning sensors

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Software Defined Networks

- Fundamentals
- SDN Model
  - SDN Controller
- Traditional Networks vs SDNs
- SDN Benefits

Software Defined Networks (SDN)

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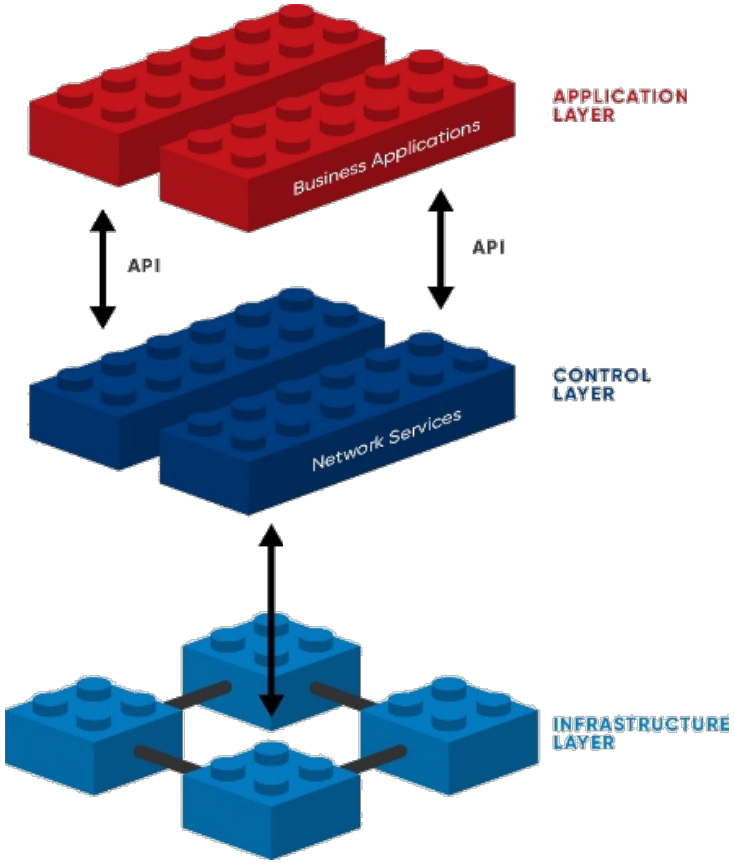
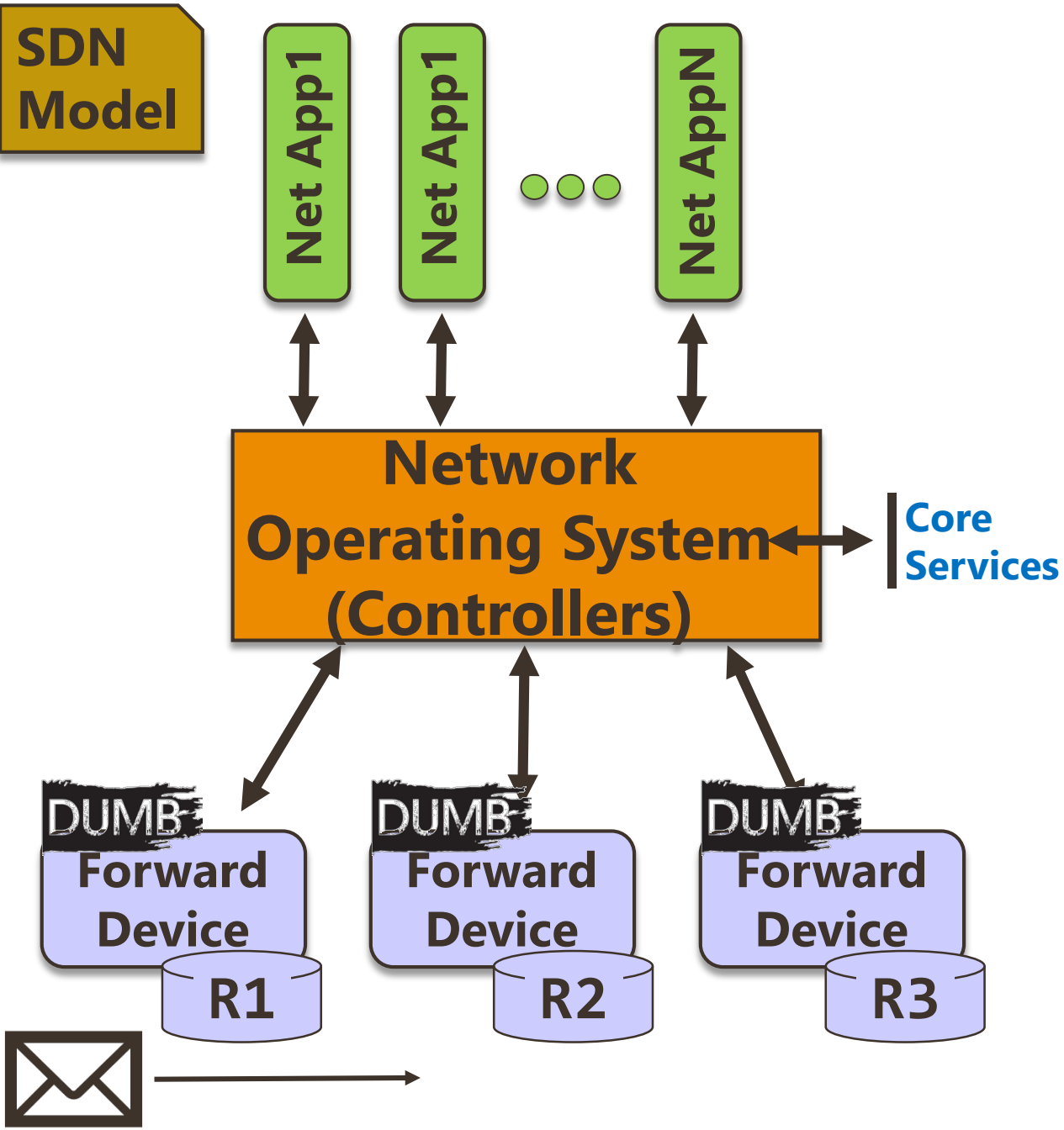
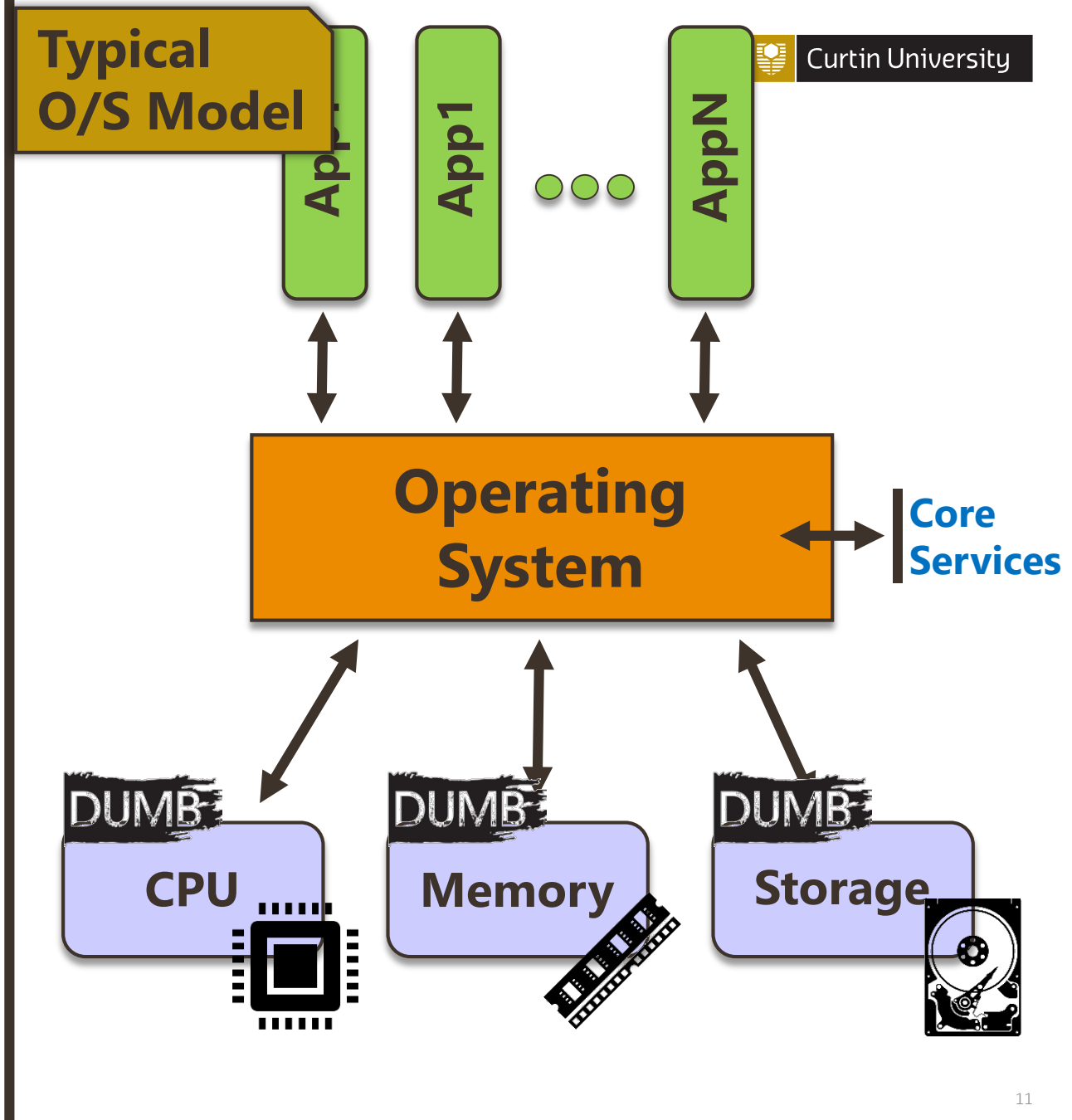
Goal: Network to be dynamic and programmabl

- Achieves agility, flexibility, and scalability that mobility, cloud, and IoT demand
- SDN attempts to centralize network intelligence in one network component by disassociating the forwarding process of network packets (data plane) from the routing process (control plane)
- Enabling the network control to become directly programmable and the underlying infrastructure to be abstracted from applications and network services




SDN Model
Net App1
Net App1
Net AppN
Network Operating System (Controllers)
Core Services
DUMB
Forward Device
R1
DUMB
Forward Device
R2
DUMB
Forward Device
R3


Typical O/S Model
App1
AppN
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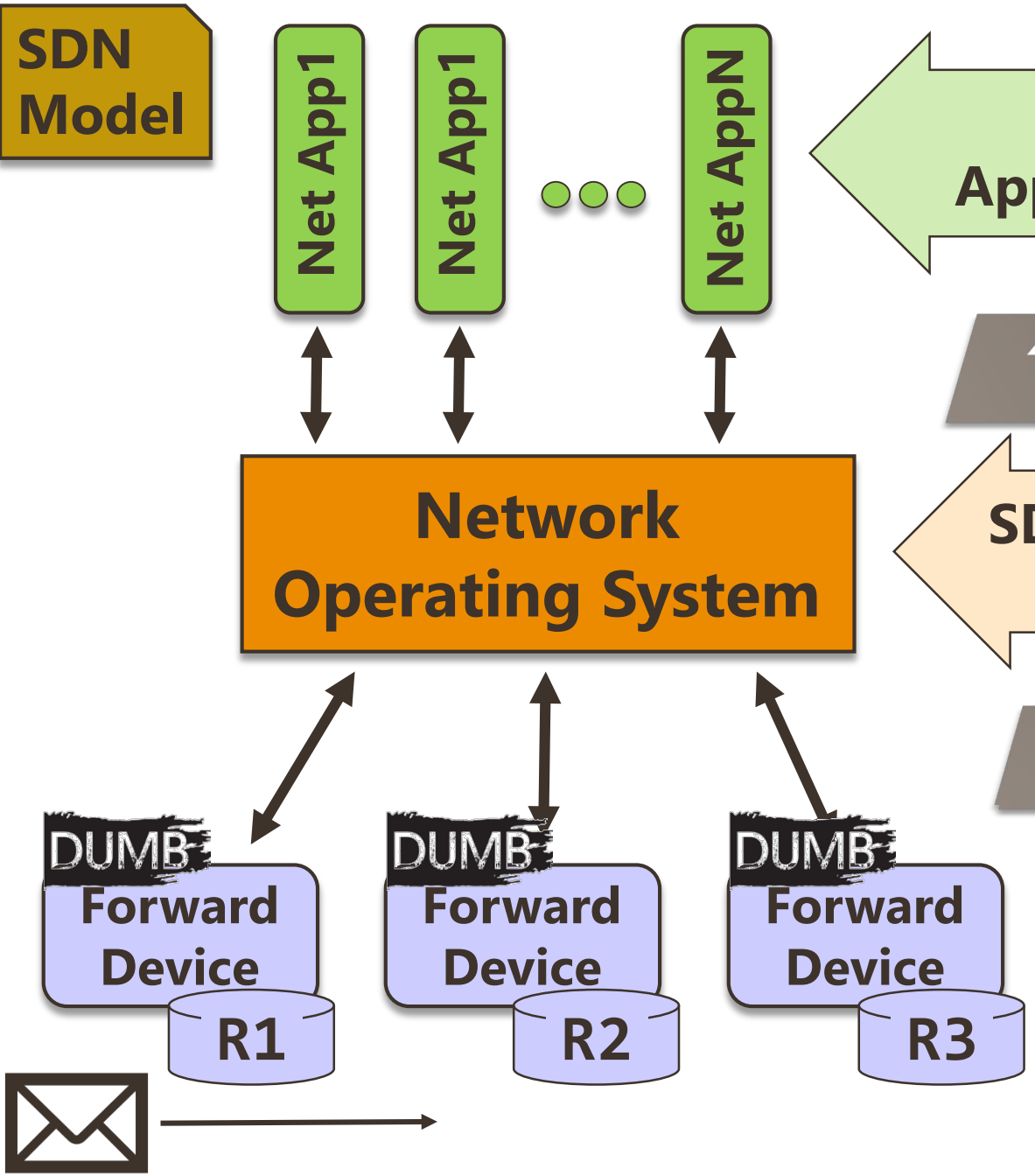
Operating System
Core Services
DUMB
CPU
DUMB
Memory
DUMB
Storage



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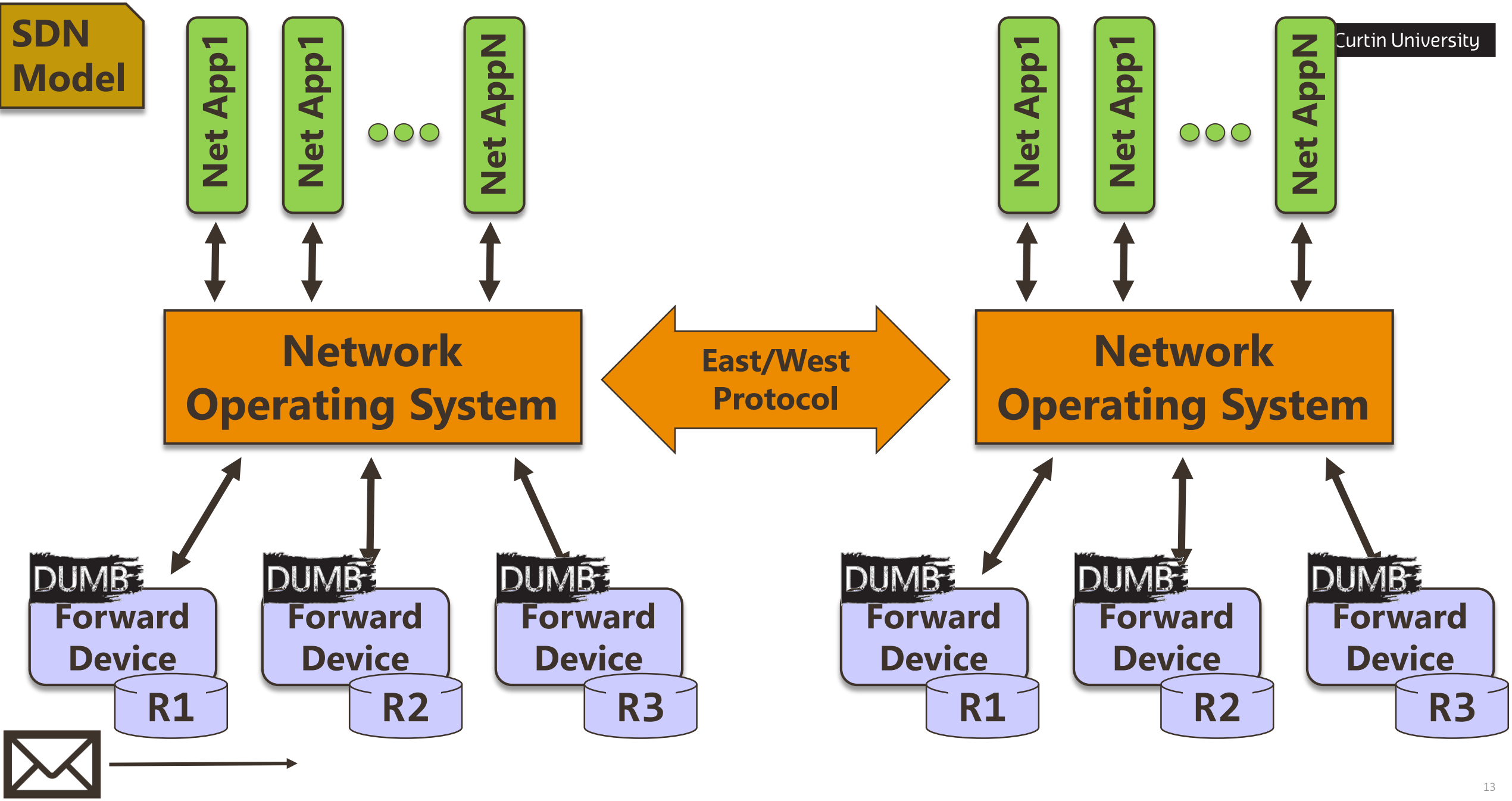
Network Applications
- Customized routing logic
- Portability across SDN controllers

Application Interfaces
- Java API
- Northbound (e.g. RESTful API)

SDN Controller/ Control Plane
- Topology Service
- Statistics Service
- Inventory Service
- Host Tracking

SouthBound Interface
- OpenFlow
- OVSDB
- NETCONF
- SNMP

Forwarding Devices/ Data Plane


SDN Model
Net App1
Net App1
Net AppN
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Net App1
Net App1
Net AppN
Network Operating System
East/West Protocol
Network Operating System
DUMB
Forward Device
R1
DUMB
Forward Device
R2
DUMB
Forward Device
R3
DUMB
Forward Device
R1
DUMB
Forward Device
R2
DUMB
Forward Device
R3

SDN Controller (a.k.a Network O/S)

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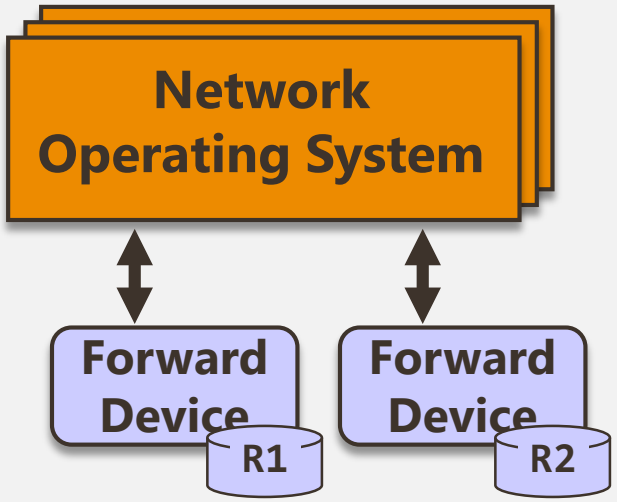
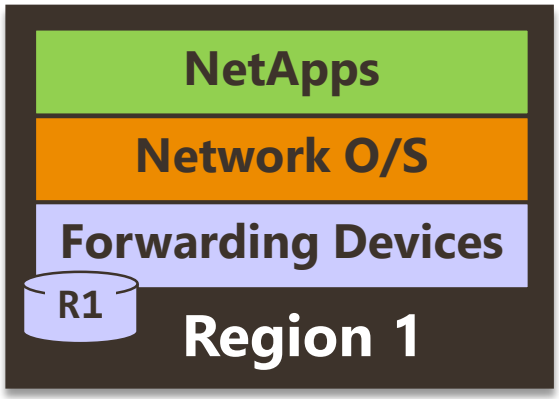
- Logically Centralized Network O/S has a global view of all forwarding devices below it.
- Provides a programming interface to the network applications

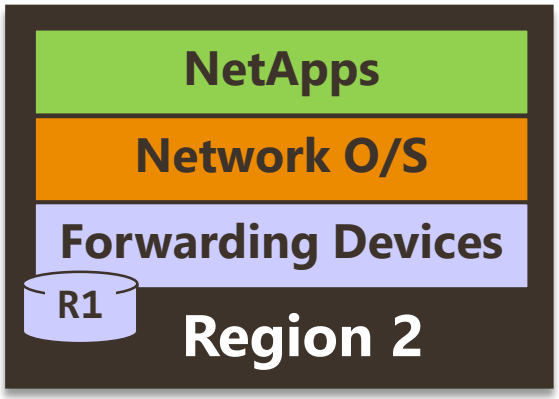
Network Operating System

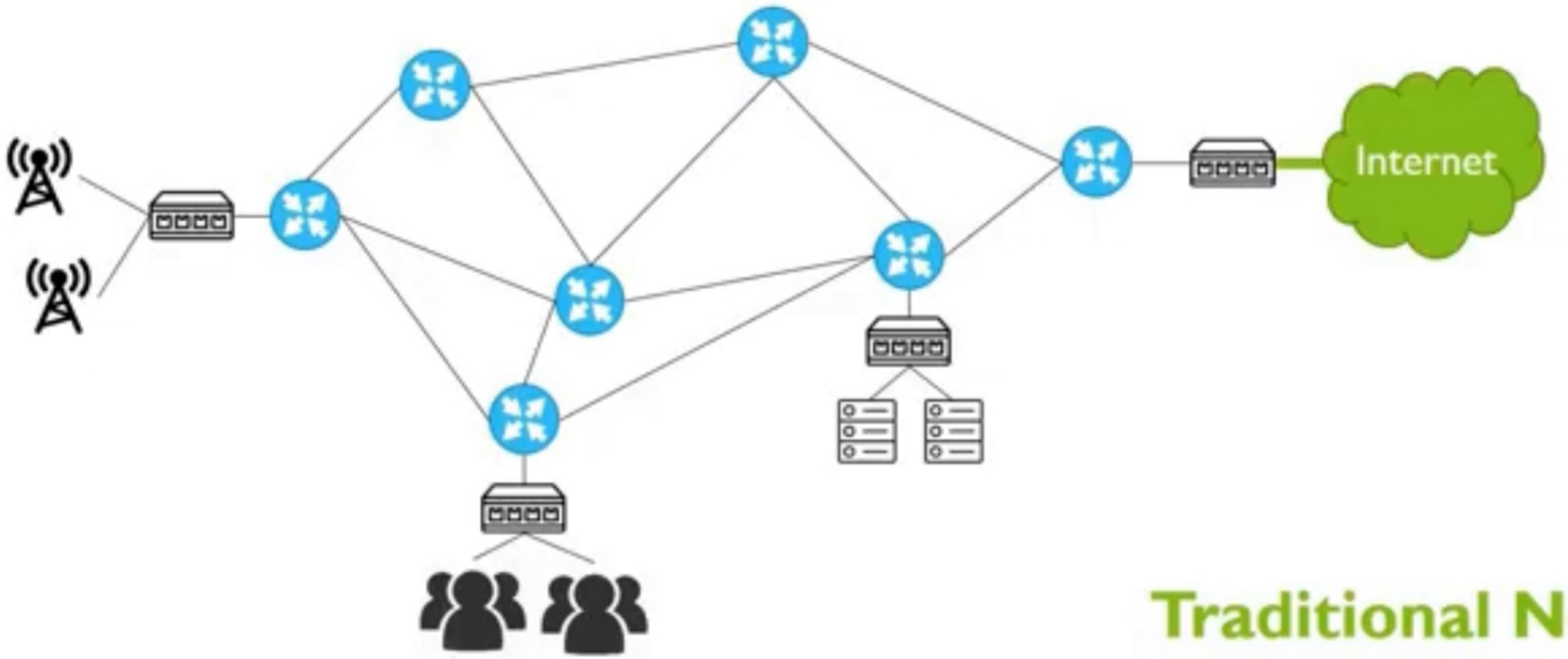
- Logically centralized
- Physically can be in a **cluster**



Regional
SDN Controllers





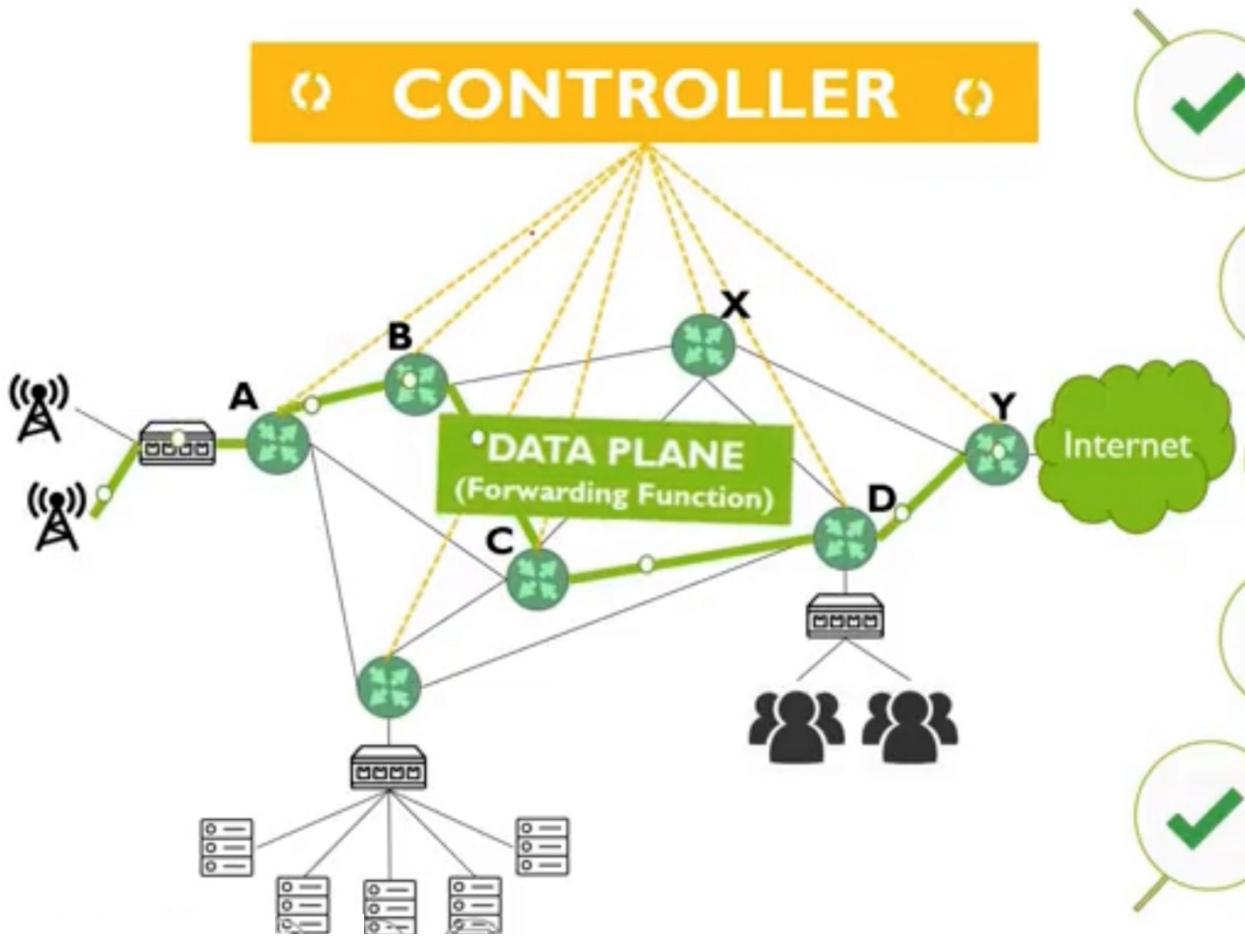


Traditional Network

Use of Integrated Hardware & Software

- Data or Forwarding Plane
- Control Plane
- Management Plane

SDN : Separation of Control & Data layer



Features of SDN

- Makes Networking & IP Routing flexible
- Decoupling control & Data plane
- Offloads brain to centralized controller
- Central View of Resources
- Programmable Network , Centrally Managed , Agile for any Need

Why Is SDN a Big Deal ?

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- **Greater speed and faster delivery of services:**
  - Configuring hundreds of routers can be done all at once
- **Accuracy and reliability:**
  - The human error that comes with traditional manual methods can be vastly reduced with a validated network application that operates with total consistency
- **Simplicity:**
  - The SDN controller manages complex rules and policies behind the scenes so that you can focus on the higher-level aspects of what you want to do

Why Is SDN a Big Deal ?

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- **Ability to optimize the network:**
  - Programmable networks allow you to adjust to changes automatically for optimal use of resources and maximum efficiency and speed.
- **Dynamic prioritizing of traffic:**
  - Shape traffic depending upon current need
  - One interface allows you to configure all network equipment at one place
  - “I want this protocol to have maximum priority right now!”
- **Better analytics:**
  - Deeper data and faster insights, plus improves security visibility

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Blockchain

- Fundamentals
- Elements
  - Block
  - Genesis-block
- Block Tampering
- Public and Private Blockchains

Blockchain

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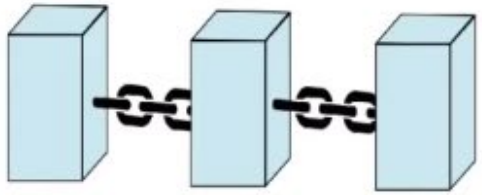
- Blockchain is a **distributed immutable ledger**
- Allows to **track anything tangible and intangible**
  - i.e. Bitcoin transactions, blockchain in logistics

collection of records



linked with each other

strongly resistant to alteration

protected using cryptography

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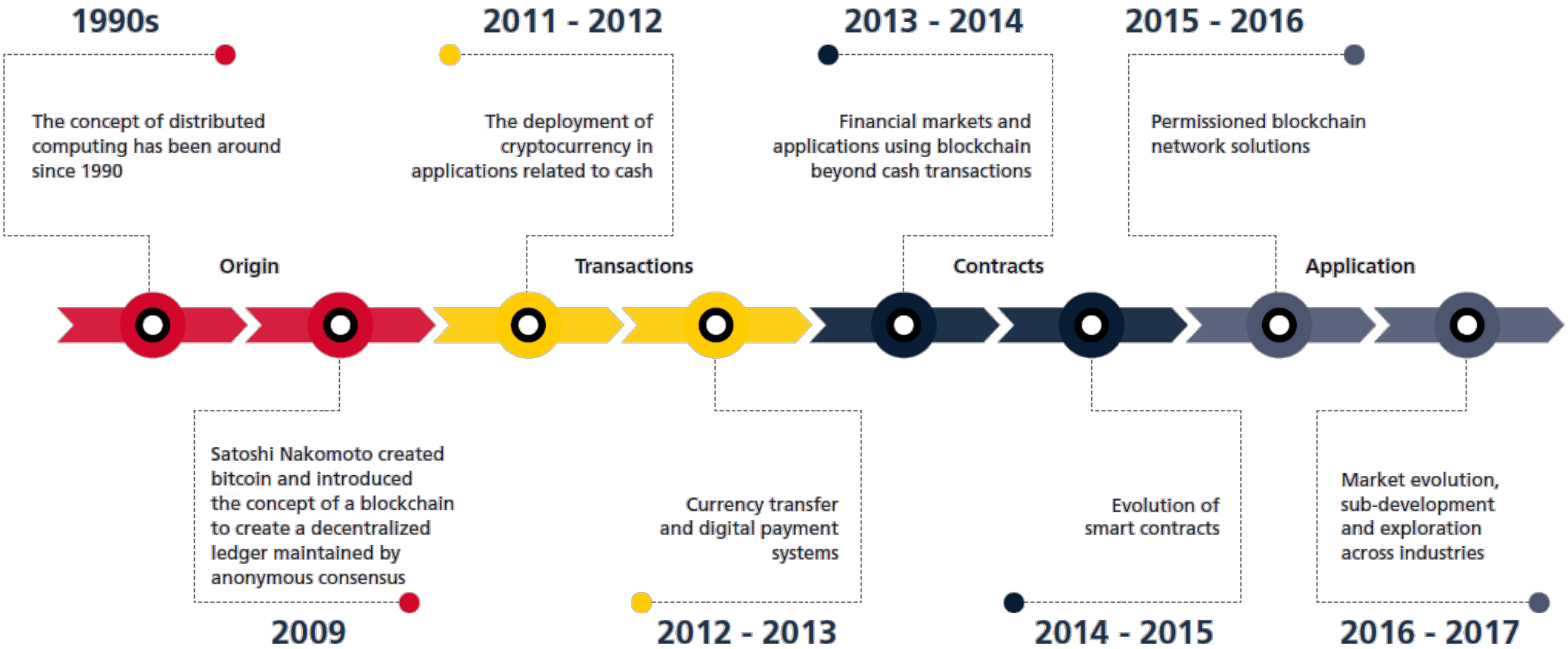

Blockchain – Cont.

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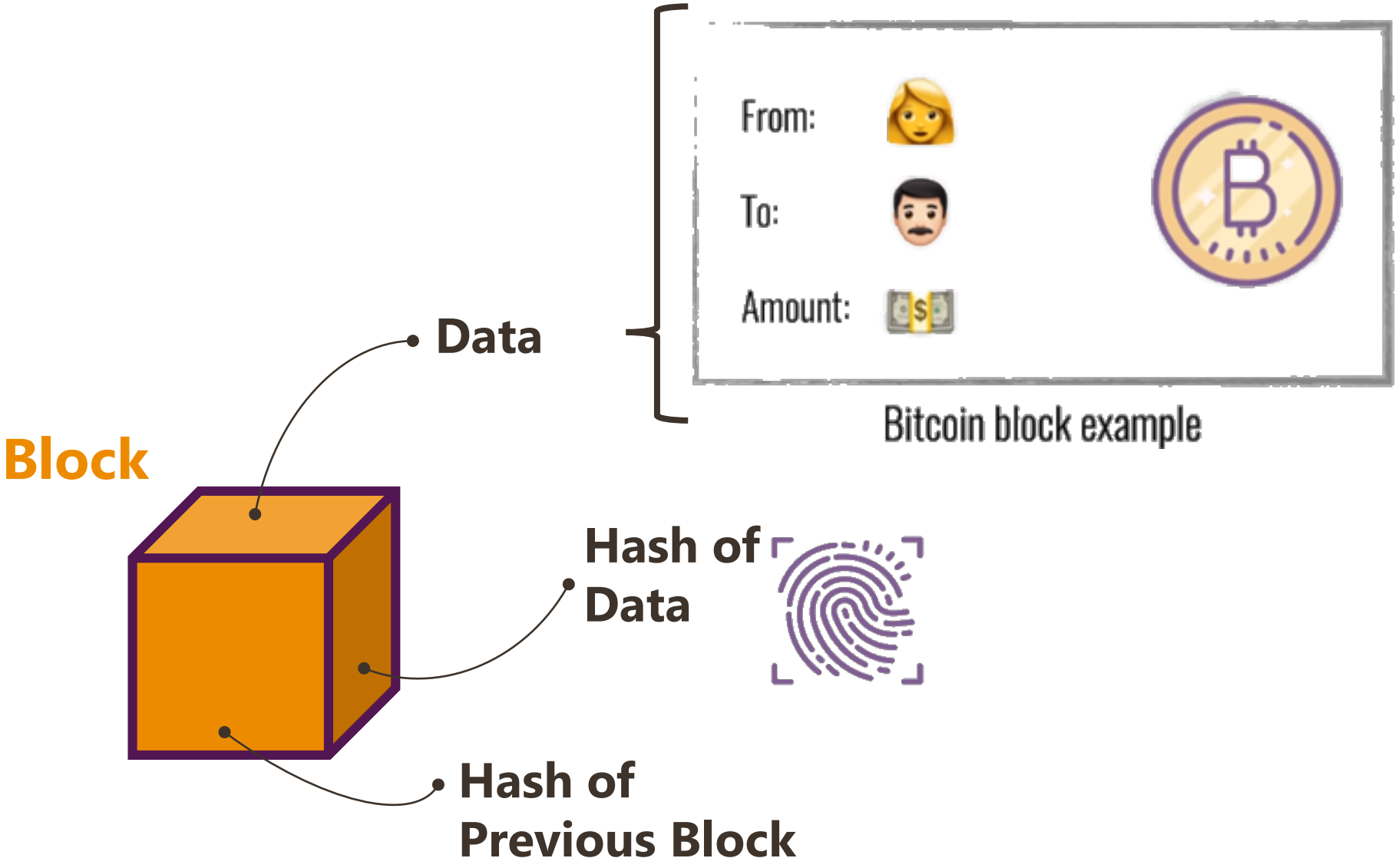

Chained Blocks

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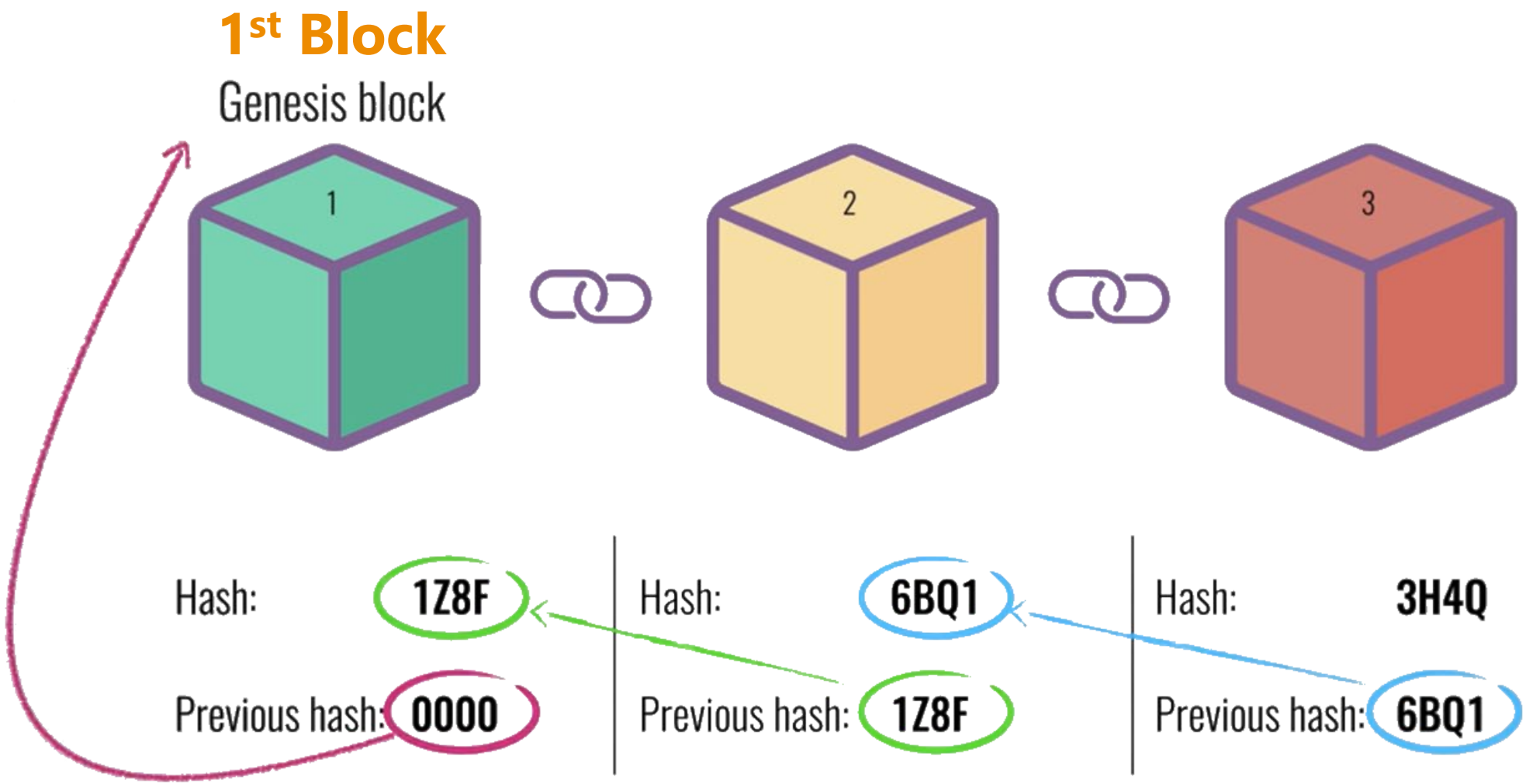

Block Tampering

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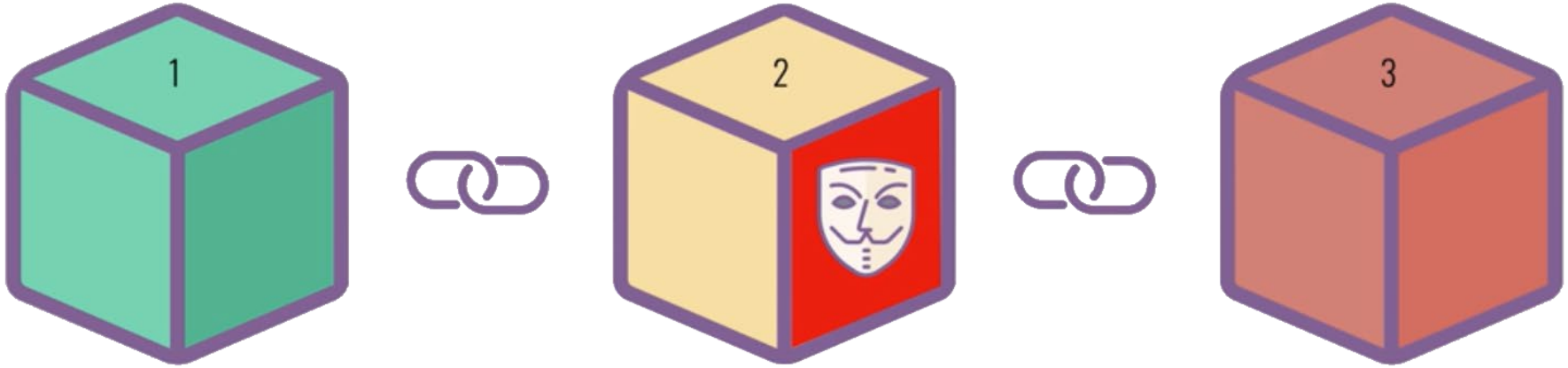
This invalidates all the blocks ahead!



Hash: 1Z8F	Hash: ~~6BQ1~~ H62Y	Hash: 3H4Q
Previous hash: 0000	Previous hash: 1Z8F	Previous hash: 6BQ1

Uh thats not right??

Block Tampering – cont.

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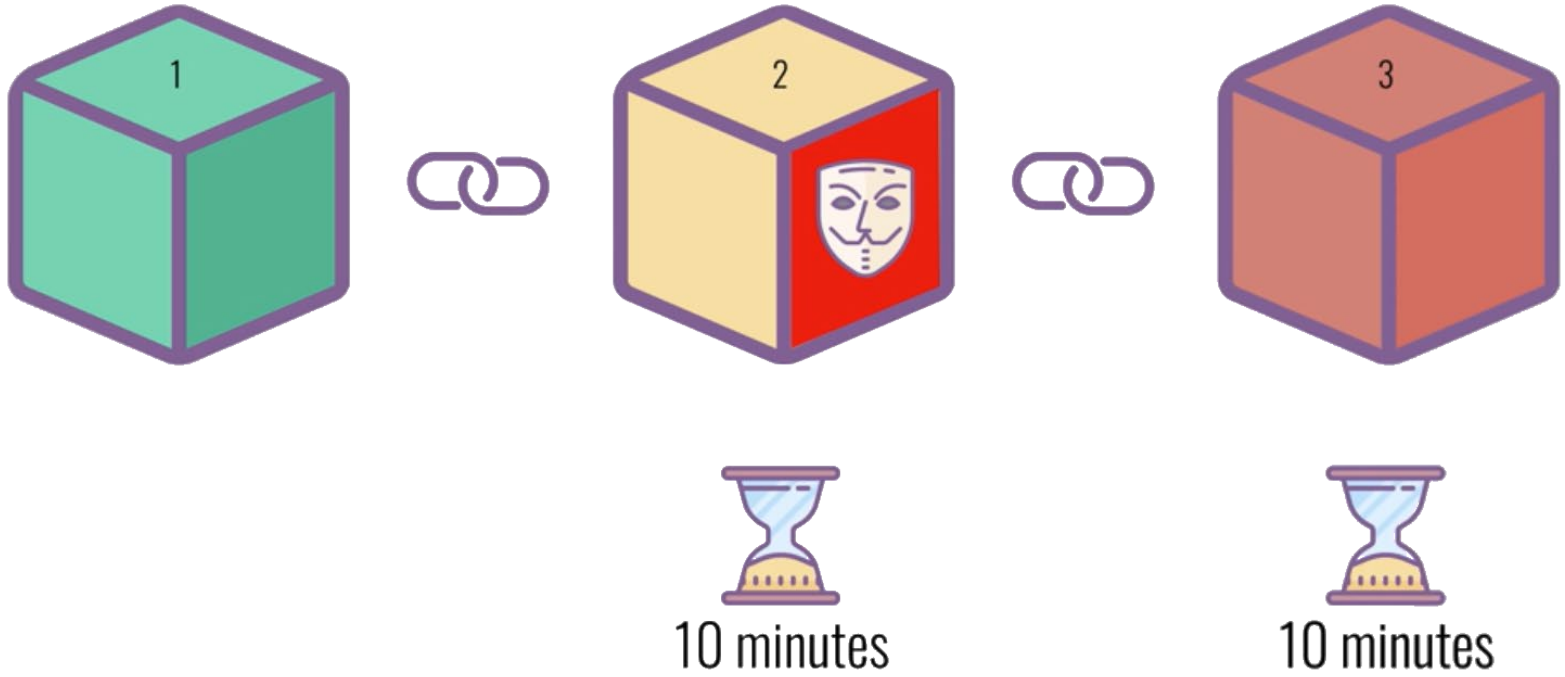
Problem: Can recalculate all hashes of affected blocks

Solution 1: Proof Of Work (PoW)

Mechanism to increase difficulty and slow down the creation of new blocks



Block Tampering – cont.

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Solution 2: Being distributed (P2P Network)

Let everyone (nodes) keep a copy of the ledger

Being Distributed…

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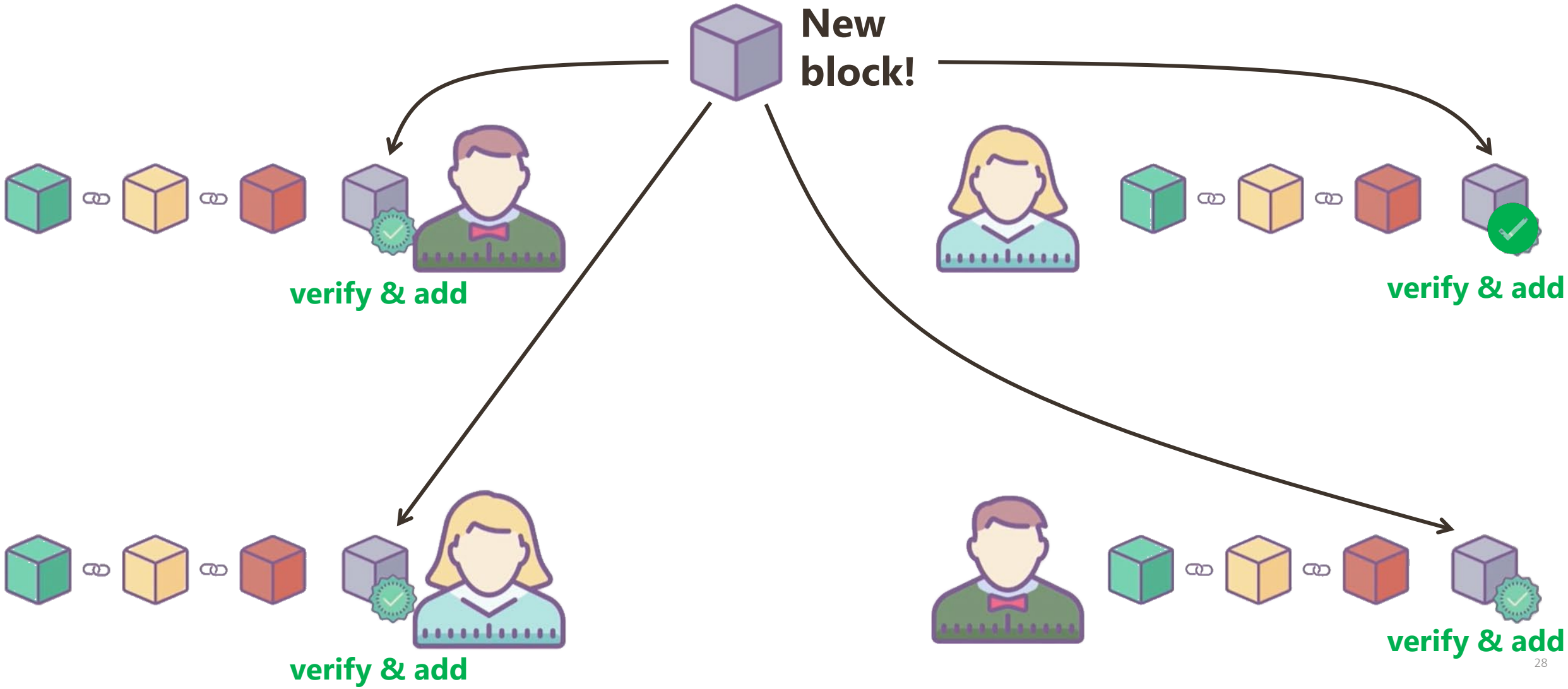

Distributed Consensus on valid/invalid blocks

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- Nodes able to come to agreement on what the state of the ledger should be
- No need to trust 3rd party
- Trustworthiness **without a 3rd party**

Tempered Blocks will be rejected by other nodes

Block Tampering

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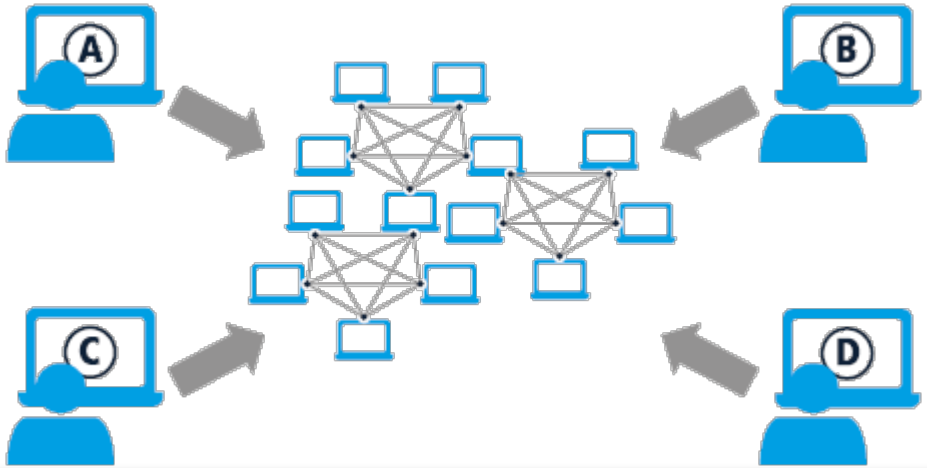
- To be successful:
  - ✓ Tamper with all the blocks in the chain
  - ✓ Redo the proof of work (PoW) for each block
  - ✓ Take control of > 50% of the P2P network

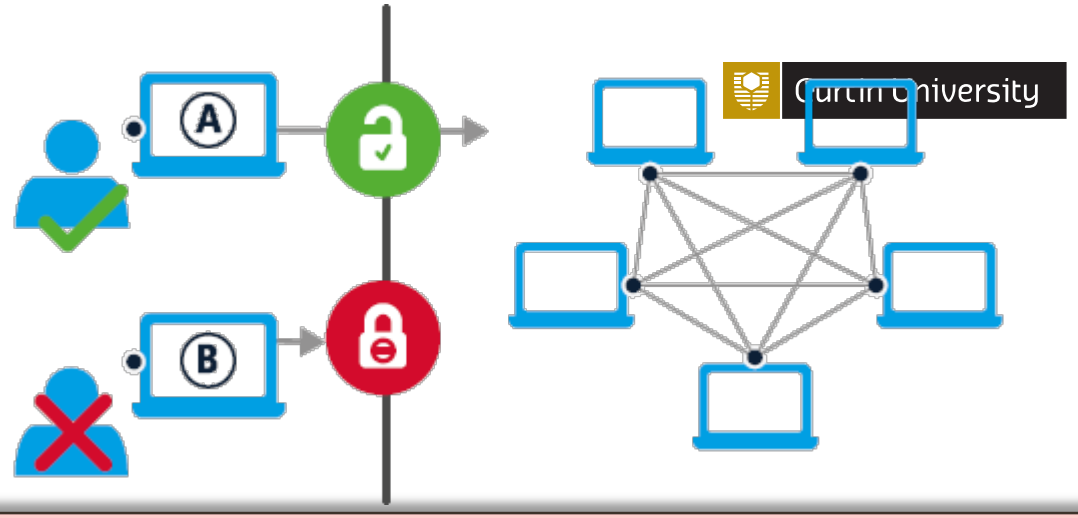
Only then the tampered block will be accepted by other nodes

- **Blockchain technology will provide**
  - ✓ Decentralization
  - ✓ Transparency
  - ✓ Immutability



PUBLIC BLOCKCHAIN

- Anyone can join the network and submit transactions
- Anyone can contribute computing power to the network and broadcast network data
- All transactions are broadcast publicly



PRIVATE BLOCKCHAIN

- Only safe-listed (checked) participants can join the network
- Only safe-listed (checked) participants can contribute computing power to the network and broadcast network data
- Access privileges determine the extent to which each safe-listed participant can contribute data to the network and access data from the network

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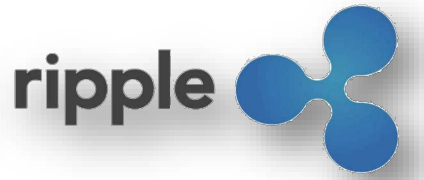
Blockchain in-depth with Crypto Currency

- Fundamentals
- Bitcoin
  - Ledger
  - Adding/Verifying Transactions
  - Proof of Work (Miners / Participants)
  - Bitcoin Protocol Summary
  - Bitcoin vs. Legacy Financial System
  - Challenges of Bitcoin
  - Proof of Stake

Crypto Currency

ethereum



- Digital Currency, Currency on bit-torrent like protocol
- Leverage blockchain technology
- No bank, **No third party**
- Can transfer directly between two parties via the use of private and public keys (no processing fees)

cryptocurrencies are immune to counterfeiting

don't require a central authority

protected by strong and complex encryption algorithms

Bitcoin 

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- **Leading digital currency** stored on a global, decentralized **P2P** blockchain

- **Blockchain is the underlying technology**
  - *enables transactions to take place in a secure and trusted manner between pseudo-anonymous parties*

- **Anyone can participate in the bitcoin (no intermediary)**
  - *Anyone can participate in the bitcoin blockchain and ownership can be digitally transferred without the need for an intermediary*

- The **creation or 'mining' of bitcoins** is done **through computers**
  - *solving complex equations; Currently, it is heavily energy-intensive, requiring improvements in energy efficiency*

Bitcoin Ledger

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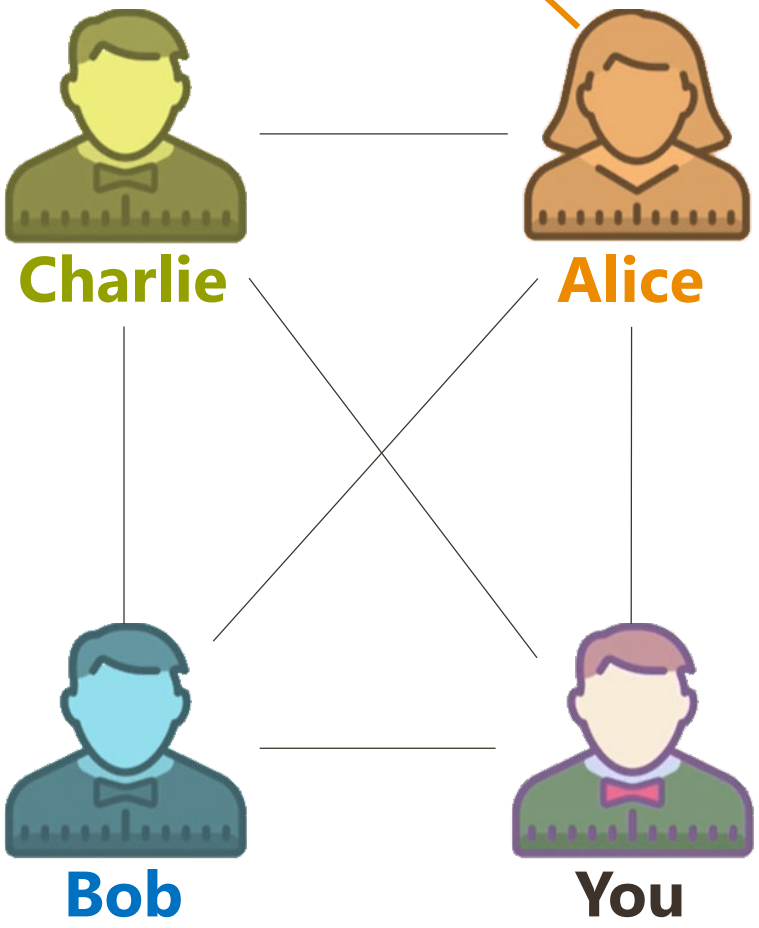
Ledger

1. **Alice** gets $100
2. **Bob** gets $100
3. **Charlie** gets $100
4. **You** get $100
5. **Charlie** pays **Alice** $50 — *Charlie*
6. **Charlie** pays **Bob** $50 — *Charlie*
7. **Alice** pays **You** $30 — *Alice*

Anyone can add records

Charlie (money sender) digitally signed

UniqueID
Prevent duplicating the Entry



Verifying a Transaction

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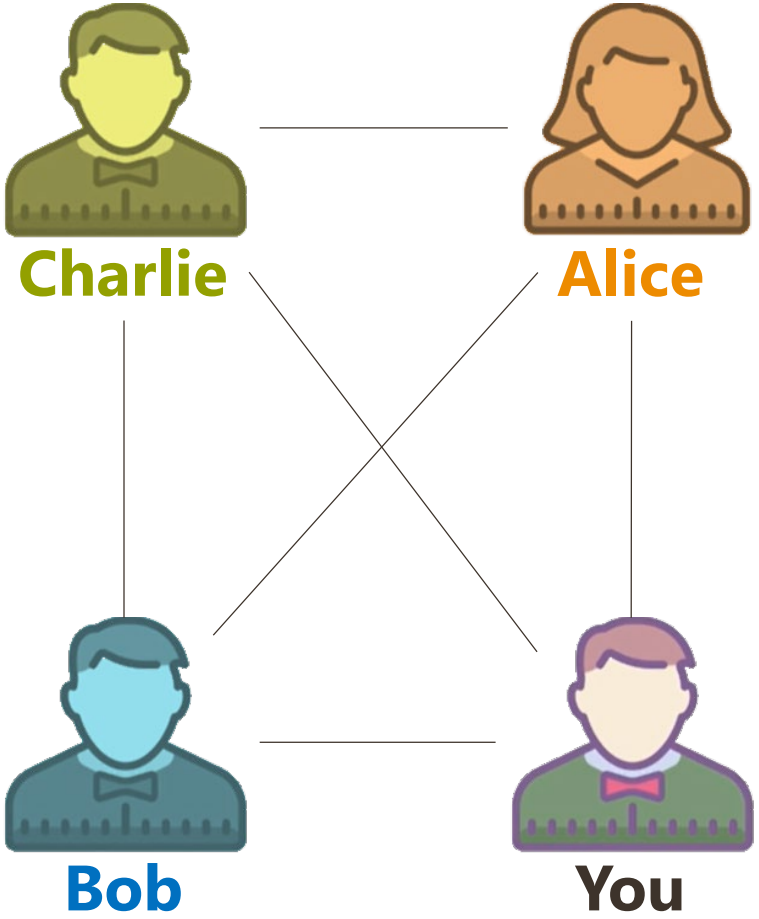
Ledger

1. **Alice** gets $100
2. **Bob** gets $100
3. **Charlie** gets $100
4. **You** get $100

5. **Charlie** pays **Alice** $50 — *Charlie*
6. **Charlie** pays **Bob** $50 — *Charl*
7. **Alice** pays **You** $30 — *Alice*
8. **Charlie** pays **You** $50 — *Charlie*

INVALID !



Verifying a transaction requires knowing the full history of Charlie

Ledger

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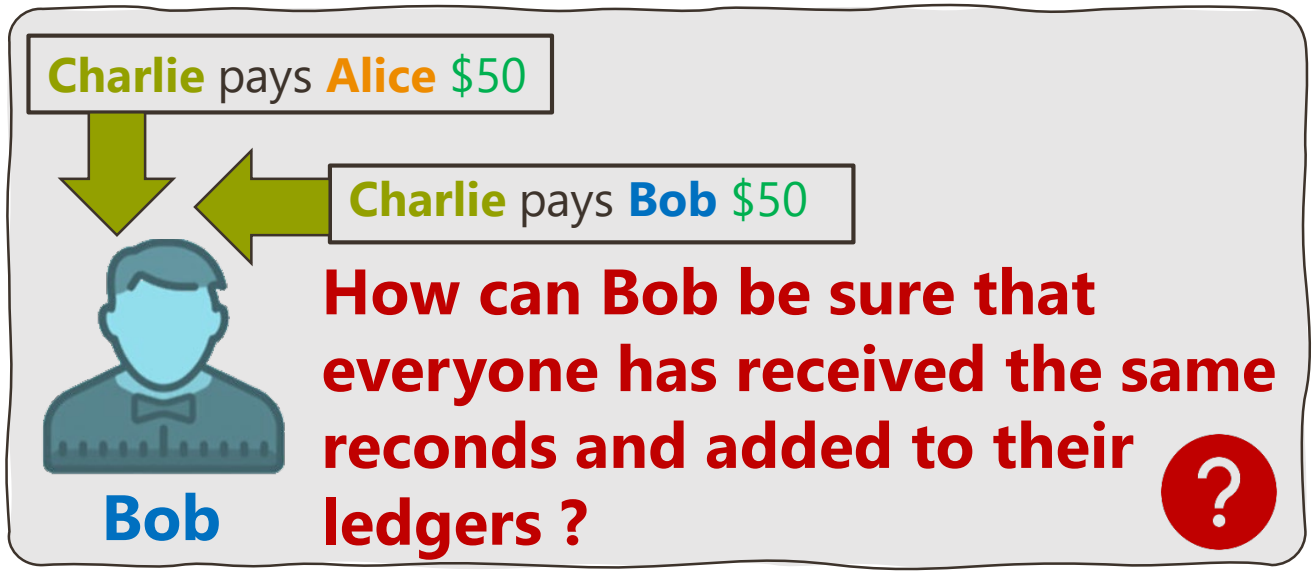
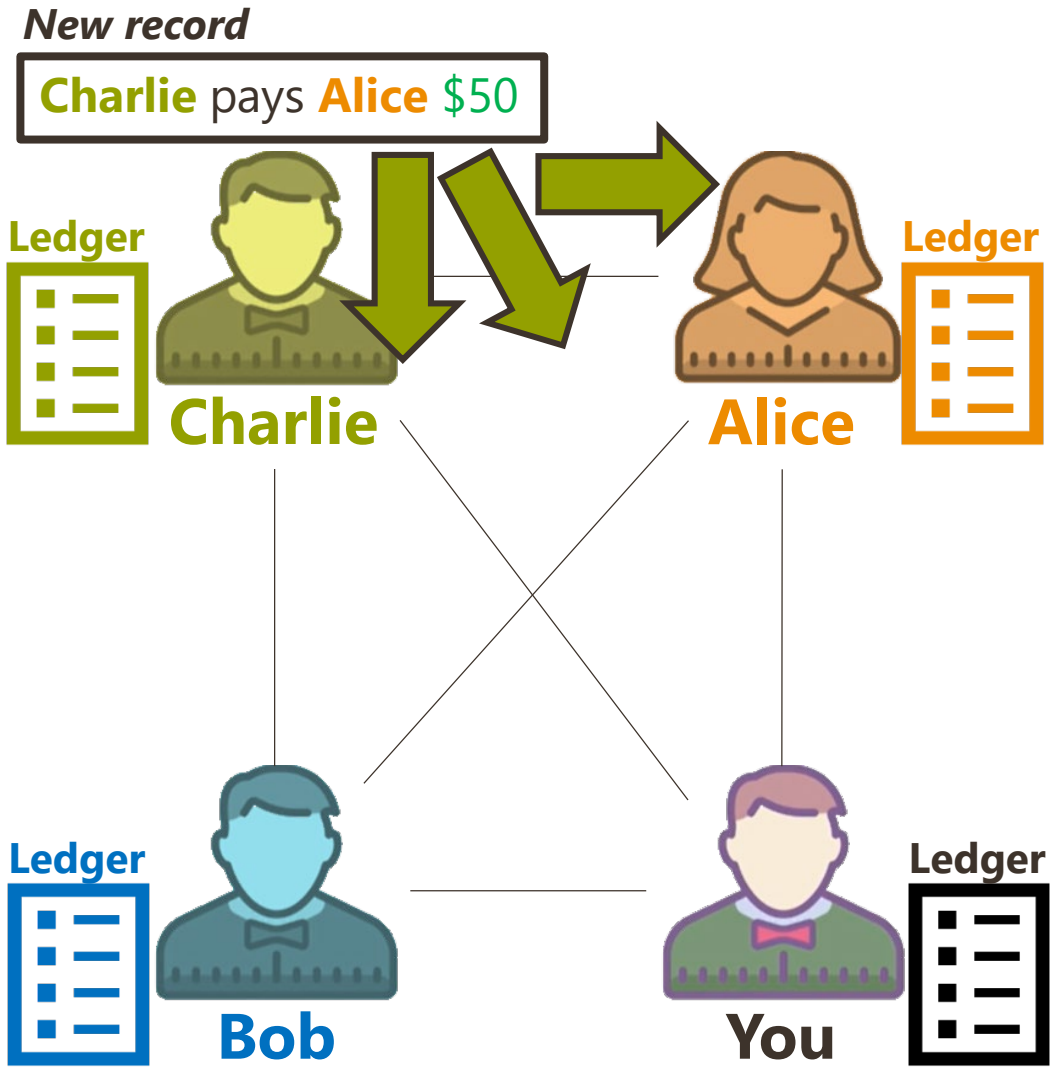
- Who owns the ledger?
  - ✓ Everyone (transparency)
- When a new record is added
  - ✓ Broadcast it to others
  - ✓ Others can verify and add to their ledgers





Ledger – cont.

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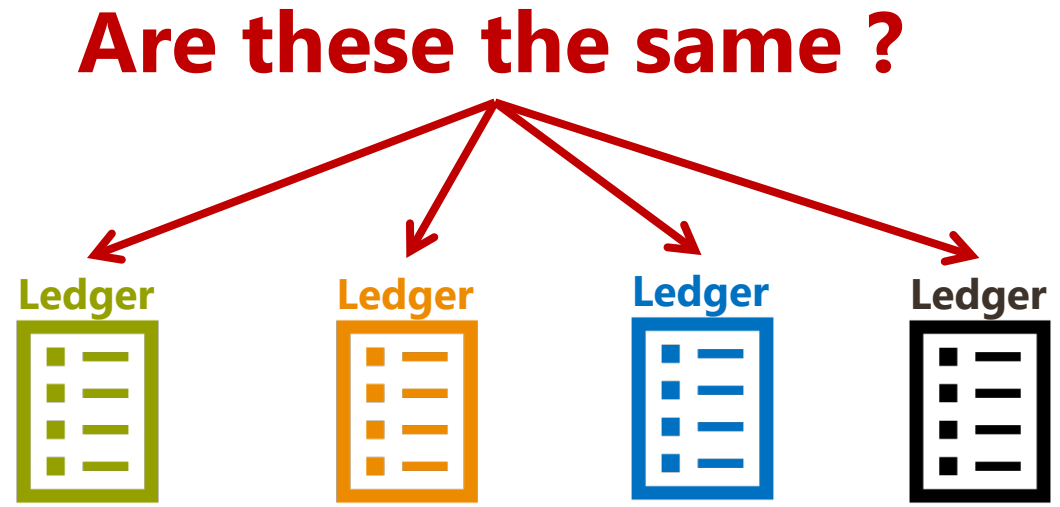
- How can you get everyone to agree on what the correct ledger is?



Trust whichever ledger has most work put into it

"Proof of Work"

Proof of Work

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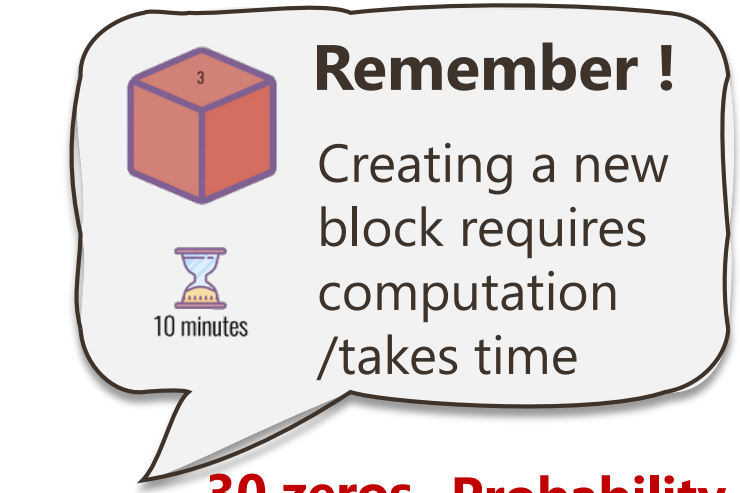
- Find **the special number** such that:
  - ✓ Put it to the end of transactions
  - ✓ Apply SHA-256 to whole ledger/block
  - ✓ Hash value must start with 30 zeros

SHA-256



30 zeros, Probability = $\frac{1}{2^{30}}$

00000000000000000000000000000011
11110101111101100000110010001011
00110101101101100110110010011010
11011000110110110000110010001000
01110001101101100100110010001000

"Proof of Work"

Proof of Work – cont.

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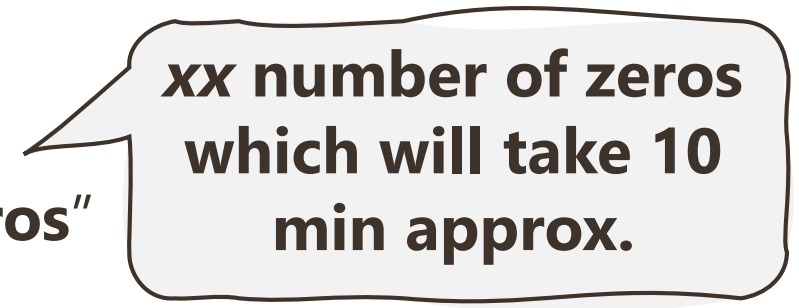
- **PoW verifies** you went through a large amount of work

- All work in **PoW is intrinsically tied** to the list of transactions in ledger
  - ✓ If you change one of those transactions, you will have to find the special number again

- **PoW takes approx. 10 min**
  - ✓ PoW: "Hash value must start with **30 zeros**"



Ledger into Chain of Blocks

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- Organize a given ledger into blocks & chain the blocks

- **Transaction** is **only valid** if digitally signed by its sender
- **Block** is **only valid** if it has a proof of work

Bitcoin Protocol

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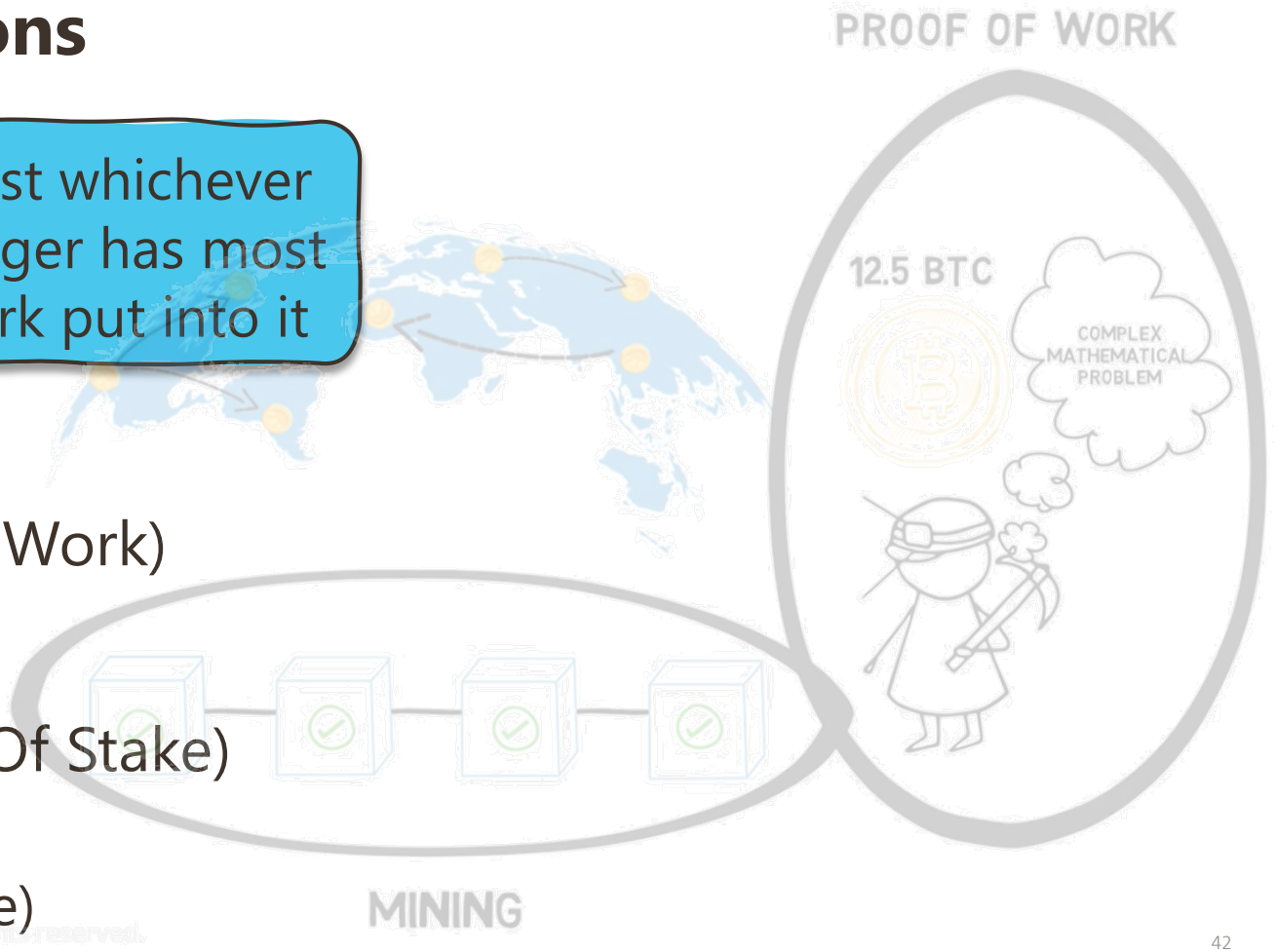
- ✓ **Broadcast Transactions**
- ✓ **Only Accept Signed Transactions**
- ✓ **No Overspending**
- ✓ **Distributed Consensus**

Trust whichever ledger has most work put into it

- ✓ **Mechanism to Prove Work**
  1. **Miners** to perform **PoW** (Proof Of Work)
     - **Reward:** Bitcoin (Block Reward)
  2. **Validators** to perform **PoS** (Proof Of Stake)
     - **Hold a stake**
     - **Reward:** Bitcoin (transactions charge)



Miner (Block Creator)

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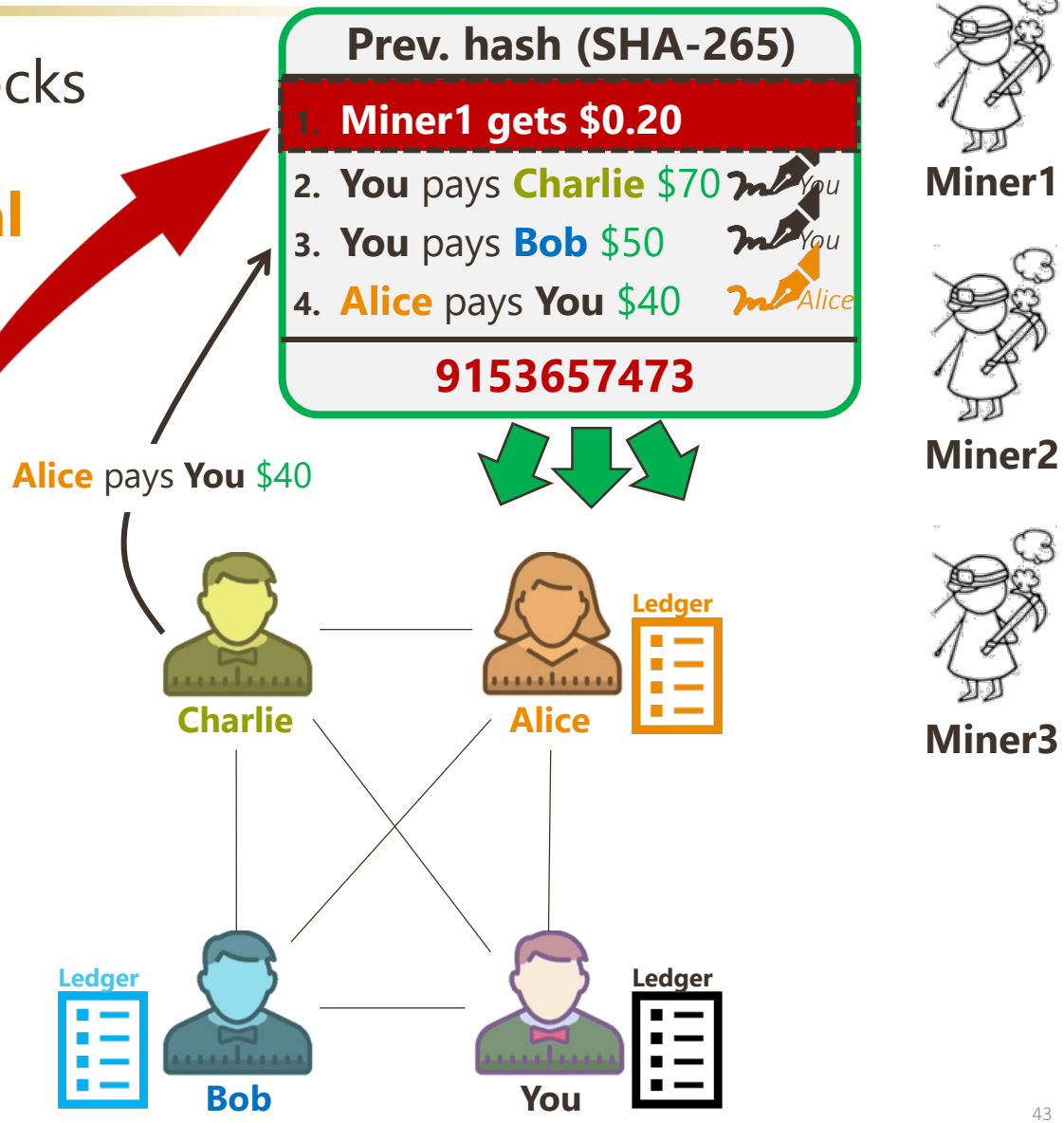
- **Listen to transactions**, collect them into blocks
- Mine until one of the miners **find the special number**
- **Block Reward:** Get $0.2 **from the network**
  - ✓ No sender / signature
  - ✓ Adds to total money supply
- **Create a block** (mining), **broadcast** to Alice, Charlie, Bob and You
- **A node could be a miner or participant**



Participant (Non-Miner)

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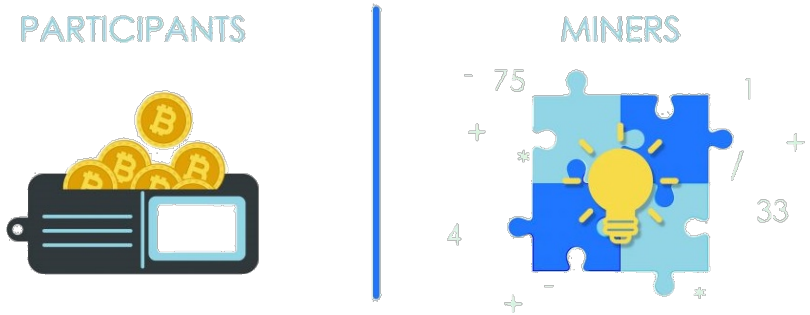
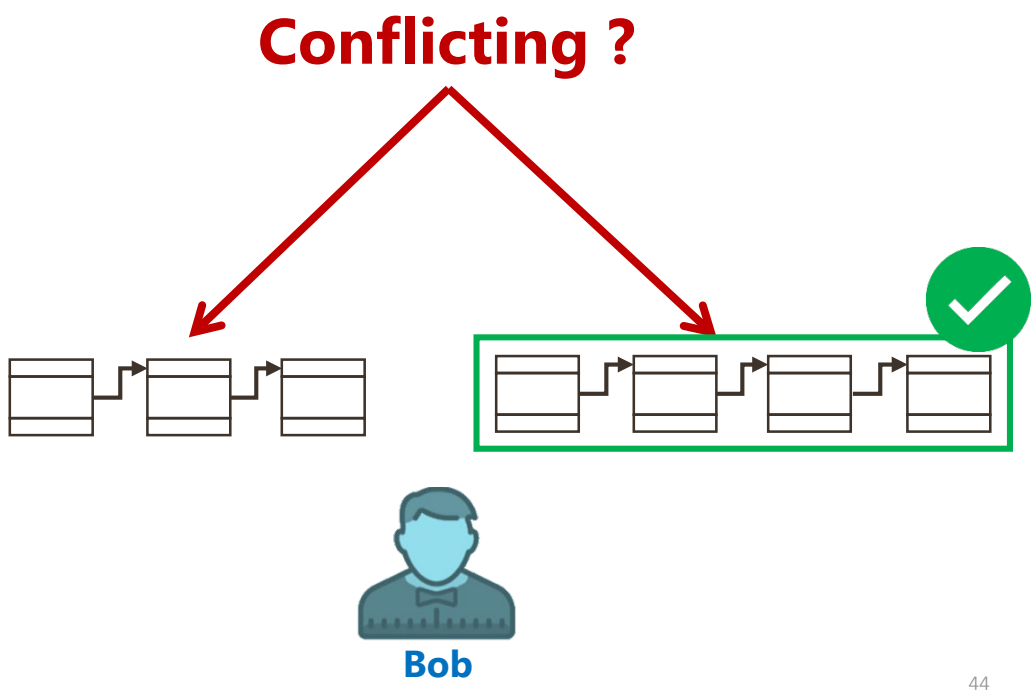
- People who use the system to make payments



- **Listen to blocks** broadcasted by miners,
  - Update the personal copies of the block chain

- What if you hear **two conflicting block chains?**
  - Refer to the longer one (one with more work)
  - If there is a tie, wait a few round to see who is longer



- **Distributed Decentralized Consensus**
  - Everyone agrees to give preference to the blockchain with most work put into it

Let's try to fool Bob

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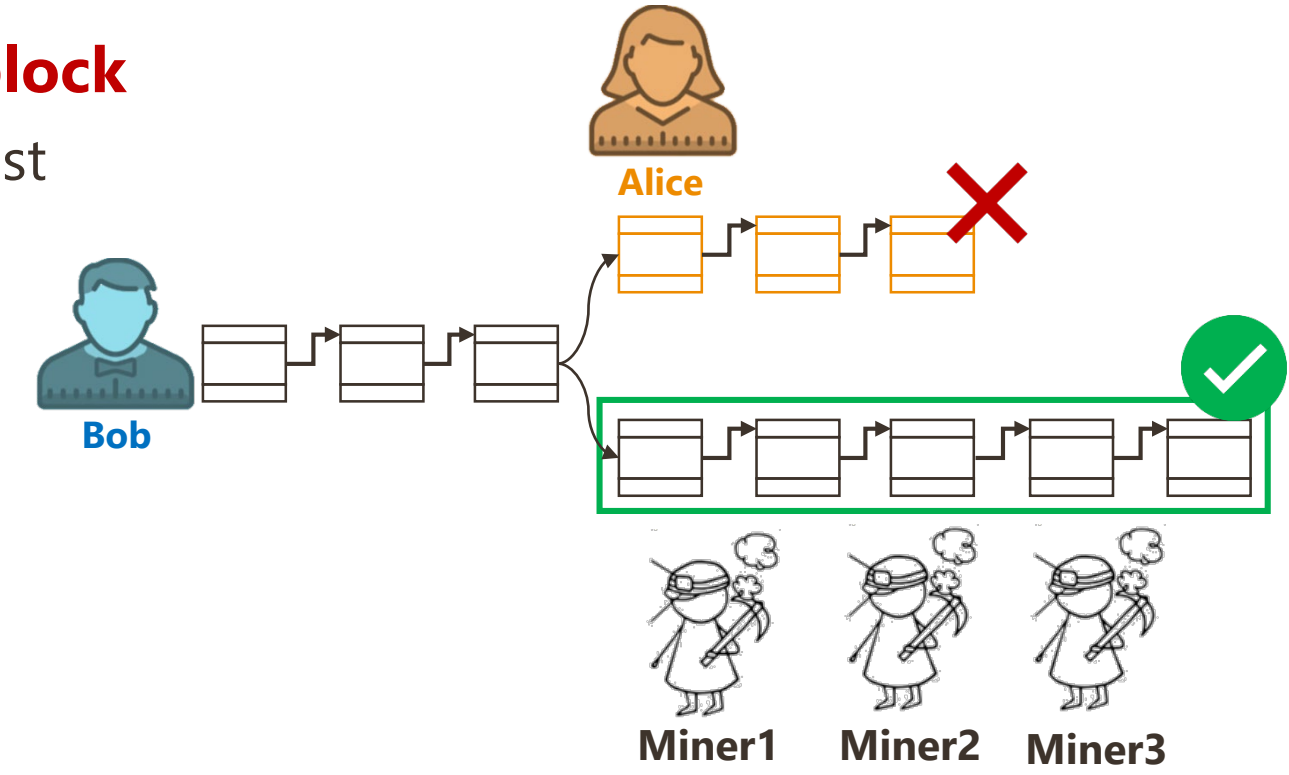
- **If Alice try to fool Bob with a fraud block**
  - by sending it only to Bob, but no broadcast
- Alice may be able to create a block
  - Find the special number (lucky winner)
- But to be the longest chain
  - Alice must have **>50%** of the computing **resources among all miners**
- Bob will eventually **reject** Alice's chain **in favor of the longer chain**



When to Trust?

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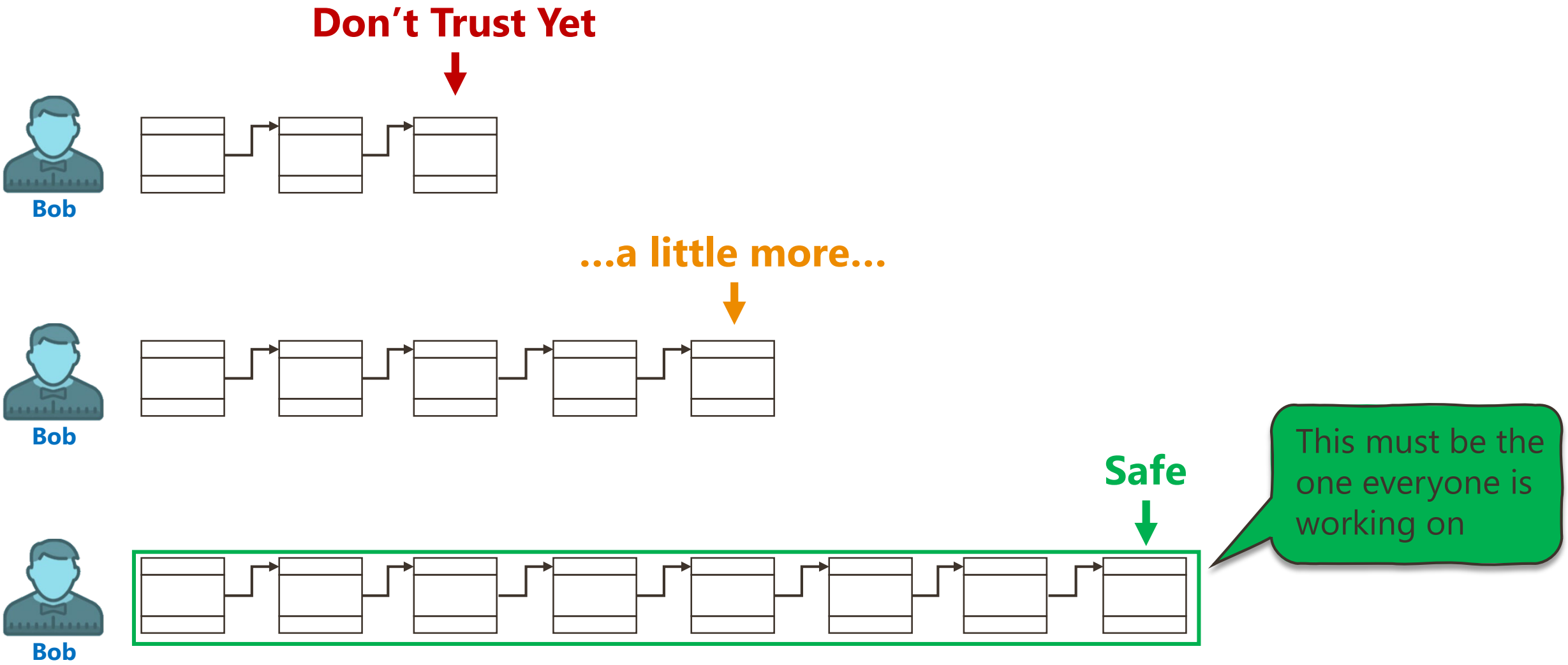

Bitcoin Generation

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- **Miners generate Bitcoin via mining**
  - Inject Bitcoin to the total economy
- **Bitcoin Halving**
  - Happens after every 210,000 blocks
  - It cuts the supply of new Bitcoins in half via halving the miner's block production rewards
  - 50% fewer BTC for verifying transactions
- **Bitcoin – The 21 million upper cap**
  - There will only be 21 million Bitcoins that will ever exist

Miners would still be rewarded with transaction fees associated with the block they mine

Someone requests a **transaction**.

The requested transaction is broadcast to a **P2P** network consisting of computers known as **nodes**.

The P2P network of nodes validates the transaction and the user's status using **known algorithms**.

A **verified** transaction can involve **cryptocurrency**, contracts, records, or other information.

The transaction is complete!

The new block is then added to the existing blockchain in a way that is **permanent** and **unalterable**.

Once verified, the transaction is combined with other transactions to create a new **block of data** for the **ledger**.

Cryptocurrency

Has no **intrinsic value** in that it is not redeemable for another commodity.

Has no physical form and exists **only in the network.**

Its supply is not determined by a central bank, and the network is **completely decentralized.**

Bitcoin Summary

Blockgeeks

Bitcoin vs. Legacy Financial System

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- 33% credit card transactions are fraud (nobody wants to accept)
- With bitcoin, funds are legit
- Challenging the legacy financial system

		$
User Facing	Phone 	Card 
Verification	**Decentralized Trust List Verification** *Digital signatures* *Cryptographic hash functions*	Bank (3rd party)
Underlying System	**Bitcoin Protocol**	Banking System

Challenges

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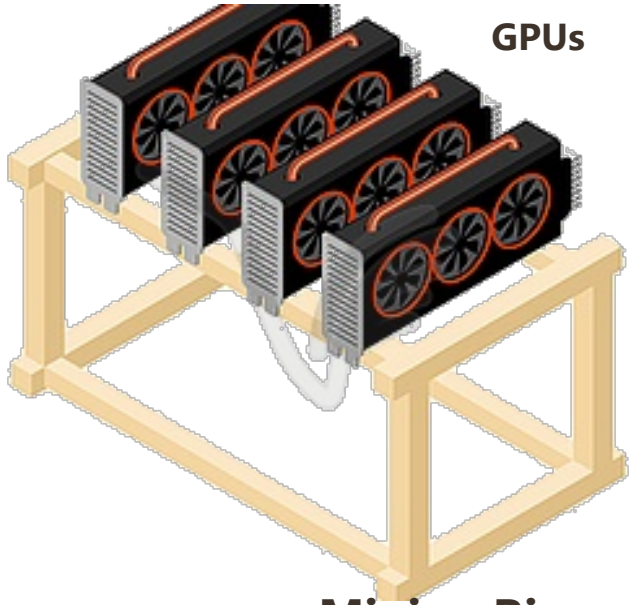
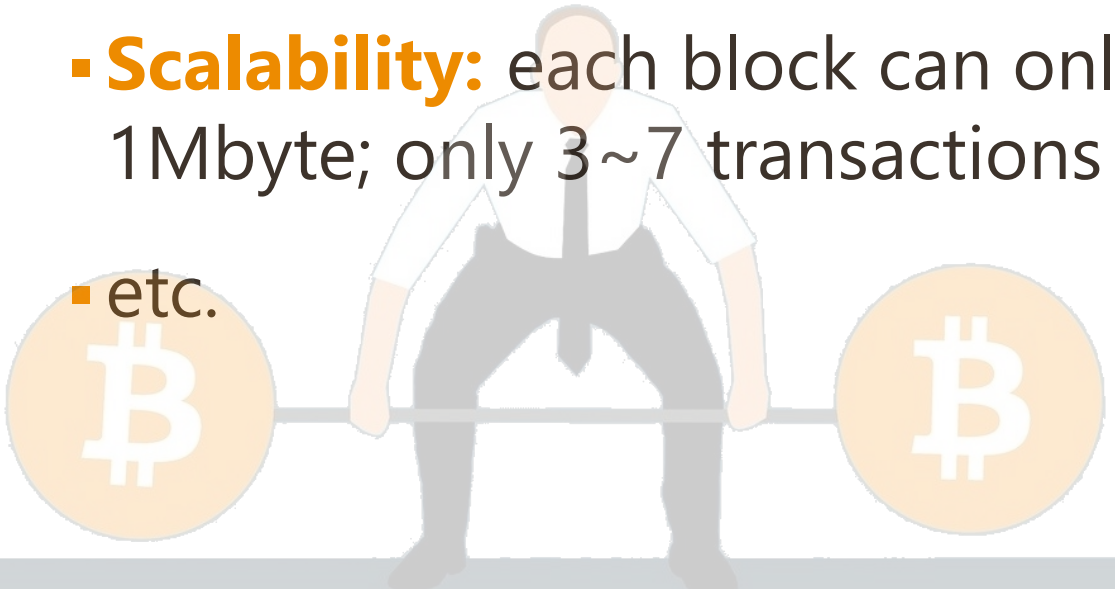
- Every transaction needs **computational power**
- **Latency** per transaction
- Unstable pricing make it too popular for speculators but not helping as a currency
- **Scalability:** each block can only contain 1Mbyte; only 3~7 transactions per second
- etc.





Computational requirement

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Proof of Work - Issues

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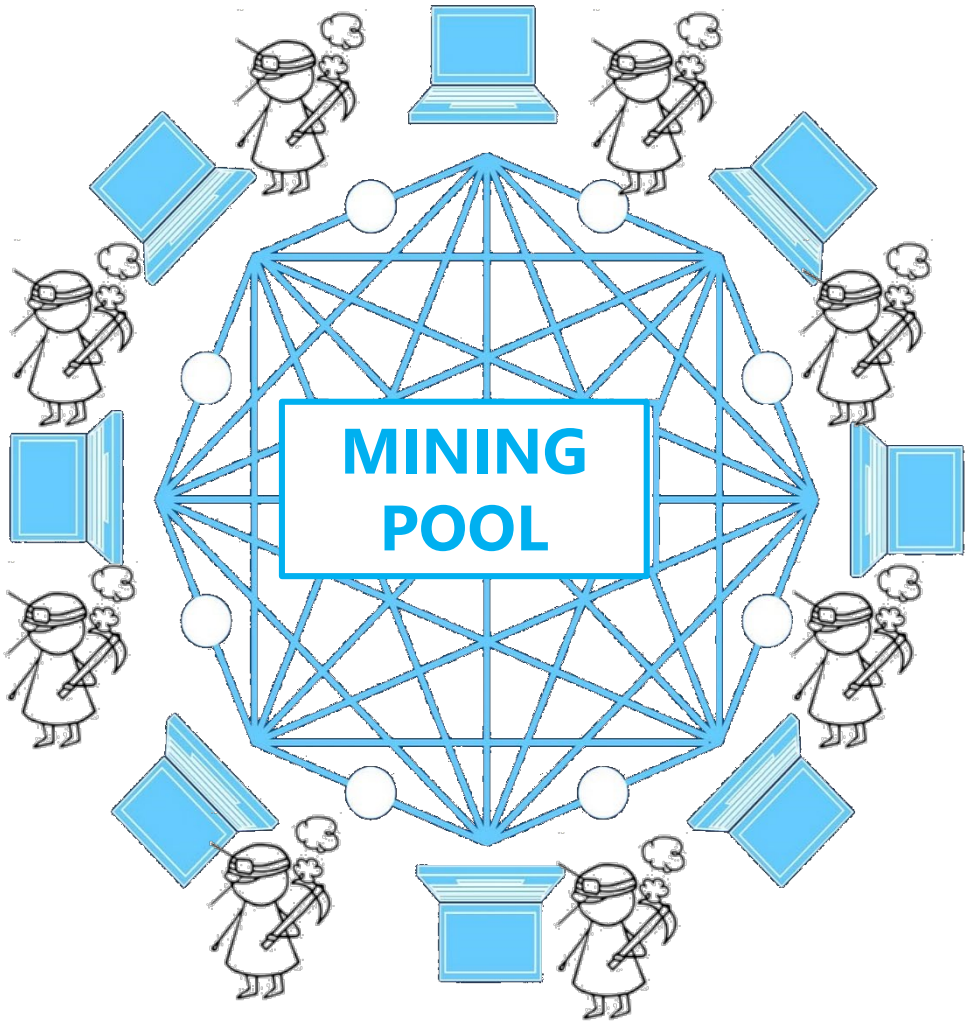
- High energy usage
  - Bitcorn miners use 54TWh – enough to power 5M households in US
- Encourage users to use **mining pools**
  - This will make **blockchain more centralized** ☹
- Need an *alternative method*
  - **Proof of Stake**



Mining Pools

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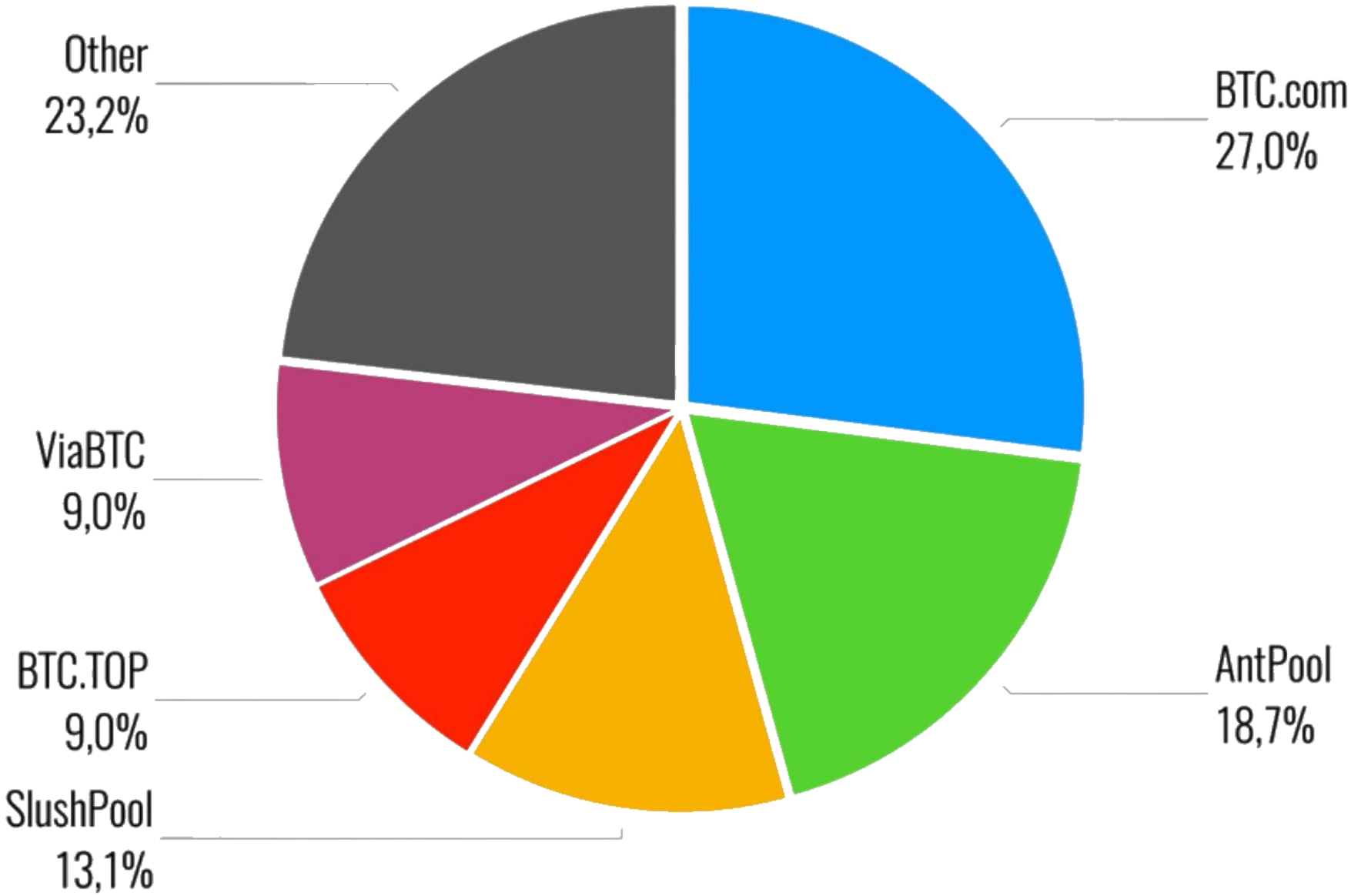

Proof of Stake

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- **Terminology**

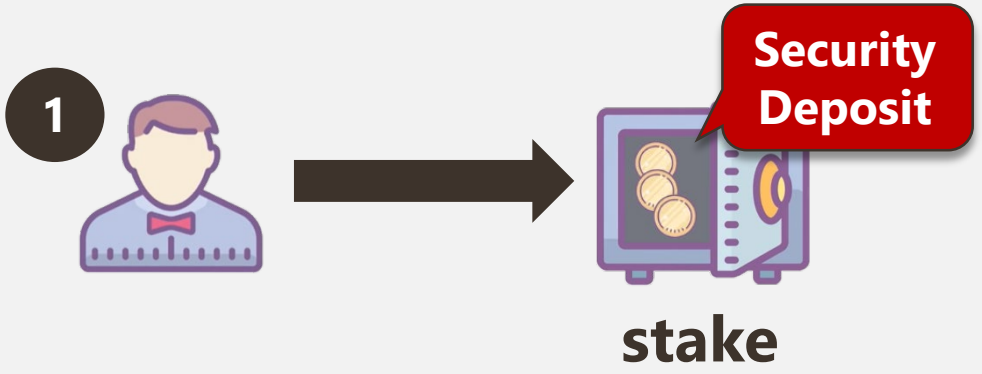
~~Miners~~

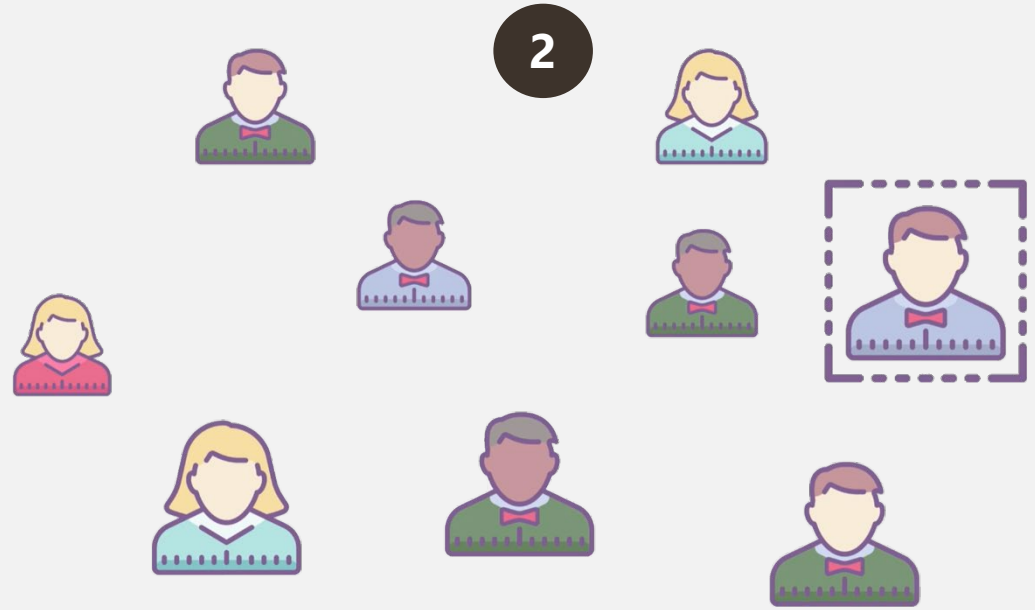
~~Mining~~

Validators

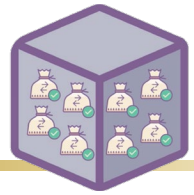
Minting / Forging

- **Validator Node**
  - Elect a node based on stake





Proof of Stake



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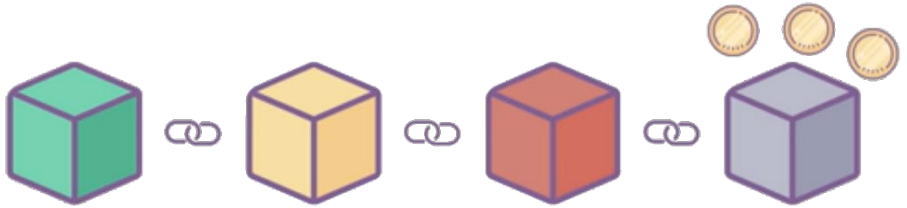
- Validator validates all transactions inside a block



- **Block Reward:**
  - Fees associated with the transactions inside the block

- **How to trust other validators?**
  - **Validators will lose** part of their **stake** if they approve fraudulent transactions
  - Stake will be held until sum of **all transaction fees > stake**

- All transaction fees + stake will be released after certain period of time

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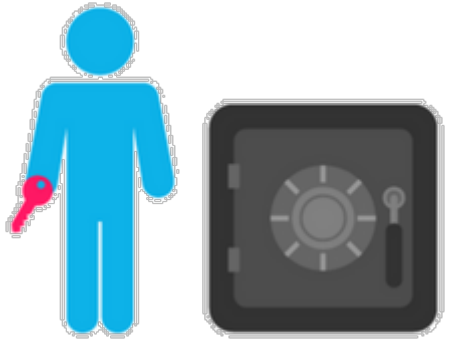
PoW

PoS



Proof of work is a requirement to conduct an expensive computer calculation, also called mining

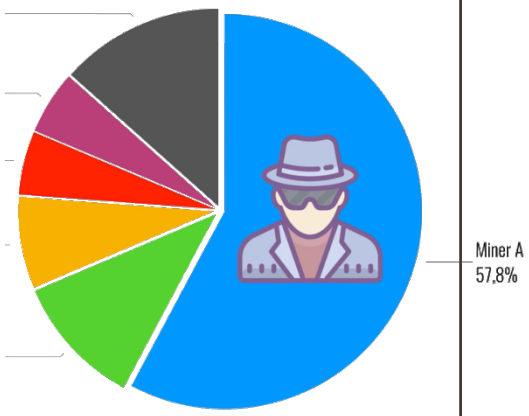
Proof of stake, the creator of a new block is chosen in a deterministic way, depending on its wealth, also defined as stake

Everyone can mine

Only select a **few** "validators"

More centralized with Mining Pools

- ✓Control large portion of blockchain
- ✓If 3 join, can start approving fraudulent transactions
- ✓Acquiring 51% is easier hence highly risky



More decentralized
51% is practically impossible

= $79,826,299,343.76

Expensive mining equipment

Encourage more people to mine/validate

PoS Shortfalls ?

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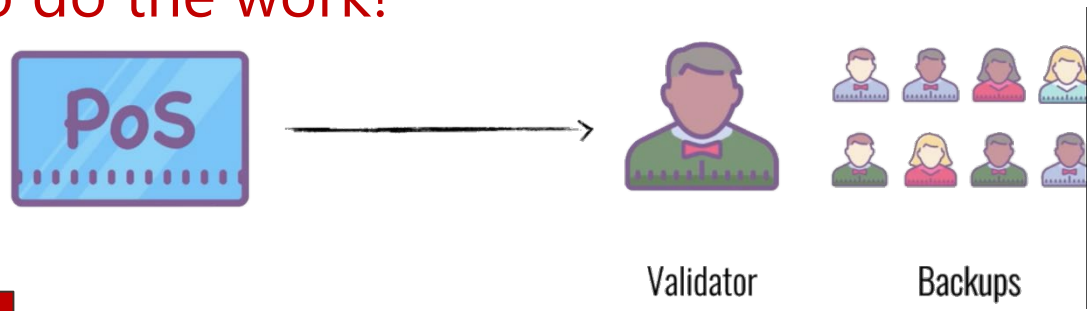
1. Richer will get high priority to be chosen
   - If chosen, Richer can earn more money

- **Proposal: Coin age-based selection**
  - proof-of-stake system combines randomization with the concept of **"coin age"**
  - a number derived from the number of coins multiplied by the number of days the coins have been held

2. Validator is chosen but doesn't show up to do the work!
   - **Use backup validators**



In short, PoS brings different risks compared to PoW

PoS Systems

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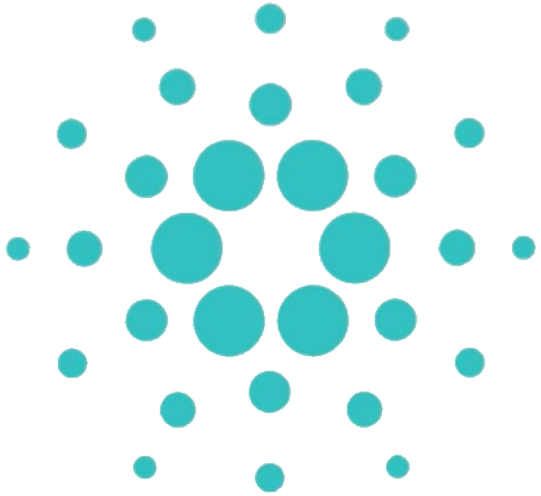
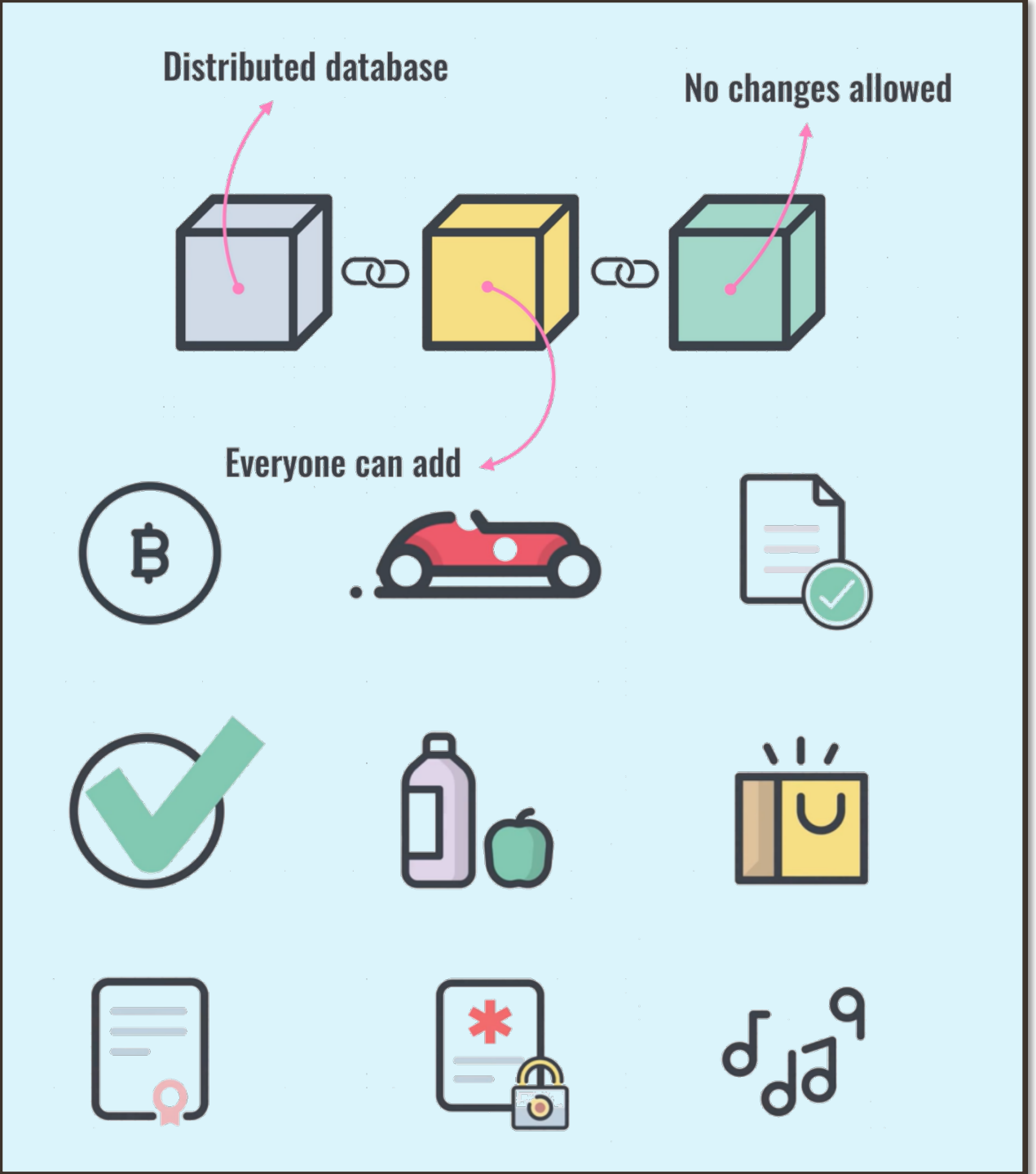
Casper



Cardano



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Blockchain Applications

- Smart Contract
- Other Blockchain Applications
- Blockchain in Logistics

Smart Contract

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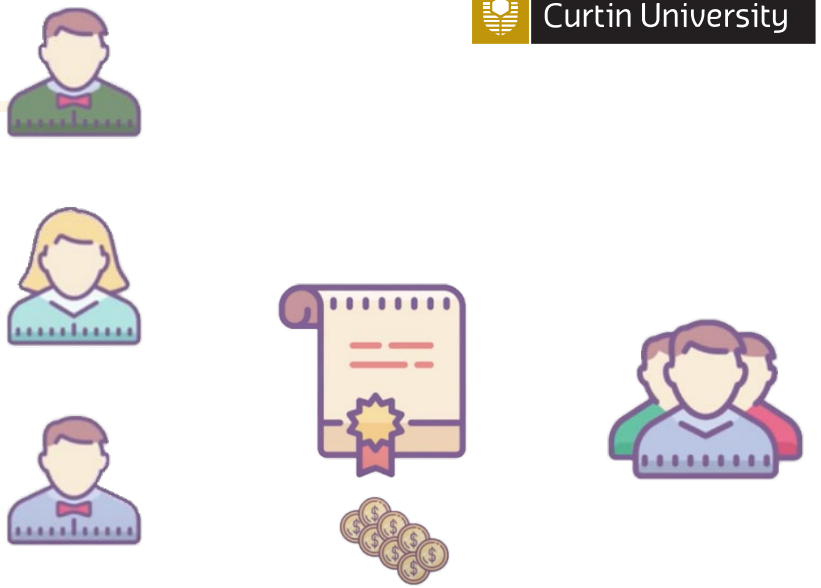
- **Digital Contracts,** tiny computer program stored in Blockchain **(immutable**, **distributed)**

- **Once** smart contract is **created**, it **can never be changed**

- Output of the contract is **validated by everyone** in the network
- A single **person cannot force** the contract to release the funds!



- i.e. **Ethereum** (smart contract approach)
- i.e. Kick Starter (manual approach, 3rd party)

Smart Contract – Kick Starter

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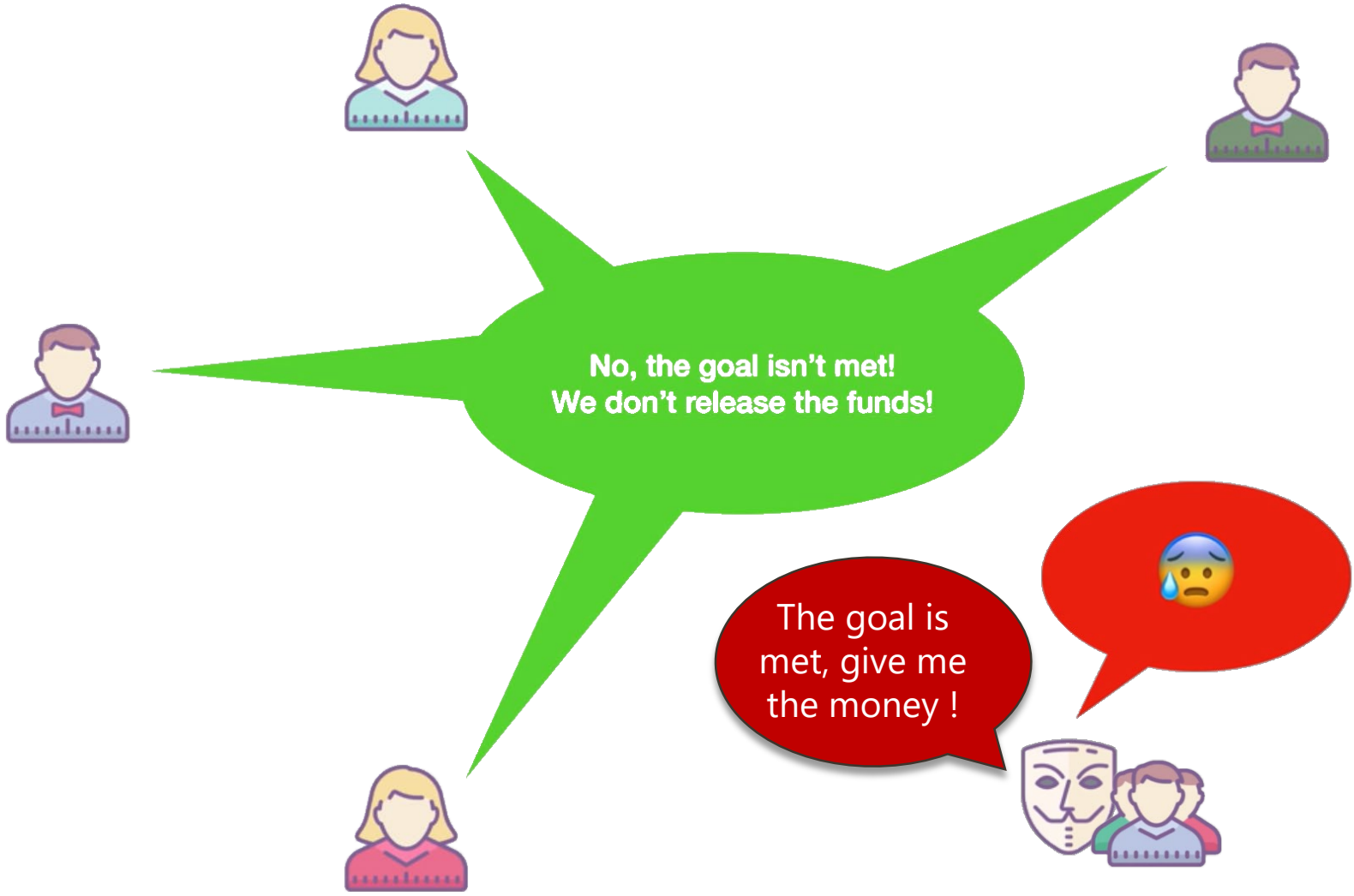
- **Hold all the money** until a certain goal is reached
- **If reached, money will be debited to the project**
- **If failed, money will be refunded**
- This is an **automatic process**



Extending the Idea

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- Banks could use to issue loans / automatic loan payments

Banks
Loans
Automatic payments

Insurance
Process claims

Postal
Payment on delivery

Medical records

E-notary

Collecting taxes

Blockchain in Logistics

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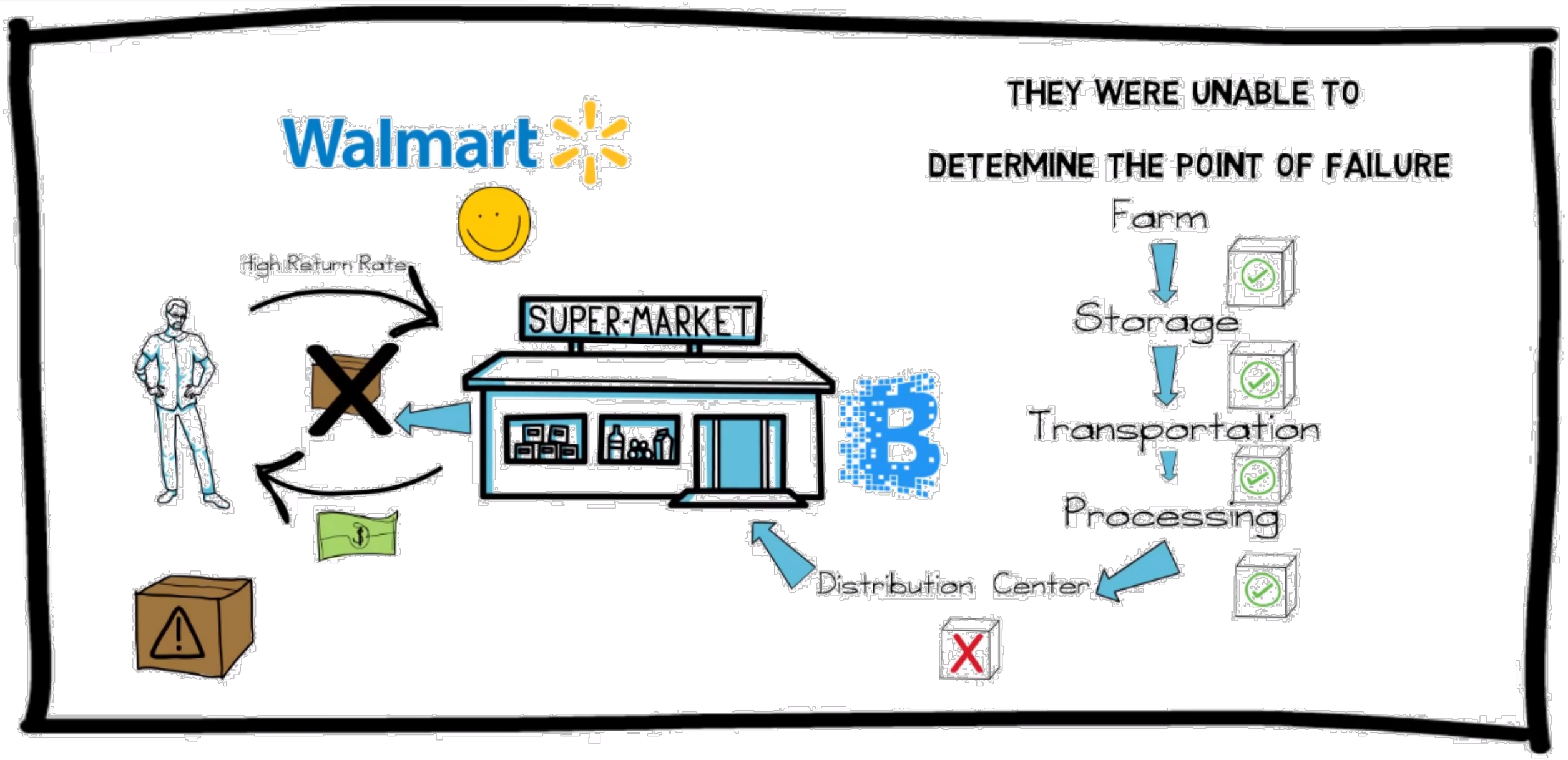

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Future of Networking

- More Emerging Networking Technolodgy
  - Network Automation
  - Wireless Technology
  - Networking Hardware

More Emerging Network Tech

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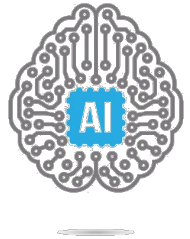
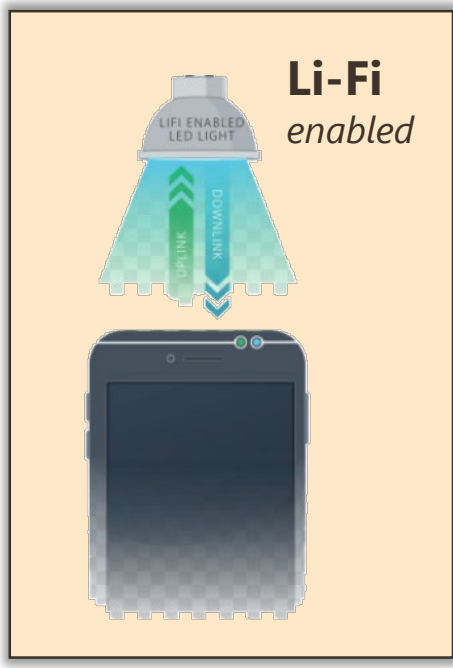
- Software-Defined Wide Area Network **(SD-WAN)**
- Networking **automation with Machine Learning /**

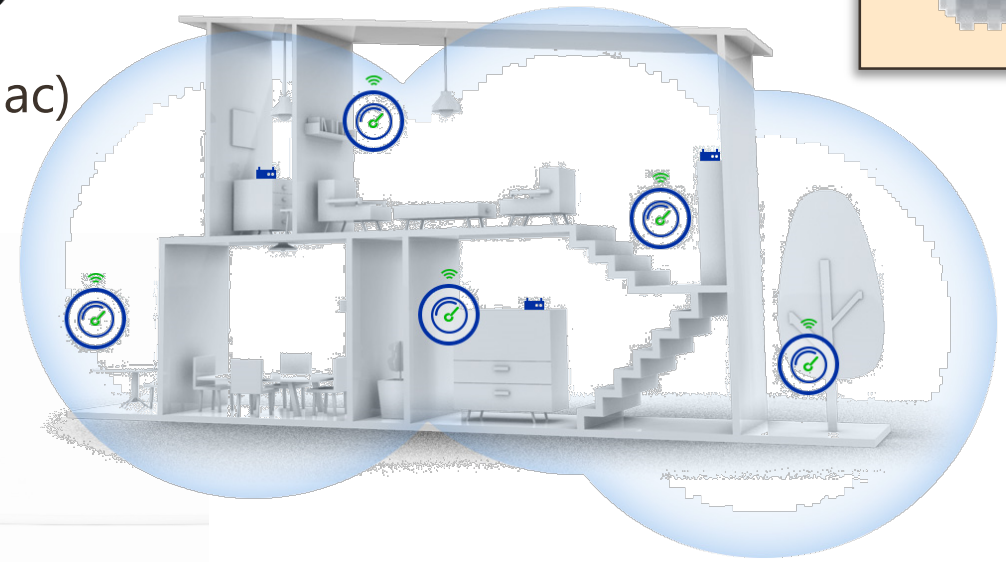


- **Wireless Technology**
  - Wi-Fi 6
  - Li-Fi



- **Home Networking Hardware**

  - Gaming Routers (tri-band, MU-MIMO, 802.11ac)
  - Mesh WiFi
    Smart wireless extender
  - Intelligent Google Nest WiFi
  - Networking via power lines



What does the network of the future look like?

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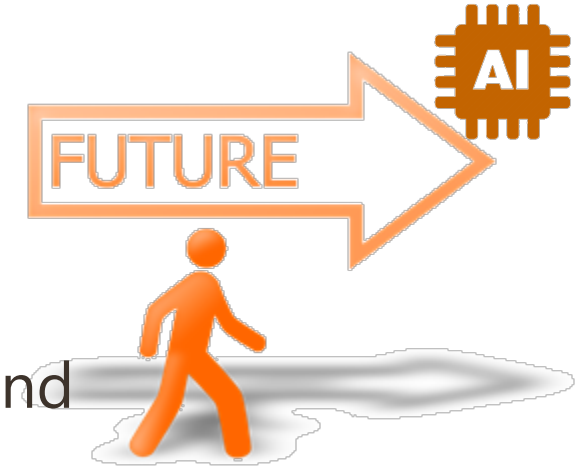

- Fast, smart and increasingly **autonomous**.
- **Self-driving, self-healing** and **self-operating** most of the time, and help solve problems across all industries and organizations.
- E.g., remotely connecting doctors with their patients or **powering next-level robotics**, to **identifying mission-critical parts** wherever they are within the supply chain on Earth and **sending them up to** the **international space station** when they're needed.
- The power of these autonomous networks and the freedom they provide to organizations around the world will be **almost limitless**.

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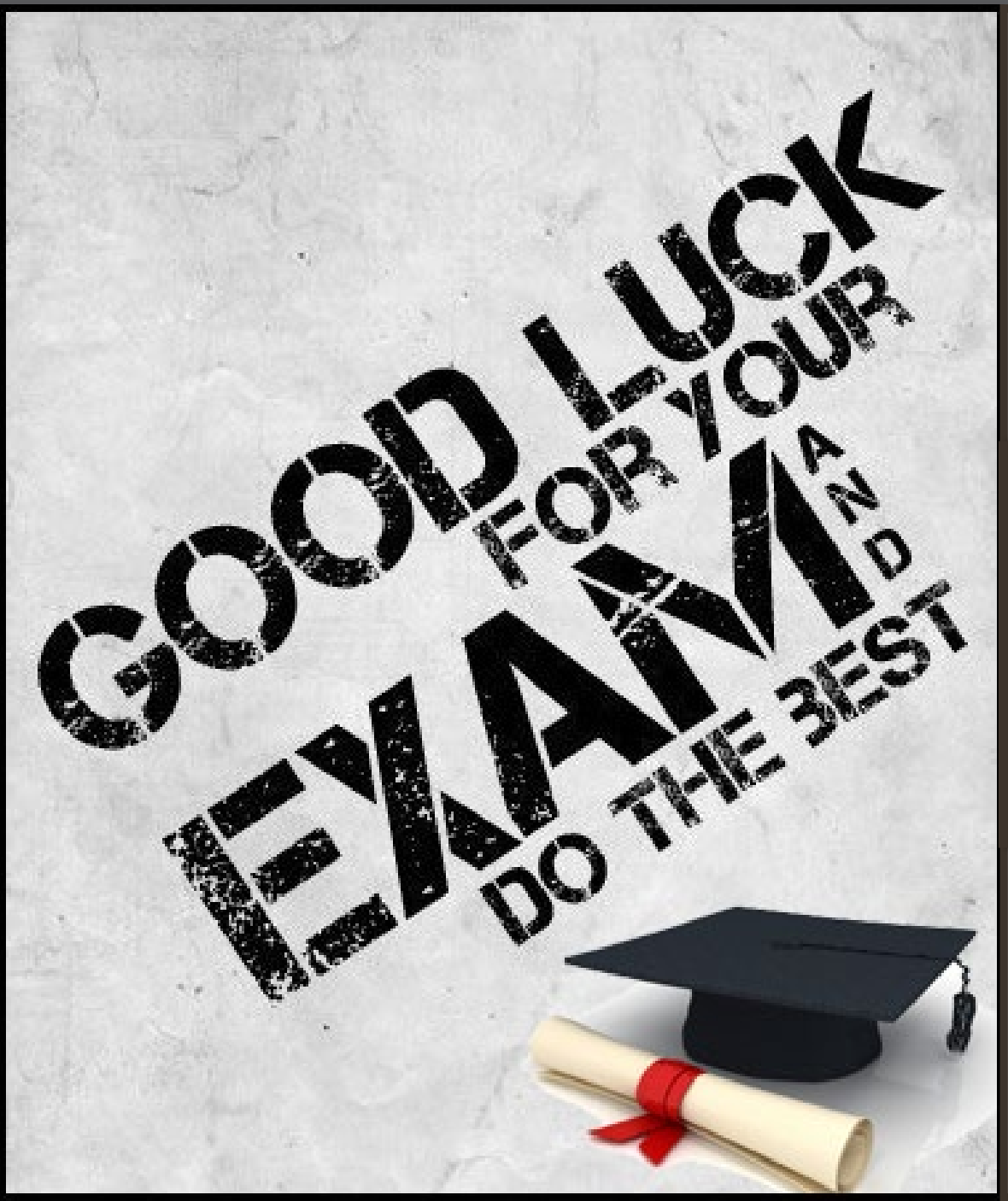
- **IoT**
  - Main categories
  - Applications
- **SDN**
  - Fundamentals
  - SDN Model
  - SDN Benefits
- **Blockchain**
  - Fundamentals
  - Block Tampering
    - Proof of Work
    - Distributed Consensus
  - Public and Private Blockchains
- **Blockchain - Bitcoin**
  - Fundamentals
  - Ledger
    - Adding Transactions
    - Verifying Transactions
    - Proof of Work
      - Miners
      - Participants
  - Bitcoin vs Legacy Financial System
  - Challenges
    - Proof of Work Issues
  - Proof of Stake
- **Blockchain – Other Applications**
  - Smart Contract
  - Other Blockchain Applications
  - Blockchain in Logistics
- **Future of Networking**
  - Wireless Technology
  - Networking Hardware



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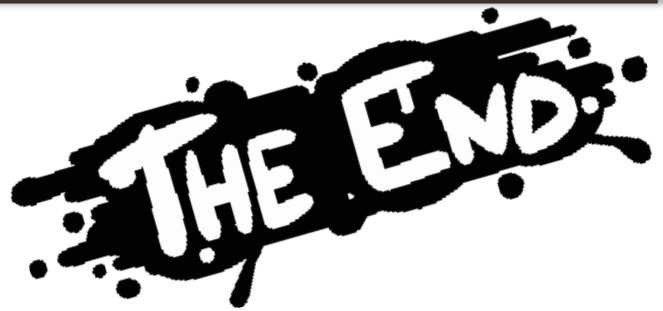


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THANK YOU
Make tomorrow better.