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Benefit and limitation of using blockchain in smart cities to improve citizen services

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Abstract This paper examines the potential of blockchain technology to create more efficient, secure, and transparent smart cities. The paper covers the six main components of smart cities and how blockchain can address challenges and provide benefits in areas such as governance, transportation, environment, economy, living, and citizen. It includes use cases, technical requirements and potential limitations of blockchain implementation in smart cities. Additionally, the paper explores the current state of smart cities and their challenges and how blockchain can address them. Furthermore, it delves into the future impact of blockchain on urban life, including improved governance, business models, citizen engagement, transportation, security, sustainable development and real-estate. The paper highlights the potential benefits of blockchain in smart cities but also emphasizes the need to approach its implementation with caution, considering limitations and engaging all stakeholders to create smart cities that better serve citizens.

Keywords Smart cities · Integrated smart city · Blockchain technology · Urban life · Cryptographic techniques

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Abbreviations

IoT The Internet of Things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet

AI Artificial intelligence (AI) is firstly an academic discipline with various, often conflicting, views on what constitutes its area of research, as well as goals and approaches used, including logical, knowledge-based approach

Introduction

Smart cities utilize cutting-edge technology and data analysis to enhance the well-being of their residents and urban environments. They aim to create more livable, sustainable, and efficient environments through the use of innovative solutions in areas such as transportation, energy, and healthcare. Smart cities use technology to improve the efficiency and effectiveness of city services, which can help tackle urbanization challenges like traffic congestion, air pollution, and energy consumption.

The concept of smart cities is not new, but in recent years, the development of new technologies such as IoT, big data, and cloud computing have enabled the deployment of smart city solutions on a large scale (Farimani et al., 2020). Smart cities rely heavily

on data and technology to provide citizens with better services and improve the overall quality of life. The IoT (Internet of Things) is a key technology for smart cities as it enables the collection of large amounts of data from various sources, such as sensors, cameras, and mobile devices. This data is then analyzed by big data and cloud computing technologies to provide valuable insights and improve the operations of city services (Ahmad et al., 2021).

The key features of smart cities include (Attaran et al., 2022):

- Smart environment: Smart environment in a smart city refers to the use of technology to monitor and manage the natural resources and environmental conditions of a city in an efficient and sustainable manner. This can include things like monitoring air and water quality, managing waste and recycling, implementing green infrastructure, and optimizing the use of resources such as energy and water. These technologies can also be used to help reduce the impacts of climate change, including mitigating greenhouse gas emissions and adapting to the effects of extreme weather events. Additionally, smart environment solutions can also improve the livability of a city for its citizens, for example, by reducing pollution and noise levels and promoting the use of public transportation and active transportation modes like walking and biking.
- Smart economic: Smart economic in a smart city refers to the use of technology and data-driven approaches to improve the economic performance and competitiveness of a city. This can include things like promoting and attracting new businesses, creating a skilled workforce, and enhancing the city's overall economic performance. Smart economic solutions can also help to reduce poverty, inequality and unemployment.
- Smart living: Smart living in a smart city refers to the use of technology and data-driven approaches to enhance the quality of life for residents. This can include things like improving public safety, increasing access to healthcare, and providing more efficient and convenient public services.
- Smart citizen: Smart citizen refers to the use of technology and data-driven approaches to empower citizens to participate in the governance and management of a smart city. This can include things like providing citizens with real-time information and services, giving them a voice in decision-making processes and creating opportunities for them to actively participate in shaping the city.
- Smart government: Smart government refers to the use of technology to improve the efficiency, effectiveness and accountability of government services and operations. This can include things like the use of digital platforms and online services, the adoption of mobile technologies, and the integration of automation and AI into government processes. Smart government solutions can help to streamline and optimize the delivery of public services, make it easier for citizens to interact with government, and increase transparency and accountability in government operations.
- Smart transportation: The utilization of technology to enhance the effectiveness, safety, and sustainability of transportation systems is known as smart transportation. This can include things like the implementation of intelligent transportation systems (ITS), the use of real-time information and communication systems, and the integration of automation and connected technologies into transportation infrastructure. Smart transportation solutions can help to reduce traffic congestion, improve public transportation, and increase the safety and efficiency of transportation systems without relying on data-driven approach.

Blockchain is a decentralized system that records and authenticates transactions. In fact, it is a digital ledger of transactions that is copied and distributed throughout the entire network of computer systems. Each block in the chain contains several transactions, and every time a new transaction is made in the block chain, a record of that transaction is added to the ledger of each participant. One of the key aspects of blockchain is its ability to create a tamper-proof record of transactions. This is achieved through the use of complex algorithms and cryptographic techniques, which make it very difficult for any one participant to alter the contents of a block once it has been added to the chain.

Blockchain technology holds significant relevance in the context of smart cities, particularly in its ability to enhance trust, transparency and security in citizen services. By providing an immutable and transparent record of transactions and data, blockchain can foster trust in public service delivery, urban planning, and

citizen engagement within smart city environments. Additionally, its decentralized and cryptographic features can address concerns related to data security and privacy, safeguarding sensitive information generated within smart city applications.As mentioned above, Blockchain can be utilized in smart city in different areas such as, energy management, transportation, governance, public services and so (Alnahari & Ariaratnam, 2022). On the other hand, the use of this technology also faces challenges, as regulatory obstacles, scalability, Interoperability, privacy and security. By highlighting these aspects, it becomes evident that blockchain technology has the potential to significantly improve citizen services within smart cities while also acknowledging its limitations and challenges. In this article, firstly, related work are reviewed, then the definitions and features of the smart city and blockchain technology, which are explained under the title of the background, then some cases for using blockchain in smart cities, are introduced, in the following, the benefit and the limitation of blockchain technology in the smart city are presented. Finally, there is conclusion and a look to the future of smart cities.

Related work

Recently, there has been study and development in the blockchain concept and smart cities. Some studies have examined the potential applications and benefits of blockchain technology in smart city development, as well as the challenges and barriers to adoption. In the following, we review the important articles that have been published in this field.

The paper cited in (Singh et al., 2020) provides an extensive examination of the security and obstacles that impact the adoption of Blockchain systems in smart cities. It offers a comprehensive evaluation of various crucial factors that must be taken into account for the fusion of Blockchain and AI technologies, which will aid in creating a resilient and sustainable smart society.

The article referenced in (Bhushan et al., 2020) examines the use of blockchain technology in smart cities to address security concerns. It provides an overview of the topic and explores how blockchain can be utilized in various smart communities such as healthcare, transportation, supply chain management, financial systems, and data center networks. The article concludes by suggesting areas for further research based on a review of literature on blockchain-based smart city systems.

In reference (Espositoa et al., 2021), a new method for managing identity verification and licensing policies in a decentralized manner is introduced. The approach involves using blockchain technology to establish a worldwide system for regulating security policies in various systems. This system is incorporated into the FIWARE platform, which facilitates easy access and coordination of security policies across numerous entities.

The review presented in (Mora et al., 2021) offers a thorough analysis of the essential characteristics of Blockchain technology that can effectively tackle societal challenges. It examines the technology from three viewpoints: service provision, resource management, and urban governance, with a focus on the United Nations' Sustainable Development Goals to encompass the entire spectrum of contemporary social problems.

Reference (Hakak et al., 2020) strives to recognize and delineate the distinguishing characteristics of blockchain technology. Moreover, the paper outlines the critical requirements that must be met for successful incorporation of blockchain technology into smart city ecosystems. In pursuit of this goal, the authors propose perceptual architecture for securing smart cities using blockchain technology, which is then elucidated using a potential use case study. In addition, a real-world case study of a smart city implemented using a three-blockchain model is presented. Finally, the paper identifies and discusses several significant research challenges that must be addressed to advance the use of blockchain.

Reference (Treiblmaier et al., 2020) delves into the subject of blockchain technology as a groundbreaking catalyst for technological advancement, encompassing a multitude of underlying protocols and technologies that have the potential to revolutionize smart cities. The paper specifically examines and answers questions regarding the ways in which blockchain technology can facilitate the growth and development of urban areas. Drawing on an extensive review of the existing literature, the authors present a comprehensive framework and a set of research propositions. They identify and discuss nine distinct fields of application for blockchain

technology in the smart city context: healthcare, mobility logistics and supply chains, e-voting energy, administration and services, factory, home, and education.

The paper (Nam et al., 2021) aims to highlight the essential characteristics of blockchain technology in the smart city/tourism framework and make predictions about its future development and influence on the industry. Furthermore, they examine significant issues, challenges, and common misunderstandings associated with blockchain technology.

The authors of reference (Majeed et al., 2021) conduct an extensive examination of the role that blockchain technology plays in enabling IoT-based smart cities.

In reference (Bagloee et al., 2021), the authors first provide a contextual background to the concept of blockchain, exploring current and emerging trends in its development. They subsequently survey various potential urban applications of this technology, with a particular focus on governance, transport, supply chain, and logistics domains. The paper goes on to present the challenges that must be addressed for the successful adoption and deployment of blockchain technology at scale.

In reference (Hasan et al., 2022), the authors introduce a hierarchical platform that utilizes blockchain technology to ensure the reliability and consistency of Internet-of-Things (IoT) data in smart cities. This platform is designed with a focus on blockchain interoperability, allowing for seamless integration of multiple blockchain systems.

In reference (Uchani Gutierrez & Xu, 2023), she proposed a model that would make the buying and selling of real estate more fair. With the use of smart contracts, the requirements already set by the government can be implemented As a result, the possibility of fraud or third party interference is reduced.

In this article (Khawaja & Javidroozi, 2023), a review has been conducted to investigate the comprehensiveness of using blockchain technology in the development of a smart city, focusing on the integration of interdepartmental systems.

In (El Bekkali et al., 2023), a comprehensive framework and architecture based on blockchain, big data and artificial intelligence is proposed to improve the cyber security of smart cities.

The purpose of (Ullah et al., 2023) is to investigate the role of blockchain technology in sustainable smart city applications by providing a detailed study of blockchain applications in the food supply chain, tourism industry, smart healthcare system, intelligent transportation system, next-generation 5G and 6G communication, and smart energy management.

Table 1 shows the works carried out in connection with the application of blockchain technology in each of the components of the smart city in the period from 2020 to 2024.

As Table 1 shows, most of the works are related to the components of smart environment and smart transportation, and more studies should be done in connection with smart citizen and smart economy.

Background

The current state of smart cities varies widely depending on the specific city and the level of investment and development that has taken place. In general, however, many smart cities are still in the p stages of development, and there are a number of challenges

Table 1 the works carried out in connection with the application of blockchain technology on each of the components of the smart city

	Blockchain
Smart environments	(Li et al., 2022), (Fadi et al., 2022), (Ebrahim & Hafid, 2022)(Pathak et al., 2023)
Smart economic	—-
Smart living	(Florea & Anghel, 2022)
Smart citizen	——
Smart government	(Rahman et al., 2022), (Parenti et al., 2022), (Balan et al., 2022)
Smart transportation	(Wazid et al., 2022), (Liu et al., 2022), (Awan et al., 2022), (Akhtar, 2023), (Bagga & Das, 2022), (Valchanov & Aleksieva, 2022)(Shari & Malip, 2023)

that must be overcome in order to fully realize their potential. One of the big challenges facing smart cities is the lack of standardization and interoperability of different systems and technologies. This makes it difficult for cities to share data and information, and can limit the potential benefits of smart city projects. Another major challenge is the need for significant investment in infrastructure and technology. Many cities struggle to secure the funding necessary to develop and implement smart city projects, and this can limit the pace of development. There are also challenges related to data privacy and security, as cities collect and store large amounts of sensitive information about citizens and businesses. This has raised concerns about data breaches and the potential misuse of data. Cities also face challenges in terms of citizen engagement and participation. There is a need to ensure that smart city projects are designed and implemented with the needs and perspectives of citizens in mind, and that there are opportunities for citizens to provide input and feedback on development plans. Finally, there are challenges regarding governance and coordination. Smart city projects often involve multiple stakeholders and different levels of government, and it can be difficult to align priorities and coordinate efforts effectively. Overall, while the potential of smart cities is vast, there are many challenges that must be overcome in order to fully realize that potential. These include lack of standardization and interoperability, funding and investment, data privacy and security, citizen engagement, and governance and coordination. Figure 1 summarizes these challenges.

The use of blockchain technology for enhancing security in smart cities is discussed in an article referenced in (Bhushan et al., 2020). The article explores different applications of blockchain technology in healthcare, transportation, supply chain management, financial systems, and data center networks. It also suggests further research areas based on a review of the literature on blockchain-based smart city systems. The block structure in blockchain technology consists of a block body with transaction data and a header with essential metadata such as nonce, nBits, timestamp, Merkle tree root hash, parent block hash, and block version. Figure 2 provides a visualization of the overall blockchain architecture. The categorization of blockchain technology is based on their control and authentication mechanisms, and can be divided into three types: public, private, and consortium blockchain.

A public or permissionless blockchain operates on a decentralized open-source framework that enables anyone to join and perform mining activities independent of any organization.
In contrast, a private or permissioned blockchain allows for decentralized sharing of information within a designated group or organization while also guaranteeing confidentiality and privacy.
A consortium blockchain is a type of blockchain that combines features of both private and public blockchains. It involves a group of people who work together to make decisions regarding consensus and block validation within the blockchain network.

Consensus protocols ensure the stability of blockchain systems by ensuring that nodes reach a consensus on a particular transaction or value. In general, the blockchain architecture is composed of six main layers namely the data layer, network layer, consensus layer, incentive layer, contract layer and application layer.

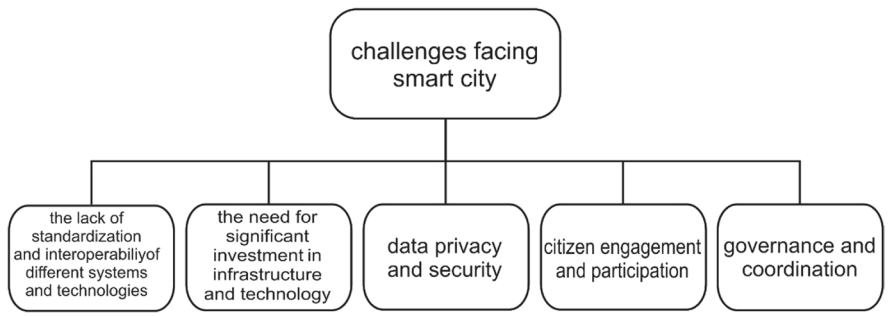

Fig. 1 Challenges of smart city

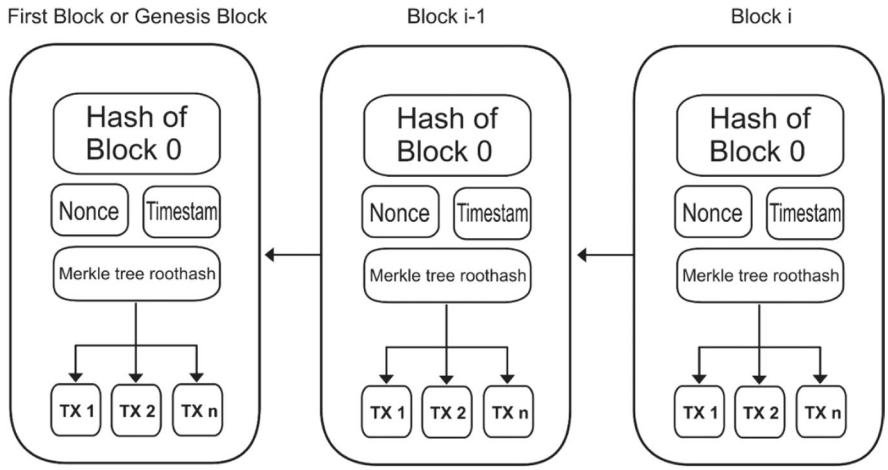

Fig. 2 General block structure

The Data Layer enables the manipulation of various types of data gathered from online, physical, and social environments.

The Network Layer is responsible for validating, transmitting, and disseminating blockchain transactions.

The Consensus Layer is crucial in a decentralized setting as it ensures that unreliable nodes can efficiently reach an agreement.

The Incentive Layer plays a vital role in a blockchain network by incorporating economic factors, such as the distribution of rewards and incentives, to ensure its proper functioning.

The Contract Layer is crucial in a blockchain network as it is responsible for incorporating economic elements like reward distribution and allocation mechanisms to ensure the network operates effectively.

The Application Layer consists of the end user or customer.

Figure 3 shows a new smart city structure contains blockchain concept. The components of a smart city can be placed on top of the blockchain architecture. The robust features of blockchain, such as its transparency, reliability, authentication, and decentralized nature, make it well-suited to support the growth of smart cities (Alam, 2022).

In some studies, blockchain has been introduced as a middleware that can improve the quality and sustainability of smart cities (Loss et al., 2022, Al Mahfuj Shaan et al., 2022). The incorporation of blockchain technology has the potential to enhance the sustainability of smart cities by establishing a comprehensive platform that links various city services, resulting in increased transparency and security for all processes and services (Riđić et al., 2021).

Blockchain technology can address many of the challenges facing smart cities in areas such as governance, transportation, environment, economy, living, and citizen in the following ways:

1. Governance: Blockchain can be used to create a tamper-proof record of votes and other public records, which can improve transparency and trust in government operations. Smart contracts can also be used to automate and streamline government processes, reducing bureaucracy and increasing efficiency. Blockchain can also be used for public procurement and tendering, and digital identity management.
2. Transportation: Blockchain can be used to create a secure and transparent record of transportation data, such as traffic congestion and parking availability. This information can be used to improve traffic management and reduce congestion, as well as enable peer-to-peer car sharing and enable micropayments for transportation services. Blockchain can also be used for logistics and cargo tracking, and digitalized toll and fare collection.
3. Environment: Blockchain can be used to create a secure and transparent record of environmental data, such as air and water quality. This information can be used to monitor and manage natural resources in a sustainable way, and also enable peer-to-peer trading of carbon credits. Blockchain can also be used for tracking and certifying the origin of green energy, and for monitor-

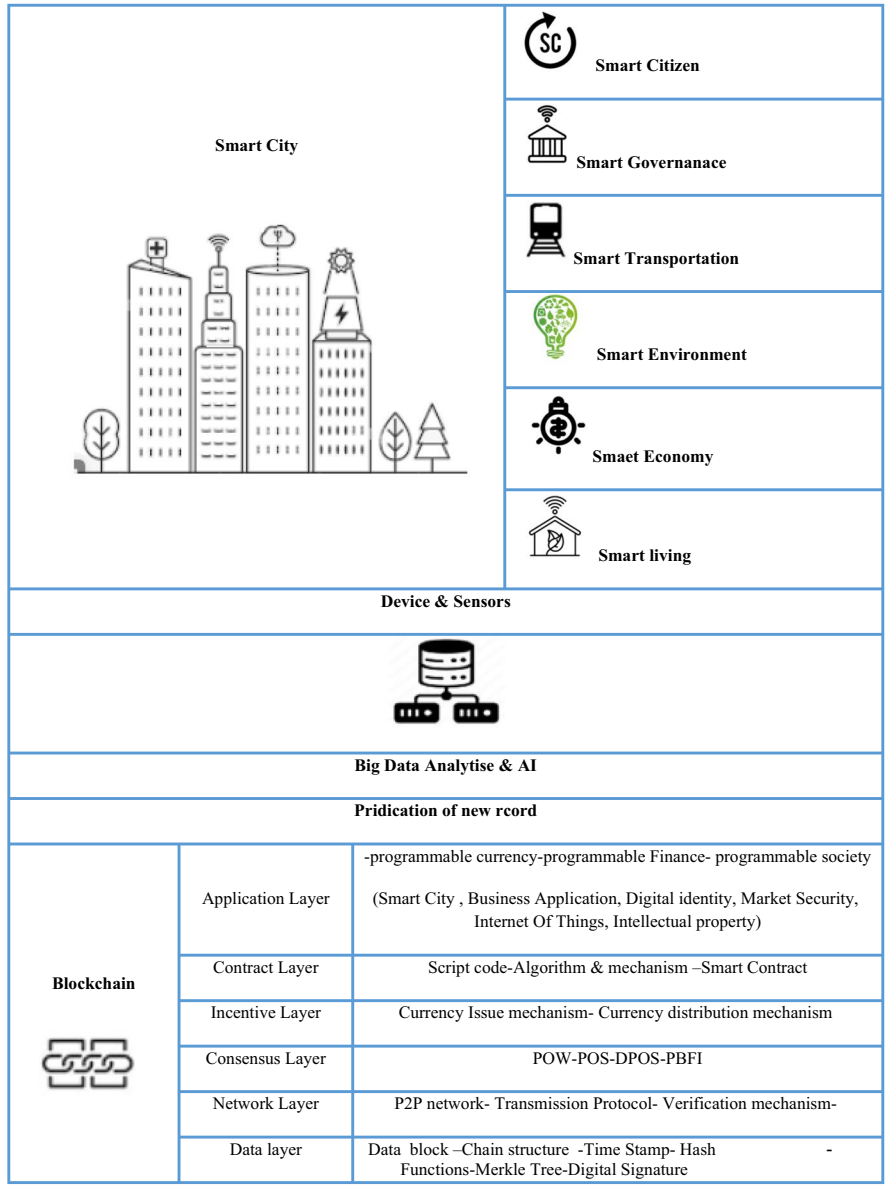

Fig. 3 New smart city structure including blockchain concept

ing and recording the use of shared vehicles and other assets to reduce emissions.

4. Economy: By using blockchain technology, it is possible to improve the sustainability of smart cities by creating an immutable ledger of financial transactions, promoting transparency and dependability in economic operations, enabling direct peer-to-peer trading of goods and services, and facilitating micropayments. Blockchain can also be utilized for digitizing financial services and tracking and verifying the source of goods and services.
5. Living: Blockchain can be used to create a secure and transparent record of living data, such as public service delivery and public safety. This information can be used to improve the living conditions, and also to enable peer-to-peer sharing of underutilized assets. Blockchain can also be used for tracking and certifying the origin of goods and services, and for managing and recording property ownership and transactions.

6. Citizen: Blockchain can be used to create a tamper-proof record of citizen data, which can improve transparency and trust in government operations and also to enable peer-to-peer sharing of underutilized assets, and micropayments. Blockchain can also be used for digital identity management and for tracking and certifying the origin of goods and services.

In smart cities, blockchain technology can be utilized to enhance efficiency, security, and transparency through various means. Some specific ways in which blockchain can be used in smart cities include:

1. Digital Identity: Blockchain can be used to create a secure and tamper-proof digital identity for citizens, which can improve access to services and reduce fraud. This could include things like digital passports, voting systems, and personal health records.
2. Supply Chain Management: Blockchain can be used to create an immutable record of transactions and provenance for goods and services, which can improve transparency and efficiency in supply chain operations. This could include things like tracking the origin of products and ensuring that they are ethically and sustainably sourced.
3. Smart Energy Management: The implementation of blockchain technology in smart cities can lead to improved effectiveness, safety, and clarity by enabling the development of a decentralized energy trading system that enables citizens to exchange surplus solar energy with one another without relying on a central authority. This can increase the adoption of renewable energy and reduce dependence on fossil fuels.
4. Real-Estate: Blockchain can be used to manage and record property ownership, transactions, and all other related records, making it more efficient and secure.

Use case of blockchain in smart cities

In the following, examples of the use of blockchain technology in prominent cities of the world are presented (Smartcityindex, 2023).

- In Seoul, South Korea, the city government is using blockchain to create a digital identification system for residents, which will be used to access city services and make micropayments.
- In Dubai, the government is using blockchain to create a system for tracking the flow of goods through the city's ports
- In Moscow, Russia, the city government is using blockchain to create a platform for citizens to report issues such as potholes and broken streetlights, and track the progress of repairs in real-time.
- In Taipei, Taiwan, the city government is using blockchain to create a digital voting system that is more secure and transparent than traditional voting systems.
- In Buenos Aires, Argentina, the city government is using blockchain to create a platform for citizens to purchase public transportation tickets using cryptocurrency.
- In the Netherlands, the city of Groningen is using blockchain to manage and track the use of shared electric vehicles, in order to reduce emissions and improve the efficiency of transportation systems.
- In the United States, the state of Vermont is using blockchain to create a secure and tamper-proof record of land ownership and property transactions, which will help to improve the efficiency of real estate transactions and reduce fraud.
- In Singapore, the government is using blockchain to develop a national digital identity system that will be used to access government services and make payments.

These examples demonstrate the wide range of ways in which blockchain technology can be used in smart cities to improve efficiency, security, and transparency, and to create new opportunities for citizen engagement and participation in the governance and management of the city.

Implementing a blockchain-based smart city will require a number of technical requirements, including both hardware and software considerations. Some of the most important technical requirements include (http://www.mdpi.com):

1. Hardware: Blockchain technology is based on a distributed network of computers, which means that it will require a large number of servers and other computing resources. Depending on the

size and scale of the smart city, this may include things like cloud-based servers, edge computing devices, and specialized mining hardware.
2. Networking: A blockchain-based smart city will require a high-speed, low-latency network infrastructure to support the large number of transactions that will take place on the network. This may include things like fiber-optic cables, 5G networks, and wireless networks.
3. Software: Blockchain technology is based on a complex set of algorithms and cryptographic techniques, which means that it will require specialized software to run. This may include things like blockchain platforms, smart contract platforms, and software development kits (SDKs).
4. Security: Since blockchain-based smart cities will be dealing with sensitive data, it will require robust security measures to protect data from unauthorized access. This may include things like advanced encryption, multi-factor authentication, and intrusion detection systems.
5. Data Management: A blockchain-based smart city will require a large amount of data storage, management, and analysis capabilities to store and process the data generated by the smart city. This may include things like data warehousing, data lakes, and big data analytics platforms.
6. Interoperability: for blockchain technology to be effectively utilized in smart cities, there needs to be a seamless exchange of data and information between systems through interoperability and communication. This may include things like application programming interfaces (APIs), data exchange protocols, and middleware.
7. Scalability: As more and more devices and systems get connected to the blockchain network, the system should be able to handle increased data and transactions. This can be achieved by implementing different consensus mechanisms and distributed ledger technologies such as sharding, state channels, and sidechains.
8. Privacy: The privacy of the data shared on the blockchain network must be protected and this can be achieved by implementing different privacy-enhancing technologies such as zero-knowledge proof, homomorphic encryption, and ring signatures.

The benefit of using blockchain technology in a smart city

Several potential benefit of utilizing blockchain technology in smart cities, including (Bhushan et al., 2020):

1. Increased transparency: Blockchain creates a tamper-proof record of transactions, which can be used to create a transparent and auditable record of government operations, economic activities, and other important information. This can help to build trust and improve accountability in smart cities.
2. Improved security: Blockchain technology is inherently secure, as it uses advanced encryption and cryptographic techniques to protect data and transactions. This can help to reduce the risk of data breaches and other security threats in smart cities.
3. Increased efficiency: Blockchain technology can be used to automate and streamline many processes in smart cities, such as supply chain management, transportation, and governance. This can help to reduce bureaucracy and improve the speed and efficiency of these processes.
4. Peer-to-peer interactions: The utilization of blockchain technology in smart cities can enhance efficiency, security, and transparency by facilitating the creation of a decentralized energy trading platform that allows individuals to trade excess solar energy with each other without depending on a central entity. This enables peer-to-peer transactions and interactions, which opens up novel possibilities for citizen involvement and contribution in the administration and operation of the city (http://www.researchgate.net).
5. Smart Contracting: Smart contracts can be used to automate the execution of agreements, reducing the need for intermediaries, and increasing the speed and efficiency of transactions. This can be used for things like property and asset management, supply chain management, and energy trading.
6. Decentralization: Blockchain creates a decentralized network where all the participants have equal rights and responsibilities, and the power

is distributed among the nodes, which can make the system more robust and less prone to attacks.
7. Cost-effective: Blockchain can help to reduce costs associated with intermediaries, middlemen and fraud, by eliminating the need for intermediaries in some transactions, and providing a tamper-proof record of transactions which can help to reduce fraud.
8. Improved data management: Blockchain can be used to create a secure and tamper-proof digital ledger of transactions, which can be used to store and manage data in smart cities (content.iospress.com). This can include things like citizen information, land registry records, and other important data.
9. Enhanced asset tracking: Blockchain can be used to create a tamper-proof record of the ownership, location, and condition of assets in smart cities. This can be used for things like tracking vehicles, equipment, and other valuable assets.
10. Improved supply chain management: Using blockchain technology in smart cities can enhance the transparency, security, and effectiveness of managing supply chains. This can include things like tracking the movement of goods, verifying the authenticity of products, and reducing fraud.
11. Better energy management: Blockchain can be used to create new opportunities for distributed energy generation and consumption, Like peer-to-peer energy trading, and to create a transparent, tamper-proof record of energy usage and consumption (Nepal et al., 2022).
12. Improved public safety: Blockchain can be used to improve the transparency, security, and efficiency of emergency services and public safety operations in smart cities (Singh et al., 2020).

Limitations and challenges of using blockchain technology in a smart city

Figure 4 shows briefly the limitations and challenges ahead in using blockchain technology in the smart city.

Implementing blockchain technology in smart cities has the potential to bring many benefits such as increased transparency, security, and efficiency. However, as showed in Fig. 4 there are also some limitations and challenges that must be taken into account (Biswas et al., 2023). One of the main limitations is that blockchain technology is relatively new and complex, which can make it difficult to implement and manage. It requires a dedicated team of experts with knowledge in blockchain technology, data management, and smart city planning. Another challenge is scalability, as the system must be able to handle increased data and transactions as more devices and systems get connected to the blockchain network. This can require significant investment in hardware and infrastructure. Additionally, blockchain technology is still largely unregulated, which can make it difficult for cities to comply with existing laws and regulations, creating legal and regulatory uncertainty. Security is another limitation (Pires et al., 2023), while blockchain technology is inherently secure, it still can be vulnerable to certain types of attacks such as 51% attack, and smart contract vulnerabilities. Data privacy is also a concern, as blockchain technology is based on transparency which can make it difficult to protect personal data and comply with data protection regulations. Furthermore, Interoperability is a major challenge, especially as different blockchain platforms have different standards and protocols. Lastly, blockchain technology is still not widely adopted, it may take some time for citizens, businesses, and governments to fully understand and embrace the technology (Jiang & Ræder, 2022). To overcome these challenges, It is important to have a thorough knowledge of technology and its limitations, as well as a well-planned strategy for implementation and management. Another limitation is the high cost of implementing and maintaining blockchain technology, which can be a barrier for smaller cities or communities with limited resources (Xia et al., 2023).va This can include the cost of hardware and infrastructure, software development and maintenance, and training and education for city officials and staff. Another challenge is the lack of standardization, as different blockchain platforms and technologies have their own unique features, protocols and standards. This can make it difficult for cities to choose the best solution for their specific needs and can also make it difficult for different systems to communicate and share data with each other. Additionally, the lack of technical expertise and knowledge in blockchain

Fig. 4 limitations and challenges of blockchain

technology can be a barrier for cities looking to implement blockchain solutions. This includes a lack of understanding of the technology, its potential use cases, and best practices for implementation and management.

Conclusion

In conclusion, blockchain technology offers a wide range of potential benefits for smart cities, including increased transparency, security, efficiency, peer-to-peer interactions, smart contracting, decentralization, and cost-effective solutions. However, there are also several limitations and challenges that It should be considered in the implementation of blockchain technology in smart cities. These include complexity, scalability, regulation, security, data privacy, interoperability, adoption, cost, lack of standardization, and lack of technical expertise. To overcome these challenges, cities should have a clear understanding of the technology and its limitations and also a well-planned strategy for implementation and management. It is also important to consider the specific use case and tailor the solution accordingly. With the appropriate planning and execution, blockchain technology can play a significant role in creating more efficient, secure, and transparent smart cities for the benefit of citizens and communities. Furthermore, it is worth considering that blockchain is not a silver bullet for all smart city issues. It should be used in combination with other technologies and approaches for a more holistic solution. For example, blockchain can work together with IoT, AI, and Big Data to create a more robust and comprehensive smart city infrastructure. Another important aspect to consider is the involvement of citizens, businesses, and Governments in expansion and implementation of blockchain-based smart city solutions. Collaboration and engagement with all stakeholders is crucial for the success of any smart city initiative, including those based on blockchain technology. This can include involving citizens in the decision-making process, creating opportunities for citizen-driven innovation, and involving local businesses and organizations in the

development and operation of smart city services. Overall, blockchain technology has the potential to bring significant benefits to smart cities, but it is important to approach its implementation with caution, taking into account the limitations and challenges, and to involve all stakeholders in the process. With the right approach, blockchain technology can help to create more efficient, secure, and transparent smart cities that better serve the needs of citizens and communities.

Future of blockchain in smart cities

The future of blockchain in smart cities holds great potential for improving various aspects of urban life. Blockchain technology can be utilized to enhance transparency, security and efficiency in government operations, resulting in more accountable and efficient public services. It can also enable new peer-to-peer business models, bringing new economic opportunities to citizens and businesses. Additionally, blockchain can enable new forms of citizen engagement and participation in the governance and management of smart cities. Smart city transportation and mobility can also be improved through the use of blockchain, reducing congestion and increasing mobility for citizens. Furthermore, it can be used to enhance security and safety by creating tamper-proof records of transactions and enabling secure and transparent communications between devices and systems. Blockchain can also create new opportunities for sustainable development such as managing and tracking the use of renewable energy and reducing waste and pollution. Lastly, it can be used to improve real-estate by managing and recording property ownership, transactions and also it can be used to make the whole process more efficient and transparent.

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Declarations

Competing interests The authors have no conflict of interest.

Appendix

Therefore, for a better understanding, it is recommended to conduct a more complete research on the potential of blockchain technology in providing better services in the smart city.

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