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ScienceDirect

Procedia Engineering 196 (2017) 638 – 645

Procedia Engineering

www.elsevier.com/locate/procedia

Creative Construction Conference 2017, CCC 2017, 19-22 June 2017, Primosten, Croatia

Potentials of Blockchain Technology for Construction Management

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Abstract

Blockchain technology enables distributed, encrypted and secure logging of digital transactions. It is the underlying technology of Bitcoin and other cryptocurrencies. Blockchain is expected to revolutionize computing in several areas, particularly where centralization was unnatural and privacy was important. In the paper, we present research on where and how this technology could be useful in the construction industry. The work is based on the study of literature on open issues that exist in construction process management. These are than matched to the capabilities of blockchain.

We are motivated by the fact that construction projects involve a dynamic grouping of several companies. We study the degree to which the relationships among them are hierarchical or peer-to-peer and note that particularly in information intensive phases, centralization of information management was necessary because of technology. When using un-constraining technology, communication patterns among participants show a peer-to-peer nature of the relationships. In such environment, blockchain can provide a trustworthy infrastructure for information management during all building life-cycle stages. Even if building information modelling (BIM) is used, which assumes a centralized building information model, there is a role for blockchain to manage information on who did what and when and thus provide a basis for any legal arguments that might occur. On the construction site blockchain can improve the reliability and trustworthiness of construction logbooks, works performed and material quantities recorded. In the facility maintenance phase, blockchain's main potential is the secure storage of sensor data which are sensitive to privacy.

We conclude that blockchain provides solutions to many current problems in construction information management. However, it is more likely that it will be built into generic IT infrastructure on top of which construction applications are built, rather than used directly by authors of construction related software. It has a potential to make construction processes less centralized which opens needs for research in that direction.

Keywords: blockchain, building information modelling, building information management, information systems, intellectual property rights, construction contracts, trust

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Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2017
doi:10.1016/j.proeng.2017.08.052

1. Introduction

Construction has always been a collaborative process involving a larger or smaller group of participants. Throughout history, communication technology has a significant impact on the relationships among those involved [1].

Before on-paper documents and drawings became standard, the designing, planning, and constructing work was organized around a master builder. Paper documentation enabled the first wave of specialization and consequently fragmentation of professions, businesses and processes. Companies specialized either into information processes (such as designing and planning) or material processes (such as construction, maintenance, and demolition). Information processes took place in firms and consultancies that were held together by a flow of paper documents that were created collaboratively by people working closely together. The information was exchanged by other firms typically as rather large and complete documents – such as conceptual design, basic design, detailed design or tender documentation. The authorship and intellectual property of such documents was very clear. Information with legal significance passed the boundaries of a business rather infrequently, were properly signed and the medium – paper – made possible alternations very visible.

Today, digital technology is allowing even greater specialization which results on one hand on the greater sum of knowledge deployed, better quality and safety and higher productivity. But on the other, it is also causing more fragmentation. Since the end of the master builder era, construction has been organized in what recently became known as the “Hollywood business model” [2] of economy. For each movie project a unique set of contributors is assembled to work together and are dismantled at the end of the project. In construction, this set of contributors have been companies but this is changing due to digital communication. Companies are getting smaller and individual consultants are having bigger roles, just as is the case in the Hollywood movie business. The information exchanges across organizational and legal boundaries of companies are much more frequent than before.

The processes of planning and design are today almost entirely digitalized with information being shared and exchanged in a digital format. In recent years, an increasing share of all information is managed by building information modelling (BIM) technology. BIM is changing the entire AEC industry and disrupting the building processes. What used to be a problem of modeling of buildings is now understood as a problem of managing building information [3].

It is important to note that building information management is the management of legally significant information that can be used in case of disputes and litigation among the numerous and fine-grained contributors to the process. Several authors have identified these legal issues as barriers to BIM technology adoption. Arensman and Ozbek [4] warned on legal uncertainty associated with BIM. Redmond et al. [5] identified legal and security issues as a main obstacle to using cloud platform for BIM. Thomas [6] claims these are:

- who owns the model;
- who has modification rights;
- who has distribution rights;
- who has liability for changes or errors;
- how to manage copyright protection;
- how to protect digital intellectual property.

There are also other legal and organizational concerns such as who owns the datasets, who pays for the datasets, who is responsible for the accuracy and correctness. They present a challenge for BIM implementation and identify legal barriers and model ownership management as barriers of BIM adoption by owners and facility managers [7]. Foster [8] identified the following barriers to BIM adoption:

- difficulties in assigning responsibilities and liabilities,
- collaborative nature of the design process,
- risk allocation,
- blending of roles and responsibilities by BIM,
- privity and third party reliance,
- distributed design decisions by third parties,

- software agents,
- difficulty in assigning intellectual property allocation.

Cubitt and Codwell [9] also warn of the issue of risk allocation, intellectual property, traceability, confidentiality of data in BIM.

1.1. Problem statement and hypothesis

The most notable difference between the old document-based and recent BIM-based construction process is that in the traditional process information associated with legal consequences were generally concentrated in a bundle of signed, stamped and firmly bound pieces of paper. In that way, copyright over each part of the aggregated information in physical binder together with consequent responsibilities was hardly an issue. On the other hand, information in BIM process is dispersed among one or more BIM models, model views and experts where a small attribute of a trivial building block can be an entity with its unique history, dependencies, provenance, proprietor and consequently legal significance.

This problem is addressed by BIM best practices defining increasingly detailed guidelines for implementing BIM projects [10] including organizational and legal issues. However, they are relying on legal tools from the paper world to address problems in the digital environment.

It is our hypothesis that blockchain technology can be a major part in addressing these problems.

2. Blockchain technology

Blockchain technology is the technology known mostly in connection with the cryptocurrency Bitcoin. While some [11] argue that blockchain is merely a name given by Nakamoto [12] to the design of the system running Bitcoin, others [13] see it as a decentralized database technology that works on a network, usually that network being the Internet. The steps to run the (blockchain) network were presented in a whitepaper [12] and are based on transparency. New transactions are broadcast to all nodes where they form a block that is (after some computing intensive work) accepted only if all transactions in it are valid. Nodes express their acceptance of the block by working on creating the next block in the chain, using the hash of the accepted block as the previous hash.

Due to strong ties between blockchain technology and cryptocurrency Bitcoin it is difficult to differentiate between the infrastructure and the product using that infrastructure. That is why the term blockchain 2.0 was introduced in order to make a distinction. Blockchain 2.0 is therefore defined as “a programmable distributed trust infrastructure” [14]. This is how we understand blockchain in this paper.

Technically, blockchain – as the name suggests – is a chain of blocks of information (see Fig 1). What makes it special is that:

- the chain is copied across several devices in many copies;
- once “chained”, the contents of the blocks cannot be modified; and
- in spite of data being copied on several devices, the blockchain algorithm ensures that there no conflicts and that all copies are identical.

This results in two features of blockchain-based data stores which are generally not available in traditional databases:

- The entire history of data with all its modifications as well as the metadata (timestamps, author information) is recorded and protected with the equivalent of a cryptographically strong digital signature.
- The solution is not centralized and has no need for a central trusted authority.

Both features correspond to the nature of a building design process taking place in a peer-to-peer collaborative network of companies and individuals.

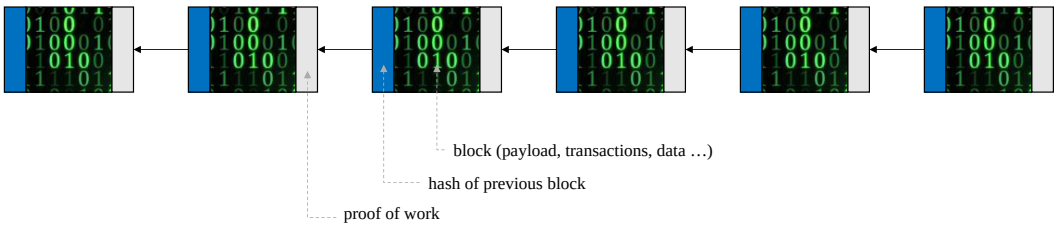

Fig. 1: The idea of blockchain.

The essence of the algorithm is that verifying the validity of a block's proof-of-work is far cheaper than solving it correctly [11]. That makes determining the correct status of ownership of the block both economic and lucrative and opens the window for various applications. Nevertheless, in order to use the blockchain technology as underlying foundation, some fundamental principles have to be met (see Fig. 2), at least at a high level [15]. Greenspan [16] argues that most of the requirements today are more than fulfilled with relational databases. But not all of them.

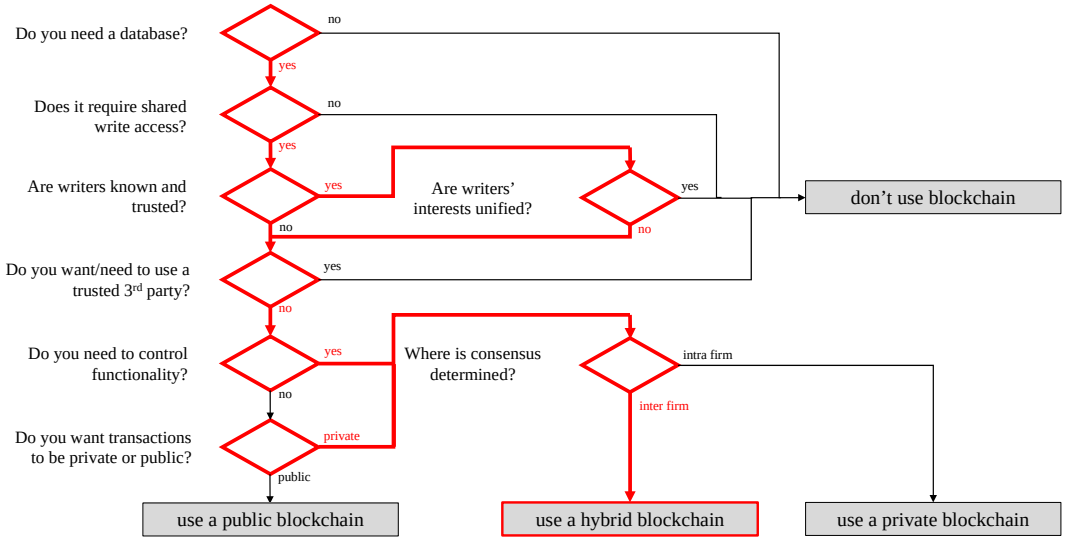

Fig. 2. The decision taken on what kind of blockchain to use.

In our opinion, the nature of transactions in collaborative building projects as well as legal consequences in case of project failures constitute an ideal use case for the application of blockchain technology. Due to requirements regarding the control over individual data and privacy over individual/all parts of the resulting models it fits well to the description of a hybrid blockchain (Fig. 2, red path):

- Yes, we do need a database (of building information).
- Yes, shared access is required.
- Yes, writers are well known. It is unclear whether they can be trusted.
- No, writers' interests are not unified.
- No, we do not want to use a trusted third party. Trusted 3rd parties have not been usual in construction projects.
- Yes, we need control functionality.
- No, transactions are not public.
- Consensus is determined inter-firm.

2.1. Blockchain in construction

In addition to cryptocurrencies blockchain has been used in several industries. Among the most interesting applications running on a new set of protocols defined by blockchain 2.0 are "smart contracts". Gronbaek [13] describes them as computer protocols that embed the (human readable) terms (the source code) and conditions of a contract that is compiled into computer code running on a network. Another potential use of the 2nd generation of blockchain technology is to provide services such as insurance contracts and share issuance [17]. It has even been proposed as a solution for the clearing and settlement of financial assets [18].

So far, the use of blockchain in construction has been limited. Some are using it to store sensor data from buildings in a trustworthy and distributed way [19]. There were also speculations that Ethereum could host BIM applications [20]. The use of blockchain in co-housing projects has also been suggested as it could "*provide a useful tool for managing and recording changes to the BIM model throughout the design and construction phases by using smart contracts to negotiate editing privileges and storing an immutable public record of all modifications to the model*" [21].

Barnett [22] is identifying several uses of blockchain in construction industry in general such as maintaining records of digital property, timestamping acts or transactions, Multisignature Transactions, Smart Contracts which are computer programs that monitor a situation and execute themselves and Smart Oracles which are real world depositories of information to be used in conjunction with smart contracts. The use of blockchain in automated dispute resolution and smart cities [22] as well as in real estate investment [23] has also been envisioned.

3. Four scenarios for blockchaining building information

In this section we present four different architectures to managing building information with blockchain. The key difference between traditional blockchain applications such as Bitcoin and blockchain for BIM is the different ratio between the number of transactions, number of participants and size of the data to be managed. Bitcoin is about billions of transactions between millions of users, about a kilobyte each. Building information blockchain is about hundreds of transactions between dozens of users up to a couple of gigabytes each.

3.1. Chained and very decentralized

In the chained scenario building information is copied into the blockchain. Blockchain is copied across workstations of participants. An operating system plugin presents it very much like a shared Dropbox folder, the exception being that all versions of all files are preserved and that a valid "last" version of every file is maintained. Commercial systems that do roughly this exist, for example Fazoid (http://fazoid.com/). See Figure 3.

3.2. Chained and slightly decentralized

The main problem of the chained scenario is that the size of the blockchain would soon grow very, very large and would exceed the capacity of individual workstations much like the entire Bitcoin does. The solution would be to distribute the blockchain across a few key partners in the project but to offer just a "wallet software" to the clients on the workstations. It would appear to the client that a file is local while in fact it would be pulled from the blockchain and cached locally if and when needed. At least one project partner would need to host the blockchain and every project partner that would want to have it could have it.

3.3. Unchained

The unchained scenario does not store the files themselves in the blockchain but just their fingerprints and perhaps the metadata. The files are stored in the cloud or on a file management server. All members of the project could have a copy of the blockchain – proof that a certain file existed at some point; they would also have a possibility to prove

that the file is the one whose fingerprint is in the blockchain. However, it would be left to other software to guarantee that all the files mentioned in the blockchain would be preserved somewhere.

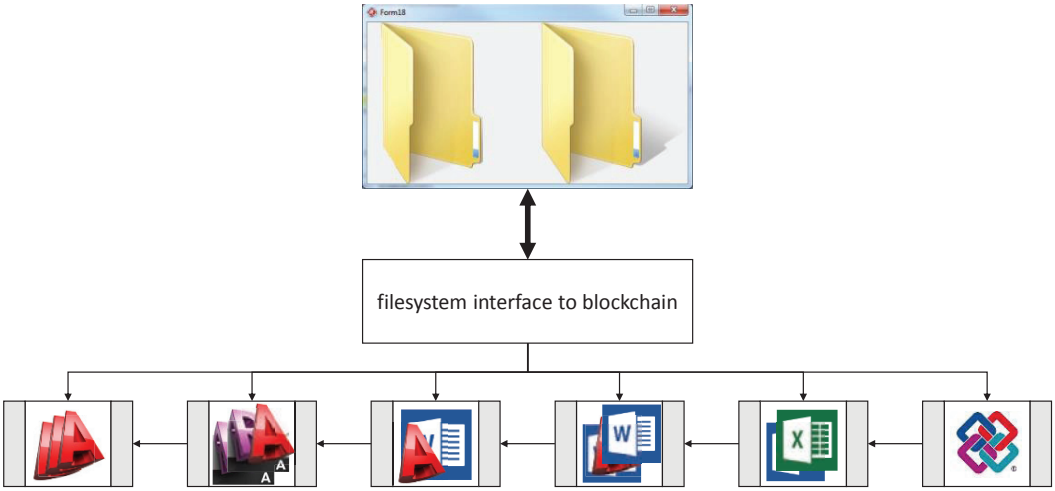

Fig. 3. Scenarios 1 and 2. They differ on the physical locations of the chained content.

3.4. Blockchain of BIM transactions

The previous scenarios can be used to manage any building information that is stored in files, including BIM files. A proper way to implement blockchain in a BIM setting, however, is to integrate it with a BIM server. The architecture is presented in Fig. 4.

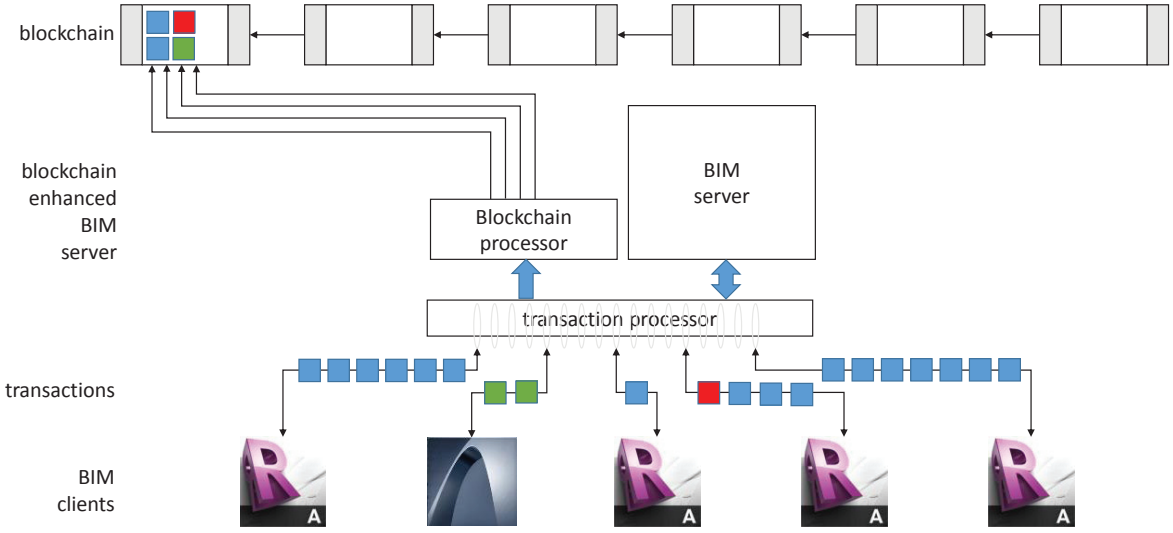

Fig. 4. The architecture of a system using blockchain for BIM transactions.

We are implementing the latter architecture with BIMserver.org's open source BIM (http://bimserver.org) server and open source blockchain services. Initial results show that the size of the blockchain can be expected to be one order of magnitude larger than the size of the database on the BIM server which is manageable with current technology. Impacts on speed and usability are yet to be determined.

4. Conclusions

Blockchain has the potential to address some issues that discourage the industry to use BIM such as confidentiality, provenance tracking, disintermediation, non-repudiation, multiparty aggregation, traceability inter-organizational recordkeeping, change tracing, data ownership, etc.

We have been using generic business solutions to manage building information as files using blockchain. Because of the huge size of BIM files and poor capabilities to manage differences between versions the usability of those solutions was limited. The proper position for the integration of blockchain is between the transaction processing component of the BIM server and its storage functionality. Additionally, blockchain should be fingerprinting and/or chaining all other information exchanges and communication.

Further research is needed into smart contracts that would – as part of the blockchain – evaluate and respond to the state of the blockchain (state of the BIM database) and perform actions on it to check if the designer has performed the design task to a certain level of detail.

Acknowledgements

The work presented has been funded by Slovenian Research Agency under the e-Construction Programme.

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