Usurping Double-Ending Fraud in Real Estate Transactions via Blockchain Technology

Atefeh Mashatan, Ryerson University, Canada
Victoria Lemieux, University of British Columbia, Canada
Seung Hwan (Mark) Lee, Ryerson University, Canada
Przemysław Szufel, SGH Warsaw School of Economics, Poland
Zachary Roberts, Ryerson University, Canada

ABSTRACT

This paper discusses the problem of double-ending fraud in real estate transactions – a type of transactional fraud wherein agents handling real estate transactions unfairly benefit, e.g., by simultaneously representing both the buy and sell side of a real estate transaction in a manner that unfairly boosts the commission they receive, or colluding to increase their commission in a real estate transaction at the expense of the buyer and/or seller of the real property. The paper proposes a unique blockchain solution design that leverages blockchain's properties of transparency and ability to create tamper-resistant audit trails to reduce opportunities for double-ending fraud and increase real estate market participants' trust in the handling of their transactions. The paper discusses the implementation of a prototype of the solution based on Hyperledger Fabric and Sails; it presents the results of an agent-based modelling simulation validating that the inherent transparency of the proposed design offers optimal allocation for both sellers and buyers.

Keywords: Blockchain Technology, Real Estate, Double-ending Fraud, Transparent Transactions, Agent-Based Modelling, Hyperledger Fabric.

INTRODUCTION

Blockchain is a decentralized peer-to-peer technology that can be seen as a ledger of records representing transactions (Peters & Panayi, 2016). It is a type of distributed ledger technology which was originally developed for cryptocurrencies (Brühl, 2017; Nakamoto, 2008). While still in its infancy, there has been optimism surrounding blockchain's capability to positively impact economies and disrupt traditional business models (Nowiński & Kozma, 2017). Beyond the early applications of blockchain in cryptocurrencies, the value exists in blockchain's ability to record transactions that are shared across a network of users. Blockchain technology is also said to shorten transaction times and make systems more transparent and reliable (Pinna & Ruttenberg, 2016). As such, the functionality and application of blockchain technology has evolved from a trade currency to secure, decentralized smart contracts that can record and track asset ownership (Bal, 2017).

Blockchain platforms are beneficial to markets where technology helps accelerate the different processes that bring more safety and transparency into the market. Thus, blockchain technology has continued to be developed for use in numerous different fields and industries. By creating a digital economy, this technology has the potential to disrupt existing markets. One market that can benefit from the integration of blockchain technology is the real estate market. Traditionally, the real estate market has been labeled as an inefficient market that suffers from lack of transparency, high transaction costs, and slow transaction processes (Shiller, 2007). A paper-based real estate transaction system has been depicted as slow due to the repeat process of validating information and the manual components that are involved in verifying the transaction; it has also been described as inefficient and error-prone (Graff & Webb, 1997; Marsh & Zumpano, 1988). The industry is also susceptible to fraudulent activities that may include title fraud, double-ending, paper-flipping (property scalping), and mortgage fraud (Cardoso & Annett, 2017; FCT, 2017; Malik & Foxcroft, 2016).

Typically, a real estate transaction occurs in five steps: listing, searching, evaluating, negotiating, and execution (Crowston & Wigand, 1999). Unfortunately, in any one of these steps, an agent representing both sides, buyer and seller, (i.e., a dual agent) may take advantage of either party to benefit their own interests. With listings, a dual agent can restrict or be selective in the types of listings that they show to potential buyers. During the search process, a dual agent can influence buyers to view certain properties that are directly under the agent's portfolio. And throughout the evaluation process, a dual agent may induce subtle or undue pressure to sway clients, such as encouragement to commit to a price that is above market value. When negotiating with either party, a dual agent may set a price point that maximizes their own commission. And finally, in the execution stage, a dual agent may inappropriately accelerate the transaction process to fulfill their own interest of moving on to the next client.

In attempts to reduce such occurrences, ethical codes of conduct have been created across jurisdictions to educate and oversee agents' behaviors and roles as transaction agents (Jennings, 2011). Due to the principal-agent relationship, real estate agents have a fiduciary and moral responsibility to represent and advance the interests of their clients (Rutherford, Springer, & Yavas, 2005). The current brokerage system model is not immune to fraudulent activities because it relies on a percentage-based commission system that may generate a bias between the agent and the principal client. For example, a seller typically wants to maximize the housing price. And while the agent representing the seller may also want to maximize the price of the house being sold (i.e., higher commission), they do so while trying to minimize the time the house is listed on the market. Thus, such quandary may create a diversion of interest between the seller and the agent.

Moreover, real estate agents often incur expenses in the form of advertising, conducting open houses, accompanying visits, and negotiating offers (Levitt & Syverson, 2008). However, because these agents only receive a small percentage (typically 1.5%-3%) of the negotiated price, there is often a concern among agents that they are not able to recoup the time and effort associated with selling or finding a house for their clients (Levitt & Syverson, 2008). As such, this may encourage some agents to engage in unethical behavior to maximize their income; one such method is to engage in the practice of double-ending.

Depending on jurisdiction, double-ending may not constitute as an illegal activity. The double-ending fraud (or dual-agency fraud) occurs when a real estate agent represents both the seller and the buyer to potentially double his or her commission at the expense of the seller (Jennings, 2011; Malik & Foxcroft, 2016). Double-ending can lead to unethical sales behavior, service quality issues, and cause strain to agent-client relationships in service-based transactions such as real estate (Lee, 2012). It is a form of deception that is often not discovered until after the transaction has been completed (Galaty, Allaway & Kyle, 2008). Further, since people are predisposed to maximize their utility, double-ending may create opportunistic temptations for agents to increase profits while minimizing their utility of effort (Hölmstrom, 1979). This parallels the tenets of agency theory which establishes the notion that people act out of self-interest and perceived incentives; it can encourage agents to break the moral responsibility of agency representation (Eisenhardt, 1989; Kadiyali, Prince, & Simon, 2014; Perrow, 1986).

A large number of studies that address the issue of fraudulent behavior focus on data mining methods of detection (see, e.g., within this journal, Rajagopalan and Krovi, 2002; Ma et al., 2013; Chua et al., 2016). This paper extends the body of literature on fraud by focusing on the upstream prevention of fraudulent behavior by means of the application of blockchain technology to better facilitate the trustworthy flow of real estate transactions. The goal is to propose mechanisms and processes that discourage double-ending fraud, while improving transaction efficiency, deterring unethical agent behavior, improving accuracy, and increasing transparency. Blockchain technology – a distributed ledger with confirmed blocks organized in an append-only, sequential chain using cryptographic links – offers a solution to the problem of double-ending for two main reasons. First, it affords transaction transparency that incentives honest behavior, since dishonest behavior would become evident and liable to punishment. Second, it decentralizes control over the transaction ledger, ensuring that no one participating party can "game" the system. It thus offers a superior form of protection against the double-ending problem to offering buyers a publicly available database. With a publicly available database, dual agents can still hide some critical bids from their seller in a market with closed bids. This is because the public databases which include all of the listings do not include any information about the bids. The proposed blockchain solution can solve this problem by making sure that the seller has access to all the bids directly on TBB, if they wish to. Whereas without TBB, the seller is depending on their agent, who might not be 100% transparent, to show them the bids. Even in a public database that includes all the bid information, a centralized database containing such information may be controlled by a single party (i.e., the real estate brokerage). In this case, the information may be easily manipulated by an agent, even with the support of the brokerage (since it may have a vested interest in a reputation of closing deals). Therefore, a decentralized database solution, such as a blockchain, better guards against the manipulation of data and engenders greater consumer trust. This avoids having the larger players dominate the system and reduce the influence and abilities of smaller players.

There is an additional advantage to using a blockchain solution. Computer automation has been used by the organizations involved in real estate transactions, but the process has resisted automation across organizational boundaries. This is due to issues of trust and standardization. If one party provides all of the process software, they get to set the standard features. All the other parties in the process have to trust that the party managing the software has their best interests in mind, that they are not favoring their own transactions and that they will not modify the data without approval. Blockchain systems are well positioned to provide automation for real estate transactions across parties and organizational boundaries. The uses of a consortium blockchain ensures that any one party can leave and the system will continue to run. Each organization that runs their own server has their own fully operational system. There is no hierarchy, they are all peers. This avoids having the larger players dominate the system and reduces the influence and abilities of smaller players. There are no favorites to the system. A democratic governance system is put in place that ensures that all parties have a say over future enhancements to the system. Real estate transactions are well served by blockchains. All parties can see a full and unadulterated history of all of the actions executed by everyone. No parties can gain an edge over the others by controlling aspects of the system.

With these advantages in mind, the paper first reviews the tenets of blockchain technology as it relates to the real estate industry. It then reviews the origins and implications of double-ending fraud and proposes a blockchain-based process design (Transparent Bidding Blockchain (TBB)), which offers a solution to the issue of double-ending fraud. The paper then discusses the implementation of TBB using Hyperledger Fabric and Sails. Finally, the paper presents the results of an agent-based modelling simulation conducted in the Julia programming language which asserts that the inherent transparency of TBB secures optimal allocation for both sellers and buyers.

BACKGROUND

As previously discussed, the benefits of blockchain include increasing transaction efficiencies in the exchange of data between users (Pinna & Ruttenberg, 2016). While it is not intended to supplant traditional transaction intermediaries, especially for industries that require high levels of transparency and safety, blockchain can be used to record transactions. Blockchain provides an alternative mechanism for recording the fact that a transaction has taken place and any recorded representation (i.e., ledger record) of that transaction entered on a blockchain remains tamper-free (i.e., maintaining integrity). However, it may not guarantee all aspects of the reliability and authenticity of a record necessary to fully rely on blockchain-based records as evidence of transactions (Lemieux, 2017a & b). For instance, unless specifically designed to do so, a blockchain may not explicitly establish requirements such as only those with the authority and competence to undertake a transaction are able to do so. As well, a recorded representation of a transaction (i.e., ledger record) may not be linked back to its transactional context or records relevant to the transaction stored off chain, called the archival bond (Lemieux, 2017b). These potential shortcomings can be overcome, however, if blockchain solutions are properly designed to address the standards of electronic records as documentary evidence. If properly designed, blockchains have the potential to afford advantages over and above traditional modes of recordkeeping in real estate transactions (Canada, 2017).

Transactions are tied to all previous transactions on the blockchain, either individually or in groups, using a cryptographic technique called hashing that makes altering the record history nearly impossible (Bal, 2017; Shu, Yu & Yan, 2019). Cryptography can be used to maintain complete information, without compromising privacy (Choy, Kwan & Leong, 2000). For example, the Ethereum network is a decentralized platform on which custom applications can be coded to represent transaction procedures (Shu, Yu & Yan, 2019). It has approximately 30,000 in its user base, each holding a replica of the ledger; all of these replicas would need to be altered simultaneously to tamper with the record (Buterin, 2013). Combined, these characteristics of blockchains are said to lead to increased decentralization, user empowerment, traceability, auditability, immutability, and transparency (Hans, Zuber, Rizk, & Steinmetz, 2017).

To date, the prospects of blockchain have been explored in various fields. In the financial industry, blockchain can facilitate payments and remittances, lending and borrowing, insurance and risk management, as well as audits (Tapscott & Tapscott, 2016). In the retail industry, blockchain can be used to validate product authenticity (Chakrabarti & Chaudhuri, 2017). The information stored on the blockchain can be visible to customers, retailers, and suppliers, all of which can be used to identify product source, decreasing the chances of misinformation and counterfeiting, while increasing customer confidence. In the auto industry, blockchain may allow companies and individuals to share and monetize their driving information in a secure marketplace (Alam, 2016). In the music industry, the Open Music Initiative creates digital footprints to better track property rights and how music is shared across networks (Crosby, Pattanayak, Verna, & Kalyanaraman, 2016). In the insurance industry, blockchain can be critical to the underwriting process. It improves accuracy in records, lowers risks of fraudulent claims, reduces unnecessary intermediaries, and enables real-time updates (Nath, 2016). Sequential updates of a distributed system guarantees correctness of the information (Choy et al., 2000). A prospect which is gaining particular attention is the use of blockchain in registries for important assets, such as tracking diamond sale transactions (Bal, 2017). The authors contend that these benefits are not unique to these industries. Indeed, the potential for the real estate industry to benefit from blockchain technology remains optimistic. Specifically, blockchain technology has the potential to reduce fraud and unethical practices among the stakeholders involved in real estate transactions.

Blockchain technology may be particularly suitable for the real estate industry; it is designed to prevent fraudulent behavior and double-spending (selling the rights to the same asset more than once). If well-designed, blockchain can improve the transparency of a system enabling detection and prevention of fraudulent behavior. The architecture of blockchain also enables the creation of a tamper-evident ledger record which can be trusted to remain unmodified; something which is not easily accomplished with traditional electronic records. In certain jurisdictions such as India, blockchain has the potential to guarantee and enforce land title rights, remove deficiencies, and standardize the country's land titles system. The benefits of a blockchain system in real-estate extends to cost effectiveness, efficiency and alleviating administrative burdens. For these reasons, some jurisdictions are exploring the implementation of blockchain-based title tracking systems to address issues of fraud and unreliability of land transaction records (e.g., Brazil, Estonia, Honduras, Ghana, Georgia, Sweden) (Bal, 2017; Dale, 2016: Lemieux, 2016; Lemieux, 2017a).

The application of blockchain in the real estate sector is gaining momentum as companies such as Ubitquity, REIDAO, and RexMLS are exploring ways to provide value to real estate markets. For instance, Ubitquity is a US-registered blockchain company that focuses on recording and tracking real estate title ownership in specific jurisdictions around the world (Ubiquity LLC, 2017). REIDAO is a Singapore-based real estate start-up that focuses on enabling fractional ownership of large commercial real-estate assets and the ability to easily trade the ownership stakes through an online exchange (REIDAO, 2017). RexMLS is a US and Australia-based property listing platform that has plans to expand their scope to enable property transactions globally (Gallagher, 2017). These are some current use-based examples of companies leveraging the features of blockchain technology to add value to the real estate industry.

Notwithstanding, research into the compensation structures in real estate show that the interests of property sellers and their agents may be misaligned. Levitt & Syverson (2008) revealed that a form of fraud perpetrated by real estate brokers, called double-ending, may be quite common. This type of fraud can occur when a broker represents both buyers and sellers of a property (Malik & Foxcroft, 2016). A recent academic study found that in certain cases, double-ending correlated with significant differences in the selling prices of government owned properties (Johnson, Lin, & Xie, 2015). Here, the authors contend that there is potential for blockchain technology to reduce such frauds via a smart contract-based system that enhances the credibility of real estate transactions.

The Double-Ending Fraud

There are two types of double-ending fraud. The first type is when an agent acts on behalf of both the buyer and the seller and commits fraudulent activities to maximize his or her own gains at the expense of the client, typically the seller (Rotte & Chandrashekaran, 2008). The second type is when two separate agents in the same brokerage represent both parties, leaving themselves open for possible collusion between the agents. In either case, there are inherent conflicts with dual agents where the interest of the agent may become misaligned with the interest of the client.

A self-serving agent may unethically utilize the double-ending technique for their own benefit. On one hand, an agent representing the seller in a real estate transaction may provide confidential information to a buyer they represent in order to help them win the bid. This unethical practice accelerates the transaction process, allowing agents to move on to their next transaction, by lowering the selling price of the home, ultimately causing financial harm to the seller (Gardiner, Heisler, Kallberg, & Liu, 2007). On the other hand, an agent may use confidential information provided by both the seller and the buyer to maximize the sold price of the housing unit to ensure that they are able to maximize the commission that they can receive from both parties (Gardiner et al., 2007). Lastly, during the negotiation stage, an agent may pressure either the buyer or the seller to rush the sale (Kadiyali et al., 2014). This is not surprising given that research has shown that agents are more than willing to accept a lower housing price in order to complete a sale (Levitt & Syverson, 2008).

Historically, until the 1980s, real estate agents were not required to disclose their relationship to their clients (Gardiner et al., 2007). In response, certain jurisdictions have placed regulations and policies in place as preventative mechanisms to reduce such unethical practices; many brokerage professional associations have responded with ethical guidelines to inform and teach agents about double-ending practices (Richard & Phillip, 2005). For example, in 1984, the state of Hawaii made it mandatory for agents to disclose when one is representing both sides of the transaction (Gardiner et al., 2007). Other jurisdictions have followed by instigating policies and rules to either ban such practices or have stringent disclosure practices that reduce conflicts of interest (Miceli, Panak, & Sirmans, 2007). In some areas, acquiring consent from both parties is necessary for dual representation (Jennings, 2011). These legislations and ethical guidelines are important to ensure that agents do not misuse information, but more so to maintain trustworthy discussions between parties (Freybote & Gibler, 2011).

In many parts of North America, housing bids are kept secret, making it difficult to track how common this practice is. It is estimated that dual agency situations make-up nearly 28% of home sales (Rotte &

Chandrashekaran, 2008). In Canada, it has been estimated that 10% of the deals in Ontario involve double-ending, raising concerns of policy-makers and resident-seekers alike (Malik & Foxcroft, 2016). In some provinces such as Alberta, it is illegal to represent both sides in a real estate transaction (Malik & Foxcroft, 2016). Today, the rules and policies that govern double-ending vary (Brastow & Waller, 2013; Rotte & Chandrashekaran, 2008). Some jurisdictions have banned dual representations altogether, while others have allowed dual representations, but only through full disclosure and consent. Lastly, some have maintained the status quo citing that the risks inherently associated with double-ending are enough of a deterrent. Interestingly, despite such conflicts and potential harm to buyers and sellers, there have been reported benefits to double-ending such as the supplying of information and transactional efficiencies (Kadiyali et al., 2014). For example, double-ending may expand the pool of houses that an agent can show to a buyer and it may accelerate the matching process based on the criteria that is provided by the parties. It may also increase transactional efficiencies as an agent may help to mediate any unresolved issues related to the purchase. Further, dual relationships may enhance communication, potentially reducing buyer-seller conflict and the conflict of interest that may arise from dual representation (Shannahan, Bush, Moncreif, & Shannahan, 2013). Despite these potential benefits, double-ending often poses a net negative effect and preventing unfavorable outcomes requires a complex and costly regulatory response. This opens the door to exploring how blockchain technology might create efficiencies in the system.

Previous work has identified real estate title registry systems as a good use case for blockchain technology (Deloitte, 2017; Speilman, 2015). However, little information exists on how these applications should be designed or the purported benefits. As such, the goal of this paper is to develop a proposal for two blockchain applications with the aim of reducing instances of fraud and unethical practices (i.e., double-ending) by stakeholders in real estate transactions. Here, the authors conduct a comprehensive review of blockchain technology and the Canadian real estate market, then use this information to propose a blockchain process design. To facilitate this, the following steps were followed: 1) investigate the current systems to quantify the baseline cost of fraud using publicly available information and interviews with industry associations; 2) investigate the principles behind process and blockchain system design including blockchain types and process design principles; 3) apply design knowledge to real estate bidding and transaction processes to create new process designs; 4) implement the process and blockchain system design; and 5) evaluate the new process and blockchain system design using an agent-based modelling simulation.

PROCESS DESIGN DEVELOPMENT

The authors first review the components essential to developing the blockchain process design.

Common Design Decisions (Parameters)

While distributed systems are able to handle higher throughput and varying scales of data traffic, different blockchain types and features are well suited for certain workloads and require a decision (parameter) to be made prior to the systems design (Choy et al., 2000). The proposed systems were designed for use in the real estate industry and have been designed with common characteristics that make them well-suited for this market.

Permissioned Users.

The applications that authors propose require that users of the blockchain based system are permissioned, rather than permission-less. This means that each user will need to be authorized to use the system. This enhances the security of the system and enables more flexible consensus building mechanisms due to the existence of a trusted user class. By only allowing an approved list of users to access the system, information privacy concerns can be managed, and the risk of the system being controlled by a group of anonymous users is removed. Having permissioned users also allows the system’s operators to restrict access to certain types of users. Users would likely include registered agents, lawyers and banking professionals working directly in the real estate industry. This would ensure that only those who are deemed necessary and trustworthy for the transaction have direct access without external intervention. By choosing to include only permissioned users, one can place more trust in the authentication of the users as opposed to relying upon a strong consensus mechanism, such as Proof of Work. Therefore, one can use a somewhat weaker consensus mechanism (please refer to the section on Centralized Consensus Mechanisms below). In summary, the incorporation of trust and security into the system places greater reliance upon identity management and authorization mechanisms inherent in the organizations involved than in the computing power of blockchain participants and their relative ability to confirm and record transactions on the ledger. This design pattern is associated with permissioned blockchains as opposed to permission-less blockchains. Permissioned blockchains may be privately governed (i.e., owned and operated by a single entity, such as a corporation or a single public body) or governed by a consortium of entities. The classification of blockchains into private, consortium, or public blockchains is primarily based on whether there is any restriction on which nodes can participate in validating the transactions on the blockchain.

With any public system, privacy is a primary concern (Choy et al., 2000). Because consortium blockchains are not accessible to any node and require a level of authorization to access the blockchain, the level of trust that can be placed in certain participating nodes is higher, removing the requirement for complex consensus gaining mechanisms such as Proof of Work (Narayanan & Clark, 2017). In addition, consortium blockchains support an ecosystem of multiple organizations and individuals, allowing for enhanced communication efficiency relative to a private blockchain governed by a single entity, which may be enclosed. Consortium blockchains are a very flexible type of blockchain implementation and the choice enables other design decisions including permissioned users, centralized consensus mechanisms and multiple user classes.

Centralized Consensus Mechanisms.

The proposed blockchain uses a consensus mechanism called proof-of-authority (POA). This is only practical for private or consortium blockchains. The consensus is conducted by validators who are a group of users/nodes trusted among the organizations involved in transaction validation. While use of the systems will be enabled for organizations and individuals without the authority to approve transactions, they will not be able to make any official changes to the record by themselves. By using a central authority as a final check on transactions, the owners of each proposed blockchain can maintain a greater level of control.

Many organizations are not yet comfortable adopting blockchain technologies due to fears related to cybersecurity. Public blockchains are made possible as a result of architectural decisions that minimize the risk of collusion, thus ensuring the integrity of a shared ledger. However, there are still theoretical risks that have not yet been tested to the satisfaction of potential users. This makes a centralized consensus mechanism more attractive to organizations for which a fully decentralized model is still a step too far. A centralized consensus mechanism can reduce the risk of fraudulent authorizations, resulting from collusion, by only allowing a single trustworthy organization to maintain control over the record of transactions. However, this model depends on the assurance that the centralized authority does not become corrupted or operate as a bad actor. Still, this design decision can increase the comfort of potential users who lack trust in public blockchains' consensus reaching mechanisms – with a potential transition to a more decentralized future operating model. In addition, having a single approver more closely matches the current transaction systems in place, and thus is a more familiar model or basis of trust. The authors acknowledge that this design choice is only suited to socio-political contexts in which users interacting with the system (i.e., citizens of a state) already have a high degree of confidence in the central authority. In other contexts, the central authority would not be sufficiently trusted for this model to work and, consequently, users of the system may be open to more radically decentralized models of trust.

Multiple User Classes.

Another feature enabled through a consortium blockchain is the ability to establish multiple user classes. In each proposed blockchain, there are different permissions available to each user group. For example, each system includes a blockchain "guardian" which acts as a final approver for the ledger. This design allows for control to be facilitated by a trusted authority, likely a government agency or regulatory body, while maintaining transparency for the users of the system. In addition, by creating an administrative level account permission, government agencies can maintain full control over the ledger and make retroactive changes if needed. This is similar to the Role Based Access Control (RBAC) which is a type of system design which restricts access to permissioned users based on their roles within an organization (Ferraiolo & Kuhn, 1992).

Smart Contract Functionality.

Each of the proposed systems uses smart contract functionality to efficiently carry out processes without manual intervention. The title tracking system uses smart contracts and asset tracking to allow for an efficient exchange of assets. The asset tracking would likely be done using custom tokens, similar to how the feature is implemented on the Ethereum public blockchain (Buterin, 2013).

A Unified Blockchain Platform.

The proposed design for a blockchain solution that addresses the bidding aspect of a residential real estate transaction could be coupled with another blockchain that deals with the transaction itself (Mashatan & Roberts, 2017). The design principles described above could apply to the other steps in a real estate transaction process as well. The two blockchain applications can work together to provide a complete real estate transaction platform for real estate markets. Since both share the same fundamental architectures, as described above, they could run on a single unified blockchain platform to reduce the total development costs and simplify the integration process. The platform would likely be built using an open-source codebase. As it stands, Ethereum offers a programmable framework with an unfixed codebase, which can be modified to run as a consortium blockchain with a proof-of-authority consensus mechanism (Shu, Yu & Yan, 2019). This would provide the shared platform upon which to develop and maintain the proposed systems in a standardized, but permissioned architecture.

Process Design Proposal: The Transparent Bidding Blockchain (TBB)

In jurisdictions where transactions are primarily paper-based or handled via the exchange of electronic documents via email, the bidding process is controlled by the agent representing the property seller. In this design, bids are submitted by the buyers' agent to the seller's agent who compiles them for the seller. Counter-offers are similarly communicated through the agents to the buyers. However, this design lacks transparency for the buyer and it is not possible to effectively audit the bid communications to ensure that the transaction was in compliance with real estate regulations. Without such transparency, the current design is vulnerable to double-ending fraud, as previously described. While this practice is illegal, this type of fraud is difficult to monitor and control under the current system.

The authors propose the Transparent Bidding Blockchain (TBB) process design which is aimed to improve the flow and control of information in the bidding process. This design allows information about a bid to be collected independent of the seller's agent by means of securely capturing the bids on a blockchain application. Select bidding information could then be withheld from the seller's agent until bidding is closed, but still communicated to the seller in real time, decreasing the potential for fraud.

The TBB could also improve the bidding process from the perspective of buyers as well. The seller could opt to allow buyers to view selected information following their bid. A buyer could view the leading bid amount and be given the option to submit a second offer. Buyers could check on the status of their bid through the TBB without needing to speak with the seller's agent as they do now. This would reduce inefficiencies via intermediaries and reduce the potential for misinformation and fraud. The TBB could also enable conditional bids that execute automatically within the bidding and transaction processes. This could take the form of time-sensitive offers which automatically expire or enact conditional bids (i.e., successful inspection of the property). The accepted bid could then be loaded onto the transaction blockchain, which could then be used as a basis for a smart contract. Overall, the authors propose that this would increase the system's communication efficiency, transparency and auditability.

The authors provide the process flow for each of the stakeholders: Seller, Seller Agent, Buyer(s) Agents, Buyer, and TBB Guardian, as elaborated below:

Step 1: Each user must sign-in to the TBB to perform the actions described here. This would be done through a standard application interface, installed on a workstation, accessible through the web, or through a mobile application.

Step 2: The seller's agent begins by listing the property of the seller that they represent on the bidding platform. The existence of listed properties allows the agent that represents a buyer to search through the available inventory to find properties that match their requirements.

Step 3: Once a buyer is interested in a property, the agents are able to communicate the interest through the TBB and schedule a viewing. Agents are able to coordinate multiple viewings simultaneously using this platform.

Step 4: At the scheduled viewing, all parties communicate their transaction requirements and relative interest levels offline. Buyers then make a decision on whether they will bid on the properties they have seen or not. If they decide to bid, the buyer's agent inputs the bid and any conditions into the TBB, which is then communicated to the seller and seller's agent through automatic system notifications in TBB. All bids are recorded by the TBB Guardian on the ledger to enhance transparency and auditability. If the seller's agent is also representing a potential buyer, the buyer's bid will be entered to the TBB by the same agent, acting in the role of the buyer's agent, and the seller is notified through TBB. As the buyer's bid would not only be visible to the seller but also to the buyer, and potentially to other agents, the problems associated with double-ending can be alleviated. The transparency provided by the TBB design prevents a selling agent from blocking a bid from the seller given that the seller can see all the logged bids on TBB whereas right now they rely on their selling agent to present them with the bids. In other words, a double-ending agent, who is representing the seller and one of the buyers, cannot block another, potentially better, bid from the seller and commit a double-ending fraud. Moreover, the transparency provided by the TBB design can work as a deterrence for agents who team up and systematically exchange confidential information, such as seller's bottom line, in many transactions. This exchange of confidential information is taking place outside of TBB and might not be proven in any single transaction. However, if it takes place frequently, it will produce a recognizable pattern that can be further investigated based on the auditable TBB records.

Step 5: If buyers wish to negotiate further with sellers, they may send counter-offers, with changes to bid amounts and/or conditions, to a selected a bidder through their agents on the TBB. All counter-offers, as with bids, are recorded by the TBB Guardian.

Step 6: Upon selection of a winning bid by the seller, notifications are sent to each user informing them of the decision. Losing bids are notified that their bids are no longer in consideration and the selection is recorded to the TBB record.

Step 7: The TBB Guardian compiles the agreed upon transaction terms and sends them to the SPL Guardian. The SPL Guardian uses the terms as the basis of the SPL smart contract that governs the title transfer process.

Figure 1 outlines the TBB flow.

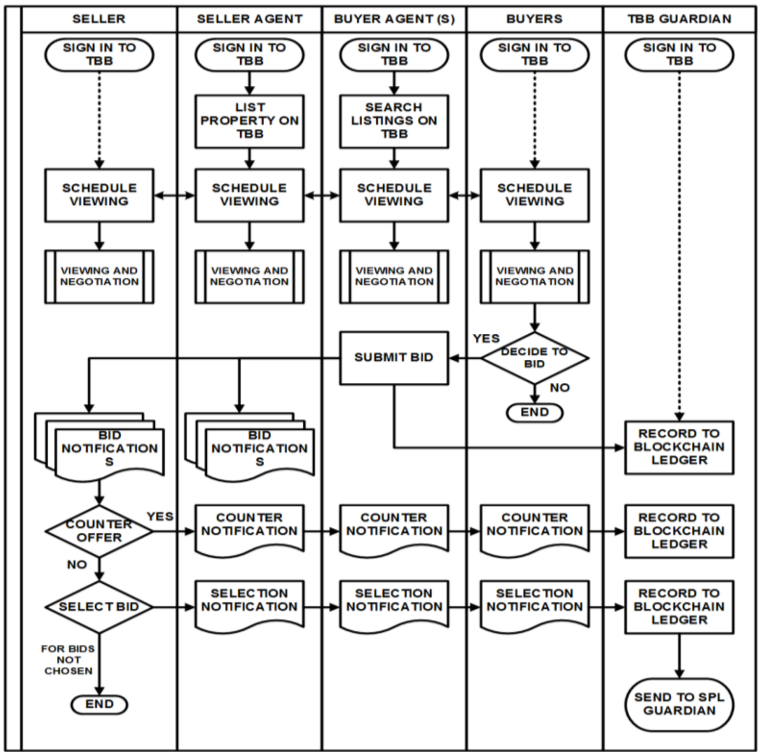

Figure 1: Transparent Bidding Blockchain (TBB)

Implementing TBB with Hyperledger Fabric and Sails

The TBB design begins with the registering of a property on the blockchain and finishes with the seller selecting a bid. Hyperledger Fabric and Sails are used to build a blockchain with a web application as the user interface. An overview of the proposed technology architecture as well as the web application is provided here. An accompanying implementation specification document captures the details of the implementation and how the interface is viewed and used by the distinct roles of users, i.e., sellers, buyers, their agents; what blockchain platform is being used and how to install and access the system; how the system functions for each of the roles; what policies were used; and how the web app calls and adds data to the blockchain. The system is hosted on the Microsoft Azure cloud. Azure has a pre-existing template for a high-availability Hyperledger Fabric network. Another server is added to run the web application. All hosted servers run Ubuntu Linux Server 18.04 LTS. Figure 2 illustrates the technology stack deployed in this implementation.

Tech Stack

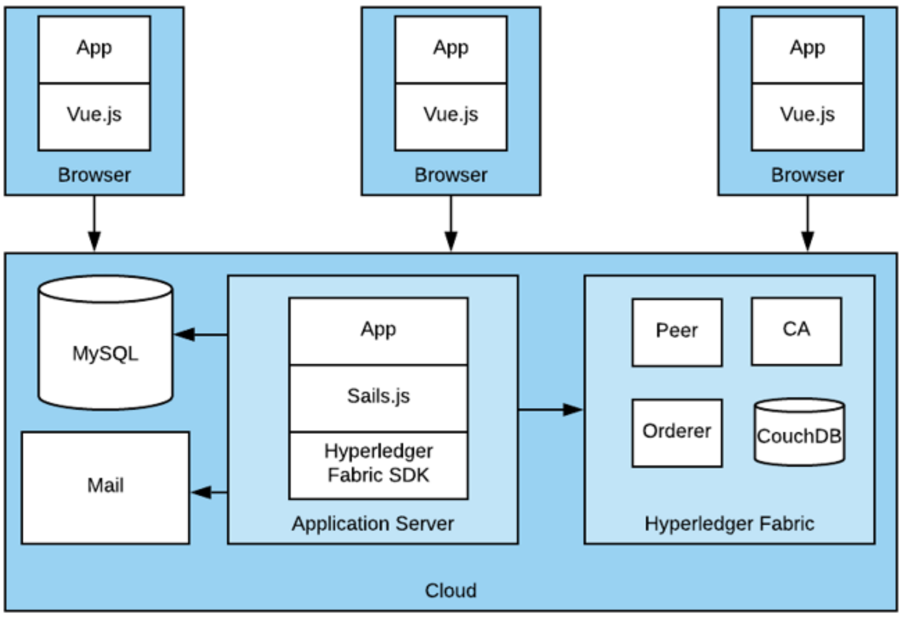

Figure 2: TBB Implementation Technology Stack.

The authors next describe the blockchain-related aspects of the implementation.

TBB Blockchain.

As mentioned, the TBB blockchain runs on Hyperledger Fabric, an open source platform for permissioned distributed ledger technology (DLT). Fabric SDK for Node.js acts as the API allowing the web application to interact with the Hyperledger Fabric blockchain. TBB hosts the smart contracts which track the properties through the system and the smart contracts move data between stages of the process, defined as property ‘states’. The state of the property is the underlying element that the system is designed to host, track, and complete. The contract goes through several stages which are reached based on a set of conditions that are met. The following three states are identified: not for sale, listed property, and bid selected. Once the conditions are met, a transition is called which changes the state of the contract. State data consists of blockchain data only (not data that is stored in MySQL). Various actions are required to build up the data, in order to meet the conditions to transition the contract from one state to another. Users are notified of specific transitions via email, depending on their role. Figure 3 illustrates a state diagram indicating all of the states that the contract goes through and the transitions which move the contract from one state to the next.

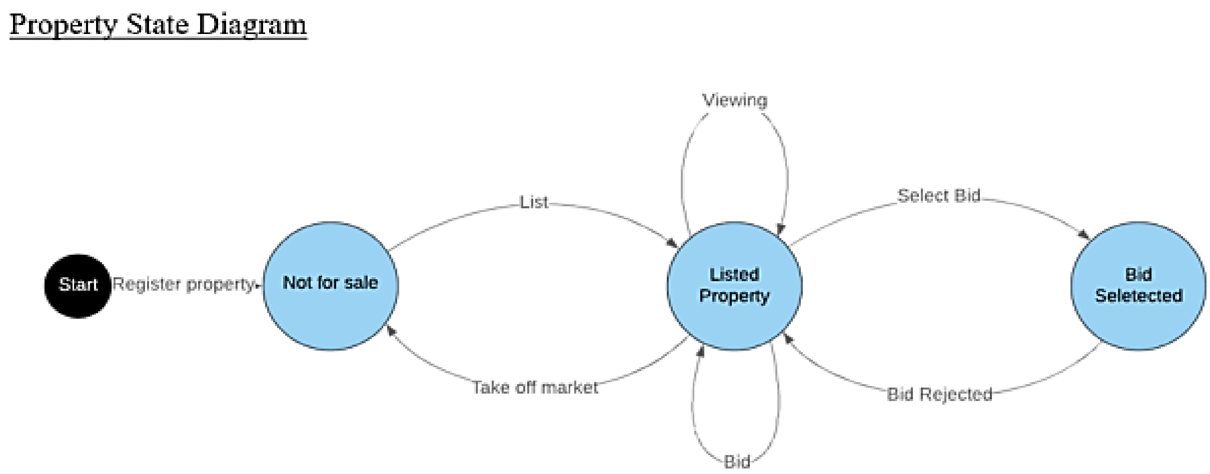

Figure 3: TBB Smart Contract Property State Diagram.

The involved parties are categorized by their roles. As such, the access control is role-based and users have different use cases according to their role. The roles are used to control access to transition functions based on the current contract state. The roles and their related access are listed in Table 1.

Role	**Access**	**Description**
Buyer	View	The buyer can view their bid and property listing.
Seller	Select Bid	The seller can approve a bid which takes the property into the ‘bid selected’ state.
	Reject Bid	If there is a problem with a selected bid, the buyer can reject it, which takes the property from the ‘bid selected’ state back to the ‘listed property’ state.
Buying agent	Create bid	The agent registers bids which are made on behalf of the buyer.

	Arrange a viewing	The agent records that they have arranged a viewing of the property.
Selling agent	Register the property	The agent registers the property onto the system, but it is not yet listed.
	List the property	The agent makes a listing of the registered property, which is viewable to everyone.

Table 1: Roles and User Access

TBB Interface.

The interface is a web application (web app) which makes a call to the blockchain using Hyperledger Fabric SDK. For the web app and the blockchain to work together, several levels of technology are required. An overview of how the blockchain and web app are integrated is displayed in the Tech Stack model followed by a breakdown of each technology. The web app interface allows a user, depending on their role, to view the unlisted properties, listed properties, bids, viewings, and invoke actions that add an updated version to the blockchain. The possible actions and view parameters are organized across different pages on the web app. There are eighteen pages in total illustrated in the Web App Interfaces diagram of Figure 4.

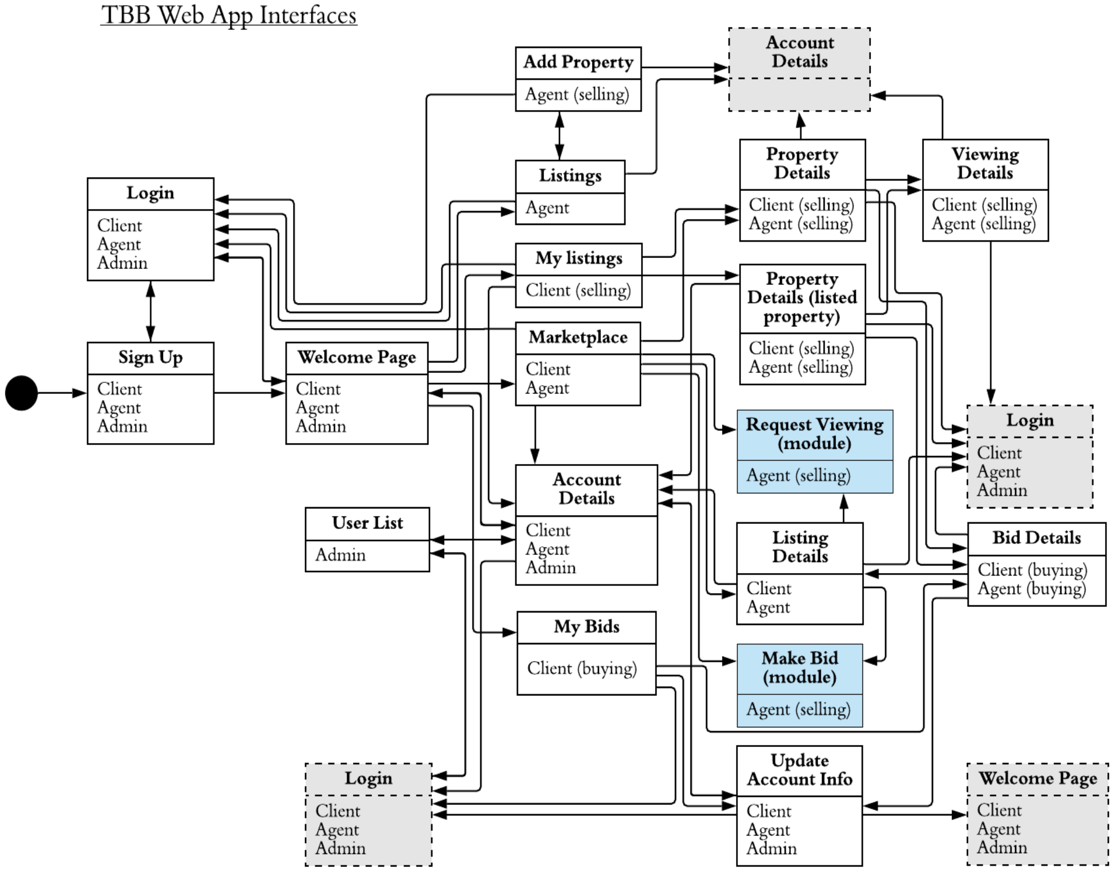

Figure 4: TBB Web Application Interfaces and Flows

Select user interfaces are included in Figure 5.

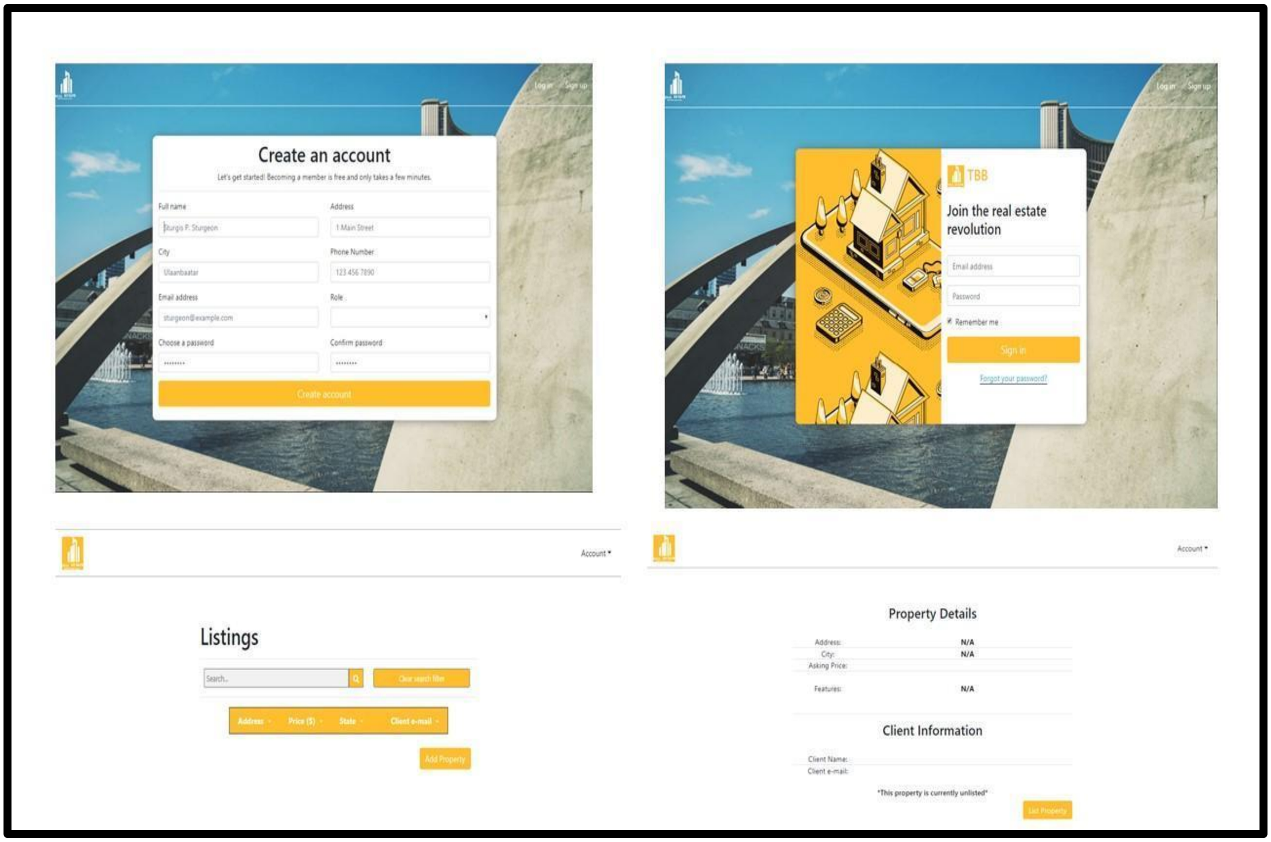

Figure 5: TBB User Interface

Next, we evaluate the efficacy of the TBB design by means of an Agent-Based Modelling simulation.

Agent-Based Modelling Evaluation of TBB

In a real-life scenario, TBB will be carried out by individuals in their roles as sellers, buyers and agents each having their own motivation and incentives. Any evaluation using a sample of hypothetical users will result in some limitations based on the size and composition of the sample and the subjectivity of its members. The authors therefore used the Agent-Based Modelling (ABM) technique to evaluate the efficacy of TBB in reducing double-ending fraud and providing a better allocation of properties to end-users. Validating a newly developed protocol through a simulation is a standard approach in the literature (Ulusoy, 2003; Gelman, 2012). This approach is particularly useful when the analyzed system is too complex and too costly to experiment with directly (Porto, Costa, Moura, and Gonçalves, 2015). To create the simultaneous interactions of the aforementioned users to measure the impact of TBB on the market, the authors executed 7,680,000 simulation runs in the Julia programming language and made source code required to reproduce the presented results publicly available via a GitHub repository at https://github.com/pszufe/ TBBSim.jl/.

TBB Agents.

The following agent types were considered in the model.

1) A homeowner, H_i, $i=1,\ldots,n_H$, who is trying to sell a property for the highest price possible while considering a minimum reserved price of r_i. The goal of the homeowner is to maximize the actual selling price p_i for the property, and we can denote her goal function as $p_i \rightarrow max$. Without loss of generality, we assume that each homeowner has one property for sale. The homeowner has no special market knowledge and chooses at random a single agent to represent her.
2) A buyer, B_j, $j=1,\ldots,n_B$ who is looking to buy a property on the market. For each property $i=1,\ldots,n_H$, the buyer has him value function v_{ij} that represents the utility of the property to the buyer. Hence, the maximum amount that the buyer j is able to pay for the property i is equal to his perceived personal utility from this property v_{ij}. The goal of the buyer is to select a property that maximizes his internal utility from the property as well as the price so that $v_{ij} - p_i \rightarrow max$. Note that this understanding of *vij* is not the "market value". For example a house might be worth \$1 million but the buyer is ready to get it for \$1.2 million because it is in the range of desirable school zone. Note that in this model, a property will be only bought if vij > p_i. Moreover, without loss of generality we assume that each buyer wants to buy a single property. The buyer has no special market knowledge and chooses at random a single trading agent to represent him. Since the same agent might already be representing that particular property, a double ending might occur naturally.
3) A real estate agent A_k, $k=1,\ldots,n_A$. The real estate agent offers the property for sale in the name of homeowners as well as represents buyers in front of homeowners. We assume that some agents might only represent buyers or only represent sellers on the market. The real estate agent receives profits in two situations: (1) if a homeowner's property is sold for the price p_i the agent receives a

commission of d_S*p_i; (2) if the agent successfully closes the buying transaction in the name of the buyer they receive a commission of d_B*p_i. Additionally, each time the price is checked by the potential buyer both the buying and selling agents incur a fixed cost of c_B and c_S, respectively, that represent the time and effort devoted by the agents to present the property (the "information cost"). Hence, the goal function of the agent k representing the seller s can be represented as: $d*p_i - q_{Si}*c_S \rightarrow max$ where q_{Si} is the number of times the property i has been presented to potential buyers. The goal function of an agent representing a buyer j who has purchased the property i can be represented as $d*p_i - q_{Bj}*c_B \rightarrow max$ where q_{Si} is the number of times the buyer j has been visiting potential properties. Note that this function means that neither buying nor selling agent might want to present the property to the buyer/seller if they regard the probability of closing the transaction as very low.

Dynamics of the TBB Model.

The goal of the simulation is to compare the following scenarios:

a) *Agent-only scenario*: buyers and sellers use the real estate agents to close the price. The information about the bids and the status of transactions are managed by real estate agents and their offices, which results in an information asymmetry in the market.

   a. Sub-variant: double ending is allowed. Agents push forward the transaction whenever the double ending is possible and convince the buyer to bid around their maximum value v_{ij}. Additionally, in this variant the agent might decide to manipulate the buyer's perception about the property and make them increase their perceived value of the property and, consequently, make them overbid over their internal value. For simplicity, the authors assume that $b_{ij} = v_{ij}z - \varepsilon$, where z is a value manipulation factor such that $z \in \{1.0, 1.1, 1.2\}$ and ε, $\varepsilon>0$ is some smallest value that guarantees that making the transaction increases the subjective utility of the buyer. Since both buyers and homeowners select real estate agents randomly, a double-ending scenario might occur when both parties are represented by the agents. Additionally, the authors assume that whenever double ending opportunity exists, the agent will persuade the seller and potential buyers to close the bid sooner.

b. Sub-variant: double ending is not allowed. In this scenario, agents do not have information about the bids of other market participants. The authors assume that they will place a bid randomly with the value from triangle distribution. That is, their bid is $b_{ij} \sim T(r_i, v_{ij}-\varepsilon, v_{ij}-\varepsilon)$, where T represents the triangular distribution and ε, ε>0 is some smallest value that guarantees that making the transaction increases the subjective utility of the buyer.

Note that a situation where a specific percentage of double-ending agents operate on the market can be modelled as a mixture of the two aforementioned scenarios.

b) *TBB scenario*: the real estate agents help to contact buyers and sellers. However, both parties use TBB to place the actual bids. All bids are fully transparent to the seller. In this scenario, double-ending is not possible due to full information transparency. Buyers and sellers still need to use agents to carry out the transaction. The authors assume that the buyers place bids in the middle of the current highest bid and their internal value. That is, they place the following bid: $(v_{ij} - u_i)/2$, where u_i is the highest current bid placed on the property i.

TBB Simulation Parameters.

Table 2 captures the model calibration parameters considered by the authors.

Parameter	**Value(s)**	**Comments**
Number of buyers	100	Fixed number of buyers
Number of sellers	{ 70,80,90,100,110, 120,130,140 }	This setup makes it possible to measure how the market imbalance is going to influence the price levels.
Number of agents	10	This parameter only influences how often the double ending occurs, and is hence, irrelevant.
Reserved price r_i	~LN(6.5, 0.1)	Generated for each house
Utility value of the property *i* for the buyer *j*, i.e., $\underline{v_{ij}}$	$\sim N(p_p r_i, c_v r_i)$	Generated for each agent and for each house
House utility value multiplier p_p	{0.9,0.95,1.0,1.05, 1.1,1.15,1.2,1.25}	Used to generate utility values
House utility value standard deviation multiplier c_v	{0.05,0.1,0.15, 0.2,0.25,0.30}	Used to generate utility values

Table 2: Model Calibration Parameters.

The total size of parameter sweep for the TBB simulation is therefore 8x8x6=384 scenarios.

Table 3 lists the different decision making regimes considered in the model.

Regime id	Description	Number of simulation runs
DE_0_0	Effects for double ended transactions are allowed, agents do not manipulate utility value of a buyer	4000x384 scenarios
DE_0_1	Effects for double ended transactions are allowed, agents manipulate subjective utility value of a buyer and increase it by 10%	4000x384 scenarios
DE_0_2	Effects for double ended transactions are allowed, agents manipulate subjective utility value of a buyer and increase it by 20%	4000x384 scenarios
nDE	Double ending not allowed	4000x384 scenarios
TBB	Full market transparency provided by TBB. Since the parameters of transaction are visible to all parties, double ending does not take place	4000x384 scenarios

Table 3: Decision Making Regimes Considered in the Model

TBB Simulation Results.

A total of 5x4000x384=7,680,000 simulation runs were executed using a 96-vCPU core EC2 virtual machine at Amazon Web Services. This high number of simulation runs ensures that all the presented results and comparisons are statistically significant with confidence interval widths below 0.5% of observed averages. Since the source code is published on the aforementioned Githhub repository all results are fully reproducible.

For buyers as well as for sellers their internal "profit" can be calculated. The total utility of a buyer j from closing the transaction on house i can be presented as $v_{ij} - p_i$ while the total utility of the seller can be presented as $p_i - r_i$. In other words we can define a "happiness" of buyers when they buy for less than their internal value and "happiness" of sellers when they sell for more than their internal value. Figures 6 presents the utilities of buyers and sellers depending on the supply on the market and the market regime.

It should be noted that TBB can not only increase the utility of buyers but also those of sellers' (compared to the situation where the sellers cannot significantly manipulate the price in double-ending). This happens trough the fact that, on one hand, the buyers have heterogeneous subjective values of the property and, on the other hand, the transaction transparency offered by TBB can provide a better match of buyers and sellers. Hence, the better-matched buyers might be willing to offer a better price to the seller which in the end increases the utility of the seller. The utility of the buyer also increases because he gets a property that better fulfills her needs.

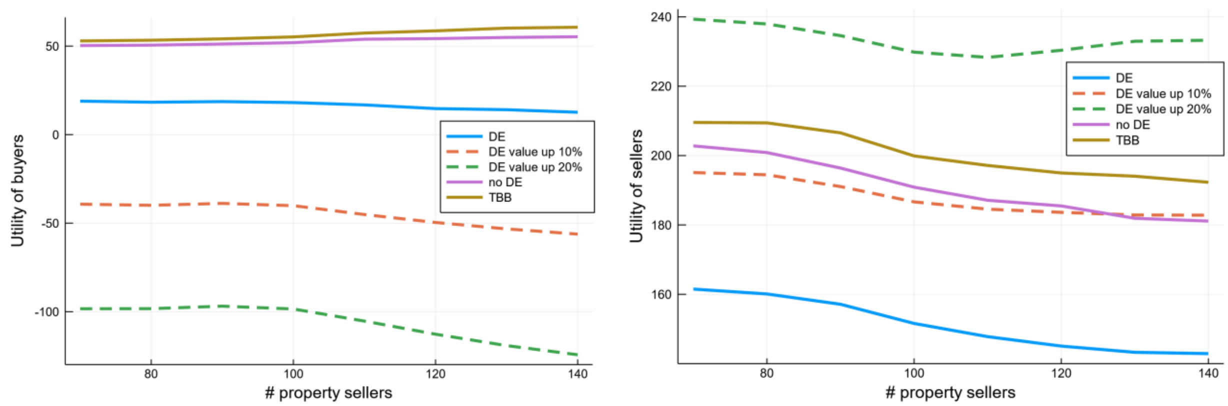

Figure 6: The utility of buyers and sellers, respectively, for p_p=1.1 and c_v =0.2.

The utility of buyers is the highest in the TBB-based scenario given that the information transparency makes optimal bidding possible for buyers. Moreover, in a double-ended scenario the baseline utility of sellers is lower than then their utility in a transparent TBB market. The authors further analyzed these values for differences between the reserved price *ri* and the subjective value of property to buyers *vij*, represented by House utility value multiplier p_p. The analysis showed that the TBB market design maximizes the utility of both buyers and sellers. Figure 7 shows the aggregated utility for both buyers and sellers.

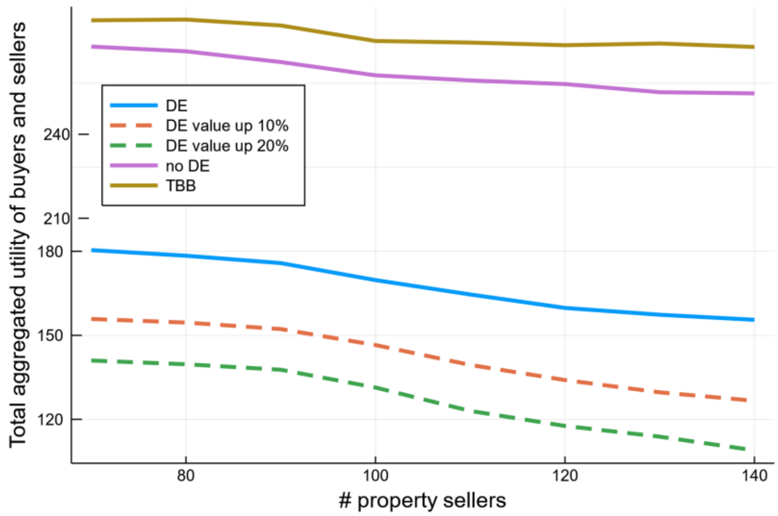

Figure 7: The total aggregated utility of both buyers and sellers, for p_p=1.1 and c_v =0.2.

Issues, Controversies, Problems

While a major benefit of the proposed TBB derives from the greater transparency and auditability of bids that it affords, privacy and the protection of personally identifiable information (PII) must also be considered. The proposed system captures the identifiable information that is captured currently with the traditional system. The difference is that the bids, which are accessible to both the selling and buying brokerages, are written on paper and the seller cannot be sure if the agent has presented them with all filed offers. Depending on who the actors are in the current system, they may see more or less of what is committed on the blockchain. For instance, agents and appraisers can see a lot more than a member of the public on these websites. However, no seller can be sure that they were presented with all submitted offers, whereas in the proposed system, they would be able to see this information. Despite the benefits that greater transparency delivers in the proposed TBB solution, paper or traditional electronic documents can be destroyed after a set retention period, whereas blockchain ledger records are intended to be immutable. Thus, the implications of retaining PII on a ledger for what could be an indefinite period must be considered in the context of any legislative requirements, e.g., to delete PII after the initial reason for its processing and other business requirements for its retention.

To alleviate the problem of storing PII on an immutable ledger, some blockchain solutions store the PII offline but in a manner accessible via the blockchain (e.g., via a cryptographic link). However, given the relative frequency of data breaches, it is worth considering whether this approach provides greater security and privacy protection. Finally, it is important to consider that the PII on the ledger may remain there for an indefinite period but the cryptography used to secure it may eventually be broken. Given this, the implications of keeping the PII on the ledger even if it is stored there in ciphered text must be taken into consideration. These are all considerations that future iterations of the TBB design will aim to address.

CONCLUSION

In this paper, the authors looked at double-ending fraud in real estate and how blockchain technology could help reduce the occurrence of this type of fraud in jurisdictions where double-ending itself is not illegal and is being practiced very commonly. A new blockchain-based process design, entitled Transparent Bidding Blockchain (TBB), was proposed to improve the existing bidding processes to provide transparency, auditability and accountability.

A proposed future work is to examine jurisdiction-specific data known for the occurrence of double-ending fraud, e.g., Ontario, Canada, and implement the TBB as a proof-of-concept. Another future research topic is to look at what happens in a real estate transaction after the bidding has taken place and propose new designs for efficient, transparent and auditable real estate transaction processing based on blockchain technology. Moreover, the authors have implemented the TBB design using Hyperledger Fabric as the backend blockchain and Sails for the frontend web application. Furthermore, the authors have deployed agent-based modelling simulation to evaluate the efficacy of the TBB design in providing transparency and reducing double-ending fraud.

A major benefit of the solution design is the transparency it affords, which promotes good behavior among all the participants in the transaction. However, this must be balanced with privacy and the risks that may occur if personally identifiable information is recorded on the ledger, whether in clear text or even in cypher text (since the security of the encrypted text cannot be indefinitely guaranteed). PII on the blockchain may result in victimization if bad actors discover a property is for sale. There may also be difficulties complying with emerging international best practices and standards for privacy and data protection. The authors will explore this aspect further in a future phase of the project.

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Atefeh Mashatan, PhD, CISSP, is an Associate Professor of Information Technology Management as well as Founder and Director of Cybersecurity Research lab at Ryerson University. Her research is focused on the development of novel cybersecurity designs based on emerging technologies such as IoT, Blockchain, and Quantum Computing. She investigates challenges and opportunities brought forward by these new technologies and how they change the threat landscape of cybersecurity. Collaborating with industry partners, Dr. Mashatan studies industry relevant research problems and proposes solutions that can be developed as part of the industry-academic collaborations she oversees. Prior to joining Ryerson, Dr. Mashatan was a Senior Information Security Consultant and Solutions Architect at CIBC. Prior to that, Dr. Mashatan was a Scientific Collaborator at the Security and Cryptography Laboratory at EPFL (Swiss Federal Institute of Technology, Lausanne).

Victoria Lemieux, PhD, CISSP, is an Associate Professor of Archival Science at the University of British Columbia in Vancouver, Canada and Founder and Co-Lead of Blockchain@UBC, a multidisciplinary blockchain and distributed ledger technology research and education cluster. Her current research is focused on risk to the availability of trustworthy records, in particular in blockchain record keeping systems, and how these risks impact upon transparency, financial stability, public accountability and human rights. She holds a doctorate from University College London (Archival Studies, 2002), and, since 2005, has been a Certified Information Systems

Security Professional (CISSP). Lemieux also serves as an associate editor for the journal Frontiers in Blockchain and as an expert on the International Standards Committee's Technical Committee 307 on blockchain and distributed ledger technology.

Seung Hwan (Mark) Lee (PhD) is an Associate Professor at Ted Rogers School of Retail Management at Ryerson University. He earned his Ph.D. in Business Administration from the Ivey School of Business at Western University. He completed his MBA at University of Windsor and Bachelor's degree in Arts & Science at McMaster University. His previous work experiences include working for Coca-Cola and General Motors. Dr. Lee's primary research interests are in the consumer behavior discipline, specifically focusing on the structural dynamics of social networks and its impact on retail consumers. Professor Lee also contributes to the topic of branding, marketing education, and sensory marketing. He has published in top tier journals which include Journal of Consumer Research, Journal of Consumer Psychology, Journal of Business Ethics, and Journal of Business Research.

Przemysław Szufel (PhD) is an Assistant Professor at SGH Warsaw School of Economics, Warsaw, Poland, Adjunct Professor at Ted Rogers School of Management, Ryerson University, Toronto and a Researcher at Computational Methods in Industrial Mathematics Lab, Fields Institute, Toronto. Przemysław Szufel main research focus is in applying advanced analytics methods, and in particular, agent-based simulations, optimization and machine learning in modelling and automating decision making. He is a co-author of several tools and algorithms for optimal and cost efficient high performance computing in the cloud. He is a co-author of over 30 publications, including handbooks and journal papers, in the area of applying advanced analytics, machine learning and simulation methods to making optimal business decisions. He is currently also involved in development of Julia programming language and is a co-author of book "Julia 1.0 Programming Cookbook".

Zachary Roberts is a Senior Account Manager at Dell Technologies and an alumni member of the Cybersecurity Research Lab at Ted Rogers School of Information Technology Management at Ryerson University. His research is focused on the application of blockchain technologies within financial and real estate markets to address regulatory and cybersecurity concerns. Zachary holds a Masters of Business Administration in the Management of Technology and Innovation from the Ted Rogers School of Management at Ryerson University as well as a Bachelors of Management and Organizational Studies, with a Specialization in Finance and Administration from Western University.