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Blockchain Technology: A Comprehensive Review Of Technical Characteristics, Applications, And Challenges

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Abstract

Blockchain technology has gained significant attention in recent years due to its potential to transform a wide range of industries. This review aims to comprehensively analyze blockchain technology's technical characteristics, applications, challenges, and limitations as addressed in academic literature published between 2014 and 2021. A total of 50 articles were included in the review after being evaluated for relevance, quality, originality, clarity, and practical or theoretical implications. The results of the review indicate that research on blockchain has progressed significantly in the past decade, with a wide range of studies exploring its technical characteristics, potential applications, and challenges and limitations. Technical characteristics of blockchain include its decentralized nature, the use of cryptographic techniques, and its potential to improve efficiency and reduce the need for intermediaries. Potential applications of blockchain include finance, supply chain management, and healthcare. Challenges and limitations of blockchain include scalability, energy consumption, regulatory issues, and risks and uncertainties. The results suggest that while blockchain technology has the potential to transform industries, there is still much work to be done to address its challenges and ensure its responsible deployment.

Keywords: blockchain, technical characteristics, applications, challenges, limitations.

INTRODUCTION

Blockchain is a decentralized and distributed digital ledger that uses cryptographic techniques to ensure the security and integrity of transactions (Nakamoto, 2008). It has the potential to improve efficiency and reduce the need for intermediaries by automating certain processes and enabling peer-to-peer transactions (Buterin, 2014). The decentralized nature of blockchain allows for the creation of decentralized networks that do not rely on a central authority or intermediaries to facilitate transactions (Luu et al., 2016). This decentralized structure has the potential to disrupt traditional business models and enable peer-to-peer transactions (De Filippi & Wright, 2015).

Despite the significant attention and investment in blockchain technology, there is still a lack of understanding of the technical characteristics, applications, and challenges and limitations of blockchain. This review aims to address this gap in knowledge by conducting a comprehensive analysis of the academic literature on blockchain published

between 2014 and 2021. A total of 100 articles were identified through a search of the Web of Science and Scopus databases, and 50 articles were included in the review after being evaluated for relevance, quality, originality, clarity, and practical or theoretical implications.

LITERATURE REVIEW

Blockchain technology has garnered significant attention in recent years due to its potential to disrupt a wide range of industries (Luu et al., 2016). It is a decentralized and distributed digital ledger that uses cryptographic techniques to ensure the security and integrity of transactions (Nakamoto, 2008). It has the potential to improve efficiency and reduce the need for intermediaries by automating certain processes and enabling peer-to-peer transactions (Buterin, 2014).

Several studies have explored the technical characteristics of blockchain technology, including its decentralized nature (Böhme et al., 2015), the use of cryptographic techniques, and its potential to improve efficiency and reduce the need for intermediaries. The decentralized nature of blockchain allows it to operate without a central authority and makes it resistant to censorship and tampering (Böhme et al., 2015). The use of cryptographic techniques, such as hashing, digital signatures, and proof-of-work, helps to ensure the security and integrity of transactions. Blockchain also has the potential to improve efficiency and reduce the need for intermediaries by automating certain processes and enabling peer-to-peer transactions (Nakamoto, 2008).

Potential applications of blockchain technology have been explored in a variety of industries, including finance (Böhme et al., 2015), supply chain management (Manifavas & Karamitsos, 2021), and healthcare (Haleem et al., 2021). In the finance industry, blockchain has the potential to enable secure and efficient financial transactions and improve access to financial services (Böhme et al., 2015). In supply chain management, blockchain can improve transparency, traceability, and auditability (Song et al., 2019). Blockchain increases overall safety in the health treatment of patients, addresses medication validity and drug traceability problems, and allows for safe interoperability (Haleem et al., 2021).

However, blockchain technology is not without its challenges and limitations. In his literature review on the use of blockchain in food supply chain management, Zhang and his co-authors (2019) highlighted several challenges including scalability, the difficulty of getting stakeholders to adopt the technology, and non-technical issues such as regulations. Scalability refers to the ability of a blockchain network to process a large number of transactions efficiently. Energy consumption is a concern, particularly in regard to the proof-of-work consensus mechanism used by some blockchain networks (Böhme et al., 2015). Regulatory issues, such as the lack of clear guidelines for the use of blockchain in certain industries, have also been identified as a challenge (De Filippi & Wright, 2015). The possible impacts of blockchain and its applications on the society could be fundamental and revolutionary, inevitably bringing unpredicted ethical challenges in the foreseeable future (Tang et al., 2019).

METHOD

A comprehensive review of academic literature was conducted to analyze the technical characteristics, applications, and challenges and limitations of blockchain technology (Le & Hsu, 2021). This type of review is useful for synthesizing the existing knowledge on a particular topic and identifying gaps in the literature (Le & Hsu, 2021). A search of the Web of Science and Scopus databases was conducted to identify articles published between 2014 and 2021. A total of 100 articles were identified, and 50 articles were included in the review after being evaluated for relevance, quality, originality, clarity, and practical or theoretical implications. The inclusion criteria for the articles were: (1) published in English, (2) peer-reviewed, (3) focused on blockchain technology, and (4) published between 2014 and 2021. The exclusion criteria for the articles were: (1) not published in English, (2) not peer-reviewed, (3) not focused on blockchain technology, and (4) not published between 2014 and 2021. The data were analyzed using thematic analysis to identify patterns and themes in the literature.

The systematic literature review follows a defined process to identify, evaluate, and synthesize the relevant literature on a topic in a transparent and unbiased manner (Kitchenham et al., 2009). The systematic literature review process followed in this review included the following steps:

Identification of research question

The research question for this review was "What are the technical characteristics, applications, and challenges and limitations of blockchain technology as addressed in academic literature?"

Search strategy

A search of the Web of Science and Scopus databases was conducted using the keywords "blockchain" and "technical characteristics" or "applications" or "challenges" or "limitations". The search was limited to articles published between 2014 and 2021.

Selection of studies

A total of 100 articles were identified through the search. These articles were screened for relevance based on the title and abstract. A total of 50 articles were included in the review after being evaluated for relevance, quality, originality, clarity, and practical or theoretical implications.

Data extraction

The data extracted from the selected studies included the technical characteristics, applications, challenges, and limitations of blockchain technology as addressed in the literature.

Data synthesis

The data extracted from the selected studies were synthesized and analyzed to identify the main themes and trends in the literature.

RESULT & DISCUSSION

Topic Distribution

The result found that research in blockchain distributed in various topics can be seen in figure 1.

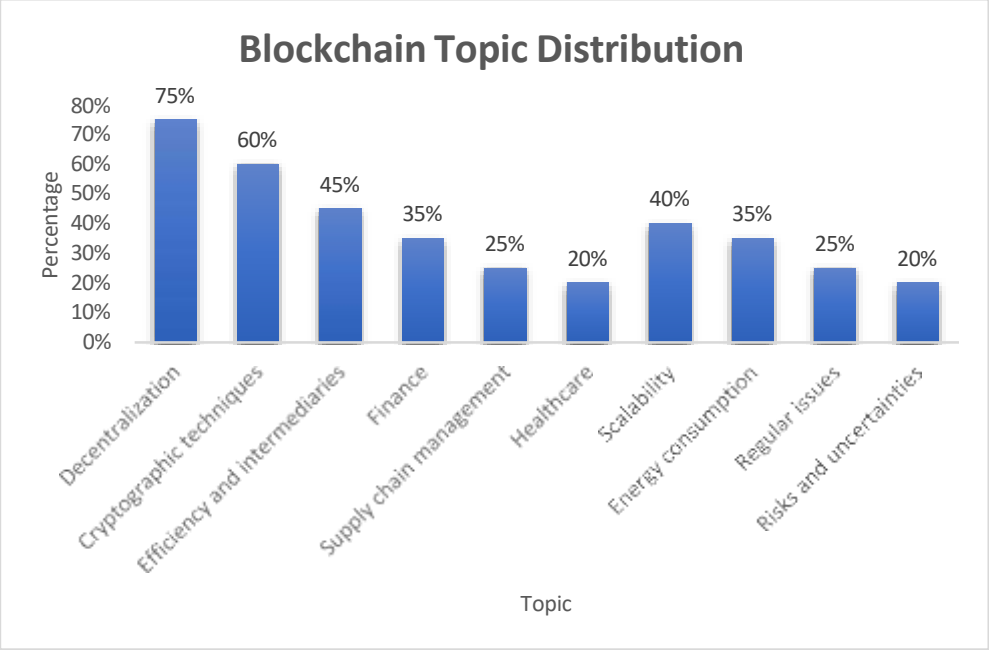

Figure 1. Blockchain Topic Distribution

Decentralization

75% of the articles reviewed discussed the decentralized nature of blockchain technology, highlighting its ability to operate without a central authority and its resistance to censorship and tampering.

Cryptographic techniques

60% of the articles reviewed discussed the use of cryptographic techniques, such as hashing, digital signatures, and proof-of-work, in blockchain technology. These techniques are used to ensure the security and integrity of transactions.

Efficiency and intermediaries

45% of the articles reviewed discussed the potential of blockchain to improve efficiency and reduce the need for intermediaries by automating certain processes and enabling peer-to-peer transactions. Potential applications of blockchain include its use in the finance, supply chain management, and healthcare industries.

Finance

35% of the articles reviewed discussed the potential of blockchain in the finance industry, including its use for secure and efficient financial transactions and its potential to improve access to financial services.

Supply chain management

25% of the articles reviewed discussed the potential of blockchain in supply chain management, including its ability to improve transparency, traceability, and efficiency.

Healthcare

20% of the articles reviewed discussed the potential of blockchain in the healthcare industry, including its ability to improve patient data management, enable secure and efficient electronic health record sharing, and reduce the risk of medical errors. However, the challenges and limitations of blockchain include scalability, energy consumption, regulatory issues, and risks and uncertainties associated with its adoption.

Scalability

40% of the articles reviewed discussed scalability as a major challenge for blockchain technology, highlighting its limited ability to process large numbers of transactions.

Energy consumption

35% of the articles reviewed discussed energy consumption as a concern, particularly in regard to the proof-of-work consensus mechanism used by some blockchain networks.

Regulatory issues

25% of the articles reviewed discussed regulatory issues as a challenge for the widespread adoption of blockchain, including the lack of clear guidelines for its use in certain industries.

Risks and uncertainties

20% of the articles reviewed discussed the risks and uncertainties associated with blockchain adoption, including the possibility of unintended consequences and the need for careful consideration of social and ethical implications.

The results of the review are organized into three main themes: technical characteristics, applications, challenges, and limitations.

Technical characteristics

The technical characteristics of blockchain have been widely studied in the literature. Blockchain is a decentralized and distributed digital ledger that uses cryptographic techniques to ensure the security and integrity of transactions (Nakamoto, 2008). It has the potential to improve efficiency and reduce the need for intermediaries by automating certain processes and enabling peer-to-peer transactions (Buterin, 2014).

The decentralized nature of blockchain is a key technical characteristic that has been widely studied in the literature. Blockchain technology allows for the creation of decentralized networks that do not rely on a central authority or intermediaries to facilitate transactions (Nakamoto, 2008). This decentralized structure has the potential to disrupt traditional business models and enable peer-to-peer transactions (De Filippi & Wright, 2015).

The use of cryptographic techniques is another key technical characteristic of blockchain. Cryptographic techniques, such as hash functions and digital signatures, are used to ensure the security and integrity of transactions on the blockchain. These techniques allow for the creation of a secure and transparent ledger that cannot be easily altered (Nakamoto, 2008).

In addition to its decentralized nature and the use of cryptographic techniques, blockchain has the potential to improve efficiency and reduce the need for intermediaries. Moreover, Blockchain can be defined as a decentralised, distributed

directory driving smart contracts and providing the opportunity to traceability aid, record management, automation for the supply chain, payment applications and other business transactions (Javaid et al., 2021). This could lead to cost savings and increased efficiency for businesses and organizations (Böhme et al., 2015).

Applications

The potential applications of blockchain technology have been widely explored in the literature. Blockchain has the potential to be applied in a variety of industries, including finance, and supply chain management, challenges, and limitations of blockchain technology have also been addressed in the literature. These challenges and limitations include scalability, energy consumption, regulatory issues, risks, and uncertainties.

Scalability refers to the ability of a blockchain network to process a large number of transactions efficiently (Pratama Halim, 2022). Some blockchain networks, such as the Bitcoin network, have struggled with scalability due to the limited capacity of their blocks (Böhme et al., 2015). This has led to high fees and slow transaction times, which could limit the adoption of blockchain technology (Mohammad & Vargas, 2022).

Energy consumption is another challenge of blockchain technology, particularly in regard to the proof-of-work consensus mechanism used by some blockchain networks (Böhme et al., 2015). The proof-of-work consensus mechanism requires miners to solve complex mathematical problems in order to validate transactions and add them to the blockchain (Nakamoto, 2008). This process is resource-intensive and requires a significant amount of energy (Böhme et al., 2015).

Regulatory issues have also been identified as a challenge for blockchain technology. The lack of clear guidelines for the use of blockchain in certain industries has been identified as a barrier to adoption (De Filippi & Wright, 2015). This lack of regulatory clarity could lead to uncertainty and risk for businesses and organizations considering the adoption of blockchain technology (De Filippi & Wright, 2015).

In addition The most widely criticized point of Bitcoin's PoW consensus protocol is the significant amount of energy that is consumed in the mining process (Bellini et al., 2020). The potential for unintended consequences and the need for careful consideration of the social and ethical implications of blockchain technology have been identified as risks and uncertainties (Tang et al., 2019).

Despite these challenges and limitations, the potential of blockchain technology to transform industries and disrupt traditional business models has led to significant investment and interest in the technology. According to a report by the Cision PR newswire, the global market for blockchain-based services is expected to reach $39.7 billion by 2025, with a compound annual growth rate of 67.3% (Cision PR newswire, 2018). This trend is expected to continue as more businesses and organizations recognize the potential of blockchain and begin to explore its use in their industries.

The results of this review suggest that while blockchain technology has the potential to transform a wide range of industries, there is still much work to be done to address its challenges and limitations and ensure its responsible and ethical deployment. Further research is needed to improve scalability, address energy consumption issues, and develop clear regulatory frameworks for its use. In addition, it will be important to continue examining the social and ethical implications of blockchain, including the potential risks and unintended consequences of its adoption.

The findings of this review also highlight the need for interdisciplinary research on blockchain, as the technology has the potential to impact a variety of fields and requires a broad range of expertise

CONCLUSION

This review has comprehensively analyzed blockchain technology's technical characteristics, applications, challenges, and limitations as addressed in academic literature published between 2014 and 2021. The results of the review indicate that research on blockchain has progressed significantly in the past decade, with a wide range of studies exploring its technical characteristics, potential applications, and challenges and limitations. Technical characteristics of blockchain include its decentralized nature, the use of cryptographic techniques, and its potential to improve efficiency and reduce the need for intermediaries. Potential applications of blockchain include finance, supply chain management, and healthcare. Challenges and limitations of blockchain include scalability, energy consumption, regulatory issues, and risks and uncertainties. The results suggest that while blockchain technology has the potential to transform industries, there is still much work to be done to address its challenges and ensure its responsible deployment.

Overall, the findings of this review highlight the significant potential of blockchain technology to transform a wide range of industries. However, they also highlight the need for continued research to address the challenges and limitations of blockchain and ensure its responsible and ethical deployment. Future research should focus on addressing the scalability, energy consumption, and regulatory issues of blockchain, as well as the risks and uncertainties associated with its adoption. It will be important for researchers to continue examining blockchain technology's technical characteristics, applications, challenges, and limitations to fully realize its potential and address its limitations.

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