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The potential of integrating blockchain technology into smart sustainable city development

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P F Wong[1*], F C Chia[1], M S Kiu[1] and E C W Lou[2]

[1] Department of Surveying, Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman (UTAR), Sungai Long Campus, 43000 Kajang, Malaysia.
[2] School of Engineering, John Dalton Building, Manchester Metropolitan University, Manchester M1 5GD, United Kingdom.

*E-mail: pfwong@utar.edu.my

Abstract. The rise of global urbanisation has led to massive pressures on resources such as food, water, infrastructure, and energy demand to support growing populations. It brings adverse impacts on the liveable condition and economic growth of a country if this problem remains unsolved. Smart city is a potential solution to address the challenges of urbanisation by leveraging the technological breakthrough such as internet of things (IoT), Artificial Intelligence (AI), machine learning, big data, and cloud computing to facilitate scarce resources planning and management. With numerous connected devices and vast communication networks, it poses a challenges of security threat which cannot be addressed by the conventional cybersecurity solutions. Blockchain offers a solution in securing the huge numbers of connected devices in smart city network. The application of blockchain technology is leading in the banking and financial industry. However, the uses and implementations in smart city have emerged in recent years. The combination of blockchain technology and smart city has offered a great potential for sustainable development. Thus, it is imperative to discuss the potential of these two elements in making the city safer and sustainable. This paper explores how the blockchain technology application can help in managing smart city and achieve sustainability. The findings revealed that there are five key areas of blockchain application in smart city which are smart governance, smart mobility, smart asset, smart utility and smart logistic. A framework for smart sustainable city with blockchain technology is presented as an outcome of this study. It gives a clear overview for the policy makers and regulators of how blockchain supports within smart city framework. It facilitates the transition towards smart and sustainable cities through the use of blockchain.

1. Introduction

The growing population rate due to urbanisation, demographic and social change, climate change and resource scarcity have been a challenge to most of the countries. It is estimated that two third of the world's population will be living in an urban area by 2050, as compared to 55% in 2018 [1]. With the increasing urbanization rate, the problems of traffic congestion, rising energy consumption demand, increased carbon dioxide and greenhouse gas emissions have impacted people's living conditions [2].

For instance, if the population rate keeps increasing, the limited resources will be spread out to all which compromising the capacity of future generations. Eventually, it triggers food, water and resource crisis due to scarcity. All these have emerged to be a global problem and these problems putting tremendous pressure on cities around the world to discover solutions in order to optimise living standards of citizens. Thus, various researches and developments have been formulated to tackle these challenges. Developing a smart city is viewed as a new way to response to these problems [2].

Smart city is an urban environment that implement information and communication technologies (ICT) in city administration and services in order to improve several aspects such as environment, economy, security, efficiency and quality of life of citizens. It means connecting everything to each other by using state-of-the-art technologies such as internet of things (IoT), artificial intelligence (AI), machine learning, big data, and cloud computing. All these are viewed to underpin the development of efficient infrastructures and services in a smart city. With many machines and appliances are connected, more data are created, shared, transferred, and stored. There is also an increase in transactions and payments between IoT machines, and thus, it requires a fast and secure processing to guarantee the authenticity of data and transaction. Blockchain as an emergent technology is adopted to compliment smart city transformation as supported by Orecchini et al. [3]. Blockchain has various features and potentials such as decentralisation, transparent records of transactions and high level of data security.

Various initiatives have been taken by different countries to grasp the potentials offered by blockchain technology. For instance, Estonia established the use of blockchain technology in E-resident program. In China, the country is looking for a way to integrate blockchain technology for its smart cities [4]. Whereas in Dubai, e-Democracy has been explored with the aid of blockchain technology [5]. It showed that most of countries are moving towards digitalisation and start to grasp the potential of using blockchain technology. However, the application of blockchain technology in smart sustainable city development remains unclear especially in Malaysia.

Orecchini et al. [3] pointed out that the main goals of a smart city are reducing wastes, better use of renewable resources and improve quality of life of the citizens. Sustainability-related issues are playing a critical element in a smart city, with demand for lower energy consumption and conserve nature resources. Thus, the aim of this study is to examine to what extent and how blockchain assist smart city development and also achieve sustainability. This objective of this study is to identify the possible blockchain application that showcase in which ways blockchain technology can offer critical support in the process of developing smart sustainable city. The real potential of integrating blockchain application in smart city could able to help in achieving sustainable development goals (SDGs) as highlighted by United Nations.

2. Blockchain Technology

Blockchain is a promising technology and it has received extensive attentions from various industries recently. It has become a buzzword due to Bitcoin, which was first introduced in 2008 as cryptocurrency. Blockchain has been viewed as one of the next technological breakthrough that will influence every sectors and industries such as banking, healthcare, manufacturing and other industries. Blockchain is often known as distributed ledger technology (DLT) across a network of users that relies on the consensus of a global peer network to function. The digital ledger is encrypted into blocks and chained it to the previous block which form an ever growing chain of blocks.

Traditionally, many transactions and application are operated in a centralised system. A centralised system is often criticized due to its single point of information capture, storage and analysis. Moreover, the transactions between seller and buyer will need a trusted intermediates to mediate the transactions which will slow down the process and incur additional cost. On the other hands, blockchain technology adopted decentralise system which contains of distributed consensus that allowing peer-to-peer (P2P) assessment. Transaction could happen in a network without any central authority (banks, dealers and agents) which could expedite the transaction process. Thus, it eliminates intermediator whereby innovative digital transactional replaced traditional institutional entities [6].

Information are distributed across various geographies, institutions and countries through a connected network. As a result, a more transparent and trusted record of transaction is created which removing uncertainty. Immutability is viewed as one of the great traits of blockchain technology which make it favour in multiple industries [7]. Transaction cannot be changed, modified and deleted once it is chained into a block as each block (unique cryptographic number) contains a hash (cryptographic signature) of the block before. Hence, these blocks are unchangeable once they have are added to the chain which result in high reliability. As a result, blockchain can be used to support smart contract since blockchain are capable to execute and enforce the negotiation or performance of an agreement [6]. A smart contract consists of information about an agreement and will only be executed if the terms and conditions are verified by all nodes in the network and enforced by consensus protocol without centralised control [7].

3. Research Methodology

This study begins with a review of the previous studies on the blockchain application in smart city. Related journals, articles and books on this topic are reviewed. A list of potential application of blockchain technology in smart city is compiled from past relevant studies. The findings of the literature review revealed that there are five key potential areas of blockchain application in smart city framework as shown in Figure 1.
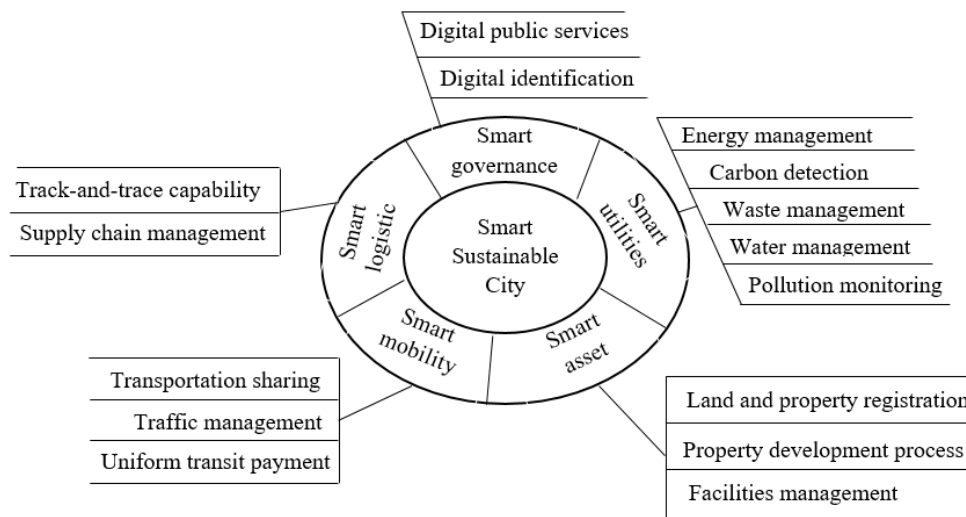

Figure 1. Smart sustainable city-blockchain (SSCB) integration framework

4. Blockchain Technology Potential applications of Blockchain Technology in Smart Sustainable City

There are several applications which blockchain technology will impact in developing smart city and achieve sustainability. There are smart governance, smart mobility, smart asset, smart utility and smart logistic as shown in Figure 1.

4.1. Smart governance

Blockchain technology could assist governments in the governance of a smart city [8]. It has the potential to improve the public service delivery and operation. By using blockchain technology, government records such as incomes, expenses, contracts and others can be recorded and interconnected which reinforce the transparency by avoiding corruption. Furthermore, a decentralised voting platform can be created which eliminate voter fraud. As explained by Ølnes et al. [7], a smart contract will ensure

a voter only cast a vote once and the identity of the voter can be accessed based on blockchain which eliminate manipulation of voting results.

Identity of every citizen can stored securely within a smart city network. Citizen's identity and information such as national identity, birth and death registration, passports, health and employment records can be tied to blockchain to reduce fraud of using these identities [8]. The identity can be securely store, link, share, and authorise the use of personal information by relevant agencies. The data and records remains encrypted and protected within the network. Thus, it eliminates the tedious processes and paper works with fast detection and documentation.

4.2. Smart mobility
One of the areas in which blockchain is increasingly being utilised is mobility [7]. The growing of sharing economy and collaborative consumption presented problems such as trust issues which benefit from the unique strengths of blockchain. For instance, ride sharing has become a common usage in sharing economy. By storing the vehicle and citizen information within blockchain networks, it creates a trust networking for citizens to access the data of shared vehicles by using a verified digital identity. The identities of the drivers and customers can be verified easily also when engaging ride sharing services.

Moreover, a more efficient systems for ticketing (e.g. bus, trains, bikes) is needed in smart city. Blockchain offers a single platform for the purchase of digital tickets and facilitating transactions by using digital tokens. Blockchain can be used as a single platform to store records and facilitating transactions for various types of public transport used in smart city. The uniformity of this single platform will ease the transaction and remove the hassle to visit multiple ticketing machines or desks.

Besides, city planner can reward citizens who take a shared ride or public transport by using digital tokens and the record can be stored at blockchain. These incentives can be distribute effectively by using blockchain technology based on the immutable records. Traffic data can be integrated with IoT sensors and blockchain. City planner can access to real time traffic data to monitor and manage the traffic situation by providing real time solution. The problem of traffic congestion in city can be solved especially during peak hours or seasons. By integrating blockchain in smart mobility area, less vehicles on road and traffic could be managed efficiently. Thus, it decreases fossil fuel emission and air pollution which contribute to sustainability.

4.3. Smart asset
Blockchain can facilitate land, property, and housing registration and transaction due to emergence of smart contracts. Thus, it replaces the traditional black and white agreement with intermediate. The problem of tenuous asset transaction, double-registry and frauds can be eliminated [6]. Besides, it also assists in property development process which include land registry, design, construction and maintenance stages. All drawings, approvals, reports, and records can be captured and stored by using blockchain. Thus, it provides an immutable view throughout the lifecycle of an asset, resulting in accuracy in record keeping and transparent system. Li et al. [9] explained that smart contracts can be executed to automate payment upon completion of works by builders. It could potentially aid in the maintenance and operation of buildings for timely repairs based on schedule as records stored at blockchain can be access easily in the future for facilities management [9].

4.4. Smart utility
There are several ways that blockchain technology will assist the smart utility especially energy management system [3]. Blockchain will assist in recording energy usage and demand accurately. Pieroni et al. [10] proposed a Smart Energy Grids based on blockchain technology. Several devices and equipment are connected to energy accumulator via networks and an app (Blockchain_SEG App) via mobile to reach the trading platform. With that, the user can view the quantity of the energy stored in the accumulators and check the sales rate in the trading platform. Information regarding actual energy consumption can be tracked transparently. It is easy for the consumers to aware of their feeding needs.

It also alert the user on their own usage and consumption patterns. In turn, the user may react accordingly. Similarly, water consumption can be monitor as well by using blockchain technology to regulate water usage for different areas in the city.

Moreover, energy transaction can be occurred with the combination of blockchain technology and Internet of Things (IoT). For instance, homes with solar panels on their roof could sell excess energy to neighbours on the same road [8, 10]. A transaction occurs when the user decides to sell the energy and the transaction will be recorded in the blockchain ledger. Thus, it creates a decentralised energy market by allowing transaction and payments between consumers and buyers without the need for intermediate. In addition, it can use to track carbon footprints of home appliances, tools, vehicles and equipment. Both suppliers and consumers are able to understand the environmental impact of each products. As the records in blockchain based application cannot be changed, this in turn can be used to determine the amount of carbon tax to be charged. If a product with large carbon footprint is expensive to purchase, this would discourage the buyers from buying. Thus, it reduces the demand of the products in the market. As a consequence, the company will restructure their supply chains to lower down the carbon footprints in order to boost up the demand.

Blockchain could be integrated with IoT sensors and AI to facilitate effective waste management and prediction modelling. IoT detect the waste accumulation and alert the waste collection operators to clean up and dispose the waste. This information can be stored by blockchain and shared to the users and relevant parties. The waste production level can be tracked and monitored, and waste management strategies can be formulated. By tracking the waste level easily and real-time, it helps to optimise waste collecting schedules and optimum routes for collection. It also helps to ensure maximum utilization of fuel by waste collection trucks.

A blockchain could integrate with IoT sensors to inform the citizens on the air quality index or measure the levels of pollutants for monitoring purpose. It helps to maintain a healthy environment and devise more efficient ways to combat pollution before the issue escalates. As a conclusion, in the area of smart utility, blockchain applications can provide solutions which contribute to CO_2 emission reduction and achieve sustainability. It is useful in monitoring and tracking due to data transparency and decentralisation. Thus, impact assessment and evaluation would be easier to track which leading to faster results and strategies can be proposed.

4.5. Smart logistic

Blockchain technology has huge potential in improving supply chain transparency and facilitate track-and-trace [9]. Most materials are not produced by a single company, but a chain of suppliers who sell their components to make the materials for the production. Blockchain application can help in tracking the provenance of each products along the supply chain. It could provide a permanent record on the state of the product from mining, extraction, production, transportation and in use. It streamlines the operation of the supply chain by making the process transparent. It helps in informing the customers on how each good and product were made and shipped which create responsibility and sustainability in sourcing and production. Most importantly, it helps to pinpointing the source easily in the event of contamination. It creates transparency by removing the need for multiple verification by different parties [9].

5. Conclusion

With ever-growing population in urban cities, it has placed a huge burden on the existing infrastructure and resources. Digital transformation is the feasible way to ensure cities' infrastructure fulfil the rising need of the residents. Combining smart city with emerging technologies enhances living standard, but the threats of cyber-attack cannot be neglected. Cybersecurity is a pertinent threat that needs to be solved before developing smart city. With many devices and machines connected, it poses a new set of security challenges that cannot be addressed by the conventional cybersecurity solutions. Thus, it makes both government agencies and service providers hesitant to develop smart cities in reality. However, smart city could leverage the decentralised blockchain to secure the city from cyber threats. Beyond this virtue, the impact of this technology is being felt in the sustainable development in various aspects such as

environmental, economic and social. There is a strong alignment of blockchain technology with Sustainable Development Goals (SDGs) which the implementation can contribute in achieving SDGs in the framework of smart city.

This study presented a list of possible applications of blokchain technology in smart city development and management. Blockchain will empower cities to improve in several areas such as mobility, utilities, governance, resources and logistics. Five key areas of blockchain applications were identified and a smart sustainable city-blockchain (SSCB) integration framework has been proposed. The next stage of this research will be conducting a survey to a large population to uncover the Malaysian citizen's perception on smart sustainable city development by integrating blockchain technology. This will serve an evaluation framework for local authorities and regulators to design appropriate public policies related to this technology in developing smart sustainable city for Malaysia.

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