Blockchain Technology as an Enabler of Service Systems: A Structured Literature Review

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Abstract. Blockchain technology is expected to revolutionize the way transactions are performed, thereby affecting a vast variety of potential areas of application. While expectations are high, real world impact and benefit are still unclear. To be able to assess its impact, the first structured literature review of peer-reviewed articles is conducted. As blockchain technology is centered around a peer-to-peer network, enabling collaboration between different parties, the service system is chosen as unit analysis to examine its potential contribution. We have identified a set of characteristics that enable trust and decentralization, facilitating the formation and coordination of a service system.

Keywords: Blockchain technology · Service system · Technology impact

1 Introduction

Blockchain technology is known as the underlying basis of Bitcoin [1]. Apart from its utilization in the Bitcoin network, many researchers and practitioners expect it to generally revolutionize the way we interact and transact over the Internet, resulting in the dawn of a new economy (e.g. [2, 3]). A vast potential for its application is predicted, for example affecting the way governments [4], public notary services [5] or contracts in an online environment [6] work. Expectations towards the potential of this new technology are rising, which can be seen in Gartner's Hype Cycle, where blockchain technology has already reached the peak of inflated expectations [7]. But as the term *inflated expectations* indicates, there is a difference between expectations and experienced real world impact [4]. In that context, Gideon Greenspan, the CEO of Multichain a blockchain provider, is stating that businesses are still "waiting to gain a clearer understanding of where blockchains genuinely add value in enterprise IT" [8]. While, there are several startups, that already offer blockchain solutions to their customers, no application has yet achieved large scale recognition, as they face competition of existing and well-established systems [9]. Therefore, additional and pervasive use cases are needed to foster the adoption of blockchain technology [2] and to reveal real world benefits for its users [10].

In order to facilitate the identification of practical use cases, it is necessary to be aware of potential impacts, which result from the application of blockchain technology. As it is built upon interaction in networks or systems, we investigate its implications in

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the context of service systems, which themselves are characterized by collaborative processes and, therefore, serve as an excellent unit of analysis [11].

Performing the first structured literature review on blockchain technology, which is entirely based on peer-reviewed literature, we derive a distinct set of characteristics that we illustrate in a concept matrix and interpret. The characteristics are then assessed concerning their contribution to service systems, developing a better understanding of the potential of blockchain technology.

The structure of this paper is as follows: Sect. 2 presents the methodological approach for conducting the literature review. Section 3 lays the theoretical foundations concerning blockchain technology by synthesizing a definition for the concept as well as presenting its inherent characteristics. Subsequently, Sect. 4 gives an overview over the concept of service systems and discusses the implications of applying blockchain technology in service systems. Section 5 closes with a conclusion and gives an overview over the research agenda.

2 Research Methodology

Since blockchain technology is a rather new field of study [12], publications have based their research on available white papers and practitioner-oriented sources, such as related forums (e.g. [2]). Until now, the extent of peer-reviewed publications was very limited and therefore an analysis of peer-reviewed articles has not yet been conducted. With rising academic interest, more and more publications ensuring scientific rigor are surfacing. Therefore, this work intends to focus on peer-reviewed publications as principal source of information. Non-peer-reviewed literature is used to support and underline the derived results.

In order to fully explore the concept of blockchain technology and its underlying characteristics, a structured and systematic literature review is conducted. Google Scholar is used as search engine to retrieve relevant literature.

Table 1. Overview over keywords and hits

Keyword	*Number of hits*
Blockchain	6.790
Block chain	4.570
Keyword combined with "blockchain"	*Number of hits*
Peer-to-peer database	1.110
Immutable database	213
Consensus database	1.430
Consensus protocol	1.180
Distributed ledger	1.170

As a first step, keywords, covering the field of blockchain technology, have to be identified. The terms "Blockchain" and "Block chain" are used as starting points for a database search, as they are treated synonymously throughout the blockchain community.

Furthermore, they do not describe unrelated concepts or technologies and are therefore suited as initial set of keywords. In order to incorporate additional perspectives on the technology, the list of keywords is gradually and iteratively extended through the analysis of the identified results. The applied set of keywords as well as their hit counts are presented in Table 1. For each of the presented keywords, the first 50 search results are analyzed and examined for relevance. Results that do not fulfil the following filtering requirements are discarded: Publications are written in English and have passed a peer-review process.

As a means to uncover different characteristics of blockchain technology, the resulting 31 peer-reviewed articles are used to develop a concept matrix [13], thereby synthesizing the literature at hand.

3 Review on Blockchain Technology

In this section, we present the results of our literature review on blockchain technology. We start by formulating a definition for the basic concept, which is followed by a presentation of the technology's inherent characteristics.

3.1 The Concept of Blockchain Technology

Although blockchain technology was first introduced in the year 2008 in Nakamoto's whitepaper as the underlying technology of Bitcoin [1], a generally accepted definition of the concept has not been established. Therefore, this section, provides a definition of the concept based on peer-reviewed literature.

While some authors refer to a blockchain as a distributed data structure, database or system [4, 9, 12, 14–17], others call it a decentralized network [18, 19]. Serving as a log or ledger to document all transactions and activities that took place within the construct [12, 14, 15, 19–24], it is a linked sequence of transactions [9, 25], in which time-stamped transactions [26] are broadcasted to and shared with participating entities, located in its belonging peer-to-peer network [12, 16]. Transactions are secured through public-key cryptography and verified by the participants for correctness [9, 12, 17, 23, 26]. Once a transaction is verified by the participatory community, it is added to an unpublished block. Amongst others, a block serves as storage unit for transactions and contains a reference to the settled and verified chain of blocks. Through the use of a consensus mechanism new blocks are added to the blockchain in an append-only manner and then cannot be altered anymore [20, 21, 25, 27].

Based on the presented statements, we synthesize the following definition for a blockchain:

A blockchain is a distributed database, which is shared among and agreed upon a peer-to-peer network. It consists of a linked sequence of blocks, holding timestamped transactions that are secured by public-key cryptography and verified by the network community. Once an element is appended to the blockchain, it can not be altered, turning a blockchain into an immutable record of past activity.

Furthermore, a distinction can be made between public and private blockchains. Public blockchains are not restricted in terms of access rights and allow all participants to append new blocks, whereas private blockchains may be used in a stricter setting in which it is important to limit who enters and contributes to the network [25].

3.2 Characteristics of Blockchain Technology

Although blockchain technology can be regarded as an emerging technology [28] and therefore still has room for improvement in terms of efficiency and technical aspects [12], its underlying characteristics can already be discussed. To assess these characteristics in a structured and systematic manner, the identified peer-reviewed articles and the respectively mentioned attributes are presented in the concept matrix in Table 2.

Our analysis shows that blockchain technology brings to bear a variety of characteristics, which are, in the following, analyzed concerning their interrelations, deriving a set of key characteristics. For example, it is assumed that the characteristics "shared and public" as well as "low friction" lead to increased transparency in a system, since information is made publicly available between participants without being influenced by a third party. An overview over the resulting key characteristics and their underlying elements is presented in Fig. 1 and is further elaborated in the following.

Two principal characteristics are to be identified when looking at blockchain technology, namely its trust evoking and decentralized nature.

Its decentralization facilitates the creation of a private, reliable and versatile environment, which is further described below.

As blockchain technology is based on a peer-to-peer network [9], which combined with the technology's ability to secure interactions between two individuals by using public-key cryptography, and the fact that identities are covered by pseudonyms, a high degree of privacy for its participants is enabled [37].

Reliability within the system is established through use of two factors. On the one hand, information on transactions is shared and stored throughout the network and is therefore treated in a redundant way [25] and on the other hand, since the technology is based on data and code, the introduction of automated measures is facilitated [40], which in turn may reduce individual mistakes as there is little need for manual intervention [34].

By enabling its participants to integrate their own programs, develop and distribute their own code, thereby shaping their own environment, blockchain technology facilitates the creation of an open and versatile system [4]. A popular example for this characteristic is a so-called smart contract, which is a piece of code that serves as programmed contractual agreement between two parties [2].

While some authors explicitly mention blockchain technology's trust enabling notion (e.g. [4, 20, 24, 41]), others describe it in an indirect manner as through the establishment of transparency via a shared and public view on occurring transactions throughout the peer-to-peer network (e.g. [27, 36]), through ensuring the integrity of data in the blockchain (e.g. [23, 42]), or its immutable architecture (e.g. [9, 39, 40]).

Table 2. Concept matrix of the reviewed literature

Author(s)	Characteristics										
	Trust	*Shared and public*	*Low friction*	*Peer verification*	*Cryptography*	*Immutability*	*Decentralization*	*Pseudonymity*	*Redundancy*	*Versatility*	*Automation*
Barber et al. [29]	✓		✓	✓		✓	✓			✓	✓
Beck et al. [20]	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Böhme et al. [9]		✓				✓	✓	✓		✓	✓
Bonneau et al. [19]	✓			✓			✓	✓			
Cai and Zhu [30]	✓	✓		✓	✓	✓					
Cucurull and Puiggalí [23]	✓	✓		✓	✓	✓	✓				
Delmolino et al. [31]		✓		✓	✓					✓	✓
Eyal et al. [32]				✓			✓				
Garay et al. [15]		✓				✓	✓	✓			
Garman et al. [33]	✓	✓		✓		✓	✓	✓			
Garay et al. [15]		✓				✓	✓	✓			
Gerstl [24]	✓	✓		✓		✓	✓	✓	✓		
Guo and Liang [34]							✓				✓
Heilman et al. [35]							✓	✓			
Herrera-Joancomartí and Pérez-Solà [36]		✓		✓			✓	✓			
Hull et al. [37]	✓	✓			✓		✓	✓	✓	✓	✓
Idelberger et al. [27]		✓		✓		✓	✓			✓	✓
Kosba et al. [18]	✓			✓	✓		✓				
Kraft [21]	✓	✓			✓		✓				
Lewenberg et al. [14]							✓				
McCorry et al. [38]	✓	✓		✓		✓		✓			
McCorry et al. [22]					✓	✓		✓			
Ølnes [4]	✓		✓		✓		✓			✓	
Sharples and Domingue [25]		✓				✓	✓		✓		✓
Sun et al. [39]	✓	✓	✓	✓	✓		✓	✓			✓
Tschorsch and Scheuermann [17]	✓	✓		✓			✓	✓			
Wang et al. [16]	✓	✓		✓			✓				
Weber et al. [40]	✓	✓		✓	✓	✓	✓				✓
Wilson and Ateniese [41]	✓			✓							
Xu [42]	✓	✓		✓	✓	✓	✓			✓	✓
Zhao et al. [12]	✓	✓		✓	✓	✓	✓	✓			✓
Zyskind et al. [26]	✓	✓		✓	✓		✓	✓			

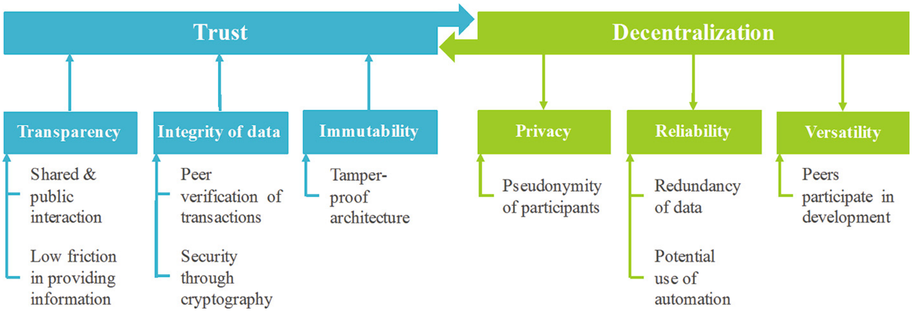

Fig. 1. Characteristics of blockchain technology

Using blockchain technology enables its participants to establish a shared and publicly unfolded relationship. As there is a shared view on all passed and current transactions, participants have full disclosure on activities of the system [33]. New transactions are broadcasted through the entire network [31] and as there is no single intermediary who controls the system, users can interact directly, resulting in a reduction of friction [20, 39].

Trust may also be facilitated through the technology's inherent characteristic of ensuring the integrity of data, which is stored in the database itself, since direct interaction is secured through public-key cryptography and the fact, that through its transparent nature every user is able to verify broadcasted transactions based on pre-defined rules [31].

Another factor that contributes to establishing trust is the immutable design of the database, meaning that once a transaction is added to a block, which in turn is added to the blockchain, this transaction cannot be altered [23]. This process is facilitated by applying a so-called consensus mechanism, which e.g. require the calculation of a proof-of-work. A proof-of-work may be regarded as a computational puzzle, which takes a lot of effort to solve, but whose solution is easily verifiable by others. In case a user finds the solution, it is shared with the remaining participants in the network, who in turn can verify its correctness, thereby reaching a consensus on the solution. One crucial aspect of the proof-of-work is that the puzzle a user is solving, depends on the previously accepted and agreed upon blocks of the blockchain. Since a variety of participants is trying to form and append new blocks to the blockchain, changes in the blockchain would result in varying solutions, revealing misuse or manipulation [33]. Both trust and decentralization are closely connected and interrelated in case of blockchain technology. On the one hand, the mechanisms used to establish trust, such as transparency, integrity and immutability of data, are needed for the creation of a decentralized network, in which reliable and dependable transactions can take place without a trusted third party. On the other hand, decentralization provides the mean for users to get involved in the network, establishing the foundations for consensus mechanism thereby rendering the necessity of a trusted third party obsolete.

4 Impact on Service Systems

This section lays the theoretical foundations for the concept of service systems and elaborates the way they might be influenced utilizing blockchain technology. Therefore, the first subsection deals with presenting the notion of service systems as well as their inherent characteristics. The second part of this section discusses the results of Sect. 3 and applies them to the context of a service system.

4.1 Service Systems

For decades no common basis has been established concerning services [11]. Even at the beginning of the 20th century, in which services have already accounted for a remarkable share of economic performance, service still remained on a residual place of the economic worldview [43].

With the introduction of the Service-Dominant (S-D) logic by Vargo and Lush [44], this worldview changed, shifting the overall perspective on services. They define a service “as the application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself”. Thereby they introduce a truly inclusive notion of the term service.

Knowledge-intensive as well as customized services call for a closer integration of customers [45]. In this context, S-D logic is embracing the thought that value creation takes part through the involvement of service providers and beneficiaries in a co-creating manner. To be more precise, they argue that operant resources, which might be machinery or employees, act upon operand resources, increasing their value [44].

Through the integrated reflection of at least two participating parties, S-D logic motivates the creation of the service system abstraction. Instead of calling the involved parties provider or beneficiary, Maglio et al. [11] express the need to regard them in a more generic and conceptual way, as both entities are needed for the process of value creation, therefore calling each of them as well as their combination “service systems”.

In general, there exists a variety of definitions for the term *system*, since a system may incorporate different characteristics depending on its underlying purpose [46].

Spohrer et al. define a service system as a “value-coproduction configuration of people, technology, other internal and external service systems, and shared information (such as language, process, metrics, prices, policies, and laws)” [47].

By separating between internal and external service systems, the concept allows for describing interactions between “unique identities”, which are “instances of a type or class of service systems”. The collaboration between two service systems may be installed in two different ways. The composition may be based upon a hierarchical structure in which only the decision maker needs to addressed or market-based structure, in which an immediate collaboration between participating service systems is established. [11].

Furthermore, a distinction can be made between formal service systems, which are bound to a set of legal and economic rules in order to fulfill pre-defined contracts, obligations and expectations, and informal service systems, in which cultural and behavioral norms play a predominant role [48].

An important aspect for the functioning of a service system is the availability and distribution of information, as collaboration requires a shared basis of information as a mean for coordination. Language, laws and measures are the principal types of shared information in a service system setting. Since service systems are subject to both change within their system as well as their environment, the characteristics of shared information may change over time [47].

Although service systems are to be characterized by their complexity, adaptive nature [47], openness and dynamic composition of operant and operand resources as well as their expandability with other service systems, the integration of two individual service systems does not necessarily end in the development of a greater service system. Generally, in order to facilitate co-creation of value, there has to be at least one operant entity who delivers a proposal to the other operant resource, who settles a mutual agreement concerning the aspired result and who further promotes the realization of value. Given these prerequisites, a service system has the ability to improve both the partner system's as well as its own state [11].

4.2 Understanding the Impact of Blockchain Technology

As we have shown in Sect. 3, both the establishment of an environment for trusted interactions as well as the formation of a decentralized network constitute the core of blockchain technology. Both of which appear to be important aspects for a service system, as it is a configuration of different entities or resources, relying on trusted and shared information (see Sect. 4.1).

Since value is co-created between the involved partners of a service system, trust is an essential aspect that has to be ensured in order to facilitate collaborative processes [40]. Therefore, a typical interaction in a service system involves a governing authority, whose task is to verify and ensure that the involved parties follow shared agreements and laws [47]. The introduction of a blockchain would render the use of a third party unnecessary, as it would evoke a trusted and transparent environment, where all participating entities have full insights into ongoing processes and can rely on the integrity of immutable data. An example for this would be provenance tracking of a good, as every participant of the network would be able to reconstruct the origin of a given good [49].

As blockchain technology facilitates the exchange of information in a way that all involved parties have access to a transparent and shared database, thereby establishing a common basis of information for all users, an important prerequisite for the functioning of a service system is satisfied. Even involved parties who are located at the edges of a service system would gain access to current and direct information, thereby solving problems, which are caused by insufficient or inadequate information. An example for this may be seen in a supply chain setting, where it may seem beneficial for an individual to keep information for themselves, but sharing information would lead to an improvement of the overall system (see Bullwhip effect) [50].

In this context, Weber et al. [40] use a blockchain in two different ways as part of a collaborative setting. They call the first one "choreography monitor", as it serves as a storage unit for joint and individual data. The second one is called "active mediator", where it is used to oversee and initiate the execution of joint processes.

Regarding the latter, the blockchain technology enables a great potential for standardization and automation, as it is a transparent system, which relies on formal code and data. The implementation of both standardization and automation in service systems often releases bound productive capacity, while also reducing transaction costs and having a beneficial impact on coordination [47]. Standardization and automation might also have a favorable impact on minimizing manual mistakes and accelerating interaction processes.

As we have presented, the co-creation of value depends on making a proposal, sharing a common understanding of an interaction's outcome, which is stipulated in an agreement and whose realization is consequently monitored. A blockchain might facilitate all of these activities, as it provides a platform, in which interacting parties can transparently and precisely interact with each other, for example through the definition of coded contracts. The blockchain platform Ethereum may serve as an example for this, as it delivers a toolset for the design of coded contracts [5].

This might also have an impact on the formation of formal service systems, which are determined and regulated by rules [48]. Since interactions in a blockchain are per definition precise and pre-defined, this might facilitate the accelerated creation of such service systems.

If information, time and cost can be managed in a more effective way, a blockchain will even enable the establishment of new service systems that were not possible before. An example for this would be the Bitcoin, which eliminated the need for a trusted third party as information is shared among Bitcoin users, potentially reducing the time needed for the execution of a transaction, drastically reducing transaction cost, and therefore is not limit the minimum practical transaction size [1].

As interacting in such a system depends on strict conditions, leaving no room for vague formulations which might result in conflict, blockchain technology could even help at solving one of the key research objectives in service science, which is to understand how disputes are to be settled effectively [11].

5 Conclusion

To be able to discuss the impact of blockchain technology on service systems, the first structured literature review on the technology, based entirely on peer-reviewed literature, was performed. Thereby, a set of characteristics was revealed, enabling trust and decentralization in a collaborative setting. Blockchain technology creates a trusted environment through its transparent nature, making information publicly available thought out its entire network, while also assuring the integrity and immutability of data. Decentralization allows for the protection of privacy, through pseudonymization, and creates a reliable and versatile setting. The identified characteristics were subsequently assessed in the context of a service system. Blockchain technology addresses many important aspects, which support the functioning of a service system, such as facilitating co-creation of value, ensuring availability of information and offering mechanisms of coordination. Therefore, the technology is expected to have an extensive impact on current and contribute to the formation of new service systems.

As for further research, it would be of interest to explore blockchain technology's contribution within real world use cases. Hence, insights are to be generated by performing a large-scale empirical analysis on existing areas of application.

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