Cybersecurity Management
T9 – Blockchain

2025-2026
Marc Ruiz
marc.ruiz-ramirez@upc.edu
Fernando Agraz
fernando.agraz@upc.edu

Blockchain 101

Definition

Distributed and immutable ledger that facilitates the process of recording transactions and tracking assets in a business network.

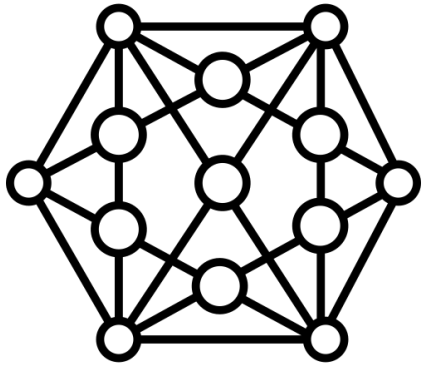
- Tangible assets: houses, cars, cash, land.
- Intangible assets: intellectual property, patents, copyrights, branding.

Blockchain is a unique system that allows the storing of data in a way that it becomes nearly impossible to tamper the existing data or cheat the system.

Source: IBM®

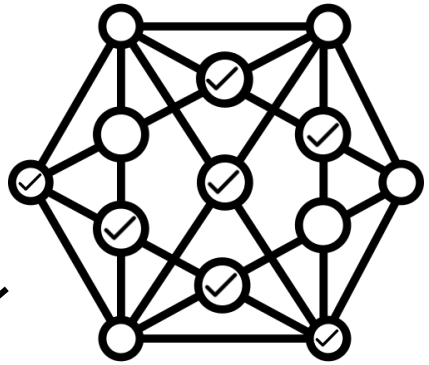
How does it work?

A member signs and sends a **transaction/data** request to the network.

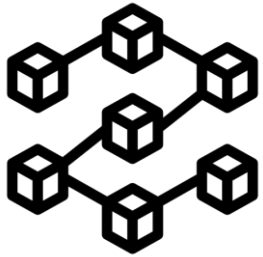


The transaction is received by the nodes of a P2P network and enters their **mempool** (waiting area) to be validated.

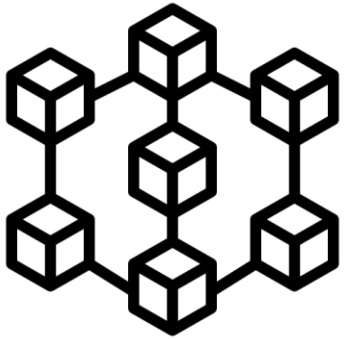
A node selects a set of valid transactions from the mempool and assembles them into a candidate **block**. The **consensus proof** is done to finalize the block.



The solved block is broadcast. The rest of the network **verifies the proof/attestations and transactions**. If the majority approves the block is deemed valid.



The accepted block is **cryptographically linked** to the existing chain.



The update is **distributed** across the network.

The transaction is finalized. It is now considered **immutable**.

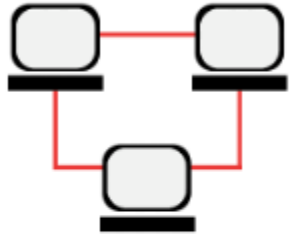
Main features

DECENTRALIZED

- The control/ power is not held by a single entity. Instead it is distributed among multiple participants.
- Even if one node is corrupted/ fails, the network repairs itself.

PEER TO PEER

- Direct peer to peer transaction of data or finance.
- Decentralized nature of blockchain instills trust in the process such that two unknown parties can directly interact/ transact with each other



DISTRIBUTED

- Data is distributed among the nodes(computers/ hard drives).
- Even if one node is tampered, the data does not get compromised.

Source: https://freemanlaw.com

Some use cases

Cryptocurrencies

- Blockchain originally designed to manage digital currencies like bitcoin. Given the anonymity of crypto coins, blockchain is the only way to keep track of transactions with accuracy and privacy for all parties concerned.

Protection against money laundering

- The encryption that is crucial to the blockchain once again comes in handy when fighting money laundering.

Trade finance

- Blockchain can digitize trade finance to make it more efficient, transparent, simple, affordable, and robust.

Supply chain transparency

- Customers may have complete insight and transparency into the items they purchase using a blockchain-based technology that tracks items from the manufacturing point through the supply chain.

Some use cases

Smart contracts

- Computer protocols that execute the terms of an agreement between peers without the need for third-party verification or approval.

IoT

- Include supply chain management, asset tracking, and keep track of machine readings taken worldwide.

Healthcare

- Managing electronic medical record data, preserving health information, safeguarding information, and monitoring disease and epidemics.

Art

- Non-fungible tokens (NFTs) have enabled the creation of crypto art.

Gaming

- Offers new possibilities such as genuine asset ownership, consensus-driven updates, decentralized marketplaces, simplified tokens.

Some use cases

Energy

- metering, billing, clearing procedures, asset management, origin guarantees, emission allowances, and renewable energy certificates.

Artificial Intelligence

- Immutability and the fact that every computer continuously verifies information on the network make it an ideal solution for big data.

Electronic voting

- The government could tally votes more efficiently and effectively because each vote would be attributed to one ID.

Security

- Self-sovereign identity, secure data transmission, private messaging.

Cybersecurity

- Because of inherent and intrinsic blockchain features.

Key elements

Distributed ledger

- Is the consensus of replicated, shared, and synchronized digital data that is geographically spread (distributed) across many sites, countries, or institutions.
- Does not require a central administrator.
- Does not have a single (central) point-of-failure.

Nodes

- The computers connected to the network that validate transactions.
- Maintain a copy of the ledger.
- Ensure the rules of the consensus mechanism are followed.

Transactions

- The fundamental action recorded on the blockchain, representing the movement of an asset (like cryptocurrency) or a piece of data from one party to another.

Key elements

Immutable records

- Once the transaction is recorded in the ledger, there is no way any blockchain participant can tamper with the data or make changes.
- In case the transaction records an error, a new transaction must be added to reverse and eliminate the error.

Smart contracts

- Self-executing agreements with the terms of the agreement written directly into code, which automatically execute when pre-defined conditions are met.
- Eliminate the need of an intermediary.
- These contracts involve information like terms for travel insurance, conditions for corporate bond transfers, and so on.

Benefits

Greater Trust (*Trustlessness*)

- Trust is placed in the code, cryptography and decentralized consensus.
  - Immutability and Security → Integrity
  - Transparency and Traceability → Verifiability
  - Decentralization → Neutrality
- Data can be 100% confidential in some blockchain implementations.
  - Private and Zero-knowledge blockchains.
  - Public → Pseudonymity, Data hash storage only.

Decentralized Structure

- No third-party involved or intermediaries included.
- Prevents single point-of-failure.

Maximum Security

- Blockchain builds an unaltered ledger with end-to-end encryption.
- The data is never stored in a single computer; eliminating the chances of unauthorized activities such as hacking.

Benefits

Reduced Cost

- Due to decentralization.

Speed

- No intermediaries and fewer manual interventions, much faster and more reliable transactions.

Individual Control Of Data

- Individuals and institutions have the power to decide with whom and for how long they want to share a piece of information or want to keep it confidential.

Visibility And Traceability

- Manage inventory, confirm the history, respond to problems within time. Blockchain can easily track the origins of various items.

Immutability

- Once the transaction is recorded on the blockchain, there is no way it can be changed or removed or tampered with.

Blockchain network types

Public

- Anyone can join and participate in, e.g. Bitcoin.
- Substantial computational power required.
- Little or no privacy for transactions.
- Updates and governance → Harder to patch critical issues quickly.

Private

- One organization governs the network, controlling who is allowed to participate, execute a consensus protocol and maintain the shared ledger.
- Significantly boost trust and confidence between participants.
- Privacy controls.
- Faster updates and governance.
- Higher centralization risk.
- Single points of failure.

Blockchain network types

Permissioned

- Private blockchain will generally set up a permissioned blockchain network (also public can be).
- Places restrictions on who is allowed to participate in the network and in what transactions.
- Participants need to obtain an invitation or permission to join.

Consortium blockchains

- Multiple organizations can share the responsibilities of maintaining a blockchain.
- Ideal for business when all participants need to be permissioned and have a shared responsibility for the blockchain.

Types of nodes

Full nodes

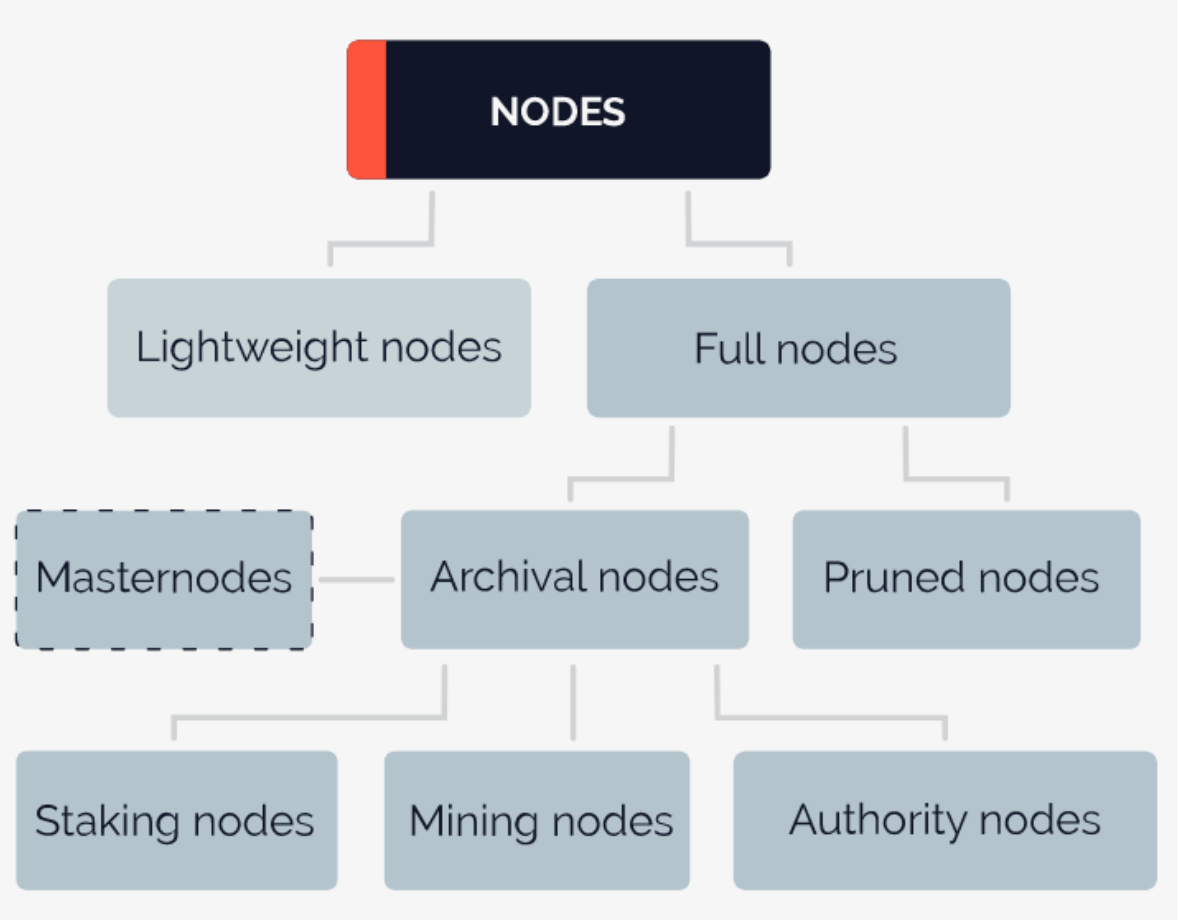
- Act as Servers.
- Preserve a blockchain's transaction history, sync, store, copy and distribute data while also validating new blocks.
- Can be **pruned** (contain metadata of all blocks + only recent blocks) or **archival** (contain the entire blockchain ledger).

Lightweight nodes

- Act as Clients.
- Store minimal amount of data (block headers).
- Rely on Full nodes to verify transactions.

Authority nodes

- Act as Moderators of a private or partially centralized blockchain.



Types of nodes

Master nodes

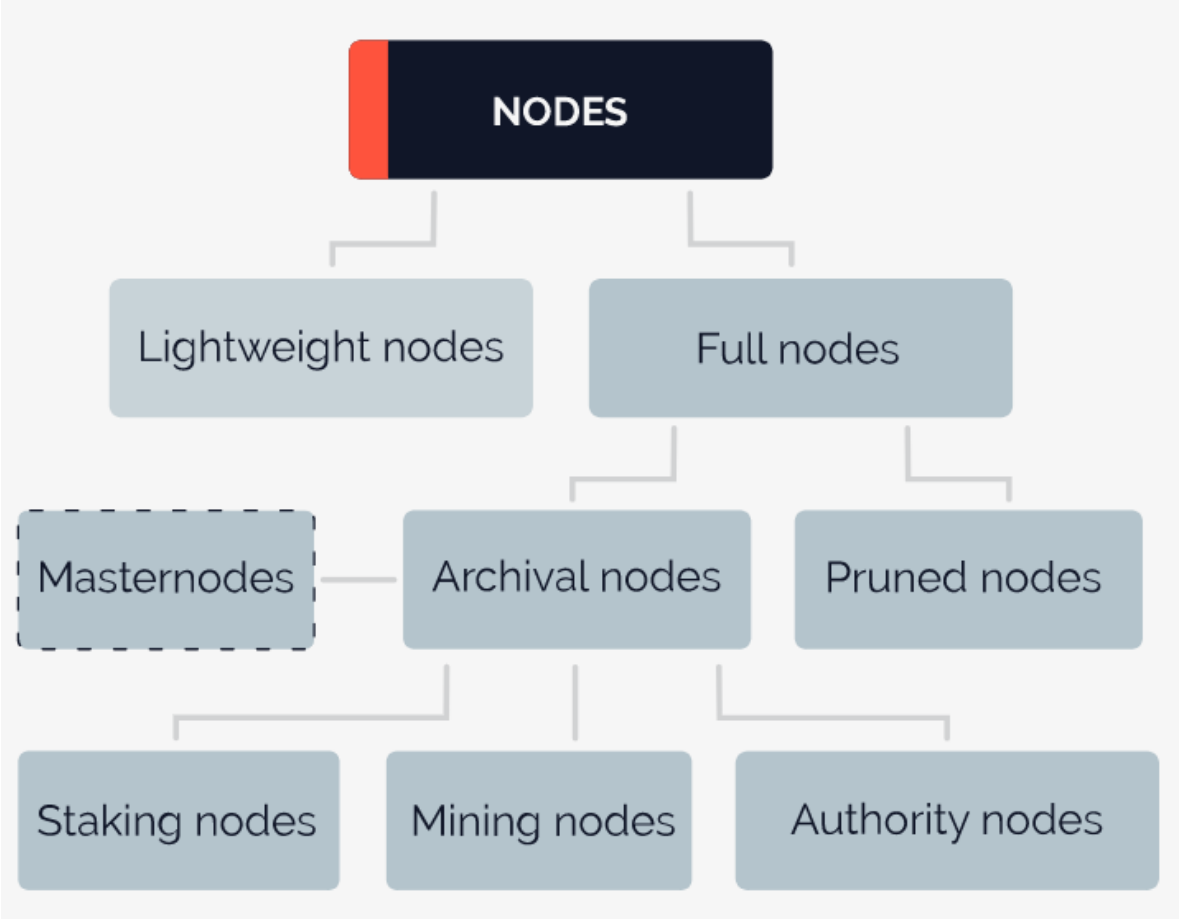
- Validate transactions and maintain records. They do not generate new blocks.

Mining nodes

- Verify transactions using a proof-of-work consensus model, unlock tokens and add new blocks to a blockchain.
- Miners are computers, typically working in a group, that are owned by an entity, such as an individual or company.

Staking (Validator) nodes

- In proof-of-stake consensus model, they are selected to propose and attest new blocks.
- Must stake a certain amount of the network's cryptocurrency to have chance to be selected as Validators.



Platforms

IBM Blockchain Platform

- https://www.ibm.com/products/blockchain-platform/demos/build-your-blockchain-network/now-any-developer-can-become-a-blockchain-developer

Ethereum

- https://ethereum.org/en/learn/

Hyperledger

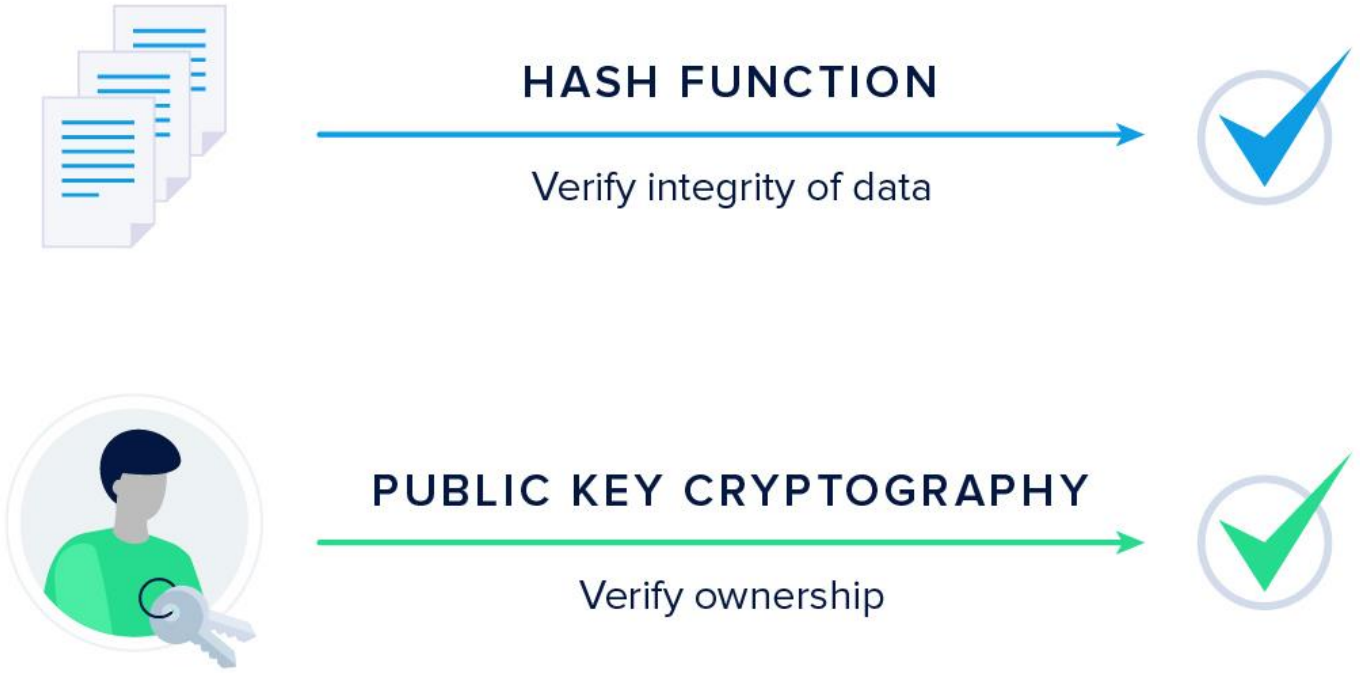
- https://www.hyperledger.org/use/tools

Blockchain Security

Why is Blockchain considered secure?

- Decentralization
- Cryptography
- Immutability
- Consensus mechanisms

Cornerstones

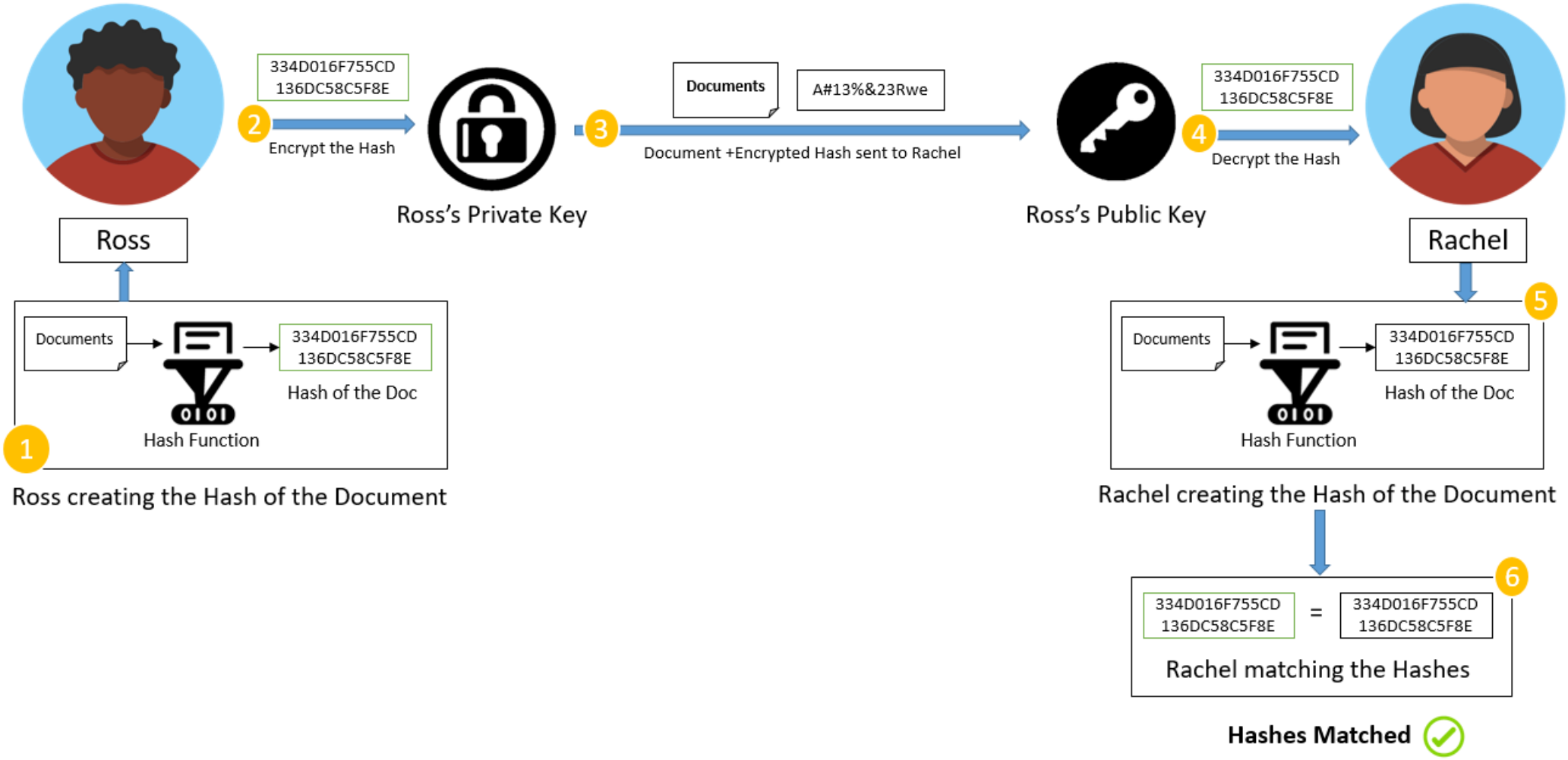


Source: https://www.horizen.io/

Public Key Cryptography

- Asymmetric cryptography, to verify ownership.
- Every user creates two keys when he/she joins the network: a public, and a private key.
- Public key (“address”) → shared, known between peers
- Private key (“password”) → never leave from owner
- Elliptic Curve Cryptography is widely used → ECDSA.

Digital Signature



Transaction Validation

Signature check

- Verifies the sender's **cryptographic signature** using their public key to prove the transaction was authorized by the private key owner.

Balance check

- Confirms the sender has **sufficient funds or assets** to complete the transaction and that the assets have not been **double-spent** (used already).

Execute scripts / smart contracts (if applicable)

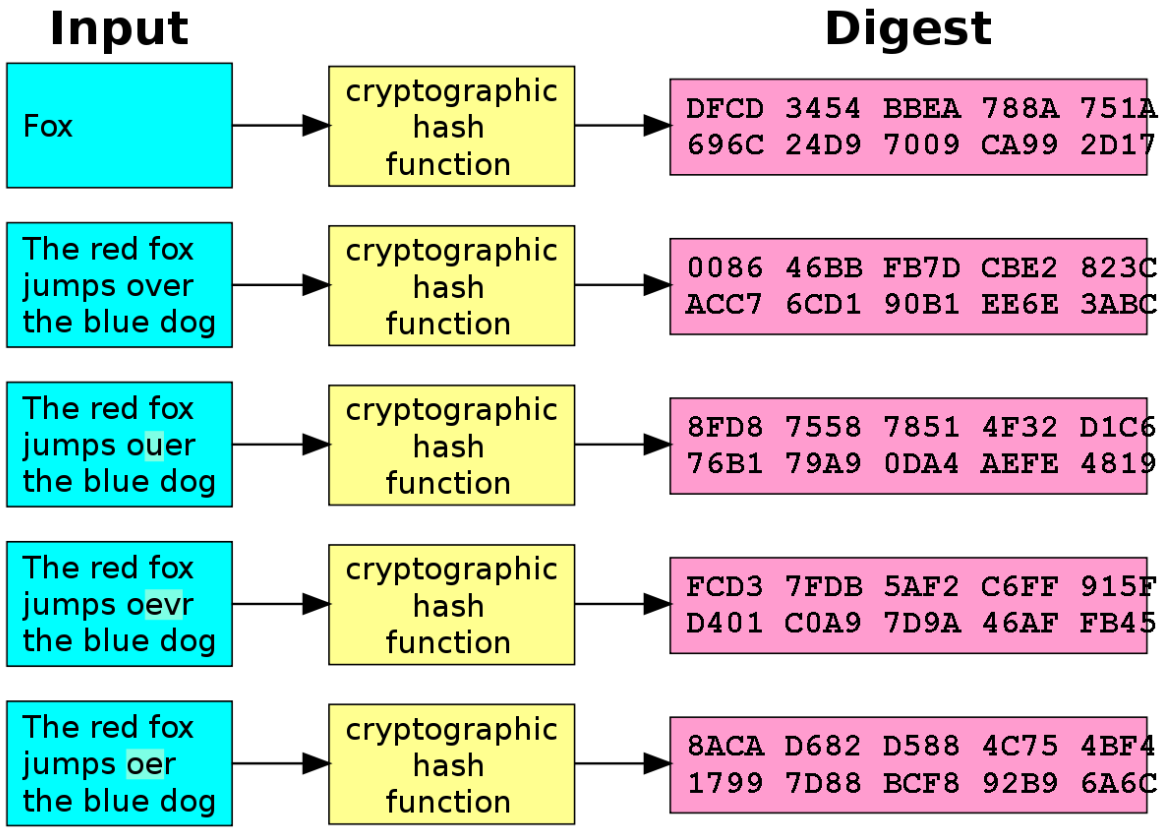
- Includes loops, storage updates, and gas calculations.

Formatting check

- Ensures the transaction data adheres to the network's rules (e.g., correct data fields, minimum/maximum fee).

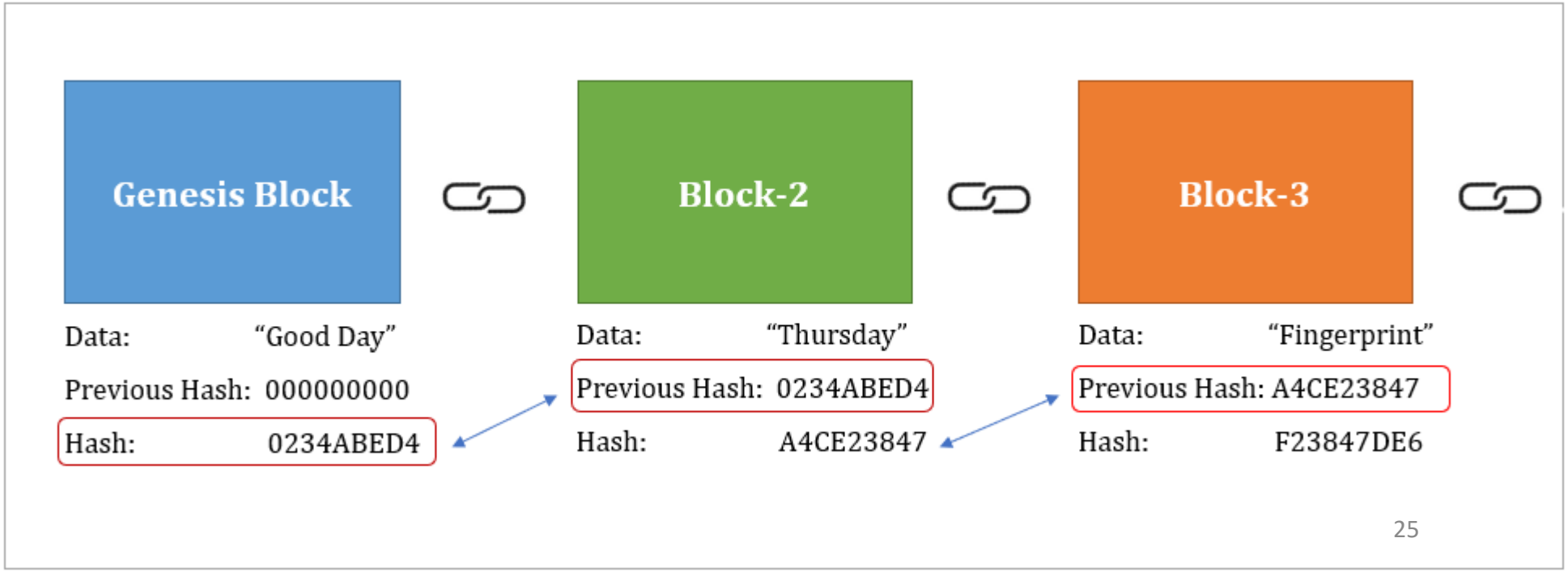
Hash Function

- Transform a variable size input message into a fixed size output hash (digest)
- Deterministic : one input → same hash
- Collision resistant: Two different messages do not have same hash.
- Quick to compute and infeasible to reverse the process (one-way).
- Avalanche effect: Small change in the message changes the hash drastically.



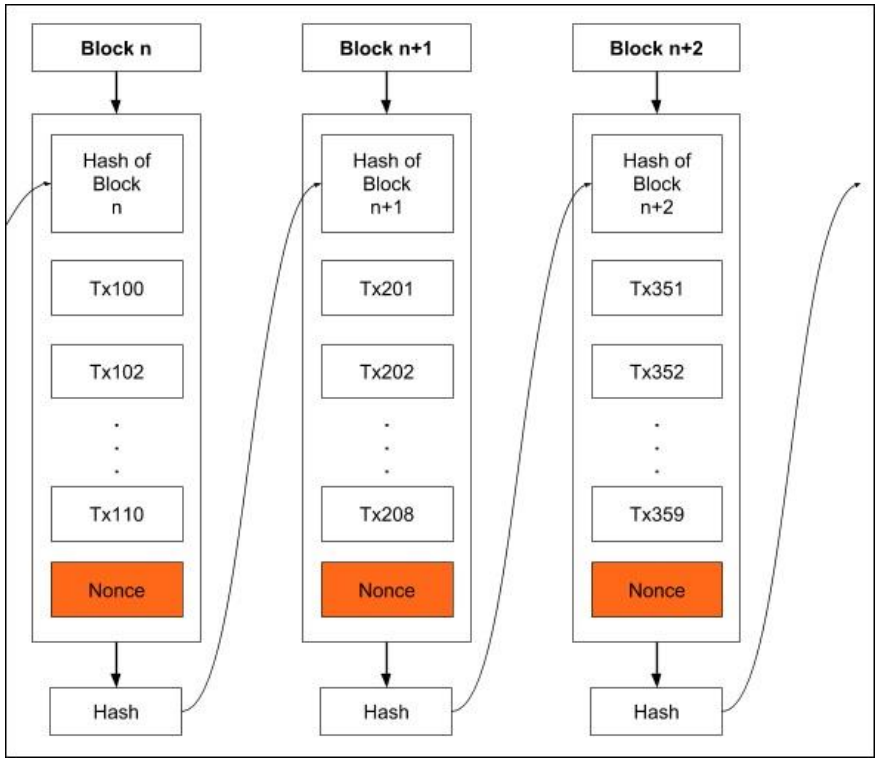
Hashing in Blockchain

- Basic cryptographic technique used in blockchain
  - SHA256 algorithm: https://sha256algorithm.com/
- Fingerprint of transactions/blocks added in a chain
- Allow easily checking if something has been changed in the transactions' history.



Block Validation

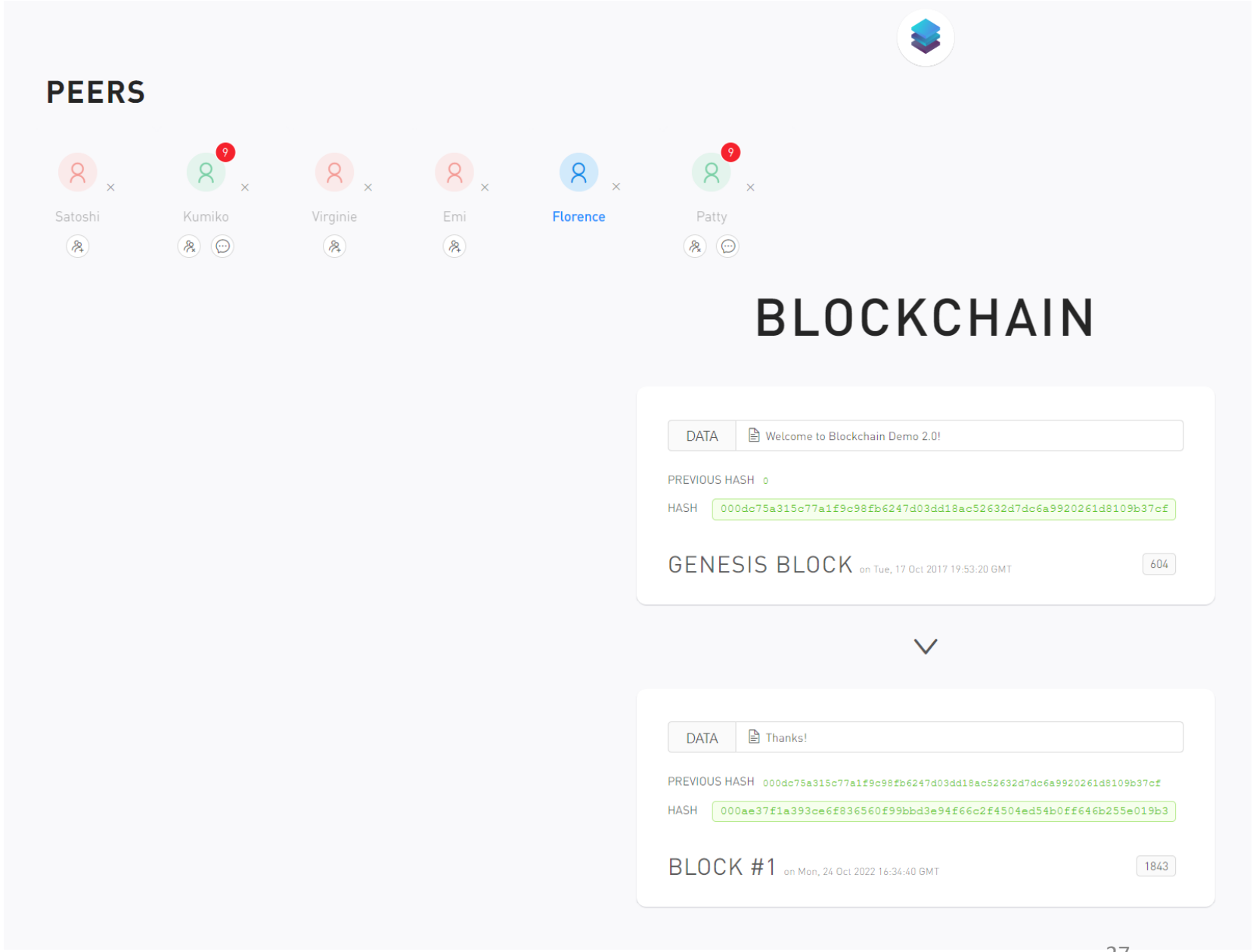
- Setting an arbitrary number of consecutive zeros is a proof of validation, i.e., the block is signed.
  - Part of the contract
- A **nonce** (number user only once) needs to be appended to transactions in order to obtain hash messages with the target number of zeros
- Mining nodes are responsible of finding the nonce that accomplishes



https://www.youtube.com/watch?v=_160oMzblY8

Demos

- https://blockchaindemo.io/
- Useful to fix concepts such as hashing, avalanches, …



Proof-of-Work (PoW) vs Proof-of-Stake (PoS)

- Under **PoW**, block creators are called miners
  - Miners work to solve a hashing problem to verify transactions.
  - In return for solving it, they are rewarded (e.g., with a coin).

- Under **PoS**, block creators are called validators.
  - A validator checks transactions, verifies activity, votes on outcomes, and maintains records.
  - Validators lock up (**stake**) their own cryptocurrency as collateral.
  - A reward is given in the form of newly-minted tokens (e.g., coins) plus transaction fees if a new block is validated.
  - But if a block is wrongly verified, a part of the stake will be lost as a penalty (**slashing**). This enforces honest behavior.

Proof-of-Work (PoW) vs Proof-of-Stake (PoS)

Proof of Stake	Proof of Work
Block creators are called validators	Block creators are called miners
Participants must own coins or tokens to become validators	Participants must buy equipment and energy to become a miner
Energy efficient	Not energy efficient
Security through community control	Robust security due to expensive upfront requirement
Validators receive transaction fees as rewards	Miners receive block rewards and fees

https://www.investopedia.com/terms/p/proof-stake-pos.asp#toc-how-is-proof-of-stake-different-from-proof-of-work

Common Attacks

Sybil Attack

- Manipulate **P2P networks** creating multiple fake identities.
- A single entity controls all these fake entities (impact on voting).
- PoW and PoS are sybil-resistant mechanisms:
  - PoW resistance is based on **computational cost**.
  - PoS resistance is based on **economic cost**.
  - Extra risk mitigation by introducing or raising the cost to create an identity.

51% attack (endemic attack)

- If a participant controls 51% of the network, he could out-mine the network and hack the blockchain.
  - PoW → 51% of computation power (hash rate)
  - PoS → 51% of staked currency
- Highly unfeasible in major blockchains
- Potential goals:
  - Double-spend
  - Censorship
  - DDoS

Common Attacks

Smart contract vulnerabilities

- Security risk is primarily in the **quality and logic of the code itself**, as deployed code is immutable.
  - Reentrancy attacks.

Phishing

- **Private Key theft:** The private key is the **sole proof of ownership** for digital assets. If it is lost, forgotten, or stolen, the assets are gone forever, even though the blockchain itself is secure.
  - Malware or poor storage can also lead to private key theft.

Other attacks:

- Byzantine Generals Problem
- DDOS

More information:
https://www.horizen.io/blockchain-academy/technology/advanced/attacks-on-blockchain/

Good Practices

Governance specific to blockchain.

- Determine how new users or organizations join or leave the network.
- Enable mechanisms to remove bad actors, manage errors, protect data and address conflicts between parties.

Data security

- Data minimization is a general best practice for determining what data is stored on-chain.
- Additional security measures should be applied to sidechains (off-chain), hash data, data in transit, cloud storage.

Network security

- Network connections from multiple parties beyond a single corporate network must interact, including IT and networking infrastructure, databases, servers and more, all of which introduce potential for security flaws or exploits

Good Practices

Application security

- Critical point of vulnerability (access to the blockchain).
- Need strong user authentication and endpoint protections.

Smart contracts security

- Another point of vulnerability because their integrity determines the reliability of the operation and trustworthiness of the results.

Interoperability

- How data, identities and interactions occur across networks, applications and smart contracts at scale.
- Threats increase as interfaces and systems complexity expand.

Use of trusted auditors and third parties

- Security assessments, penetration tests, and audits of smart contracts, source code and blockchain infrastructure should only be conducted by trusted parties.

ENISA & Blockchain

Crypto Assets: Introduction to Digital Currencies and Distributed Ledger Technologies

- Released February 2021
- This report aims to increase the understanding of blockchain technologies. It explains the underlying technical concepts and how they relate to each other.
- The goal is to explain the components, and illustrate their use by pointing to deployed instances where the ideas are utilized.

https://www.enisa.europa.eu/publications/crypto-assets-introduction-to-digital-currencies-and-distributed-ledger-technologies

References

- https://www.ibm.com/topics/what-is-blockchain
- https://www.horizen.io/blockchain-academy/technology/advanced/
- Blockchain 101: A visual demo
    - https://www.youtube.com/watch?v=_160oMzblY8
- https://www.infosys.com/insights/cyber-security/cybersecurity-blockchain.html

Cybersecurity Management
T9 – Blockchain

2025-2026
Marc Ruiz
marc.ruiz-ramirez@upc.edu
Fernando Agraz
fernando.agraz@upc.edu