Journal of Engineering Science and Technology
Vol. 17, No. 5 (2022) 3475 - 3488

INFLUENCE OF HEDERA HASHGRAPH OVER BLOCKCHAIN

MOHAMMAD ALAHMAD[1,*], IMAD ALSHAIKHLI[2], ABDULRAHMAN ALKANDARI[3], ABDULLAH ALSHEHAB[4], MOHAMAMD RABIUL ISLAM[5], MESHAL ALNASHEET[6]

[1,3,4]Computer Department, College of Basic Education, Public Authority of Applied Education and Training, Kuwait
[2,5]Department of Computer Science, International Islamic University of Malaysia, 53100 Jalan Gombak Kuala Lumpur, Malaysia
[2]Computer Department, Institute of Telecommunication and Navigation, Public Authority of Applied Education and Training-higher, Kuwait
*Corresponding Author: malahmads@yahoo.com

Abstract

From the last decade, blockchain network have a magnificent impact on our everyday digital services such as: payments, smart contracts, medicals and many mores. Blockchain provides a decentralized public ledger that can connect different enterprises and individuals with no central server. however, Blockchain suffers from scalability issue since it cannot expand fast enough as the network data rapidly increasing. Leemon Baird invented a promising decentralized public ledger called Hedera Hashgraph algorithm that able to perform and offer various benefits such as the ability of scalability. This paper explains, analyse, and compares Hedera Hashgraph algorithm with blockchain algorithm from different aspects and define the potentiality of HBAR network as a decentralized public ledger technology (DLT) in digital services. The article also focuses on the overall demonstrate active results representing the scalability and performance factors in between HBAR Hedera Hashgraph and Bitcoin blockchain cryptocurrencies networks. Though Hedera Hashgraph haven't tested publicly but this article come out with the picture of performance of HBAR over the blockchain networks based on several serves as this paper explicitly depicted.

Keywords: Blockchain, Cryptography hash function, Hashgraph algorithm, Public ledger technology, Proof of work.

1. Introduction

Blockchain technology was invented by a person (or a group of people) called Satoshi Nakamoto in 2008. It is a distributed ledger technology (DLT) used in multiple applications today such as Bitcoin and Ethereum cryptocurrencies. Blockchain suffers from scalability issue for a decade now. That means, the throughput of the blockchain is limited as the system grows linearly since the transactions executed serially. In 2016, the Hashgraph algorithm was invented by Leemon Baird and improved the scalability issue facing blockchain network. Hashgraph is asynchronous Byzantine Fault Tolerance (aBFT) distributed ledger consensus mechanism based on virtual voting algorithm that combined with the gossip protocol to achieve consensus quickly, efficiently and securely [1]. Hashgraph aims to provide the benefits of blockchain as a distributed ledger without any limitations such as scalability issue. Cryptocurrency start-up Hedera Hashgraph (or simply HBAR) launched its new cryptocurrency platform in late of 2018 year. Accredited investors contributed to raising the fund of Hedera to $18 million dollars [2].

HBAR platform is built using a mathematical approach called a directed acyclic graph or simply DAG. As a result, HBAR platform is not using a blockchain network as most of the existing cryptocurrencies using today. Mance Harmon, the CEO and cofounder of Hedera corp. claimed that HBAR's DAG network will be able to process hundreds of thousands of transactions per second while Bitcoin and Ethereum can only process 10 and 25 transactions per second, respectively [2]. Confounders of Hedera corp. Mance Harmon and Leemon Baird worked together in 1993 for the U.S. Air Force. They were part of five-person team that built machine learning algorithms. In 2015, they cofounded Swirlds corp. that builds private blockchains for corporates. Then, they started working on their own algorithm called Hedera Hashgraph by 2017 fall [2].

Slow processing speed and high transaction fees are the two factors that prevented Bitcoin and Ethereum to replace the current monetary system and become the first choice of handling everyday digital payments. For example, Bitcoin takes up to 10 minutes to reach its finality. Experts expect that Bitcoin and Ethereum will improve their speeds dramatically by using new blockchain high speed network such as lighting network [2]. Hedera Hashgraph algorithm expected to reach its finality faster with low transaction fees due to its structure design. Blockchain network processes its transaction linearly, while Hederah. Hashgraph network processes its transactions parallelly. Harmon claimed that this parallel execution will support micro transactions and micropayments. Also, he claimed that Hedera Hashgraph network will support smart contract as well - code that triggers an action if certain requirements are met, and that serve as the lifeblood of crypto networks like Ethereum - and file storage [2, 3].

This paper has a contribution by comparing of two main architectural performance, those are blockchain and HBAR. This contribution may help decision makers easy identify that how much different in between two cryptocurrency architectures and its performance based on many factors as details herein.

2. Hedera Hashgraph Architecture

Hedera Hashgraph algorithm is a distributed ledger technology (DLT) algorithm and can be built at the top of different applications such as smart contracts, file services and cryptocurrency. Hedera Hashgraph architecture is illustrated in Fig. 1.

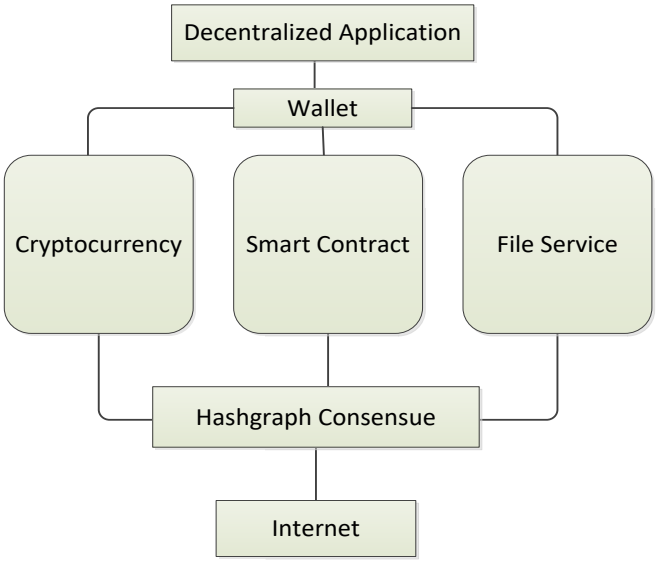

Fig. 1. Hedera Hashgraph architecture.

As shows in Fig. 1, Internet forming the nodes community of the Hedera Hashgraph network is attached directly to the Hashgraph consensus layer. This layer is responsible for taking transactions and spread them over all nodes connected to Hedera Hashgraph through gossip protocol. All nodes run Hashgraph consensus algorithm which should reach to an agreement of timestamping each transaction and consensus order history. At the top of Hashgraph consensus layer is the services layer which provide different services such as smart contract, file services and cryptocurrency that contribute and acted with ledger technologies on emerging world economy [3, 4]. Smart contract protocol tends to provide a digital agreement negotiation and obligation terms between two parties or more over Hashgraph consensus algorithm. Where file service uses the Hashgraph algorithm to provide file services such as file storage. In this case, file storages will be saved as microtransactions in all nodes of Hedera Hashgraph network and can be only accessed by the permission users or systems [5, 6]. When a cryptocurrency built over Hashgraph consensus algorithm, that will lead to have a fast network which will result in low network fees making very low microtransaction more practical than blockchain network. e.g., Bitcoin. Regarding the architectural performance of cryptocurrency, Hedera Hashgraph algorithm as detailed in following sub sections.

2.1. Potential of HBAR

The performance of Hedera Hashgraph counting throughout its security, platform's stability, effective governance as well as legal controls on it. Distributed ledger technologies (DLT) have its potentiality that transform within multiple industries existing markets which make as form being established. In terms of performance, this platform able to process 10,000 cryptocurrency transactions per second. Moreover, it provides high performance as combination with effective governance, strong security, legal controls and technical to ensure its regulatory compliance. From its technical perspective Hedera legal controls just to make sure that the platform will

not fork to another competing platform or any cryptocurrency [7]. The potentially of security compromising also improve DLT public platforms performance.

2.2. Gossip protocol

Gossip protocol where each node of Hedera Hashgraph network spread all the information as that they know to other nodes in the network randomly telling them all the information they know. Figure 2 illustrates this process.

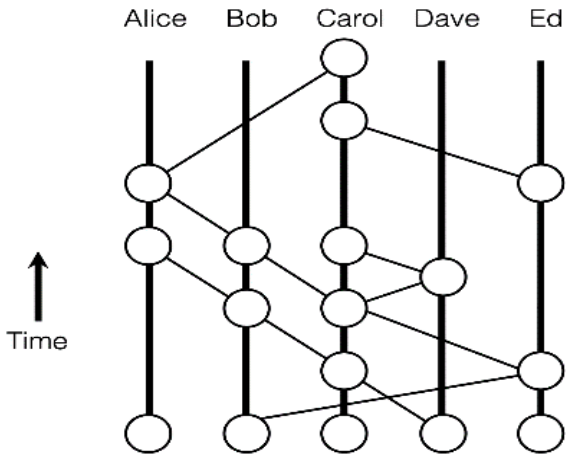

Fig. 2. Gossip protocol used in Hashgraph algorithm [3].

Figure 2 shows nodes with names for example. Alice, Carol…etc. communicating with each other using gossip protocol. For instance, Bob is sending all the information he knows to a random node, in this case Ed. In turn, Ed is sending all the information he knows to Carol. This process will create a tree without prunes which means, events will not be discarded as the case in blockchain network. Note that, each event, the circles in Fig. 2 graph, is composed of two parent events, the self-event originated from the previous event of the same node and the event sent from other node randomly. In the case of Ed second event from bottom, is composed of his first event (self-event) from bottom and Bob first event as showing in the above graph. The information sent between these nodes are only the hash digest of the previous events and the timestamp of the creation of the current event. These two little information makes the Hedera Hashgraph network fast and efficient. Moreover, in distributed peer-to-peer network system, Hashgraph function also perform first transaction which is immutable and secure [8].

2.2.1. Gossip about gossip protocol

While many ledgers use the gossip protocol, Baird combined the gossip protocol in the form of "gossip about gossip" with a virtual voting algorithm to reach consensus quickly and securely without proof of work. Gossip about gossip protocol sends the information of a specific node, e.g., In Fig. 2, Ed second event from bottom, which was received by its parents, Bob first event and Ed bottom self-event, to the next event, e.g., Carol, randomly adding the information of this event, Ed, that he knows before sending it to Carol [7]. While, the gossip protocol shares new information that

other nodes don't know, the gossip about gossip protocol includes where that new information originated within trusted community consensus [4]. In this case, gossip protocol more efficient by using bandwidth among community just because each member of community necessary to receive signed transaction. As the test of proof from the community define it's fair, fast, Byzantine fault tolerant as well as bandwidth efficient in terms of virtual voting [9].

2.2.2. Consensus algorithm

It's not enough to have nodes to know the events on Hedera Hashgraph network and where are they originated from as the two aforementioned protocols do in the previous subsection. At this point, Hedera network need to ensure the order of these events (or consensus) occurred. Timestamping each event when it is created by its two parents (itself event and the event sent from other node randomly) is needed to ensure the order fairness among other nodes. As stated before, Hedera Hashgraph algorithm will timestamp each event when it was first passed from the node through gossip protocol. As a result, all transactions (events or consensus) are ordered based on their timestamped. Figure 3 summarizes the complete process of how Hedera Hashgraph algorithm works.

```
run two loops in parallel:
    loop
        sync all known events to a random member
    end loop
    loop
        receive a sync
        create a new event
        call divideRounds
        call decideFame
        call findOrder
    end loop
```

Fig. 3. Hedera Hashgraph consensus algorithm [3].

In Fig. 3, the algorithm is performed as follows, firstly, all the events are sent randomly to other nodes in Hedera network through gossip protocol. This process will keep performing as a loop, as long as the network is syncing events. Next loop begins when these events are received by other nodes then the algorithm will create new events as explained earlier in the subsections. Note that, the two loops can be run in parallel and not serial as the case in blockchain. Next stage of the second loop, is divide Rounds which means dividing these events into rounds as Fig. 4 shows.

The first events by each node in each round called witnesses determined by virtual voting as shown in red events of Fig. 4. Virtual voting is calculated locally in each node to determine the witness in each round to achieve asynchronous Byzantine Fault Tolerant (aBFT) [9]. Note that, this process done locally "virtually" which means nodes are not sending votes to each other determining the witness which in turn makes the traffic in Hedera network less overhead and off course faster and efficient. Asynchronous Byzantine Fault Tolerant means that no single or small group of nodes can prevent Hedera algorithm community reaching a consensus correctly [10]. Nor changing once its occurred and approved by other majority nodes (2n/3 of network

nodes where n is the node number). That means, aBFT in Hedera algorithm network can achieve consensus even though a node or 1/3 of total network nodes is isolated or controlled by an attacker. Next stage of Hedera Hashgraph consensus algorithm, as shown in Fig. 3, is decide Fame which decides whether this node is famous or not. And that's accomplished if the witness can strongly see 2n/3 of network nodes, then it considered famous as Fig. 5 shown.

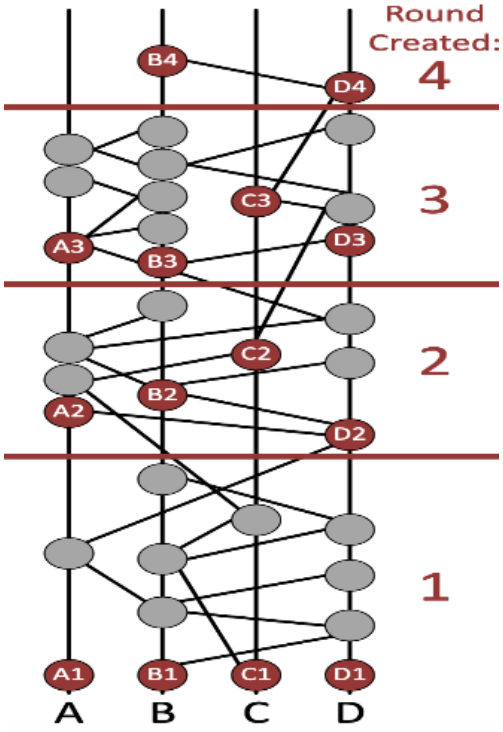

Fig. 4. Divide Rounds stage with witnesses [3].

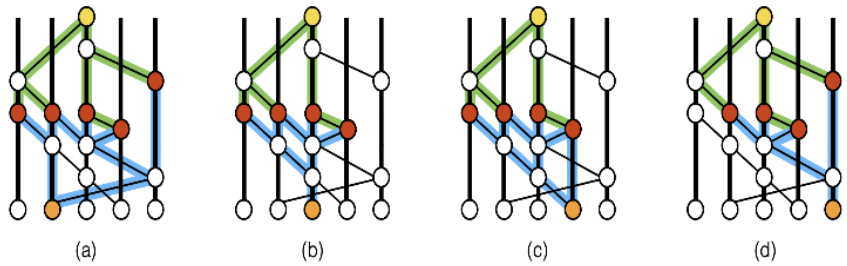

Fig. 5. Illustration of strong seeing [3].

Figure 5 depicts the strong seeing concept. In all 4 graphs (a, b, c and d), we can see different lower 4 orange events for different 4 nodes can see the upper yellow event at the top. Meaning that, almost all famous nodes can reach the yellow goal event at the top obtaining the same hash result despite the path taken.

Last stage of Hedera Hashgraph consensus algorithm is findOrder. findOrder stage is determining the correct order of consensus occurred. And that can be achieved by timestamping each event occurred to reach fair order of the consensus.

3. Discussion and Analysis

Hashgraph algorithm is a distributed ledger technology (DLT) algorithm that can be used in various applications. It is a consensus algorithm built totally different than blockchain consensus algorithm. It is faster and more efficient than blockchain in time execution phase. The main idea behind Hashgraph algorithm over blockchain algorithm is reaching the settlement of a consensus very quickly while proof of work blockchain network suffers the wasted traffic overhead processing in its network. It uses a gossip about gossip protocol to reach consensus quickly without the usage of proof of work as Bitcoin does [9]. Where the gossip protocol shares the information that other nodes doesn't know, the gossip about gossip protocol includes where that information originated from [11]. The hash of the previous message is added to the new one without the need of voting. As a result, you will have the entire history of who talked to who and in what order, again without the need of voting. Baird attests, "So I can guess how you would vote, but you don't need to vote, so you reach consensus for free. It is the fastest way known to humanity to send information." [12].

In general, cryptocurrencies have three evaluation factors: security, scalability "performance" and decentralization. Security of a cryptocurrency is concluded by implementing a robust design of Cryptography hash function which resists all generic attacks [13]. In this case, Cryptography hash function is a mathematical function that accept arbitrary input and produce a fixed output, e.g. (256 bits…. etc.) to prove the data integrity of the hashed data. Secondly, scalability and performance of cryptocurrency is the limit amount of how many transactions per second (TPS) can be performed by a cryptocurrency algorithm as described elaborately. Lastly, decentralization means all the network computer nodes maintain and calculate the needed hash value and keep them in their distributed public ledger of the blockchain [14]. Applying these three terminologies to the three aforementioned cryptocurrencies (Bitcoin, Ethereum and Hedera Hashgraph) will be resulted in Table 1. Table 1 compares Hedera Hashgraph HBAR, Bitcoin and Ethereum cryptocurrencies based on consensus algorithm used, decentralization, scalability and performance evaluation factors.

Table 1. A comparison between bitcoin, Ethereum and hedera Hashgraph (HBAR) cryptocurrencies.

Evaluation Factor Cryptocurrency	Consensus Algorithm Used	Security (Cryptography Hashes)	Scalability & Performance (TPS)	Decentralization
Bitcoin	Blockchain	SHA-256	7-10 TPS	Yes
Ethereum	Blockchain	SHA-3 (Keccak-256)	10-20 TPS	Yes
Hedera Hashgraph (HBAR)	Hash graph algorithm	AES-256, RSA 3072, SHA-384, and ECDSA and ECDH with p-384 and using ephemeral key	10,000 TPS	Yes

3.1. Factors based critical comparison

Hashgraph and blockchain holding two different mechanism and platform. For example, people can contribute to building cryptocurrencies, but Hashgraph don't allow to build since its patented algorithm. Figure 6 represents its mechanism that how performance getting down with its chain system as well as graph. Figure 6 and Table 2 try to bring picture of comparison and analysis of Hedera Hashgraph (HBAR) and Blockchain to closer view from its consistency as well as development.

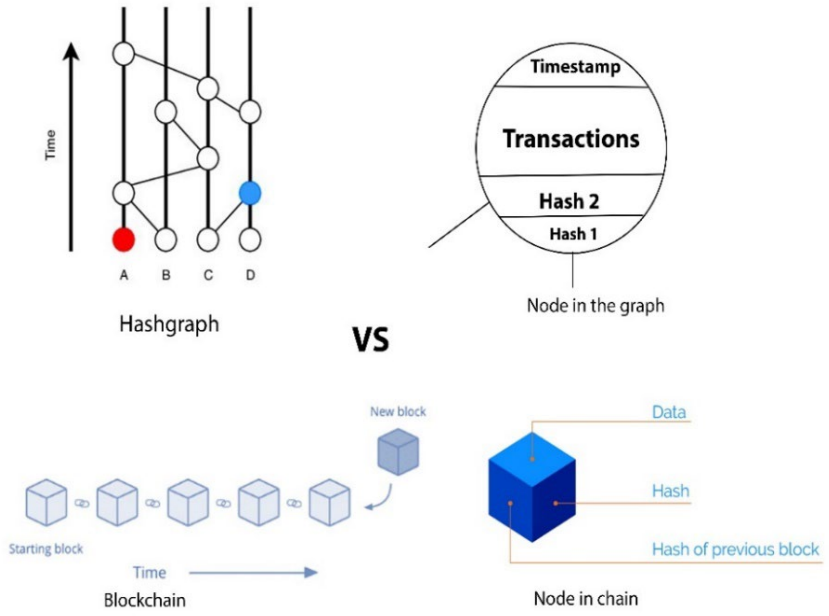

Fig. 6. Pictorial mechanism of hashgraph and blockchain.

Developers always try to maximize its platform performance, but mechanical structure define from its mechanism. Similar like a tree blockchain having hash that performs with enthusiasts to earn the trust of institutes which bring decentralized nature after quality defining [15]. It has a single and long chain that having in a form of blocks which contain network nodes as uniquely. That's why blockchain record previous data, hash, and hash record of previous block as present in Fig. 6 in the chain node and it's performed better on supply chain [16, 17]. On the other hand, Hashgraph overcome the mining task to valid transactions rather it uses directed acrylic graph that help time sequencing the transactions without dividing them into blocks. Gossip protocols to send information between nodes as seen in Fig. 6 above in Hashgraph and its node. Hashgraph unable to track record to prove comparison and analysis try to get the picture of two different performance as listed in the Table 2.

This comparison table try to represent the performance between two of them. Today, the main challenge of existing cryptocurrencies is the scalability and performance factors. As Table 1 (Bitcoin & Ethereum) and Table 2 (Blockchain & HBAR) shows that compared to HBAR rest of the features (Bitcoin, Ethereum & Blockchain) are far behind [3, 4, 13]. The consensus algorithm used in HBAR called Hashgraph algorithm which achieves the 10,000 TPS.

Table 2. Factors based analysis blockchain and hedera hash graph.

Factors	Blockchain	Hedera Hashgraph
Stability	Open source based blockchain technology always updated by locally.	Hedera Hashgraph is patented that usually done by hedera governing council.
Speed & Performance	High latency and low efficiency. E.g., Ethereum performs 15 transactions per second.	Lo latency and high efficiency as seen that Hashgraph offer 473985 transactions per second.
Consensus Mechanism	It offers multiple consensus models for effortless functioning.	It operates only with the help of Gossip Protocol and Virtual Voting mechanism.
Security	It operates with the Cryptography Hashing mechanism.	It operates with Asynchronous Byzantine Fault Tolerance (ABTF) [21]. That provides robustness against attacks like DDoD and Sybil.
Cost	Require of PoW to run on the network that make cost higher as blueprint of new economy [17].	Hedera Hashgraph doesn't required PoW and robust to run on the network that make much lower cost.

3.2. Hashgraph perform over blockchain based on experiment

In theoretical phase, proof of work blockchain consensus network can reach consensus from 100 to 10000 transactions per second. Where Hashgraph consensus network, theoretically, can generate transactions up to 500000 per second. But we can build a fast blockchain network but not secure enough or we can build a slow blockchain network and secure as the current public blockchain performing now in the market [18]. On the other side, Hashgraph is designed to be fast and secure. While Hashgraph algorithm is designed to handle massive transactions per second as the ATM does.

Today, ATM network can perform 50000 transactions per second. As a result, proof of work blockchain network could not replace the ATM system due to its latency and low efficiency. Hashgraph consensus algorithm can be a competed with ATM network which is measured in seconds, not minutes or hours as proof of work blockchain network does. ABFT is the security mechanism used in Hashgraph consensus algorithm. ABFT ensures fairness properties [19]. Fairness properties are concluded in fair access and fair ordering. Fair access ensures that no participant party can influence other party to submit and flow transactions into Hashgraph consensus network. Where fair ordering ensures that all transactions is ordered based on their timestamping. Also, aBFT is the technical term to ensure that no single node or a group of nodes can control Hedera network nor prevent the network from reaching consensus or can be changed after its occurrence as the approval of majority. Some of the performance listed out below that over blockchain just done from experiment.

3.2.1. Proven performance

Hashgraph allows more powerful as found in mathematical performance. Like distributed database Paxos are Byzantine. Indeed, Hashgraph algorithm accomplishes

being fast, ACID (Atomicity, Consistency, Isolation, Durability) compliant, inexpensive, efficient, timestamped and fair. But blockchain is neither Byzantine nor fair. Even in the blockchain, it would not be ACID compliant when someone try to know that consensus has been reached. Some proven performance also presents in Fig. 6 it out as experiment done [20].

3.2.2. Scalability

In terms of scalability, blockchain network suffer for a decade now from scalability. Scalability is the limitation of transactions that blockchain network can process. In blockchain network, e.g., Bitcoin, the size limit of a block (1 megabytes) and the creation time of a block (10 minutes) are the two main obstacles preventing the network's throughput. On the other side, Hedera Hashgraph network can expand smoothly without any scalability constraints due to the small size of its block (500 bytes per event) and it takes to 1 second to generate 10 events. Also, blockchain network must executes serially because transaction calculation results depend on the previous state. While Hashgraph algorithm executes parallelly because nodes can reach to its consensus from different paths as Fig. 5 shows earlier.

3.2.3. Efficiency

It is known in the blockchain community that Hashgraph is 100% efficient [21]. But throughout its bandwidth, Hashgraph required to inform all the nodes of a given transaction and very small overhead that has additional bandwidth and able help to achieve a consensus timestamp which put transactions into order. According to Mance Harmon, CEO of the Dallas, Texas-based company, it has ability to break the trade-off as performs first-time in both of performance and security [22].

3.2.4. Cost parameter

Hashgraph is inexpensive because its energy conservative while proof of work blockchain consumes intensive energy and needs custom mining rigs. In particular, HBAR (Hedera cryptocurrency) takes an average fee of $0.0001 for each a transaction performed in Hedera network while Bitcoin (uses poof of work blockchain network) takes an average fee of $0.20 for each transaction performed in blockchain network. This huge difference in cost refers to the energy consumed in each network.

Transaction confirmation in Hedera network takes between 3 to 5 seconds to reach consensus Byzantine agreement while other DLT networks using blockchain takes from 10 seconds up to 60 minutes to agree on a block by all parties. And that because Hedera Hashgraph consensus algorithm does not have any consumed energy in voting nor doesn't discard any of its growing events as the case of blockchain network does. This reason makes Hedera network 100% efficient and fast in reaching consensus Byzantine agreement. Leemon Baird designed the Hashgraph algorithm encountering all the needed protocols to achieve his goal such as efficiency, fastness, secureness, fairness and stableness [23]. He chose gossip protocol to send information (only two hashes of the parent events and the current event creation timestamp) randomly, to reduce the communication overhead and achieve fairness and fastness.

Baird invented gossip about gossip protocol to know where the received information by the events originated. Dividing rounds stage is breaking up the events

into rounds to deal with small fraction of events rather than a whole event which also achieve fastness of the network. Also, choosing a virtual voting algorithm by Baird to be calculated in each node purely local by Byzantine agreement rather than sending these votes to other node (resulting in high traffic overhead processing in Hedera Hashgraph network) off course, will speed up the overall Hedera network. Based on the virtual voting taken by nodes, Hedera Hashgraph algorithm will decide famous events to become the famous witnesses' leaders in each round to become the judges to find the order of events on the last stage of Hedera Hashgraph algorithm based on their timestamps.

4. Typical Implementation and Comparison

Hedera codebase will be governed by Hedera Governing Council that already released for public review with the Version 1.0 in 2020 [24]. But it's not publicly available yet. But it has proven that Hyperledger Fabric v1.4.1, as implemented RAFT protocol that is easier to manage and set up than Kafka-based ordering services (another Hyperledger Fabric) [25]. Hedera Consensus service will make a fault tolerant, cost-effective and global that ordering available services to any Hyperledger Fabric network [26]. Moreover, Swirlds corp. (owned by the founder of Hashgraph algorithm Leemon Bairds and others) is the commercial interface of Hashgraph algorithm implemented and started the public ledger network in January 2019 formed by 39 leading governance enterprises (such as Google, Boeing, etc.) and individuals. As of now, around 40,000 accounts are created around the globe.

The transactions occurrence is almost 1 million per day. HBAR cryptocurrency is the digital currency released by Swirlds corp, which uses Hashgraph algorithm, first trade took place in January 2019 and the price was $0.000001. As of April 2020, its price increased to become $0.032548. On the other hand, blockchain public ledger network established in January 2009, the first digital currency invented by the blockchain's founder, Satoshi Nakamoto, is Bitcoin and its price was $0.0008, and it increased in July 2010 to become $0.08.

The transactions occurrence in blockchain network is 400,000 per day makes HBAR in leading position over Bitcoin. As of today, some drawbacks of Hedera Hashgraph network need to be encounter [27]. The first one is that HBAR network it's not being tested using millions of nodes connected to its network. That means, Hedera Hashgraph founder claimed to provide high throughput flow data and fast network theoretically but that needs to be verified practically to prove his claim. And that will occur only when more nodes join Hedera network in near future. Secondly, Hashgraph code is patented and not an open source which means it is illegal to allow anyone to change Hedera original code. That means if anyone try to fork Hedera Swirlds company will sue him/her. Thirdly, Baird and CEO

Hedera cofounders Mance Harmon and Leemon Baird are two ex-U.S. Air Force military men. And that means Hedera Hashgraph code is a patented private code which owned by two ex-military men. Consequently, Swirlds Hedera Hashgraph company brings all kinds of questions for the public about government collusion and makes the patenting and secrecy of the Hedera code more poignant and suspicious. Today, Hedera Hashgraph network is implemented in many corporates and organizations such as, Google, Boeing, IBM and many others of total 39 global leading enterprises. These corporates and organizations realize the real benefits of Hashgraph consensus algorithm over blockchain. Note that, these governance by

these corporates and organizations will not authorize any of them to control or influence the Hedera Hashgraph network [28]. Hedera corp. involved these big brands to be part of the public distributed ledger technology network to empower, persuade and convince users to join the network.

5. Conclusion

Hedera Hashgraph algorithm considered the third generation on consensus algorithms after proof of work blockchain (first generation) and proof of stake blockchain (second generation). This paper analysed Hedera Hashgraph algorithm technically and economically, comparing it with blockchain algorithm.

Theoretically and based on Table 1. conducted in this study, HBAR cryptocurrency can calculate 10,000 transactions per second while Bitcoin and Ethereum cryptocurrencies can calculated 3 to 20 transactions per second. But practically, Hedera Hashgraph network needs massive nodes to be connected with, in order to determine the real TPS that such a network can handle.

Economically, HBAR (Hedera cryptocurrency) takes an average fee of $0.0001 for each a transaction performed in Hedera network while Bitcoin (uses poof of work blockchain network) takes an average fee of $0.20 for each transaction performed in blockchain network. Also, the interval price of the first year of establishing HBAR (Jan 2019) and Bitcoin (Jan 2009) cryptocurrencies are almost identical implying that HBAR has a promising and increasing price value in the future markets. As a conclusion of this analysis, Hedera Hashgraph algorithm is proved to be fast, efficient, secure and scalable. Scalability issue is solved with Hedera Hashgraph algorithm after suffering for a decade in blockchain network.

Overall, Baird designed a well-studied promising public ledger algorithm which might overtake blockchain networks in future and shapes the future of decentralized public ledgers despite the suspicion of its patenting and secrecy of the code which owned by two ex-military men. However, Hedera Hashgraphs has the potentiality of 180-degree transformation to the whole economy.

Although overall performance of Hedera Hashgraph is better than Blockchain Technology but replacement of HBAR does not cross the level of flaws from the developers until both reaches a mature stage. Overall pictures suggest that blockchain features overcome the scalability while HBAR perform in robust manner for sustaining in future influenceable capabilities from its speed performance and efficiency.

References

1. Correia, M.; Veronese, G. S.; Neves, N.F.; and Verissimo, P. (2011). Byzantine consensus in asynchronous message-passing systems: a survey. *International Journal of Critical Computer-Based Systems*, 2(2), 141-161.
2. Kauflin, J. (2021). Hedera hashgraph thinks it can one-up bitcoin and Ethereum with faster transactions. Retrieved March 23, 2021, from https://www.forbes.com.
3. Can hashgraph succeed blockchain as the technology of choice for cryptocurrencies? (2021). Retrieved March 23, 2021, from https://www.thehindu.com.

4. Islam, M.R.; Nor, R.M.; Al-shaikhli, I.F.; and Mohammad K.S. (2018). Cryptocurrency vs fiat currency: architecture, algorithm, cashflow & ledger technology on emerging economy. *Proceedings of International Conference on Information and Communication Technology for the Muslim World* (*ICT4M*). Kuala Lumpur, Malaysia, 69-37.
5. Mohammad, A.A.; Alshaikhli, I.F. (2013). Joux multicollisions attack in sponge construction. 6th *International Conference on Security of Information and Networks* (*SIN*). New York, United States, 292-296.
6. Mohammad, A.A; and Alshaikhli, I.F. (2013). Broad view of cryptography hash functions. *International Journal of Computer Science Issues*, 10(4), 239-246.
7. Ongaro, D.; and Ousterhout, J. (2014). In search of an understandable consensus algorithm. USENIX Annual Technical Conference. Philadelphia, United States, 305-319.
8. Castro, M.; and Liskov, B. (1999). Practical byzantine fault tolerance. *Symposium on Operating Systems Design and Implementation*. New Orleans, United States, 173-186.
9. Clement, A.; Wong, E.L.; Alvisi, L.; Dahlin, M.; and Marchetti, M. (2009). Making byzantine fault tolerant systems tolerate byzantine faults. *Proceedings of the 6th Symposium on Networked Systems Design and Implementation*. Boston, United States, 153-168.
10. Buterin, V. (2013). What proof of stake is and why it matters. *Bitcoin Magazine*, Retrieved March 23, 2021, from https://bitcoinmagazine.com.
11. Miller, A.; Xia, Y.; Croman, K.; Shi, E.; and Song, D. (2016). The honey badger of BFT protocols. *CCS '16: Proceedings of the* 2016 *ACM SIGSAC Conference on Computer and Communications Security*. New York, United States, 31-42.
12. TechCrunch is now a part of Verizon Media (2021). Retrieved March 23, 2021, from https://techcrunch.com.
13. AlAhmad, M.A. (2018). Design of a new cryptographic hash function - Titanium. *Indonesian Journal of Electrical Engineering and Computer Science*, 10(2), 827-832.
14. Fischer, M.J.; Lynch, N.A.; and Paterson, M.S. (1985). Impossibility of distributed consensus with one faulty process. *Journal of the Association for Computing Machinery* (*JACM*), 32(2), 374-382.
15. Mohanta, B.K.; Jena, D.; and Panda, S.S. (2019). Blockchain technology: a survey on applications and security privacy challenges. *Internet of Things*, 8, 100107, 1-15.
16. Mercuri, F.; Corte, G.D.; and Ricci, F. (2021). Blockchain technology and sustainable business models: a case study of devoleum. *Journal Sustainability*, 13(10), 5619-5633.
17. Forsstrom, S. (2018). Blockchain Research report. Blockchain Research Report. Retrieved March 23, 2021, from https://www.ibm.com.
18. Wood, G. (2014). Ethereum: a secure decentralised generalised transaction ledger. *Ethereum project yellow paper*. Retrieved March 23, 2021, from https://www.ibm.com.

19. Lamport, L. (2019). The part-time parliament. *Transactions on Computer Systems* (*ACM*), 16(2), 133-169.
20. Lamport, L.; Shostak, R.; and Pease, M. (2019). The byzantine generals problem. *Transactions on Programming Languages and Systems* (*ACM*), 4(3), 382-401.
21. Fischer, M.J.; Lynch, N.A.; and Paterson, M.S. (1985). Impossibility of distributed consensus with one faulty process. *Association for Computing Machinery* (*JACM*), 32(2), 374-382.
22. Islam. M.R.; and Alshaikhli, I.F. (2019). The effectiveness of adaptive driven data dictionary on inflectional text simplification for financial prediction. *Proceedings of teh 6th International Conference on Engineering Technologies and Applied Sciences* (*ICETAS*). Kuala Lumpur, Malaysia, 1-6.
23. King, S. (2013). Primecoin: Cryptocurrency with prime number proof-of-work. Retrieved March 23, 2021, from https://en.wikipedia.org.
24. Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. Retrieved March 23, 2021, from https://metzdowd.com.
25. Leemon B. (2016). The swirlds hashgraph consensus algorithm: fair fast byzantine fault tolerance. *Swirlds Tech Report Swirlds*, 1-28.
26. Harmon, (2018). Dean Takahashi. Retrieved March 23, 2021, from https:// venturebeat.com.
27. Hedera website (2021). Retrieved March 23, 2021, from https://hedera.com.
28. Hyperledger fabric, (2017). Retrieved March 23, 2021, from https://hyperled ger-fabric.readthedocs.io.