Introduction to Blockchain

Dr. Ashok Kumar Das

IEEE Senior Member
Associate Professor
Center for Security, Theory and Algorithmic Research
International Institute of Information Technology, Hyderabad
(Formerly **Indian Institute of Information Technology, Hyderabad**)

E-mail: *ashok.das@iiit.ac.in*
Homepage: http://www.iiit.ac.in/people/faculty/ashokkdas
Personal Homepage: https://sites.google.com/view/iitkgpakdas/

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What is Blockchain?

- A blockchain is considered as a chain of blocks that are created from several blocks and it potentially consists of information.
- By the words "block" and "chain", we actually specify in the context of digital information ("block") which is stored in a public domain say database ("chain").
- Since the digital information is stored in the form of "block" and it is linked in a "chain" form, the linked blocks constitute a chain, and hence, the name "blockchain".
- The blockchain's first block is known as the **Genesis block**.

What is Blockchain?

The reasons why the blockchain have gained so much admiration are that:

- It is not owned by a single entity, hence it is **decentralized**
- The data is **cryptographically** stored inside
- The blockchain is **immutable**, so no one can tamper with the data that is inside the blockchain
- The blockchain is **transparent** so one can track the data if they want to

Three Pillars of Blockchain Technology

- Decentralization
- Transparency
- Immutability

Pillar #1 : Decentralization

- Example of a centralized system is banks. They store all your money, and the only way that you can pay someone is by going through the bank.
- The traditional client-server model is a perfect example of this.
- When you google search for something, you send a query to the server who then gets back at you with the relevant information. That is simple client-server.

Pillar #1 : Decentralization
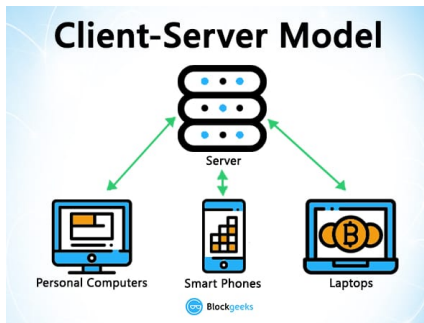
The centralized systems have treated us well for many years, however, they have several vulnerabilities.

- Firstly, because they are centralized, all the data is stored in one spot. This makes them easy target spots for potential hackers.
- If the centralized system was to go through a software upgrade, it would halt the entire system
- What if the centralized entity somehow shut down for whatever reason? That way nobody will be able to access the information that it possesses
- Worst case scenario, what if this entity gets corrupted and malicious? If that happens then all the data that is inside the blockchain will be compromised.

Pillar #1 : Decentralization

- In a decentralized system, the information is not stored by one single entity. In fact, everyone in the network owns the information.
- In a decentralized network, if you wanted to interact with your friend then you can do so directly without going through a third party.
- That was the main ideology behind Bitcoins. You and only you alone are in charge of your money. You can send your money to anyone you want without having to go through a bank.

Pillar #1 : Decentralization

The New Networks

Centralized
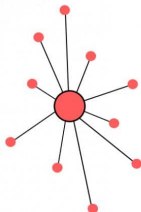
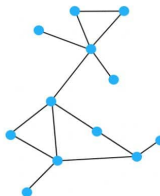**Decentralized**

Centralized systems have a core authority that dictates the truth to the other participants in the network.

Only privileged users or institutions can access the history of transactions or confirm new transactions.

Decentralized systems have no core authority to dictate the truth to other participants in the network.

Every participant in the network can access the history of transactions or confirm new transactions.

Blockgeeks

Pillar #2 : Transparency

- While the person's real identity is secure, you will still see all the transactions that were done by their public address.
- This level of transparency has never existed before within a financial system.
- It adds that extra, and much needed, level of accountability which is required by some of these biggest institutions.

Pillar #3 : Immutability

- Immutability, in the context of the blockchain, means that once something has been entered into the blockchain, it cannot be tampered with.
- The reason why the blockchain gets this property is that of cryptographic hash function.

INPUT	HASH
Hi	3639EFCD08ABB273B1619E82E78C29A7DF02C1051B1820E99FC395DCAA3326B8
Welcome to blockgeeks. Glad to have you here.	53A53FC9E2A03F9B6E66D84BA701574CD9CF5F01FB498C41731881BCDC68A7C8

| INPUT	HASH
This is a test	C7BE1ED902FB8DD4D48997C6452F5D7E509FBCDBE2808B16BCF4EDCE4C07D14E
this is a test	2E99758548972A8E8822AD47FA1017FF72F06F3FF6A016851F45C398732BC50C

Maintaining the Blockchain – Network and Nodes

- The blockchain is maintained by a peer-to-peer (P2P) network.

- The network is a collection of nodes which are interconnected to one another.

- Nodes are individual computers which take in input and performs a function on them and gives an output.

- The blockchain uses a special kind of network called *peer-to-peer network* which partitions its entire workload between participants, who are all equally privileged, called *peers*.

- There is no longer one central server, now there are several distributed and decentralized peers.
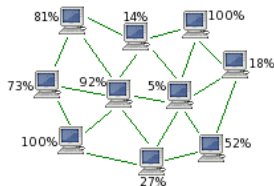

Peer to Peer Network

Maintaining the Blockchain – Network and Nodes
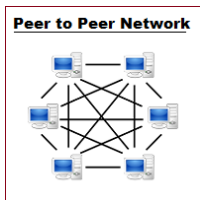
- One of the main uses of the peer-to-peer network is file sharing, also called torrenting.

Traditional Centralized Downloading

downloaders

central web-server
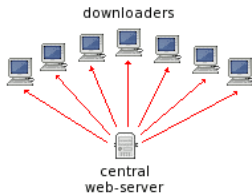
- Slow
- Single point of failure
- High bandwidth usage for server

Decentralized Peer-to-Peer Downloading

81% 14% 100%

73% 92% 5% 18%

100% 52%

27%

- Fast
- No single point of failure
- All downloaders are also uploaders

Types of blockchain

- **Public (Permissionless) Blockchain**: Everyone has the right to join, access, send, verify and receive transactions of the blocks in the blockchain to create a consensus. One widely successful permissionless blockchain is *bitcoin*.

- **Private (Permissioned) Blockchain**: The owner of the network decides which node to assign the right to access, send, receive, join and verify the block for creating an agreement between the nodes. Example: Healthcare Applications

- **Consortium or Hybrid Blockchain**: Internet of Vehicles (IoV) application
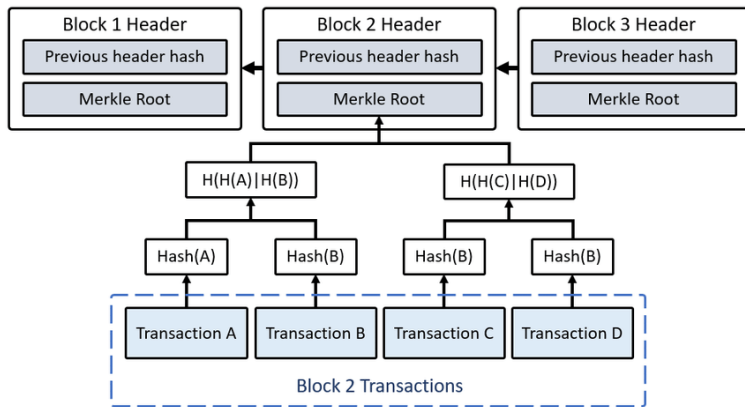
How to Make a Merkle Tree?
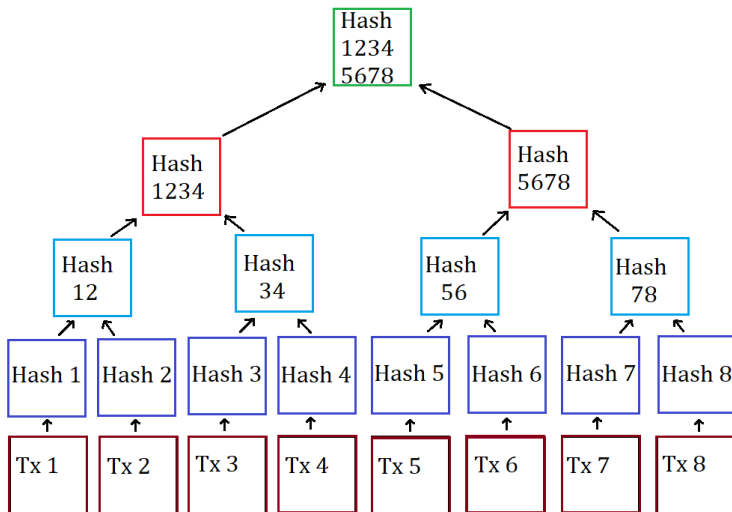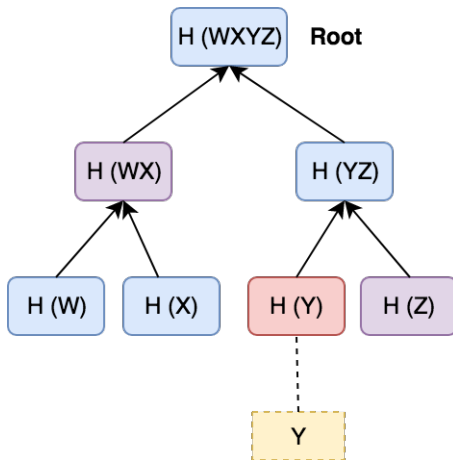

Tx_i: i^{th} transaction; H_i: Hash of ith transaction ($H_{Tx_i} = H(Tx_i)$);
$H_{Tx_1 Tx_2} = H_{Tx_1} \oplus H_{Tx_2}$; $H_{12345678}$: Merkle root

Use of Merkle Tree in Blockchain

To confirm transaction Y, one only needs to know:
$H(WX)$**,** $H(Y)$**,** $H(Z)$ **and** $H(WXYZ)$**;** $H(\cdot)$**: hash function**

Types of blockchain

Block Header	
Block Version	BV
Previous Block Hash	PBHash
Merkle Tree Root	MTR
Block Type	Public
Timestamp	TS
Owner of Block	ES_l
Public key of signer (ES_l)	Pub_{ES_l}
Block Payload (Transactions)	
Transaction #1	Tx_1
Transaction #2	Tx_2
$\vdots$	$\vdots$
Transaction #n_t	Tx_{n_t}
Current Block Hash	CBHash
Signature on block using ECDSA	BSign

Block Header	
Block Version	BV
Previous Block Hash	PBHash
Merkle Tree Root	MTR
Block Type	Private
Timestamp	TS
Owner of Block	ES_l
Public key of signer (ES_l)	Pub_{ES_l}
Block Payload (Encrypted Transactions)	
Encrypted Transaction #1	$E_{Pub_{ES_l}}(Tx_1)$
Encrypted Transaction #2	$E_{Pub_{ES_l}}(Tx_2)$
$\vdots$	$\vdots$
Encrypted Transaction #n_t	$E_{Pub_{ES_l}}(Tx_{n_t})$
Current Block Hash	CBHash
Signature on block using ECDSA	BSign

Block Header	
Block Version	BV
Previous Block Hash	PBHash
Merkle Tree Root	MTR
Block Type	Hybrid
Timestamp	TS
Owner of Block	ES_l
Public key of signer (ES_l)	Pub_{ES_l}
Block Payload	
Encrypted Transaction #1	$E_{Pub_{ES_l}}(Tx_1)$
Transaction #2	Tx_2
$\vdots$	$\vdots$
Encrypted Transaction #n_t	$E_{Pub_{ES_l}}(Tx_{n_t})$
Current Block Hash	CBHash
Signature on block using ECDSA	BSign

a) Formation of a block on public blockchain

b) Formation of a block on private blockchain

c) Formation of a block on consortium blockchain

Consensus mechanisms

Consensus mechanisms are used to verify transactional data between the nodes in a P2P network.

- **Byzantine Fault Tolerance (BFT)**: An agreement protocol which helps to tolerate the Byzantine failures in a network. BFT maintains the reliable record of transactions in a transparent and tamper-proof way, as long as the number of traitors does not exceed one-third of the general network nodes.

- **Practical Byzantine Fault Tolerance (PBFT)**: This consensus mechanism is used when BFT fails to tolerate the faults in a network system. The algorithm for PBFT works in asynchronous systems and is optimized to achieve high performance along with an impressive overhead runtime.

Practical Byzantine Fault Tolerance (PBFT)

For adding a block in the blockchain, the following procedures in PBFT are required:

- A leader acting as a miner will select by the leader selection algorithm for adding a block.

- Leader receives a block with block adding request from any nodes (or client) into the blockchain.

- Leader sends this block to every node in the network for verifying the transactions.

- After successful verification of the transaction in the block, each received node sends a valid reply for adding that block.

- Leader counts the received reply and checks the number of counts (say, RCount) if it is greater that the twice number of the faulty nodes, i.e., $RCount > 2n_f + 1$ or the two-third nodes give the same reply. The $2n_f + 1$ non-faulty or valid replies provide the liveness of the system, that is, the message delay need to be bounded in due course. If this condition is satisfied, the leader will add the block into the blockchain and broadcasts a commit for adding the block into their respective blockchain for backup purposes.

Consensus mechanisms

- **Proof-of-Work (PoW):** This is the original consensus mechanism used to verify the transactions and produce new blocks in the blockchain. Mining is a complex process, and miners need to demonstrate that they can validate the transaction block. Here, the miners are financially rewarded if they perform verification. Thus, as the complexity increases in the mining process over time, the power consumption also increases. In other words, PoW is a costly process as the miners compete with each other to solve a mathematical problem.

- **Proof-of-Stake (PoS)**: In 2017, Ethereum began the process of switching from a PoW mechanism to a PoS system. The latter was designed to mitigate the limitations of PoW, in terms of energy, cost, and processing time. Specifically, it adopts a forging process rather than the mining process to validate transaction blocks.

Consensus mechanisms

- **Delegated Proof-of-Stake (DPoS):** This is a fast, efficient, flexible and most decentralized consensus mechanism. DPoS holds the power of stakeholder for the approval of voting and resolving the consensus issues in an honest and representative way. The deterministic selection of witnesses allows the transactions to be confirmed on an average of just 1 second. This consensus mechanism is designed to protect all the participants in a free, fair, and transparent environment.

- **Proof-of-Burn (PoB)**: An alternative consensus protocol for PoS and PoW. In PoB mechanism, the miners prove that they burn one cryptocurrency to create another currency, i.e., they are sent to a bitcoin address which is unsupendable. Its significance depends on the burning tokens in an unrecoverable manner. As comparative to PoW/PoS, it is easily verifiable and hard to undo.