Blockchain Technology for Advancement of Smart Cities

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Today we undoubtedly live in one of the fastest-changing times humanity has ever seen. Blockchain is revolutionizing the whole world by bringing a new geometry to security, efficiency, and stability of systems and data. Blockchain Technology is more than just Bitcoin but it is a foundational technology that can disrupt every industry. The architecture of blockchain technology enables everybody on the system to trust the system. The incarnation of new technologies for the development of smart cities gives new ways of rethinking different services. Given the continuous development of urban areas, a new approach to urban government innovation is required for smart cities and smart technologies are essential for it. The objective of smart cities mission is to provide smart solutions to drive economic growth, increase the quality of life, development of urban ecosystems, etc. Blockchain enables our cities to exchange data with a high degree of reliability and transparency without the need for a centralized administrator. As a result, several venture capital firms and large enterprises are investing in blockchain technology research and trials to re-imagine traditional practices and business models. In this paper, we specifically address the question of how blockchain technology may benefit the development of urban areas.

Keywords: Blockchain Technology, Smart Cities, Blockchain Cities, Security.

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1 Introduction

Globally, countries are experiencing increasing levels of, while major cities are becoming magnets for top talent and businesses, resulting in these cities being a major driver for economic growth. But this comes with the risks of increased congestion and environmental issues. Increasing population numbers in cities bring with it, the issues of greater demand for resources, greater pressure on urban infrastructures, increased demand for public services, and more pressure on the natural environment. The need for Smart Cities, supported by connected technologies, is growing. The economic downturn caused by the COVID-19 pandemic showed how there is a need for more efficient and reliable urban management. Advanced technologies such as can play a key role in addressing these societal issues while also achieving efficient urban management.

In order for efficient urban services to be delivered, it is crucial for a city to ensure that effective data exchanges are conducted between the many different city stakeholders. enables network participants to exchange data with a high degree of reliability and transparency, without needing to depend on an administrator. A smart city is a geographical area with a high population density that uses information and communication technologies (ICT) to connect and monitor critical infrastructure components and services with the goal of improving the efficiency and the environmental, economic and social sustainability of its operations as well as the quality of life for its citizens. Smart-city initiatives also need to increase the level of automation and intelligence of modern residential areas, improve the quality of services, and efficiently manage diverse urban activities for the benefit of smart citizens. We discuss each field, show how block chain technology can play an important part in building smart cities, and conclude each section with one or more research propositions.

2 Blockchain technology

In 1991, Stuart Haber and W. Scott Stornetta envisioned what many people have come to know as block chain. Their first work involved working on a cryptographically secured chain of blocks where no one could tamper with the timestamps of the document[1]. In 1992 they upgraded their systems that enhanced efficiency thereby enabling the collection of more documents on a single block. Satoshi Nakamoto, accredited because the brains behind block chain technology, conceptualized the first block chain in 2008 and released it in 2009 in the whitepaper, he provided details of how the technology was well equipped to enhance digital trust given the decentralization aspect that meant nobody would ever be in control of anything [8]. Block chain Technology in simple terms is a distributive ledger that is secure and records each transaction that is done by many computers across the world. It is a data structure that holds the transactions while ensuring security, transparency, and decentralization and stores the data in the form of blocks which is not controlled by a single authority. The blocks that form a block chain hold batches of transactions approved by participants in a network. Each block comes with a cryptographic hash of a previous block in the chain. Block chain is a database, not a typical database [2].

The key difference between a typical database and block chain is how data is structured in a typical database the data is stored in the form of tables whereas in block chain it collects the information together in groups called blocks . Once the block is filled with data, it is chained onto the previous block, which makes the data chained together in chronological order. Management of the database is done autonomously using peer-to-peer networks and a time stamping server[3]. To understand block chain technology it is necessary to define some basic concepts: Nodes: a decentralized digital ledger that records all crypto currency transactions and makes the information available to everyone via a connected device. Each node is distinguished from others by a unique identifier. It helps maintain the security and integrity of the network. There are 2 types of nodes: full nodes and lightweight nodes. Hash: Block chain is a type of DLT in which transactions are recorded with an immutable cryptographic signature called a hash. The groups of blocks that the block chain miners are charged with must be validated by the system. To do this, the miners must find a password or digital fingerprint that identifies them. Besides, each time a new hash is discovered, it is distributed to the rest of the nodes in the network, so that they are always synchronized. A function that receives an input of any size and returns a unique string of a uniform length is known as a hash function. Block: The first or first few blocks of a blockchain are called the genesis block. The block is where transaction data in cryptocurrency blockchain are permanently recorded. Block store of records that, once written, cannot be altered or removed. Transaction: The transaction element is the largest because it contains the most information. It contains a list of all the transitions within a block. It is used mainly to authenticate transactions, helps secure your digital identity over the internet, and makes it valid. It ensures that a message received by a recipient has come from the sender claiming to have sent the information. Digital signatures follow asymmetric cryptography by linking two different keys with mathematical links[4]. Peer to Peer Network: P2P networks focus on connectivity rather than on information sharing. In peer-to-peer networks, each network acts as a node and the node acts as a server to the network and allows us to share a huge amount of data with security, and deleting and repairing nodes is easy in peer-to-peer networks. In every node both request and response are possible. For example, Ram wants to see the files of Raj, Ram first seeks permission from Raj to see the files, now Raj has a choice to accept or deny. And if raj gives permission, then he has to provide a key and that key gives access to Ram to see files [5].

3 Smart Contracts

In 1998, Nick Szabo used computerized transactions protocol to execute smart contracts and invented virtual currency[8]. The idea is simple behind smart contracts that it uses IF-THEN. For instance, IF you send this object, THEN money or cryptocurrency will be transferred to you. The goal of smart contracts is to simplify commercial activities between both anonymous and identified parties[6]. It eliminates procure-to-pay gaps[7]. Smart contracts are immutable, decentralized, inexpensive, secure and each smart contract has its address in the blockchain[6][Figure:2]. It is a self-executing contract as contracts are written into lines of code and code controls the execution. In smart contracts, transactions are traceable and irreversible[3].

3.1 Key Characteristics of Blockchain

Immutability: Creating immutable ledgers is one of the core values of the blockchain. All centralized databases can be corrupted and often a third party must be trusted to maintain information integrity. It enhances the transparency and traceability of data and increases the overall efficiency and clarity of many business models[13]. Cryptographic hashing establishes immutability[9,10]. (immutability = cryptography + blockchain hashing process)[11]. 51% attack is a challenge faced by immutability which can be solved by using a strong protocol that is a Consensus algorithm[12]. Decentralization: Decentralized networks strive to reduce the level of trust that participants must place in one another, and deter their ability to exert authority or control over one another in ways that degrade the functionality of the network. In the blockchain, decentralization refers to the transfer of control and decision-making from a centralized entity (individual, organization, or group thereof to a distributed network. When building a technology solution, three primary network architectures are typically considered: centralized, distributed, and decentralized[14]. Persistence: It means that it is impossible to delete or roll back any transaction once it is included in the blockchain Since each of the transactions spreading across the network needs to be confirmed and recorded in blocks distributed in the whole network, it is nearly impossible to tamper. It depends on the allocation of consensus-relevant resources and the speed of block propagation, which is subject to network topology[13]. Anonymity: Each user can interact with the blockchain with a generated address, which does not reveal the real identity of the user[15]. Note that blockchain cannot guarantee perfect privacy preservation due to the intrinsic constraint[16]. Auditability: Each of the transactions on the blockchain is validated and recorded with a timestamp, users can easily verify and trace the previous records through accessing any node in the distributed network[17].

4 Classification of Blockchain System

4.1 Public Blockchains: It is permissionless. A public blockchain is an open-source that allows anyone to join as users, miners, developers, community members. a public blockchain is highly censorship-resistant. These are primarily used for exchanging and mining cryptocurrency[18]. Data on a public blockchain is secure as it is not possible to modify or alter data once they are validated. It has a substantial amount of computational power to maintain a distributive ledger at a larger scale, each node in a network must solve a resource-intensive, complex problem (proof of work) to ensure all are in sync[19]. This takes time to process each request and hence, the speed of the network is slow and also has a higher transaction cost. the public blockchain network is fully immutable. Bitcoin, Ethereum, and Litecoin use a public blockchain[21].

4.2 Private Blockchains: In this type of blockchain it is necessary to get authorization to join a network. Private blockchains are permissioned blockchains controlled by a single organization. They are also referred to as a managed blockchain[20,22]. Private blockchains are only partially decentralized because public access to these blockchains is restricted. In a private blockchain, the access is limited and a network is more centralized.it consumes significantly less amount of energy and material resources. In this, each participant is known to have credentials to have been granted access and there is no chance of any contrary impact. The business-to-business virtual currency exchange network Ripple and Hyperledger, an umbrella project of open-source blockchain applications uses private blockchains[20,22].

4.3 Consortium Blockchains: Also known as the federated blockchain. Consortium blockchains are permissioned blockchains controlled by a group of organizations, rather than one organization. consortium blockchains result in higher levels of security and are more decentralized than private blockchains. The privacy of transactions is better in this system. It eliminates data redundancies[20,22].

4.4 Hybrid Blockchains: Hybrid blockchains are partially decentralized[22]. It is a combination of privacy and public blockchain, controlled by a single organization. It is controlled by a few predetermined nodes[22]. Hybrid Blockchain has permissions to verify, read, write on the blockchain[20,22].

5 Consensus Formation Algorithm

5.1 POW: Proof of work is a consensus Algorithm that is proposed to create a solution to the growing problem of spam mail[23]. POS requires hardware, leader selection is based on the miner's work, block generation and transaction confirmation is slow and used in public blockchains[23,24]. It is a functional protocol that validates every data. POW uses the SHA-256 hashing algorithm to create a hash that matches the target hash for the current block[23]. In this miners compete against each other to complete traction on the network.

5.2 POS: In the more recent PoS networks, the solution searching is completely removed, and the block leaders are no longer selected by computational power[25]. POS has a higher chance to be selected. With the stake-based leader selection process, a node's chance to be selected to be a leader no longer depends on its computational power, and thus energy consumption of PoS mechanisms is significantly reduced compared with that of PoW[25]. It does not require any hardware, leader selection is based on stake, the block generation and transaction confirmation are fast as compared to proof of work. Cardano and Algorand use POS.

6 Blockchain Cities

6.1 Smart City : Smart City is a collection of industries and stakeholders interacting with one another[31]. The application of technologies is specific for each application area, but when combined, can be viewed as the building blocks for a smart city. Based on the definition, to understand smart cities more clearly, a conceptual framework of smart cities [26]–[27] is proposed. (see in Fig.1), there are three core components in smart cities: technology, human and organization. The key factor of smart cities is information and com- munication technology, which can be used to improve life and work significantly and fundamentally [28]. Intelligent hardware infrastructures and software applications can achieve a sustainable smart city. The organization based on governance and policy, is fundamental to design and implement smart cities. The government aims to create a transparent and accountable environment, where citizens can access information related to their daily lives and resources are managed more effectively. In order to promote growth and encourage innovation, the government needs to interconnect with stakeholders such as enterprises, citizens, communities and non-profit organizations [29]. In smart cities, it is necessary for the government to provide interoperable, Internet-based services, which allow effective communications with smart citizens and satisfy their requirements efficiently.

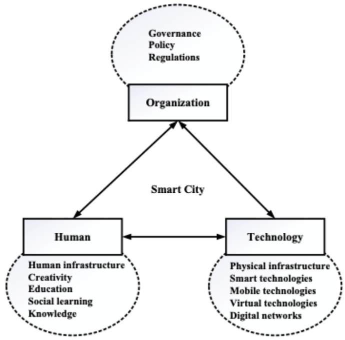

Fig 1: A conceptual framework of smart cities [26]–[27].

There are three core components in smart cities: technology, human and organization. Technology is the key factor of smart cities. Human can provide innovative ideas, creative works and solutions to promote the development of smart cities. The organization is fundamental to design and implement smart cities.

6.2 Smart Energy :The main purpose of smart energy is for the efficient consumption of clean, low-cost energy. has the potential to create a more resilient environment for the energy industry through the facilitation of peer-to-peer energy production and consumption[32]. The city or state ecosystem can benefit from the use of energy efficiency and improve the management of energy resources. Greater transparency can be brought to energy transactions through use for the regulation of energy transformation or distribution. can provide a strong communication backbone for use in the energy network, thus streamlining peer-to-peer energy trading transactions. technology can be used to store data generated from energy management system. Decision makers will therefore have greater levels of comfort in using this data to measure levels of demand and supply[33].

6.3 Smart Mobility : The concept of smart mobility is to improve access to transportation systems that are efficient for users and sustainable for the city and the broader environment. This is a key component of any Smart City. One of the major hurdles faced by any city is the effective management of a transportation network. technology can be used alongside IoT systems for continuous real-time tracking of transportation vehicles and passengers. Various applications of technology can allow transport decision-making authorities to routing strategies and schedules, plan for the differing needs of commuters, and achieve greater effectiveness with regards to environmental and sustainability goals. An efficient transportation network which leverages technology can allow users to securely pay for transportation services throughout the transportation ecosystem, regardless of which mode of transport they are using [34]. will allow for a greater level of understanding of commuter profile as it is capable of capturing and storing a vast amount of data and maintaining a complete and immutable history of commutes, driving performance, maintenance etc. can also be an enabler for Mobility-as-a-Service solutions, where various additional services can be delivered to citizens such as car-sharing, payments, insurance, and maintenance [35].

6.4 Public Administration and Services : With the growing rate of , there is more emphasis on the need for effective city administration and service delivery. Public administration needs to be redesigned in order to operate more efficiently and deliver value to citizens. This can be achieved by reducing the heavy reliance on administration systems. With its higher levels of security and privacy, it can be used to assist governments in achieving effective e-administration solutions. Smart contracts, which is a tool offered through technology can enable the transition to a Smart Government, where citizens can be more actively involved in their engagements with government services. Various services such as land registries, identity management and authentication, tax collection, and records management can be automated and delivered more efficiently through the use of smart contracts, enabled by the . is also an effective tool in ensuring government transparency and accountability. Transactions can be verified and all parties involved will be accountable to deliver on the services they have been contracted for[49].

6.5 Smart E-Voting : The strong need for governments to move online and adopt e-voting in elections has been identified in many countries. A growing body of scholarly research on e-voting istestimony to the importance of the ability of governments to provide convenience, access, and accountability in democratic elections [37]. Recently, COVID-19 has demonstrated that citizen access to secure e-voting procedures may be crucial in maintaining both public health and democratic processes in times of pandemics. As a critical component of the smart city paradigm, e-voting systems can be significantly supported by blockchain technology[36]. Key-benefits of blockchain in e-voting processes stems from the high authentication capabilities of the technology and its ability to securely store votes and enhance the transparency of elections. In this regard, Li et al. [38] argue that blockchain-based e-voting systems can increase the efficiency of voting in terms of time and cost of election services. To enhance citizen engagement, blockchain technology makes the electoral process more transparent and prevents attempts to manipulate voting data(see fig.2).

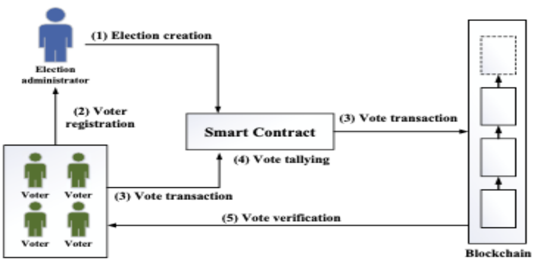

Fig 2: . A use case of applying blockchain technology to smart cities.

6.6 Smart Education :A key characteristic of a smart city is the smartness of its inhabitants, their desire for learning and for pursuing higher education degrees and their willingness to accept new technologies. The development of smart cities is therefore closely linked to the need for education. More specifically, the quality and viability of smart cities hinge on education and the quality of schools in regards to local development and the integration between educational institutions and smart cities. While ICT has widely permeated education, the digitalization of educational records has increased the pressure to ensure the security and privacy of their online storage. The field of education has witnessed significant challenges in terms of the need for securing personal data that are enriched with significant details such as citizenship, migration, financial, and social information gathered by educational establishments. Concerns over the use of student information have risen as the collection of learning analytics and big data has become more common in higher education. According to Zhou and Hu [35], the security of academic information systems constitutes a critical factor that restricts the quality of information services and also has a great effect on the storage and transfer of resources. Blockchain technology provides a highly secure design for handling huge amounts of educational data [34]. As such, the technology represents a secure ledger for storing educational documents such as student transcripts, certificates, and degrees, allowing each individual to own and share his/her own digital certificates on a peer-to-peer network. Blockchain can help to transform higher education models into sustainable lifelong learning platforms.

7 Implementation of Blockchain Cities So Far

According to the United Nations, the number of cities with a population of 11 million or more is expected to increase from 33 to 43 between 2020 and 2030. While urbanization is said to bring strong economic power due to the concentration of population and industry, it also has its risks — including the potential for increased congestion and environmental problems. Launched by His Highness Sheikh Hamdan, the Dubai Blockchain Strategy, is a result of a collaboration between the Digital Dubai Office and the Dubai Future Foundation to continually explore and evaluate the latest technology innovations that demonstrate an opportunity to deliver more seamless, safe, efficient, and impactful city experiences. The Dubai Blockchain strategy will usher in economic opportunity for all sectors in the city, and cement Dubai's reputation as a global technology leader, in line with Digital Dubai's mandate to become global leader in the smart economy, fuelling entrepreneurship and global competitiveness.Adopting Blockchain technology Dubai stands to unlock 5.5 billion dirham in savings annually in document processing alone — equal to the one Burj Khalifa's worth of value every year. Quit; The Dubai Blockchain Strategy establishes a roadmap for the introduction of Blockchain technology for Dubai and the creation of an open platform to share the technology with cities across the globe.

The Dubai Blockchain strategy is built on three pillars of government efficiency, industry creation and international leadership.Cities like Gothenburg, Chicago and Singapore are clear examples of innovative cities: highly digitised and with a more advanced and sustainable urban management model for mobility, energy efficiency, waste treatment and citizen participation. These smart cities have inspired initiatives like Blockchain Cities, a United Nations (UN) working group to determine how blockchain can be applied to running smart cities.The preliminary results of the research, in which 26 experts from various countries took part, highlight in particular the potential of blockchain for municipal governance because of its capacity to transmit information securely, with no intermediaries. Even so, experts point out that we are dealing with a technology that will not solve all urban management problems and that its use only makes sense under specific conditions.

8 Security in Blockchain

The security framework of blockchain consists of four layers: physical layer, Communication layer, Database layer and Interface layer. Physical layer consists of sensors and actuators which collect and forward data to the upper layer protocols that is the communication layer which uses different mechanisms Bluetooth, 6LoWPAN, Wi-Fi, Ethernet, 3G, and 4G to exchange information among different systems. Communication layers provide security and privacy of transmitted data. Database layer is a decentralised ledger that records data and Each record in the ledger includes a time stamp and a unique cryptographic signature. After a transaction is completed it is verifiable and auditable by any legitimate user. There are 2 types of ledger (1) Permissionless (2) permissioned.

The key benefits of permissionless ledger are that it is censorship-resistant and transparent. However, the public ledger has to maintain complex shared records and it consumes more time to reach the consensus compared to the private ledger. Further, public ledgers may also be subjected to anonymous attacks. Therefore, it is recommended to use private ledgers to ensure scalability, performance, and security for real time applications like traffic systems in a smart city. Interface Layer contains numerous smart applications which collaborate with each other to make effective decisions[30].

9 Conclusion

Smart Cities and blockchain technology are still in their early stages of development. Both concepts are very broad and incorporate multitudes of systems and processes. Significant progress and breakthroughs can be expected from both fields in the near future as more technological advancements are made and more people adopt the concepts of a Smart City and explore the possibilities of blockchain technology. As cities develop and expand their services, governance and management are becoming more and more complex. Consequently, cities must adapt to address the economic, social, engineering and environmental challenges of these transformations. Cities must become smart to face the challenges properly. In summary, research on applying blockchain technology in smart cities is quite broad and many challenges lay ahead. Nevertheless, it is favourable for the network community to address the challenges and go forward. This article attempts to briefly explore how blockchain technology works and when it should be used to solve problems in smart cities. We hope that our discussion and exploration may open a new avenue for the development and implementation of smart cities.

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