MAJOR PROJECT ARTICLE

RESEARCHARTICLE

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Is hashgraph a more suitable distributed ledger technology than blockchain for property transfer?

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Abstract

Distributed ledger technology (DLT) in the form of blockchain have become an innovative way to disrupt property transfer systems around the world. Transfer systems can be slow, costly, insecure and lack transparency. Many proof-of-concept studies have focused on blockchain systems in developing nations which show promise. Unfortunately, these studies have never matured into real applications due to confidence in DLT's and inherent blockchain drawbacks. Hashgraph is a new DLT which solves the shortcomings and brings all the benefits of blockchain to property transfer. The important variables to create a strong DLT are investigated through Ethereum and is then followed by a comparison to Hedera to assess viability for property transfer. The research showed that hashgraph is possibly a more efficient DLT than blockchain and could faciliate more reliable property transfer systems. Further research needs to be done on hashgraph and its potential application in the property transfer sector with proof-of-concepts to find out its advantages and limitations.

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Correspondence

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1 INTRODUCTION

The rapid rise of distributed ledger technologies and their new uses, notability the facilitation of property transfer in developing nations, demands a reliable platform to continue innovation. This has traditionally been done by utilizing blockchain technology to overcome systems which face information inefficiencies and high transaction costs (Alam et al., 2020).

Unfortunately, many proof-of-concept ideas using blockchain have never developed into working systems due to

limitations that blockchains have, which includes legal compliance, lack of governance and lack of trust (Konaashevych, 2020).

A new distributed ledger technology has recently emerged which provides all the benefits of DLT's and possibly overcomes many shortfalls and limitations which are present in blockchain for property transfer systems. The Hashgraph consensus algorithm also brings important features greater then blockchain like asynchronous byzantine fault tolerance and increased transaction speed of several orders of magnitude (Crary, 2021).

In this study, I began by looking at DLT's origins and its evolution from blockchain to hashgraph before highlighting current property transfer systems in developed and developing world systems. I then took a systematic approach to comparing Hashgraph and Blockchain technologies through a set of variables which highlight advantages and disadvantages of the DLT's (Akhtar, 2019) in the scope of property transfer. Based on this research, a conclusion will be drawn on Hashgraph technology and its viability for usage over blockchain in property transfer applications.

2 | BACKGROUND

2.1 | Existing land title management systems

It has been well documented that having a right of access to secure property rights, including ownership and transfer, is a key metric for economic and social development (Limmer, 2013). This is the main reason why an efficient transfer system is needed. Figure 1 shows how systems around the world differ based on jurisdiction. The systems are split into two main groups; the deeds system (French); and the title system having three variations (German, English and Torrens).

The title system involves the register of properties. The title is recorded by the government and is guaranteed by the government. The key factor here is that the government plays the major role in the titling system unlike the deeds titles. Therefore, a Torrens system works well in developed nations with robust systems in place like a trustworthy government. There doesn't seem to be the need for an overhaul on the transfer system. Rather a developed country like Australia could benefit from a 'hybrid approach' when looking for improvements of transfer.

The deeds system involves the register of owners where the transaction is recorded from person to person. It is also very common for the government of the jurisdiction to be the recipient of the deed on property transfer, to then be handed back to the new owner. It is thought that a deeds system could be replaced by a more modern and automatic means of reordination (Arrunada, 2020). A move to tokenization or scribing of deeds onto a DLT could serve as a solution, but these systems are old and entrenched into existence for some nations.

Regardless of what system is used, table 1 highlights the main principles all modern systems set out to achieve (Bennett, Miller, Pickering & Kara, 2021).

Both types of systems also carry inherent limitations which are prevalent throughout the world. Some systems, like in Australia, are very robust to these limitations. Conversely, in some developing nations like India, there are systems which are in dire need of replacement. The first weakness in most systems is the time spent to transfer ownership of title, in some cases it can be weeks or months. (Zevenbergen et al., 2013). The second is the high cost of transfer dictated by each intermediary involvement along the path of transfer, which is particularly relevant in developing nations (Lemmen et al., 2015). The third being the complexity of all the different parties involved in the transfer and finally both systems being prone to fraud (Bennett, Miller, Pickering & Kara, 2021). This can happen by the buy seller or the official body in the nation overseeing the transfer. Hence, fraud is much more prevalent in developing nations than developed ones since the lack of structure in all aspects of transfer open the possibility of bad acting parties.

FIGURE 1 Types of registration systems around the world (Enemark, 2010).

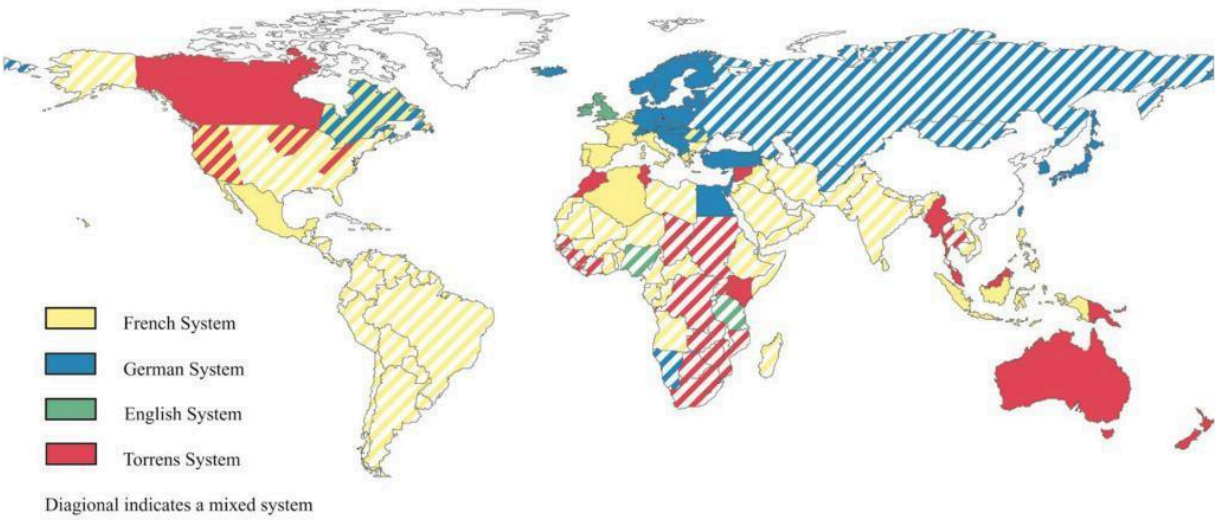

TABLE 1 Principles modern day systems set to achieve.

Principle	Demands
Registration	For a transaction to be considered legal fact, it must be recorded in an authoritative "book" (Or modern-day database).
Publicity	This book must be visible and accessible by the public to view the transaction history.
Consent	For any transaction changes to occur in the book, relating to a person or parcel, must have consent from both parties.
Speciality	Both the parties and the land units which are being transacted must be unambiguously defined.

2.2 | Distributed ledger technologies

Distributed ledger technologies are a type of digital database that spread across multiple sites, countries, or institutions, and is typically public (Government Office for Science, 2016). These ledgers store the transactions of assets across all nodes in the network once it has been verified. This allows DLT to record static data, like a registry, and dynamic data, such as financial transactions (Pratt, 2021). The key difference between current typical registries and financial transactions is that they have a central database, in contrast to DLT having no one central place of storage, see figure 2. This gives the majority of DLT's an inherent property of being decentralized and immutable. These properties have both advantages and disadvantages in terms of its application and will be discussed later in the paper.

Blockchain was the first DLT until the recent conception of other technologies like Tangle and Hashgraph. All technologies achieve the same outcome but the way the network comes to consensus on transactions is different. This also leads to inherent advantages and disadvantages of each technology and will also be discussed later in the paper.

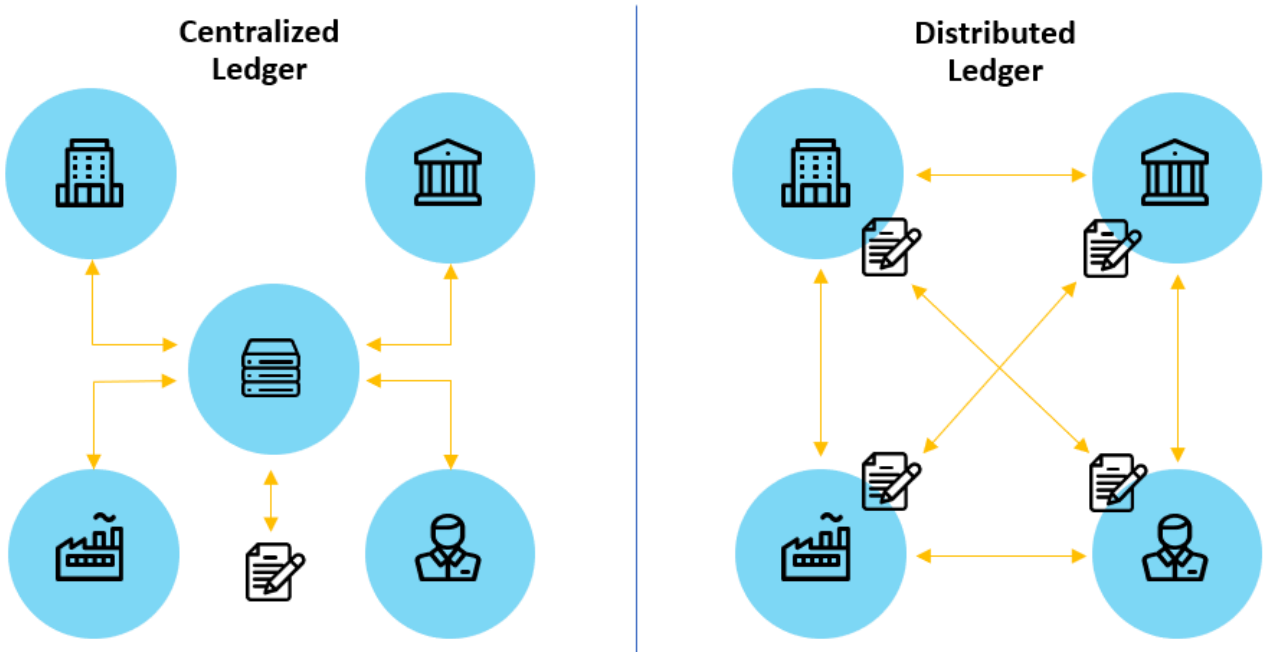

FIGURE 2 The difference between a centralized ledger (Database) and a distributed ledger.

2.2.1 | Blockchain

The origins of the first DLT came in the form of a blockchain named Bitcoin, created by a pseudo anonymous author called Satoshi Nakamoto in 2008 (Nakamoto, 2008). Nakamoto never explicitly mentioned the term 'Blockchain' in his whitepaper but rather described how transactions are placed in the ledger and verified in blocks. A block is cryptographically linked to the next block which has many blocks linked before that. Blockchain therefore refers to the structure of the ledger and is commonly interchanged with 'DLT' to describe a trustless system. However, no one definition has yet been widely adopted for blockchain to date (Treiblmaier & Clohessy, 2020). The Bitcoin blockchain was utilized to become the world's first cryptocurrency, radically shaking up the financial industry.

The main features of blockchain have been well documented in the literature. Table 2 lists all the important inherent features of blockchain technology. It is important to note that not all current blockchains have all these features as developers can change characteristics of the blockchain to suit the network's needs. Therefore it is important to specify which blockchain is being utilised to then define if the feature is still relevant. The example of a permissioned blockchain network loses the feature of transparency since the users are only a participant in the network and are not within the ecosystem.

A new generation of blockchain technology was then created, dubbed 'DLT 2.0' for its new implementations and applications. The Ethereum whitepaper was published by Vitalik Buterin in 2014 before the blockchains launch in 2015 (Buterin, 2014). This new generation of blockchain facilitated the ability to do more than just transfer currency but also assets through 'smart contracts.' These bring all the features of blockchain to a self-performing, self-enforcing, digital contract (DiMatteo et al., 2019).

It has also been well documented the inherent technical challenges facing blockchain of which effect different applications. Swan (2015) mentions some big challenges facing blockchain including scalability of throughput and latency time. This is well seen with Bitcoin only being able to process 7 tps (transactions per second) and Ethereum (30 tps). When compared to companies like Vista (2000 tps) and Twitter (5000 tps), Bitcoin and Ethereum can't compete with current systems in terms of workload (Pongnumkul, 2017).

TABLE 2 Features of Blockchain technology (Treiblmaier & Clohessy, 2020)

Characteristic	Positive	Negative
Immutability	Internet of Value, traceability	Inflexibility
Transparency	Efficiency of data retrieval	Privacy, information leakage
Programmability	Execution in a deterministic manner	Unchangeable source code
Decentralization	Disintermediation	Disintermediation
Consensus	Minimize necessary trust	Energy consumption (PoW), potential centralization of power
Distributed trust	Establish trust	Elimination of personal relationships

Another inherent problem of distributed blockchains is its ability to be 'hard forked' by the users of the network due to a lack of governance. A hard fork is when a large update of the code is required to be used by all nodes in the network. If nodes disagree on the code implementation, they can simply decide to not update the code and continue processing the old codes blockchain. This results in a 'fork' of the ledger where two chains are created, the new updated blockchain and the old blockchain. This issue is mainly created by a "lack of a central legal entity with formal responsibility over the system" (Zachariadis et al., 2019). Many hard forks have happened to Bitcoin and Ethereum where two new chains have been created and continued to be verified. This factor scares off adoption as the consequences of having two copies of the asset on two different ledgers is an unknown legal nightmare.

2.2.2 | Hashgraph

The newest generation of DLT's has since been created in the form of Hedera hashgraph to combat five big fundamental problems of blockchain; performance, security, governance, stability, and regulatory compliance (Baird, Harmon & Madsen, 2019). Along with these features, hashgraphs algorithm has been tested and proven to be asynchronous Byzantine Fault Tolerant (aBFT) (Crary, 2021) as well as being able to support high throughput (James, Hawthorne, Duncan, St. Leger, Sagisi & Collins, 2019). These features will be discussed in depth later in the paper. More academic analysis does need to be completed though to rightfully confirm all claims of performance.

The main difference between hashgraph and blockchain algorithms is the way the ledger is structured, shown in figure 3. Hashgraph is a directed acyclic graph (DAG) linked together by cryptographic hashes. The events themselves are directed on the graph from node to node but do eventually have to be linearly ordered. The structure allows the facilitation of the 'gossip-about-gossip protocol' which is an old protocol that has been proven effective in various domains (Hedetniemi et al., 1988; Kempe et al., 2003; Kermarrec & Steen, 2007). The use of this protocol in a DLT system allows for increased speeds and loads on the network.

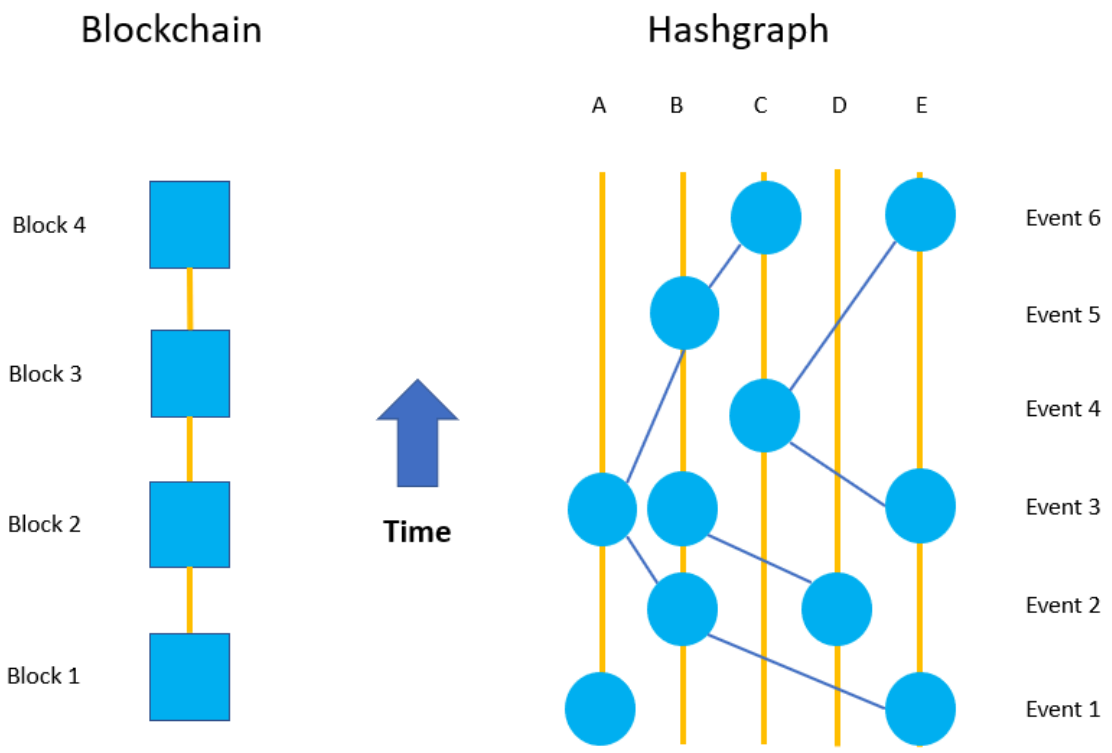

FIGURE 3 The structure of blockchain and hashgraph DLT's.

Hashgraph is also a unique DLT in that the technology has a legal patent covering it, implemented by Hedera, the legal organization utilizing hashgraph (Baird etal., 2019). The importance of a legal patent in DLT hasn't been fully investigated, but it inherently carries the inability for another organization or group to utilize hashgraph. This can happen by either the organization or group copy hashgraph code to create their own ledger or the Hedera hashgraph ledger hard forking and creating another chain. Both scenarios are now not possible due to the legal implications.

This is then tied into how governance is implemented by Hedera. Hashgraph is extremely different from common blockchains by how the decisions around ledger updates to the code are decided. Governance is who, what and how these decisions are made for a distributed ledger. Governance is a critical aspect to DLT which so far hasn't been fully addressed in the literature but is significant (Lemieux & Feng, 2021). Table 3 shows the important questions that have been theorised about governance for DLT's which hashgraph possibly answers favourably to but will be investigated further in the paper.

It is important to note that Beck, Muller-Bloch and King used the word 'blockchain,' but has been replaced with 'DLT' in this paper since blockchain is commonly used to describe a DLT (Treiblmaier & Clohessy, 2020). Since this paper is investigating blockchain and hashgraph, it is more appropriate to use the term DLT to avoid confusion.

TABLE 3 Research agenda for governance in the DLT economy (Beck, Muller-Bloch & King, 2019)

Dimension	Research Questions
Decision rights	How are decisions made in the DLT economy? How are decision management rights and decision control rights allocated? How is disagreement about decision-making resolved in the DLT economy? What is the role of ownership in the DLT economy?
Accountability	How is accountability determined in the DLT economy? How is identity engrained in the DLT economy? How is transaction enforcement embedded in the DLT economy? How are disputed transactions resolved in the DLT economy? How Is trust affected by the DLT economy? What is the role of institutions in the DTL economy?
Incentives	How is consensus incentivized in the DLT economy? How does incentive alignment work in the DTL economy? How is system use incentivized in the DLT economy? How is system development and maintenance incentivized in the DLT economy? How do business models shape the DLT economy?

2.3 | Theorised property transfer systems on blockchain

This paper will look at theorised property transfer systems on a blockchain. Most of these systems theorised are all in a proof-of-concept stage. We will begin looking at what are smart contracts and what are hybrid approaches.

2.3.1 | Smart contracts & tokenisation

The word 'smart contracts' is made up of two important words which define its functionality on a DLT. A 'contract' is an agreement which if required can be enforced by law (Saligari, 2019). They are a legally binding document between two or more parties which governs the rights agreed upon. It is generally required to have; an offer; acceptance; consideration; mutual intent; and consent to be bound (Saligari, 2019).

The word 'smart' was added onto contract by Szabo in the 1990s to define smart contracts as "set of promises, specified in digital form, including protocols within which the parties perform on these promises" (Szabo, 1997). Although blockchains were still to come out in the next century, Szabo described vending machines as a form of smart contract. By putting in a dollar, you received a can of soft drink and so the contract was fulfilled in a self-executing way. Developers began utilizing smart contract code into their blockchains the next century through Bitcoin and later Ethereum. Therefore, these smart contracts on a DLT allows for the self-execution of contracts without the need of as many intermediaries (Peiro & Garcia, 2017). Table 4 highlights the most important differences as outlined by Bennett, Miller, Pickering & Kara when investigating contracts and smart contracts.

TABLE 4 Comparison of conventional contracts and smart contracts (Bennett, Miller, Pickering & Kara, 2021).

Criteria	Conventional Contracts	Smart Contracts
Specification	Natural language and legal prose	Code
Identity and Consent	"Wet" signatures	Digital signatures
Dispute Resolution	Judges, adjudicators, arbitrators	Consensus via blockchain
Nullification	Parties via legal enforcement Process of breached terms	Parties via agreed upon digital nullification workflow and block consensus
Payment	Independent third-party process	Automatic, based on executed terms (Built into contract)
Escrow	Independent third-party process	Automatic, based on executed terms (Built into contract), or not even required

Smart contracts for property transfer and ownership were then theorised by Szabo in the form of a distributed title database (Szabo, 1998). This is commonly understood that this method wouldn't be viable for transfer since each block would require large amounts of data. The larger the data in the block, the larger the bandwidth required from all nodes since each node must distribute the updated ledger. A common theorised approach that has been used to implement a DLT solution is a hybrid approach. Tokenisation is still in early development and understand in this space and hasn't matured enough so more literature is needed on the subject.

2.3.2 | Hybrid approach

Many proof-of-concepts have been documented in the literature and there is definite certainty of the possibilities of blockchain in the conveying process (Vos, 2017). Bennett, Miller, Pickering and Al-Karim highlighted three different proof-of-concepts which focused on different areas of property transfer (Bennett et al., 2021). A Swedish concept focused on all areas of land conveyance, an Australia concept focused on just the "Discharge of Mortgage Lien" and a Canadian concept which focused on utilizing smart contracts for the transaction of the "Re-assignment Report". This has led to the understanding that taking a "Hybrid approach" to implementing a DLT to property transfer could be more beneficial than re-creating the whole sector.

A more complete implementation can also be used but can still be categorized as a hybrid approach. Alam, Rahman, Tasnim and Akther proposed the use of blockchain in the Bangladesh system for land title management. They utilized the Ethereum platform and smart contracts to facilitate transfer. On paper the system could work well for a developing nation like Bangladesh, but it was concluded that governments would need to play a role in adoption and that Ethereum transfer fees were unpredictable (Alam et al., 2020). An exploration of the Dutch blockchain scene found similar things but also added that it is an extremely complex process to integrate blockchain into land registry (Veuger, 2020).

3 | METHOD

3.1 | Definition of efficient distributed ledger technologies

In recent years, there has been many new DLT in the form of blockchain, tangle, and now hashgraph. Within these subsets of DLT's, there are even more applications, some having their own unique code to be an improvement over another. These improvements are geared towards features which improve overall performance of the network. Unfortunately, blockchain technologies suffer from a trifecta problem, being forced to make trade-offs which prevent them from conquering all three features (Halpin, 2020). These three features are decentralization, scalability, and security. A known example of this in the blockchain community is the block size debate. Increasing the block size (the number of transactions put into a block) leads to greater scalability due to increased throughput and lower fees. This has the trade-off of decreased security as less actors would be able to run a full node and opens the network to a 51% attack (Sayeed & Marco-Gisbert, 2019). By achieving the trifecta, the blockchain could be considered as efficient, but since a comparison of blockchain and hashgraph is going to be made, these factors must be broken down to find the comparison points.

3.2 | Definition of selected variables

The generated list of variables to compare blockchain to hashgraph with is taken from Akhtar work in 2019. These variables were only briefly touched on in his work but make up almost all the important features in a DLT system. The DLT for blockchain being highlighted for comparison is the Ethereum blockchain. This is due to Ethereum being the most popular smart contracts blockchain and has been used for many proof-of-concept studies. The system for hashgraph being compared to is Hedera which is the only network utilizing hashgraph. The variables being compared are as listed below:

The **Consensus** of a DLT is by what algorithm is used to confirm transactions on the ledger. The type of algorithm used influences multiple other variables including fees, throughput, scalability, and security. Since the type of consensus greatly impacts other variables, it is important to have the right one in use for property transfer. Although hashgraph currently only has one algorithm for consensus, blockchains have many, including Proof of work, proof of stake and proof of burn to name a few. They all each have their own advantages and disadvantages in creating an efficient DLT.

Latency is the time it takes the network to validate a single transaction. Latency also ties into other variables like throughput, fairness, scalability, and security. A low latency is desirable for a robust and trustworthy DLT. When latency time hits a point, network security is jeopardised allowing for double spend attacks to occur (Ozisik & Levine, 2017).

BFT systems (Byzantine fault tolerance) is the notion that the network can overcome failures or malicious activity, given by the Byzantine Generals Problem (Lamport et al., 2019). Since DLT revolve around having trust in a trustless system, you cannot be sure that every single node contributing to the network is doing it for good. Malicious activity therefore must be overcome to keep the network running. This is heavily linked to fairness and security of the network.

The **Fees** variable is the cost to the user to submit a transaction to the network. This is highly variable by the DLT being utilised and dependent on almost every other variable. It would be desirable to have low fees so users are not paying as much compared to traditional systems.

Throughput, which is closely related to latency, is how fast the network can process multiple transactions. This is translated to transactions per second (tps) and is also heavily dependent on almost all other variables. Generally, when latency increases, throughput also slows down, but it is possible to have a high latency but still maintain a high throughput. Throughput is also greatly affected by what the network is transacting. Smart contracts are large transactions and hence slow down the network more than a normal transaction.

A variable often overlooked is **Fairness** in a DLT. This is how the transactions are processed based on submission time. A 'fair' ordering of transactions would look like: Bobby submits his transaction at second 1 and Steve submits his transaction at second 3. Bobby's transaction will be processed first and then Steve's will be processed after.

Maturity is the combination of how old the network is and how many meaningful use cases there are using the

network. This is a more of an arbitrary evaluation since DLT's are still in an early development phase and it is impossible to say if the technology is or is not mature based off current understanding. Rather a comparison between two DLT's can find which one is possibly more mature, strictly between the two being compared.

Scalable is whether the network can handle increased usage through transactions and its impact on throughput. If a network does not scale well, it has the effect of not only decreasing throughput, but increasing fees and latency. Since a DLT network will be utilised by multiple applications, if the network is not scalable, then no property transfer system would want to be implemented on that network as a result.

The final variable is **Platform** which is what the network is running on and specifically, the governance and hard forks around this DLT. Governance is who, what and how decisions are made around updating and changing the network code. This includes updates to the network and implementation of new features.

It is paramount to note that these variables are important in the scope of property transfer. Some variables will not be discussed in this paper as they do not significantly impact the facilitation of a property transfer system. These variables include, architecture, transactions, copyright, privacy, security, cost, setting, and competition. Notably, security is left out of discussion. This is due to security being heavily entwined with BFT systems, as well as the immutability of DLT systems are well documented in the literature already.

3.3 | Comparison of blockchain and hashgraph

Consensus

Ethereum utilises a well-known consensus algorithm called proof of work (Buterin, 2014). This was the first algorithm created for DLT's and is an extremely robust consensus algorithm. It requires nodes of the network to guess the correct hash to process the next block in the chain which grants a payment of Ethereum. This means the greater computer power (or work) put into the network by a node, increasing the chance of calculating the hash and generating the reward. This makes proof of work networks very secure if there are lots of nodes in the network. This also has the side effect of large power consumption. Sedlmeir et al., (2020) concluded that although not a large threat to the environment, PoW energy consumption is massive compared to the number of transactions it can facilitate. It also requires a large overhead of communication between nodes to come to a consensus on the processed transactions.

Hedera consensus network is based upon some core concepts like transactions, fairness, gossip, gossip about gossip, virtual voting, and famous witnesses (Baird, 2016). Hashgraph goes about consensus in a completely different route than blockchains utilizing different protocols and structures. No heavy computation is required and so, is in turn, very environmentally friendly.

Latency

Latency for a transaction on Ethereum averages anywhere between 4 seconds and 180 seconds and even more in some instances. The range of time it takes to confirm a transaction is somewhat correlated to fees (in gas) set by the transactor (Zhang et al., 2021). The higher the gas price is set, the chance of getting a transaction confirmed is faster, but not always.

Hedera has an average confirmation time of a transaction around 5 seconds which does not change due to fees (Hedera, 2021). The low latency time is attributed to the hashgraph technology which utilises a directed acyclic graph (DAG) and protocols like gossip about gossip (Baird, 2016).

BFT Systems

Ethereum is a BFT system which solves the problem of trust if latency is kept down at a reasonable time. Since it is a BFT system, it means Ethereum is a very secure distributed network and has very little chance of malicous actors jeperdising the network.

Hashgraph is also BFT compliant but is also one grade higher. Hedera is aBFT (asynchronous byzantine fault tolerant) meaning that not only is the network secure from attacks, but is fair in ordering of transactions. This means that when transaction A is submitted before transaction B, transaction A will be confirmed before transaction B. This is in contrast to blockchain as a transaction that is submitted first will not necessarily be confirmed in order. This is inherently

an unfair network.

Fees

Fees on Ethereum change drastically depending mainly on the current load on the network. If there are a large amount of transactions submitted to the network in a small period, fee prices get pushed up as gas price is increased. This upward pressure on gas fees is due to trying to prioritise transactions to get it confirmed faster. At the time of writing, the average gas fee is around $5 AUD (YCharts, 2021).

The fees on Hedera are set to a value in USD and only change based on what type of transaction is being sent. A normal transaction costs $0.0001 USD in HBAR and a smart contract transaction, depending on how many signatures it requires, can be around $0.05 USD in HBAR. These fees are incredibly low due to the low latency and high transactions per second the network can achieve.

Throughput

Ethereum has a max throughput of around 14 transactions per second which is dependent on varying latency time and the backlog of transactions. This value is capped due to the proof of work algorithm and inherent blockchain design. Increasing transactions per second is possible but the network would begin to make trade-offs like security and decentralization.

Hedera has an estimated max throughput of around 27000 transactions per second which is not dependant on any surface layer variable. Throughput of hashgraph technology is dependent on how many nodes are in the network and the placement of these nodes around the globe (Leemon & Atul, 2020). Leemon and Atul's testing also found potential for transactions per second to reach 250000 while keep latency under 20 seconds.

Maturity

Blockchain was first utilized in 2009 and later used in Ethereum when it was then launched in 2015. Blockchain technology and even the Ethereum platform are still very early in development with improvements constantly being proposed. Ethereum also has many entities testing and building use cases, but the exact number is almost impossible to quantify. There have been multiple proof of concepts utilizing Ethereum for property transfer systems, but none have become permanent working systems.

Hedera was first launched publicly in 2017, being the only DLT to be utilizing hashgraph to date. As hashgraph is fairly new technology, there is a limited number of articles and research completed. It does however have multiple large and public use cases which are being tested on the network. No property transfer proof of concepts have been started on hashgraph.

Scalable

Blockchain will face and has been facing scalability problems since each network began. This is seen in the backed-up transaction pools and increased fees in the networks. A blockchain network can run very smoothly at low stress but as adoption increases, scalability becomes a problem. This can be overcome but the blockchain trilemma then becomes a problem.

Hashgraph so far has not faced any problems with scalability. This could be due to the high ceilings of transactions it is capable of doing and current usage has come nowhere close to its capabilities. A scaling issue would arise when throughput gets close to a maximum.

Platform

Ethereum is a completely open source, decentralized network and is the second largest blockchain network in the world. It is the largest smart contracts network along with many developers. Issues relating governance around code upgrades and network implementations are decided by this main group of developers with feedback and input from outside users. Ethereum, like many other blockchains are open to hard forks from occurring to the network.

Hedera is open review, decentralized network which is currently the only network utilizing hashgraph. This is largely due to a patent covering hashgraph, implemented by co-founder Leeman. Its network sends simple transaction, smart contracts, and tokens. It is governed by a council of diverse, industry leading companies, who vote to decide on updates

to the network. Because of the governance model and patent, hard forking of the hashgraph is highly unlikely.

4 | DISCUSSION

Hashgraph seems to stack up to blockchain favourably, namely it is more environmentally friendly, faster, cheaper, is scalable and has a strong governance system. But what effect does this have on decisions to integrate hashgraph into a property transfer system over blockchain?

Although not effecting the facilitation of property transfer, the consensus algorithm used in Ethereum is much less efficient in terms of power consumption per transaction. VISA is shown in table 5 to highlight existing networks and what its power consumption looks like. If a new technology like Ethereum can't equal or beat current technologies power consumption, it decreases its likely hood for adoption. In contrast, hashgraph is extremely efficient when compared to all networks. Having a lower carbon footprint also helps legitimise the technology. This is due to the recent understanding of climate change and how energy consumption needs to be reduced. It must be noted that Ethereum will be changing to a different consensus algorithm which could reduce energy consumption (Douglas, 2021). Since these technologies are more suited to developing nations, the energy consumption aspect also comes to the forefront. With carbon offsetting and taxes being placed on emissions, it would be advantageous for developing nations to adopt efficient technologies.

TABLE 5 Comparison of different network energy consumptions ("Can a Blockchain be Green?," n. d.).

Network	Annual Energy (kWh)	Annual Transactions	Energy per transaction (kWh)
VISA	205,555,556	138,300,000,000	0.001486
Bitcoin	99,630,000,000	112,553,498	885.179064
Ethereum	35,500,000,000	344,766,800	102.968151
Hedera	74109.6	435,623,029	0.00017

Blockchains speeds including latency and throughput also seem to be edged out by hashgraph, largely due to the scalability of the networks. It is important to be reminded that a property transfer system on blockchain and hashgraph is not the only application running on the network. The amount of property transactions that happen in Australia per year was 171351 in the 5 biggest cities (AIHW, 2021). This amount is tiny compared to the number of transactions that could happen in other much larger nations. It is also well documented that DLT's have the possible capacity to run hundreds of thousands of applications in the future. Thus, a property transfer systems success on a DLT is related to how many other applications are running on the network and its effect on speeds. If large adoption were to happen, the Ethereum network could slow down more in terms of latency and throughput, putting the network at risk to malicious attacks. Thus, low latency and high throughput is a requirement for early systems. If the Ethereum network is losing speed already with minimal usage, what chance does it stand in the future? Hashgraph solves this by having a scalable technology, planning for thousands of applications to be running on the network simultaneously. Low latency and high throughputs are somewhat expected in an emerging technology, much like energy efficiency. All this in combination could allow an efficient transition for a developing nation to skip a generation of technology and find itself utilizing hashgraph for property transfer.

This then leads onto fees for a transaction to occur. Notably, a fee to utilise Ethereum when compared to current property transfer systems in developing nations is extremely low. For example, a transfer cost in South Africa for a house worth $110000 AUD can be around $4000 AUD with half of that directly for property transfer costs (Ooba, 2021). In contrast, one Ethereum smart contract transaction is $5, dramatically lower. Changing to a DLT system does not take away all fees as the use of a conveyancer would still possibly be required, but the number of intermediaries would be

reduced. This fee is again reduced even further on hashgraph, being just a fraction of the price again at $0.05 USD. Reducing the costs of property transfer is one of the main solutions DLT's bring to property transfer. Although Ethereum might have low costs compared to what property transfer is now in developing nations, the price unpredictability due to scaling issues are a concern for adoption. Hashgraph solves this by having extremely low fees which are set and don't change.

Blockchain technologies are relatively new and are still in a proof-of-concept phase. The readiness of a technology has so many variables including technical and social aspects. DLT's largely show promise in the technical side but still lack the social acceptance and understanding. Ethereum may have many applications built around it, but legitimacy of these applications is still in question. Is a property transfer system on blockchain trustworthy? Is blockchain technology mature enough to handle a huge economic importance? Possibly not yet and this extends out to hashgraph technology. The maturity level of most transfer systems around the world are much greater, even if they are inefficient. More research needs to be conducted on the maturity of DLT's to understand a level of acceptance and when that will happen.

The final and most important variable for property transfer is platform which includes the governance around the network. Traditional property transfer systems are either run by the government or a trusted body is overseen with the responsibility, the key word being trust. In many developed nations, a form of trust can be put into these systems as laws and regulations surround malicious activity. Unfortunately, in many developing nations, these systems are broken down by corruption and greed. Trust is therefore harder and transfer systems suffer from this. DLT's therefore are a good solution since they are a trustless system, taking the responsibility away from possible bad actors. It does however open the system up to being in control from somewhat noncredible developers. Although developers can not directly interfere with property transfers as such, they do control how the network upgrades and progresses. This means that there is always a risk of a hard fork from happening on the network. Current legal laws barely cover DLT's in general, let alone a property transfer system which has two histories of transactions. A government cannot put trust in a property transfer system on a blockchain if it is developed and maintained by actors who are largely unknown and at risk of hard forks. Conversely, hashgraph possibly solves this and answers many of the questions from table 3 about governance. Still, more research is required to investigate the importance of governance in DLT's.

5 | CONCLUSIONS

This research presents a comparison between blockchain and hashgraph technology for the specific use of property transfer. The comparison was based largely on variables all DLT's share and the speed/effectiveness/characteristics of the chosen networks Ethereum and Hedera. With this, it was possible to see which DLT is better for a system of property transfer to be integrated into the network to answer the initial research question.

The literature review showed many papers on property transfer and inefficiencies in some current systems, namely in developing nations. The review also showed no studies directly comparing blockchain and hashgraph for property transfer. There were however some studies generally comparing blockchain to hashgraph with an even greater literature bank on blockchains in property transfer. This allowed lots of information to be gathered about current blockchain systems and areas it fails and excels at. As observed in the literature, blockchains show promise in the property transfer space but have yet to develop into real working systems. This left the space for investigation into hashgraph technologies and its advantages over blockchain.

Investigation shows that hashgraph seems to have the advantage over blockchain in most aspects including consensus, latency, throughput, fees, scalable and governance. These were also shown to be important for a property transfer system on a DLT. The only variable that was not in favour for hashgraph was maturity, which is an extremely hard variable to measure.

For future work, a proof-of-concept property transfer system could be created on hashgraph. This would allow for the testing of variables for performance, and it would increase the maturity for the technology.

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