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[11] paved the way for cryptocurrencies and distributed ledger technologies (DLT) using the blockchain. Ethereum[14], a second generation DLT, enabled smart contracts to operate on the blockchain. While blockhains rose in popularity, wide-spread adoption has been limited due to its ability to scale.

Gossip protocols are known to efficiently broadcast information with high reliability and throughput[13]. Achieving consensus was historically done by sending votes across the network[5]. This is an expensive operation that have not been reliably implemented in real-world conditions.

Hedera Hashgraph[3] combines gossip protocol with the concept of virtual voting for a network to efficiently reach consensus. As a result, it provides a fast, high-throughput, fair-ordering, and asynchronous Byzantine Fault Tolerant (aBFT) system alternative.

2 Overview of the Hashgraph algorithm

Hashgraph uses standard cryptographic hashes and digital signatures to securely spread events across a network (Figure 1).Each member will eventually have a consistent local copy of a Hashgraph to run virtual voting the need to send votes across the network[3].

The Byzantine Generals Problem[12] 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

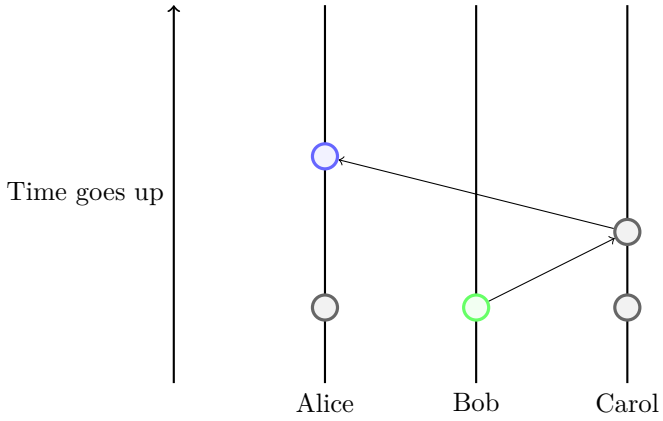

Figure 1: A simple example of how hashgraph spreads information via gossip. Bob randomly gossips to Carol, then Carol randomly gossips to Alice. Alice would have known what Bob and Carol spoke about without talking to Bob directly. Bob's green event is strongly seen by Alice's blue event as it was seen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

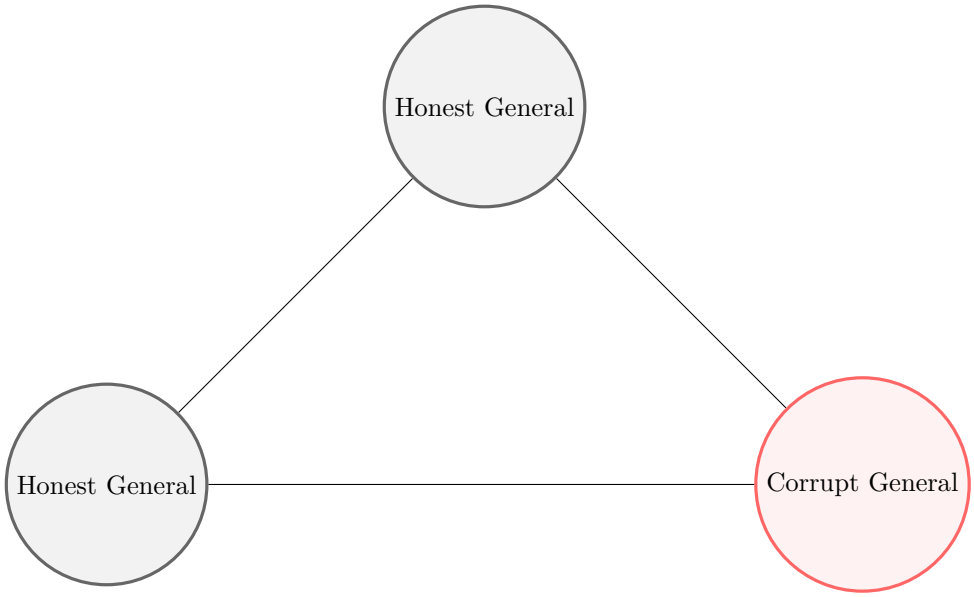

Figure 2: An illustration of the Byzantine Generals Problem. The Theorem states that consensus cannot be reached if 1/3 or more are malicious.

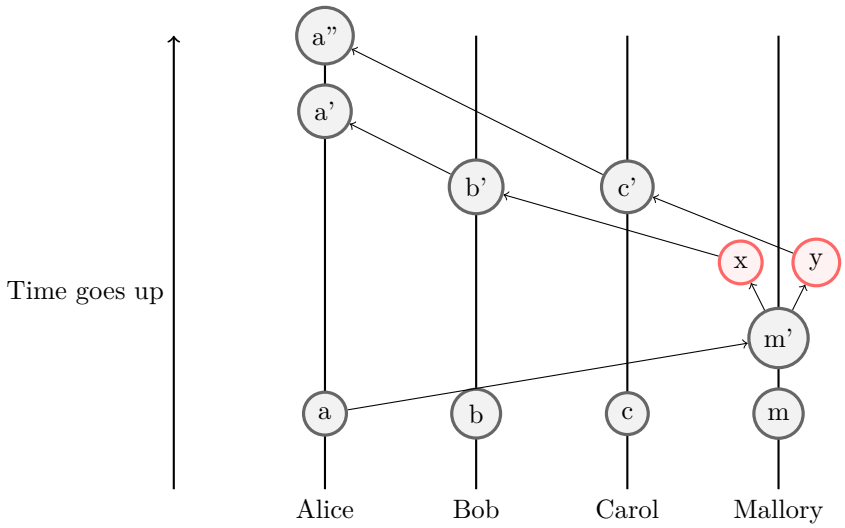

Figure 3: Suppose Mallory can cheat by forking an event, eg: she could double spend her coins by gossiping two different events (x & y) to different members. The Strongly Seeing Lemma states that a forked event will not be strongly seen by other members. A proof by contradiction shows that if 2/3 strongly sees x and 2/3 also strongly sees y, then this is impossible to be strongly seen if only less than 1/3 are malicious. If Alice, Bob, and Carol are honest and communicate further, they will agree not to strongly see Mallory's events as valid.

complexity where messages may get delayed or altered, similar to the real internet with firewalls and DDoS 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. In a proof-of-stake system used by Hashgraph, the network's security will rely on 1/3 or more of the coins are not owned by malicious actors.

3 Current state and analysis

3.1 Governance and path to decentralisation

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.

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

Well-known companies are in the council which includes Google, Boeing, LG, and Eftpos Australia.

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. Citics also argue because of it's permissioned nature, it is not true to the roots of a fully decentralised network.

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. 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 1/3 or more of the coins are not owned by malicious actors. Hedera has outlined a coin 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 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.

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.

3.4 Correctness

Gossip relies on assumptions to be fully robust [1]. Gossip is a well known protocol, 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].

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

3.5 Performance analysis

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.

3.6 Use cases

Blockchain 3.0[10] 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[4] (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.

Similar to the early days of the internet, the technical innovation of this project may enable more use-cases in the future. Hashgraph's technical capabilities and governance model is a potential enabler.

4 Conclusion and final remarks

In a saturated market of cryptocurrencies with calls to "hodl to the moon", it's easy to get lost in the hype. 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, 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. Similar to the early days of the internet, Hashgraph's technical capabilities and governance model may become a potential enabler for use cases in the future.

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