Hedera Hashgraph - A Survey Review as of Early 2021

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Abstract

Hedera Hashgraph provides a fast and efficient alternative to blockchains used by current distributed ledger technologies. This survey review investigates the project's technical innovation, history, governance and current status as of early 2021.

1 Background

Bitcoin[13] is a decentralised digital cryptocurrency that enabled transactions to be done without a central intermediary. It uses a distributed ledger technology (DLT) called the blockchain for participants to agree on their balances on the ledger. Ethereum[17], a second generation DLT, further improved the concept by enabling smart contracts to operate on the blockchain. While these early generation DLTs rose in popularity, wide-spread mass adoption has been limited due to blockchain's ability to scale.

Gossip protocols are known to efficiently broadcast information with high reliability and throughput[16]. Achieving consensus was historically done by sending votes across the network[5]. Sending votes across is an expensive operation that has not been reliably implemented in real-world conditions.

Hedera Hashgraph[3] combined a gossip protocol with the concept of virtual voting. This enabled the network to reach consensus in a more efficient manner than the proof-of-work system used in current blockchain implementations. As a result, it provides a fast, high-throughput, fair-ordering, and asynchronous Byzantine Fault Tolerant (aBFT) alternative to blockchain solutions.

2 Overview of the Hashgraph algorithm

Hashgraph uses standard cryptographic hashes and digital signatures to securely spread events across a network with the use of a gossip(Figure 1).It was mathematically proven that each member will eventually have a consistent local copy of a Hashgraph for each member to run virtual voting without the need to send votes across the network[3].

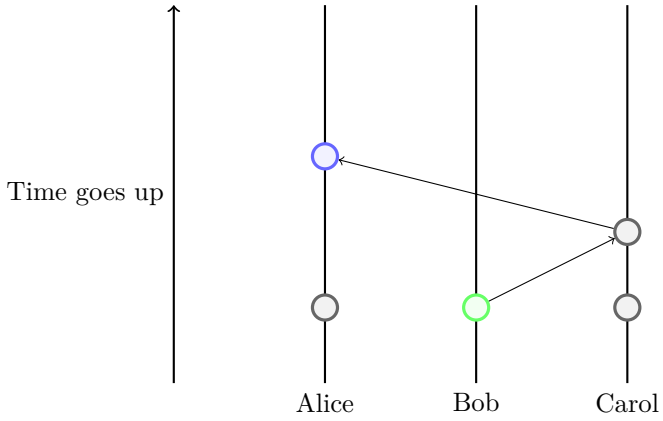

Figure 1: A simple example of how hashgraph spreads information via gossip. Bob randomly gossips to Carol, then Carol randomly gossips to Alice. Alice would have known what Bob and Carol spoke about without talking to Bob directly. Bob's green event is strongly seen by Alice's blue event as it was seen by at least 2/3 members along the way.

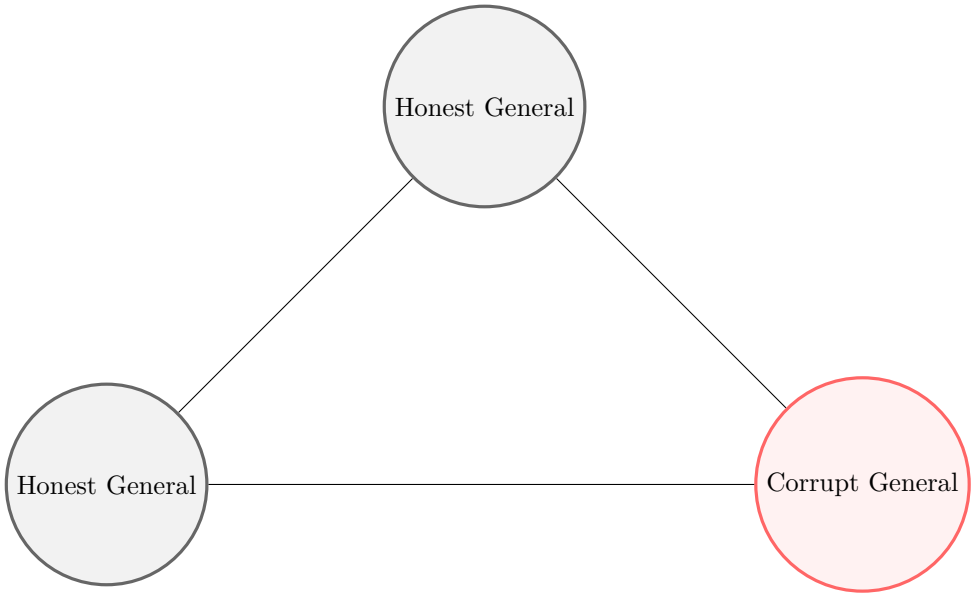

Figure 2: An illustration of the Byzantine Generals Problem. The Theorem states that consensus cannot be reached if 1/3 or more are malicious.

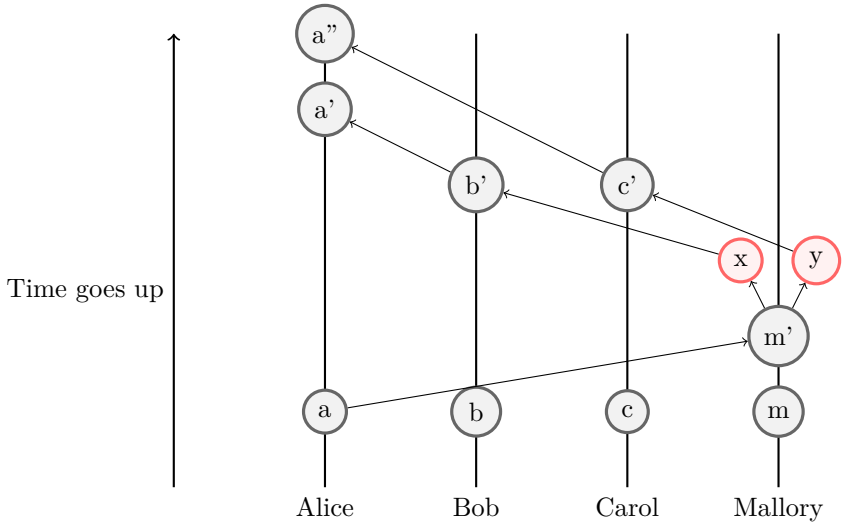

Figure 3: Suppose Mallory cheats by forking an event, eg: she could double spend her coins by gossiping two different events (x & y) to different members. The Strongly Seeing Lemma says that a forked event will not be strongly seen by honest members. A proof by contradiction shows that if 2/3 strongly sees x and 2/3 also strongly sees y, then this is impossible to be strongly seen if only less than 1/3 members are malicious. This violates the assumption that only less than 1/3 are malicious, as no honest member will strongly see both events. If Alice, Bob, and Carol are honest and communicate further, they will agree not to strongly see Mallory's events as valid.

The Byzantine Generals Problem[15] provides the motivation to solve the consensus problem. The theorem illustrated in Figure 2 states that consensus cannot be reached if 1/3 or more are malicious. To be Byzantine Fault Tolerant means that a distributed system can withstand failure with some unreliable actors. Asynchronous adds another layer of complexity where messages may get delayed or altered, similar to the real internet with firewalls and denial-of-service attacks. Asynchronous Byzantine Fault Tolerant (aBFT) is the highest level of security a distributed system can achieve[7].

Hashgraph was proven to be aBFT. While a full mathematical proof is beyond the scope of this paper, Figure 3 illustrates it's key pillar of the Strongly Seeing Lemma. Once it has completed it's path towards decentralisation, it's proof-of-stake system will rely on 1/3 or more of the coins are not owned by malicious actors.

3 Current state and analysis

3.1 Governance

Originally under Swirlds, Hashgraph's ownership was transferred to the Hedera Governing Council. It is a decentralised council of term-limited multinational companies [4].

It's decentralised governance is based on Visa's model[1] which ensures that council does what is best for the network. No single company has complete control and any malicious acts will certainly damage a member's reputation. Well-known companies are in the council which includes Google, Boeing, LG, and Eftpos Australia. It has a seat for 39 council members with only 20 seats filled at the time of writing.

A criticism of Hashgraph is that the network must agree on N, the total number of participants [9]. As of early 2021, it is currently on a permissioned system which makes N known. Council members currently operate these nodes. It's current permissioned nature has also drawn some skepticism but it has a path towards decentralisation.

3.2 Open review, not open source

The source code will only be available as open review, not open source. However, anyone can raise a proposal to improve the network by raising a Hedera Improvement Proposal (HIP)[2]. This governance model will prevent forks similar to what happened to Bitcoin Cash and Ethereum Classic because Hedera is the only authorised body that can use the proprietary Hashgraph technology.

This model can be controversial in the cryptocurrency community which has factions that favour a fully decentralised model. However, one has to look into where mining power has been concentrated in a proof-of-work system, and coin concentration in a proof-of-stake system to fully assess a network's true decentralisation of power.

3.3 Security, staking and tokenomics

Currently on a path towards decentralisation, Hashgraph's proof-of-stake system will rely on no 1/3 or more of the coins are owned by malicious actors. Hedera has outlined a release schedule without compromising the network's security. All coins have already been minted and saved in a treasury which will be released over 15 years[8]. Once all the coins are released, it will be extremely difficult for a single actor to accumulate enough coins to compromise the network, as surges in demand will increase the price of a limited supply coin.

Additionally, Hedera has plans to enable users to proxy stake their coins. This will allow users to stake their coins to well-known nodes which will help secure the network[11]. In return, users will be rewarded with additional coins

[1] https://hedera.com/council

[2] https://github.com/hashgraph/hedera-improvement-proposal

for participating. It is very different as compared to joining a mining pool where it is a system based on luck. With staking, users are rewarded in proportion to their stake.

3.4 Correctness

Gossip relies on assumptions to be fully robust [1]. The concept of gossip in a distributed system is well known, but combining it with the concept of virtual voting is novel. As it is a new concept, the algorithm was checked by a Coq system (a formal verification system) which proves that it is aBFT - the highest security possible in a distributed system [7].

3.5 Performance and efficiency

Depending on the region setup, real world experiments using AWS instances have shown throughputs of 50-000-500,000+ transactions-per-second[4]. It still remains to be battle tested in a permissionless setup, but its current transaction volumes[3] already surpass what Bitcoin and Ethereum can do. It is currently operating on a single shard, but it is possible to scale this even more with the addition of more shards.

It has recently surpassed 1 billion transactions with the mainnet being only online for only about one and a half years[10]. For comparison as of 2021, Bitcoin[4] is still at 700 million transactions while Ethereum[5] just surpassed 1 billion this year.

Compared with the proof-of-work system used by Bitcoin, proof-of-stake is more environmentally friendly as no mining is involved. It can also be argued to be fairer because it does not favour entities with economies of scale or access to cheap electricity.

It was estimated that Hashgraph uses 600,000 times less energy per transaction than Ethereum and a 5 million times less than Bitcoin[14]. A per transaction analysis has also shown that Hashgraph is almost on par with Visa at 0.000170 kwh and 0.001486 kwh respectively.

3.6 Current services and integrations

Hedera currently offers the following services[6] which enables the development of distributed applications:

- Hedera Token Service - enables minting, management and configuration of fungible and non-fungible tokens.
- Hedera Consensus Service - can provide fair ordering, verification, and transparency on streaming data.

[3] https://hedera.com/dashboard
[4] https://blockchair.com/bitcoin/charts/total-transaction-count
[5] https://blockchair.com/ethereum/charts/total-transaction-count
[6] https://hedera.com/services

- Hedera File Service - distributes files on each node which may help with storing files that need active storage on the ledger.
- Hedera Smart Contract Service - can run existing Solidity contracts. It is however recommended to use the Hedera Token and Consensus service for most use cases for higher performance at a lower cost.

Hedera also offers integrations[7] for Corda, Hyperledger, and Logstash.

3.7 Use cases

Blockchain 3.0[12] discussed use cases for a third generation DLT such as elections, micro-payments, supply chain management.

In the UK, Everyware is currently using Hashgraph to track the supply chain of the COVID-19 vaccine[6]. Temperature sensitive vaccines need a tamper-proof system to ensure the vaccine's proper delivery.

Eftpos Australia is currently developing the next-generation micropayments technology which may potentially open new ways for Australian businesses and consumers to interact. Use cases are are currently being developed as proof-of-concepts which includes sub-cent payments to unblock online paywalls[2].

Central bank digital currencies[8] (CBDC) is another potential use-case. Only a few countries have rolled out their own CBDCs. Although it is speculative which technologies central banks are evaluating, more central banks may follow given the interest and investment in the area. Hashgraph's technical innovation offers scalability while it's governance model offers stability, features central banks may consider critical.

4 Conclusion and final remarks

In a saturated market of cryptocurrencies with calls to "hodl to the moon", there is a lot of noise and hype in this rapidly changing environment. Hashgraph stands out in a number of ways. Its technical innovation offers efficiency that can enable DLTs to scale. Its governance structure can enable mainstream enterprise adoption with a path towards decentralisation. It is rare to find a cryptocurrency with these features that breaks away from the blockchain, let alone a formal verification by a Coq system that proves it is aBFT - the strongest level of security in a distributed system.

It's not so often that a technology can be disruptive and make a generational leap. Bitcoin and Ethereum may have paved the way for first and second generation DLTs, Hedera Hashgraph has the potential to take the lead of the third generation DLTs. It has a lot of potential on paper and on real world use cases. While there are tangible use cases happening today, there are still more items to be developed in the roadmap and more council members to be added.

[7] https://hedera.com/integrations
[8] https://hedera.com/learning/what-is-a-central-bank-digital-currency-cbdc

Similar to the early days of the internet, Hashgraph's technical capabilities and governance model may become a potential enabler for more use cases in the future.

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