Conceptualizing Blockchain Utilization in Persuasive Systems Design

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Abstract. Blockchain technology has recently spread widely among different business and research domains, it has not yet been fully explored in the field of persuasive technologies. This paper attempts to define how blockchain technologies can be utilized when developing persuasive technologies and to position blockchain research topics in the persuasive technology domain. Data in persuasive systems are often sensitive and can benefit from the security feature blockchain has to offer. However, the immutability of data raises notable issues that impact compliance with General Data Protection Regulation (GDPR). In this paper, we discuss other benefits and challenges that may be of interest to designers, developers, and researchers who are keen on using blockchain to design the persuasive technologies they design.

Keywords: Blockchain, Conceptual Research, Persuasive Technology.

1 Introduction

Trust has been an issue of information systems. This problem gets even more complex when sensitive data (e.g., health, financial data) is stored and used [1]. In his whitepaper Nakamoto [2] presented the bitcoin blockchain to solve this issue. In the Bitcoin blockchain, the coins are secured by users of decentralized, verifiable, and auditable peer-to-peer (P2P) networks [1].

In this research, we aim to find out if utilizing blockchain in persuasive systems design solves some privacy concerns (e.g., transparency and trust) of users of Behaviour Change Support Systems (BCSS) as well as how well blockchain can be used with a large amount of IoT (Internet of Things) data (from e.g., wearables). Also, we present the possibility of blockchain tokens to be used in persuasive technologies.

Similarly, to other information systems, BCSS and persuasive technologies often collect large quantities of sensitive data from their use as part of the behavior change process [3], [4]. Collecting data happen via wearable devices and apps, and data may provide more personalized services [3]. These technologies collect more data than

Persuasive 2022, Adjunct Proceedings of the 17th International Conference on Persuasive Technology.

needed for the application to work, which can risk the privacy of the user [3]. According to Oinas-Kukkonen & Oinas-Kukkonen [5] there are concerns that the data can be sold to third parties for profit, which raises moral and ethical concerns. This can lead to user profiling and discrimination using their data [5]. On many occasions, persuasive systems have been developed for health and wellbeing [6]. Sensitive data in general, ought not to be trusted in the hands of third parties, where they are at mercy of attacks and misuse. Users should own and control their data without compromising security [3], [7].

The remainder of this paper is organized as follows. Section two describes the Persuasive Systems Design model. The third section is about the characteristics of blockchain technology. In section four, we explore how blockchain can be utilized in persuasive systems and conclude in section five.

2 Persuasive Systems Design (PSD)

The PSD model developed by Oinas-Kukkonen and Harjumaa [6] conceptualizes the development of a persuasive system in three steps. Before implementing the system, one should understand the fundamental issues behind persuasive systems. After that, the system can be analyzed and designed. The second phase consists of analyzing the context for persuasive systems, where the intent (intention of the persuader), event (user, use, and technology context), and strategies (route of information to the user) for the use of a persuasive system are recognized.

The PSD model includes seven postulates [6]. The first four postulates concern persuasion techniques and they are (1) IT (Information Technology) is always on, (2) commitment and consistency needed, (3) direct and indirect routes, and (4) incrementality. These are not directly about system design issues. Postulates 5, 6, and 7 resonate with the blockchain context best as they relate more to the system development issues. The fifth postulate is that the system should be open. If the designer bias remains unclear for the users, the system may either lose some of the persuasive power or it may even end up misleading the users. A system based on untruthful or false information does not fit with the overall goal of users' voluntarily changing attitudes or behaviors [6]. The sixth postulate is unobtrusiveness. This means that the systems should avoid disturbing users performing their primary tasks [6]. The seventh and last postulate is easy to use and useful. This includes e.g., responsiveness, ease of access, lack of errors, convenience, and high information quality. If users find the system useless or difficult to use, it is not going to have a favorable effect [6].

3 Blockchain

Blockchain is a distributed ledger that can be used to record transactions between two parties [8]. Blocks of information are connected cryptographically and timestamped and hence trustworthy and useful for certain types of transactions [9]. The distributed database that underly blockchain enables access to the entire history of records held of transactions, immutability of recorded information, the transmission of information

among peers in the network, transparency with the possibility to remain anonymous [10]. Blockchain works when a node records new data is broadcasted to all the nodes in the network. Each of these nodes upon receiving the new data verifies its validity and confirms the validity of the new data, then all the nodes will have to come to an agreement and conclude that the new piece of data is valid [11]. Only then will this new data be added to the block ensuring auditability. Blockchain is changing the lifestyle of people due to the influence it is garnering in businesses and industries [12] and there are several use cases to demonstrate its potential for recording and storing information and transactions. Applications of blockchain include digital currency, identity management, and record-keeping (e.g., health records, contracts) asset management, and shows promise to deal with the security challenges in IoT [13].

Blockchain Characteristics. When incorporating blockchain technologies into persuasive systems, the developer should pay attention to the common blockchain characteristics. The following blockchain characteristics relate to persuasive technologies.

Decentralization: The blockchain network is P2P. Any two peers can conduct transactions in the blockchain network without authentication by the central agency. Therefore, blockchain can significantly reduce operational costs [14], [1].

Persistency: Transactions are confirmed and recorded in blocks distributed in the whole network, making them nearly impossible to tamper [14], [1]. Also, each block is validated by other nodes therefore all the transactions would be checked [14]. Falsifications are detected easily, as each user holds their copy of the blockchain [14], [1]. The consensus algorithm makes changing the records difficult [1].

Anonymity: Users may interact with the blockchain network with a generated address (or even several). There is no central agency to keep records of users' confidential information. However, blockchain cannot guarantee perfect privacy [14].

Auditability: The transactions on the blockchain are validated and recorded with a timestamp, users can easily verify and trace the previous transactions by accessing any node in the distributed network. The store data in the blockchain is traceable and transparent [14, 1].

Blockchain Taxonomy. Blockchain systems usually are categorized into three types: private, public, and consortium [14], [1], [4]. Zheng et al [14], Namasudra [1] and Casino et al. [4] made some classifications and comparisons of these three. The selected comparison is seen in table 1.

In a public blockchain, no one is in charge or control of public blockchains, and everyone can join in the writing, reading, and validating of the network [4]. Public blockchains are open and transparent to the public. Decisions are made by decentralized consensus algorithms which tend to consume more energy than other types [4], [15], e.g., Proof of Work (PoW) and Proof of Stake (PoS) [1]. In general, public blockchain is the slowest type of these three [4], [15].

A private blockchain is owned by organizations or individuals, which oversee the closed network [15]. A private blockchain is a cryptographically secure and cost-effective type of blockchain. Private blockchains are used internally by organizations which also grant the mining rights [15], [1].

A consortium blockchain is a combination of public and private blockchains [4]. The goal of this type is use is to mitigate the disadvantages of the private blockchain [1], as this offers scalability and security [15]. According to Sharma [15] this is best suited for organizations needing both (private and public) blockchain. In consortium blockchain, there are more entities in charge of the blockchain network, than in the private blockchain. It consists of a group of individuals or organizations co-operating in decision-making [1].

Due to the sensitive data, and the number of users, some semiprivate consortium blockchain could be used. There write and read rights could be given freer as in purely private blockchain, and tracking sensitive information is harder as in public blockchain such as Bitcoin, where every transaction could scrutinize and linked to a username, although pseudonym. The type of consensus algorithm should be considered as well. PoW is the first consensus algorithm used in blockchain, i.e., in Bitcoin, and now it is notorious in energy consumption [1]. However, new algorithms are developed which are seen as greener options [1].

Table 1. Differences of public, private, and consortium blockchains. Adapted from Casino et al [4]

Property	Public	Private	Consortium
Consensus mechanism cost	High	Low	Low
Identity & Anonymity	(Pseudo) Anonymous	Identified users Trusted	Identified users Trusted
Efficiency	Low efficiency	High efficiency	High efficiency
Consumption	High energy	Low energy	Low energy
Transaction speed	Minutes	Milliseconds	Milliseconds

4 Implementing Blockchain for Persuasive Systems

Blockchain security and PSD postulates. Implementing blockchain for persuasive systems could be useful. Blockchain increases trust. This means that even users who do not trust each other may use blockchain [1]. If multiple users are participating in creating the database, uniform rules need to be governed; this can happen by the smart contracts in the system [1]. Blockchain has been tried and found useful in e-health systems, Big Data, and IoT [17], [7], 18]. E-health collects sensitive data, and it is one of the most central domains of persuasive technology. Also, persuasive technologies in many cases utilize IoT and IoT-based data already [19], [20].

There are some advantages of blockchain implementation on persuasive systems. All the validated transactions are permanently saved into the blockchain that cannot be altered or deleted. This is because a Blockchain network can consist of several computers (nodes) around the world [2], [7]. The data in a blockchain is hard to tamper or forge [16], [14]. Blockchain can enhance the security for user authentication, recording data access histories [7]. Blockchain can be used to store important and sensitive data (such as health information) and to maintain the originality of data [14]. Also, the auditability

characteristic of blockchain addresses the openness postulate of the PSD model [6], [14]. So far, most APIs provided by cryptocurrencies cannot be considered easy to use [4]. As ease of use is the seventh postulate of PSD [6], the developers should pay attention to this.

Tokens as a medium for implementing persuasive principles. Blockchain technology has the potential to bring new levels of scale by designing tokens and standardizing tokens to shape behaviors [21]. A token economy is a means to shape a desirable behavior [23]. Tokens are neutral stimuli in the form of abstract items (e.g., points) e offered to users for achieving the target behavior [22]. Digital tokens can be used as a behavior change tool to achieve targeted behavior and avoid undesired behaviors to reward users when they achieve some outcomes [21]. Tokens may be used to reinforce the desired behavior such it makes the person whose behavior is been shaped progress closer and closer to the desired behavior in a similar fashion as B.F. Skinner's operant conditioning technique [21], [24]. Tokens in behavior change reinforce positive beliefs, shape habits, and sustain newly adopted behaviors [21].

Blockchain can be used to increase the adoption of sustainable transport (e.g., cycling and walking) by people [21]. To influence user travel behavior, a smartphone sensor can be used to collect data about a user's location, speed, acceleration, travel distance among other parameters to be able to determine via artificial intelligence the mode of travel a person has used [21],[25]. These pieces of data can be converted into tokens that represent the person's estimated carbon saving, and the tokens can accumulate as rewards [21]. In another research, tokens generated represented cycling journeys [21],[26] which is a means to track the user's cycling behavior.

Blockchain may be used to record earned tokens, maintain token balances, and facilitate the exchange of token rewards [21]. Blockchain smart contracts can encode commitments to engage in the desired behavior and issue tokens. Smart contracts can be signed between people with a shared behavior goal (e.g., walking), non-human entities such as pets, and the environment [21],[27]. Research by [28] enabled users to monetize geospatial and environmental data (e.g., air quality) and traffic congestion levels while cycling.

Other applications of blockchain. Blockchain can be used to track, measure, and reward environmentally sustainable behavior. RecycleToCoin is a mobile app built on blockchain technology to shape recycling behavior by rewarding users when waste is recycled [29]. Also, a blockchain ledger can be created when the different BCSS apps used by a person can be linked [8]. Smart contracts can be used to link these apps via an application programming interface to create a complete record of a person's behavior and activities [8], This information can be shared by the user, and it is particularly useful when the user wants to be anonymous. Such a blockchain ledger can be viewed as a persuasion profile that contains fine-grained information about the user which can be used to enhance behavior change experiences.

Limitations of blockchain. Blockchain implementation on persuasive systems may have also disadvantages. The consensus algorithms can consume vast amounts of energy [4], [1]. Each node must run the algorithm granting fault tolerance ability [1].

Fortunately, new efficient consensus mechanisms and procedures could be adapted to help with the energy waste issue [4].

Furthermore, when the persuasive system collects massive quantities of data, the database size is increased, as each new transaction is added to the blockchain [1]. This can bring out scalability issues [4]. Also, a blockchain network is slower than a centralized database, as the blockchain executes several extra processes, such as hashing, validation, and consensus algorithm [1], [4].

Using blockchain in persuasive technology has challenges with GDPR. To ensure compliance with GDPR, a data controller (i.e., a person who is responsible and accountable for data collection and processing activities) must be appointed. Decentralization of decisions made on data and data processing in blockchain challenges the obligations of data controllers in the GDPR. Again, the data recorded on the blockchain ledger is permanent and tamper-proof making it impossible to delete data without breaking the basic principle of irreversibility or immutability which underpins the blockchain technology. This also affects the trustworthiness and transparency of blockchain transactions and can affect the compliance to the right to be forgotten GDPR [30], [31]. Finally, there may be challenges to meet the requirements of data minimization of GDPR in blockchain applications due to replicated nature of distributed databases and the need to store data continuously [31].

5 Conclusions

This paper presents an investigation into issues surrounding blockchain and its application areas within the context of persuasive systems design.

We discussed how blockchain characteristics such as privacy, trust, transparency can be useful for designing persuasive systems. User data in BCSS is sensitive and should be protected as they are susceptible to attacks and misuse. These issues can be tackled using blockchain. In addition, users should own and control their data. For example, by combining blockchain and BCSS such as wearables, users will become aware of how data is being collected about them and how it is used as well as give them the possibility to own their data. Blockchain user data can be collected without privacy issues. The way user data is collected and processed is transparent with blockchain. This can increase trust among the stakeholders.

We also explored the use of Blockchain-based token economies to shape and support behavior change. Tokens in behavior change reinforce positive beliefs, shape habits, and sustain newly adopted behaviors [21] via mechanisms such as rewards.

It is worth mentioning that utilizing a blockchain has its challenges including energy used to conduct blockchain transactions, scalability, and other challenges that concern GDPR compliance. These issues must be addressed in the design of Blockchain-based persuasive technology.

Despite the novelty of blockchain technology, several business domains have already found it useful. We will continue to see more useful applications of blockchain considering the investment and effort to improve on the technology. We recommend further research into this topic using several research methods such as design science.

Developers of persuasive technology that utilizes blockchain should consider issues such as blockchain type, consensus algorithm, the data stored, and GDPR related issues.

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