Blockchain Enabled Secured Smart City Transactions

Dr. Swapna Salil Kolhatkar
Marathwada Mitramandal's College of Commerce
swapna.kolhatkar@gmail.com

Abstract

Smart city facilities call for security to the electronic mediums, transactions and other data. The best method for implementing security is by keeping the data in the public domain and more so at multiple locations with the concept of data distribution. Such a mechanism ensures data availability, reliability and integrity and is easily implemented through the new technical advancement - the blockchain technology. This technology has provided the necessary support & mechanism to software or application development and spawned many applications that make a smart city - a reality.

This chapter introduces the concept of smart city, transactions, blockchain technology and the various applications where blockchain technology is used to ensure the realisation of smart city. It also discusses the advantages and the various roadblocks in implementing blockchain enabled smart city applications. The statistical details of technology usage for the development and implementation of smart city applications, is beyond the scope of this chapter.

Keywords : smart city needs, blockchain for smart city, blockchain technology, transactions, smart city blockchain applications

The vast majority of people living in technologically modern urban areas use different types of electronic methods and sensors to send or receive data. They transact using electronic mediums. These transactional facilities along with a plethora of technologically intelligent systems such as transportation & infrastructure, energy & lighting, city management, and technology & urban connectivity of cities; is what distinguishes the situation as a smart city where citizens avail technological advancements in their routine activities within the comforts of their choice.

There are different ways in which a smart city transaction gets recorded. The most common types of transactions such as digital payments that are carried out between customer to customer, customer to business, business to customer and business to business. In addition to digital payments, there are smart city applications or systems where data is recorded for analytical purposes so as to benefit the citizens directly or indirectly. Transactions also include recording of documents or evidence as per the applications. The following sections explain all in detail beginning with two scenarios.

I. Smart City Scenarios

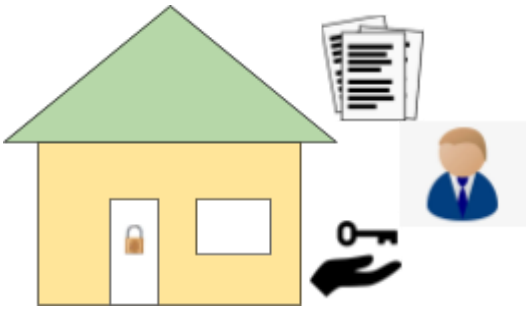

Figure 1 : Property Purchase

Scenario 1 : Transactions by Smart City person - Young professional wants to buy his dream home after looking at an online advertisement. He surveys the housing project and goes ahead for the property registration. He wants to ensure reliability of the housing scheme along with the security of his property registration transaction including his personal details as shown in Figure 1.

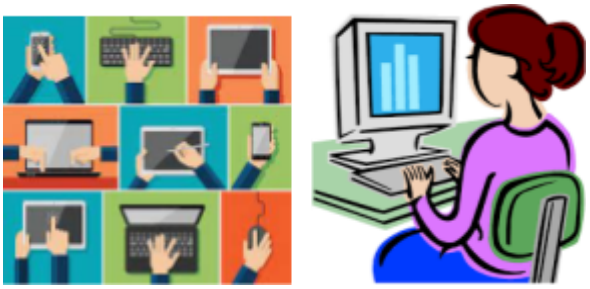

Figure 2 : online payment of dues / complaint booking

Scenario 2 : Facilities provided for Smart City person - e Governance facility exists for the citizens to avail various facilities from payment of dues to complaint booking to filing right to information. As shown in Figure 2. These facilities are provided with security for the citizens to transact for their daily activities or needs through various electronic gadgets.

In the above two scenarios, security of transactions, documents or data is vital. All software systems have an inbuilt security mechanism that ensures availability of online services to the users. The users expect ease in the use of applications or services. However, these online services or software applications are prone to attacks by hackers. Along with this, there is security concern in case of centralised data systems or applications. These issues demand for better security at all times which has led to the conceptualization and development of blockchain technology.

II. Introduction

The blockchain technology provides security and availability of a large repository of data through the concept of distributed ledger technology. Simply put, it means that data security is provided by distributing the data at many different locations in the public domain which is available for public access. In such cases, hacking attempts are futile for its availability at other locations. The following sections gradually introduce blockchain and its importance for realising the idea of a ‘smart city’.

Blockchain

Blockchain is a new technology that is developed to ensure security to digital or electronic information that is recorded and distributed but is immutable (not changeable). It is a shared, immutable, public ledger that records transactions and tracks assets in a business network. In a business scenario, an asset may be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding). All these assets and much more define and are a part of smart city. The smart city itself denotes smartness in work processes brought along with the facility of ease in transacting. Such transactions need to be secure through as implemented using blockchain technology by making it publicly available in a distributed manner. Taking business on a global level, the concept of blockchain has manifested itself in the form of cryptocurrency to address the issues of global trading, foreign exchange etc.

Smart City

India is witnessing so many schemes in tune with the ‘Smart City’ initiative and technologically driven online software applications that make ‘life’ easy and ‘work’ fast and smart. Paying bills or purchasing items online; is now possible at the click of a button. Facilities such as online bill payment, online booking, online monitoring etc have become a norm for the Indian citizen. In short, a smart city is a framework, predominantly composed of Information and Communication Technologies, to develop, deploy, and promote sustainable development practices to address growing urbanisation challenges. A “smart” city consists of elements such as smart governance, smart mobility, smart living, the smart use of natural resources, smart citizens, and smart economy, all taken together (Sun, J et al, 2016). Considering space constraints and the population density, cities are naturally designed on the concept of sharing and accessing resources.

Smart City Transactions

Transactions or digital payments are a significant component of smart cities. They define the ease in daily activities. These are required by citizens to avail the majority of basic services offered to the citizens as part of ‘Digital India’ initiative. All these

services form the core of the economic activity which includes business purchases, salaries, consumer spending, and tax collection. Digital transactions play a major role in improving the payments system across departments, companies or organisations. Such transactions are a part of citizen to Government payments as provided through e governance facility where banking applications record the transactions in their database. Along with these, there are transactions such as voting, tender bidding etc that are a part of smart city implementation and consequently, the blockchain. In short, smart city transactions aim to provide ease to citizens by ensuring availability, reliability, security, faster processing etc.

Along with digital payments, transactions such as recording of observations or documents are also considered. Such recording of observation does not happen between individuals or companies but it happens as a result of systems implemented for the smart city for eg. air quality index data, traffic data, waste management data etc.

III. Needs of Smart City

The broader idea of a smart city is as discussed above, but there are other factors too that assist in making the transition from being a city to a smart city. These factors are incremental in nature and their effect is a cumulative effect of many other changes; from finance to individual acceptability to operational challenges.The world identifies and defines the ‘needs’ considering global economic, political and environmental issues. Accordingly, the needs and expectations from the smart city are revised and redefined.

Technologically Driven City Infrastructure

Smart cities use a variety of software and communication networks alongside the Internet of Things (IoT) to ensure implementation of software systems for the citizens. The IoT comprises a network of devices that communicate and exchange data that encompasses a variety of elements; from vehicles to home appliances and on-street sensors. Data collected from these devices is stored for retrieval and analysis so as to know efficiency and performance of these services in the society.

The data that is collected from the sensors, should be secure and available for analysis. The blockchain technology provides the necessary mechanism to achieve the concept of technologically driven city infrastructure so as to know the implementation and adherence of rules and guidelines by the citizens, municipalities etc. Such a transparent mechanism leads to accountability in services and facilities by the regulatory bodies.

Environmental Initiatives

The world has taken cognizance of the need to care for the environment. Accordingly every country has been tasked with the responsibility of adhering to the carbon footprint that is left behind. This in turn, means every citizen and city to incorporate methods that comply with the need of the hour. A smart city feature also includes energy conservation and environmental aspects, such as smart consumption of power. For example, artificial intelligence or IoT for the street lights that dim when the roads or public utility places are empty. Such smart systems improvise the situation towards smarter use of energy and thereby saving it.

Paradoxically, energy is utilised by smart systems in order to conserve energy. The energy consumption due to smart systems is minimised with the incorporation of solar powered devices. The performance of these smart devices is recorded and kept in the public domain for analysis. Blockchain technology is used for this purpose and although it requires energy to power it, the awareness generated by smart devices has a larger positive effect on individuals. Smart cities are expected to offer many environmental advantages, such as smaller geographical footprints, but they also have some negative impacts, including high energy consumption to power them. However, smart technologies help tackle these challenges through awareness and public acceptance.

Public transportation

Most of the Indian cities are connected via railways, roadways, airways etc. A number of applications guide the citizens whenever they use public transportation. These smart applications like free Wi-Fi and USB charging ports, along with vehicle tracking apps, bike-sharing programmes, parking apps including online payment options; make the citizens' experience enriching. Big cities have IoT / smart devices installed that display data on temperature, pollution and noise. This data is recorded and blockchain technology is used for the data analysis on transportation usage, festival over indulgence etc. Likewise, the weather and environment data analysis benefits public travel in planning and responding to critical situations.

Progressive and Futuristic City Plans

The concept of a smart city is incremental and progressive in nature. The term - 'smart' itself shows growth in terms of intelligent cognizance. The idea of a smart city is planned and realised considering futuristic city expectations. Hence, a smart city is responsive to any internal or external changes by way of catering to needs and planning for the future. The recent pandemic tested the city infrastructure and

administrative capability. The public adapted and adopted smart city initiatives like never before by consuming a variety of online applications and services. The same momentum is useful for implementing progressive and futuristic city plans. All initiatives demand the use of blockchain technology for security and availability purposes.

Holistic Well Being of Residents

The well being and security of citizens is primary to the state and is more necessitated in current times for its uncertainty and ensure holistic well being of citizens. The increasing number of nuclear families demands attention for the well being of all through societal efforts. These efforts are realised through technology that focuses on activities that bring about physical, psychological and spiritual exercising, healing and excelling respectively. Thus, the stress of living in a city is lessened with the provision of smart amenities that assist in measuring holistic activities.

Applications are available for keeping individuals engrossed in their routine activities. Information about such activities exists as medical data, contribution to the society in the form of social work, extension activities etc. The data thus collected may assist in the well being of an individual by having blockchain enabled security.

IV. Blockchain Systems Aid In Realising A Smart City

A smart city facilitates citizens in terms of software systems, working processes, digital payments and security. Advanced and integrated software systems or applications require data security and availability to ensure digital identity of citizens. These prerequisites are addressed through the implementation of blockchain technology. The blockchain technology uses the concept of distribution, decentralisation and peer to peer (P2P) networking in order to implement security for transactions. The blockchain architecture is robust but needs energy to keep it functioning. In other words, the use of blockchain enabled systems is abundant but it also comes at the cost of energy consumption, though the benefits are many as mentioned below.

Elimination Of Middle Entity

Blockchain enabled transactions are carried out between the parties concerned where transactions are noted in the ledger for others to refer or verify. This architecture eliminates the need for a middle entity or an agent so that the probability of bribery, corruption or graft is reduced. The elimination of agents or middle entities in a tender procedure is a major benefit of urban blockchain systems. In a blockchain

approach, distributed, decentralised and open ledger records transactions, based on a P2P network.

Use Of Immutable Data

Immutability of data is the biggest advantage of the use of blockchain technology in most of the bureaucratic processes. The presence of fraud and incomplete or intermediate change in business process data is diminished. Information, once stored in the blockchain, cannot be modified, deleted or erased. It is immutable information. This is achieved through the concept of hash values through hashing technique. The hash value of the data changes in case of any change in the data. This change in hash value causes the block to be discarded from the chain of blocks. In case data changes are officially allowed, one has to rewrite all blocks that are affected by the change. Thus, blockchain systems offer a higher quality of data verification.

Transparency In Blockchains

The blockchains are automated with special software called ‘miners’ that continuously monitor the network for transactions and write them in the block after a consensus mechanism. This ensures data transparency and uniformity amongst all nodes of the P2P network. In a blockchain system no intervention is possible, so as to maintain transparency in the processes.

The above are three items; in terms of their preventive capacity to cope with corruption and bribery (Balan, 2019). The advantages outweigh the hurdles in implementing the blockchain but even then there are a few hurdles that when analysed considering the situation, assist for a better plan of blockchain enabled transactions for a smart city.

V. Roadblocks In Implementing Blockchain Enabled Smart City

Every new technology implementation needs acceptance that later on gets converted to training and user experience for it to sustain. The blockchain technology is a relatively recent one and its potential is being harnessed for the development of software applications in tune with the laws and needs of the region.

Lack Of Adoption

Blockchains function more effectively and efficiently when used across a wide network of users. Without broad adoption, blockchains will remain ineffective and scalable. Also, there is a lack of regulations for companies to tread in the unknown.

The Rising Cost Of Blockchain Implementation

A significant investment is required for hiring software experts especially blockchain experts along with management of software / transaction costs. Most organisations must completely rebuild their old system or develop a strategy to link the old system with blockchain technology as there is lack of legacy system integration knowledge.

Scalability

The main difficulty with blockchain implementation is scalability. Though transaction networks can handle hundreds of transactions per second without failure, the processing of cryptocurrency slows down considerably.

Security And Privacy Challenges

Many potential blockchain applications need smart transactions and contracts to be linked to real identities, raising significant privacy and data security issues. The absence of stringent laws and blockchain being a developing technology, have made it prone to fraudulent projects and other hackers seeking to profit from inexperienced investors.

Energy Consumption

Blockchain technology consumes energy for its network to function which in turn means large financial investment. This restricts entry for regular people into networks and prevents decentralisation and it also raises environmental concerns.

Lack Of Standardization

Blockchain technology does not conform to any world wide standard which leads to difficulties with interoperability, increased costs, and complex procedures.

VI. Selecting Potential Applications for Blockchain

The visualisation of a smart city through its various facilities, is progressive and a never ending task. The successful implementation of a smart city depends largely on acceptability and permeability of the visualisation with the citizens. Various technologies provide the architecture for a robust implementation of a smart city. Blockchain is one such technology that ensures transparency, security and availability of data through investment, infrastructure upgradation / maintenance and advancement. The blockchain technology implementation begins with small steps and progresses to encompass a large number of services or products that give identity / meaning to the smart city. Selecting these services or products may depend on a number of factors as discussed below.

Legacy Systems or Traditional Practices

There are businesses not computerised or automated heavily or a system that is person dependent. Such systems may use legacy systems for their internal processes and interact with external entities through ICT technologies but with the advent of smart city concept, these systems or people may have their reservations or inability to leave their comfort zone. Moreover, if the proposed blockchain enabled smart city system is comprehensive there will be a resistance to change as it involves people working at strategic, planning and operational level and their hierarchical structure. These applications are good candidates for the blockchain technology, provided there is acceptance due to the external situation.

Involvement of Multiple Stakeholders

The benefit for blockchain implementation is best demonstrated and realised in a situation where multiple stakeholders are involved in the business processes from different organisations and using different system frameworks. The stakeholders are based globally with well defined agreements amongst them, and blockchain technology is useful in such situations. This very fact may be a roadblock for reaching an agreement between multiple stakeholders.

Low On Criticality

The successful implementation of smart city ideas lies in the robustness and permeability of the technologies in the software systems too. The top down approach ensures that even if there is disruption due to the change, there is wider acceptance too primarily due to enforcement that later on turns to acceptance. Such software systems that have to align with the needs brought on by the external forces are low on criticality and hence are the best candidates for the blockchain implementation.

Localised Impact

Applications that are localised are good to start for the implementation of blockchain. The technology change is easier to manage and the changeover experience also provides guidelines for more challenging tasks. In case of adverse results, the impact stays localised and more manageable.

Low on Budget

An application with a modest budget is more likely to be cleared for it means less presence and focus to test its robustness. These applications expand depending on their performance but the initial success ensures its testability for more challenges.

Additionally, with the success of blockchain implementation, the service is made sustainable and not abandoned later on.

VII. Working of Blockchain Technology

According to Amazon Web Services - “Blockchain technology is an advanced database mechanism that allows transparent information sharing within a business network. A blockchain database stores data in blocks that are linked together in a chain. The data is chronologically consistent because it cannot be deleted or modified without consensus from the network”. This is the reason to use blockchain technology to create a secure or immutable ledger for tracking orders, payments, accounts, and other transactions.

Software systems and applications have made human life easy and hassle free. From online shopping to online payments to online trading to online reservations etc, the software applications have defined ways in which business is done to provide the customer with ‘rich user experience’, that is very integral to the smart city concept. All these applications record user activity in the database to be used in future for various purposes. In the past, transactions were tracked and stored by financial institutions, and auditing that information was often time consuming and limited to certain privileged parties.

Blockchain technology makes record keeping transparent and allows it to be shared across networks. No single party can change a transaction after it has been added to the ledger, and automated tools called smart contracts execute transactions without requiring an intermediary like a bank. In addition, there is no single master copy of the blockchain; instead, the information is cross-checked (validated) by other computers (nodes) in the network.

Blockchain is a distributed database of records of all transactions or digital events that have been executed and shared among participating parties. Each transaction is verified by the majority of participants of the system. It contains every single record of each transaction.

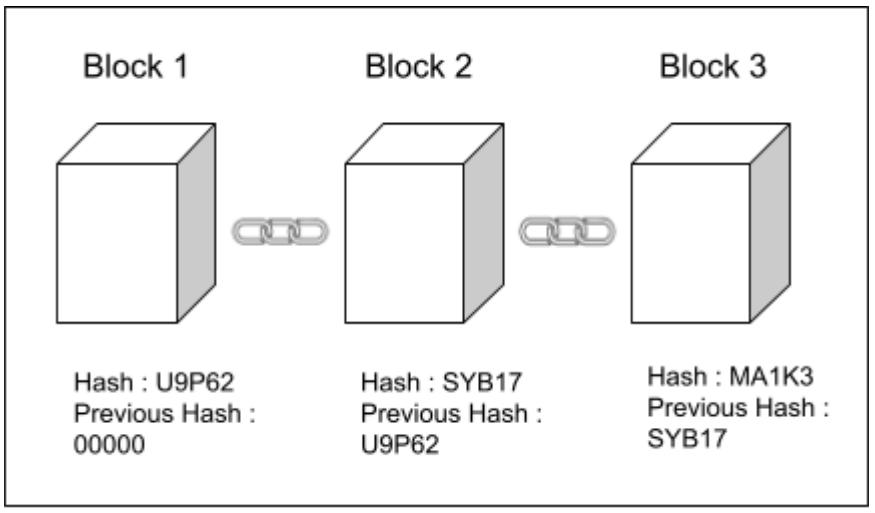

Figure 3 : Chain of Blocks that shows the use of hash code to create the blockchain

Blockchain is a concept of storing data digitally in the most secure and incorruptible way. The distributed ledger technology and point-to-point (P2P) network systems ensure the security and integrity of the blockchain. On a blockchain network, two nodes exchange data or information (transaction), the blockchain network verifies the authenticity of the transaction. Then multiple verified transactions create a block as shown in figure 3. Now, the nodes try to add this newly created block into the main blockchain through a mechanism called Proof-of-work which is an incentive-based system where nodes (also called miners) solve a mathematical puzzle of a certain degree of difficulty. A node must have the great computational power to carry out this process, which makes mining costly.

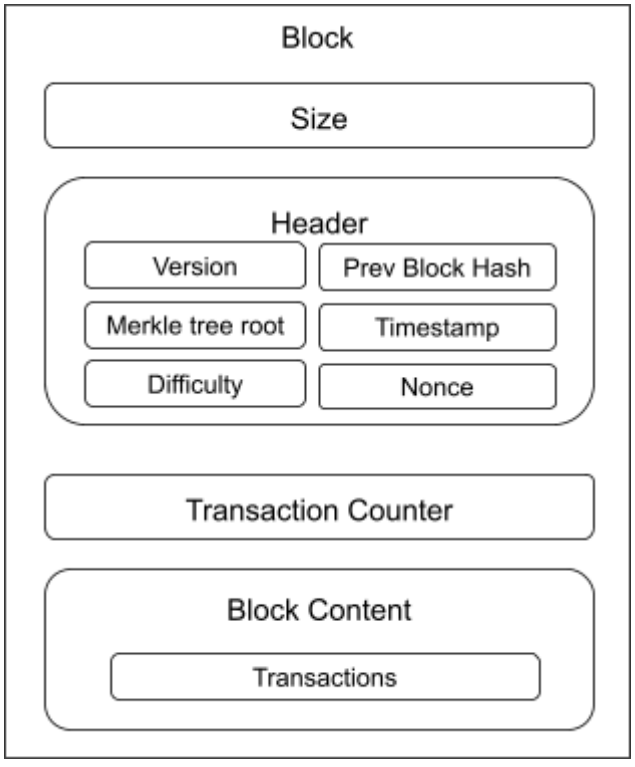

Figure 4 : Structure of a block

Once a node solves this mathematical problem successfully, a new hash value for the concerning block is created. Each block in a blockchain has a block number and a timestamp (figure 4) according to the order in which it is added to the blockchain. Also, every block is added to the previous block through hashing. The hashing gives each block a unique number that acts as its digital signature. This makes the blockchain extremely secure.

Figure 5 gives an idea of how a transaction is requested and initiated to the final step of the transaction being completed as on a blockchain.

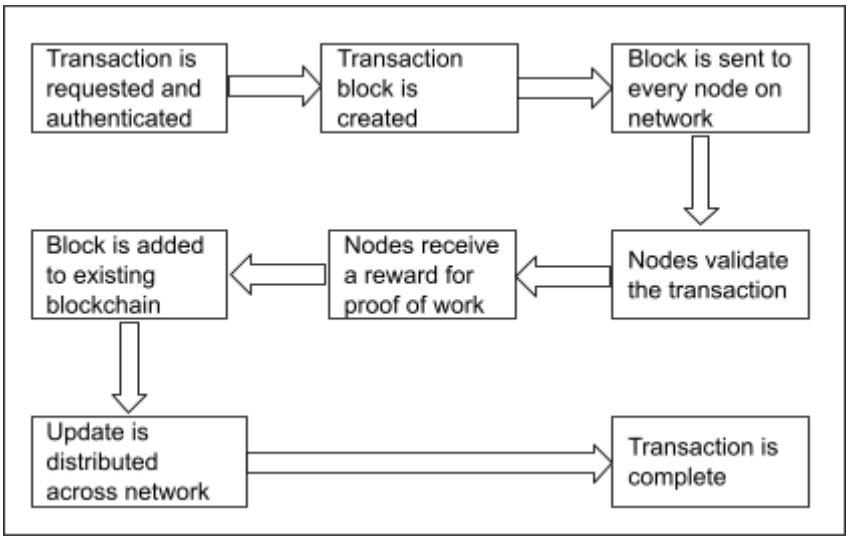

Figure 5 : Steps to add transaction to a blockchain

The entire process of completing and recording a transaction requires various IT resources and investment. IT organisations are in need of blockchain developers. Making a career in blockchain development is a smart choice. A knowledge of Programming Languages, Databases & Networking, Cryptography and Data Structures etc is desirable for the blockchain developers. In addition, practical knowledge of ethereum & DApps, Smart Contract & Solidity etc is good for a blockchain developer. There are two types of blockchain developers :

1. Core blockchain developers - The core blockchain developers design the protocols and maintain the existing blockchains
2. Software blockchain developers - The blockchain software developer develops new blockchain applications and non fungible tokens (unique digital identifier).
3. dApp developers - DApp developers build decentralised applications (dApps) on the blockchain.
4. Smart contract developers - Smart contract developers create self-executing contracts that live on the blockchain.

5. Application Developers - They create applications that use blockchain technology to improve the user experience or to increase efficiency within an existing system.
6. Systems Architects - These developers work with architects to design decentralised systems that meet specific business requirements.
7. Hardware/Software Engineers - They develop secure and reliable software platforms that integrate with other third-party systems.

VIII. Blockchain Applications

Blockchain is a new technology. It is evolving and is realising its full potential with the number of applications that are providing services to all. These services carry out the transactions as discussed in the beginning of the chapter. The transactions may be digital in the form of payments, records, documents etc and may be between parties or simply record keeping for the public. The use of blockchain is felt in various sectors as discussed below.

Healthcare

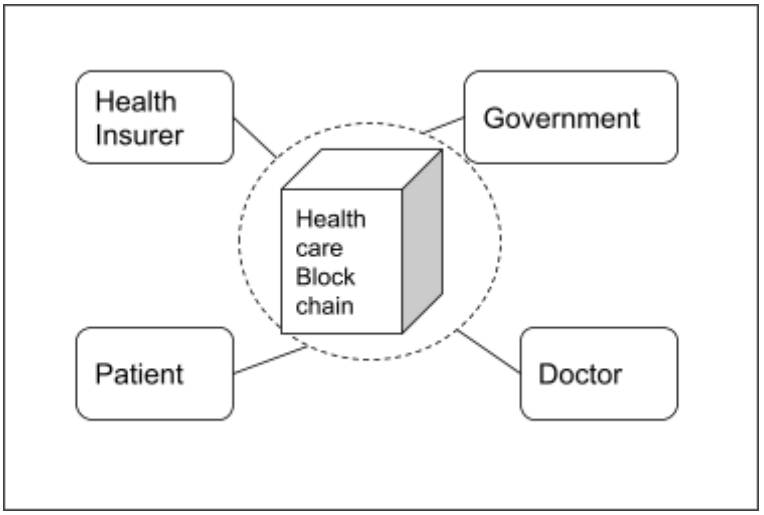

Figure 6 : Healthcare blockchain

The digitisation of health records has brought about significant change in the public health sector. The healthcare infrastructure of doctors, patients, hospitals, insurance has made the system transparent. The use of blockchain technology is used for facts and figures or statistical reports to present the health scenario of a smart city. Such software systems ensure that the smart city is well equipped for any healthcare challenges by providing necessary resources and facilities as depicted in figure 6. In addition, by putting all medical licences on a blockchain, only the genuine doctors practise and give treatment to the patients.

Education

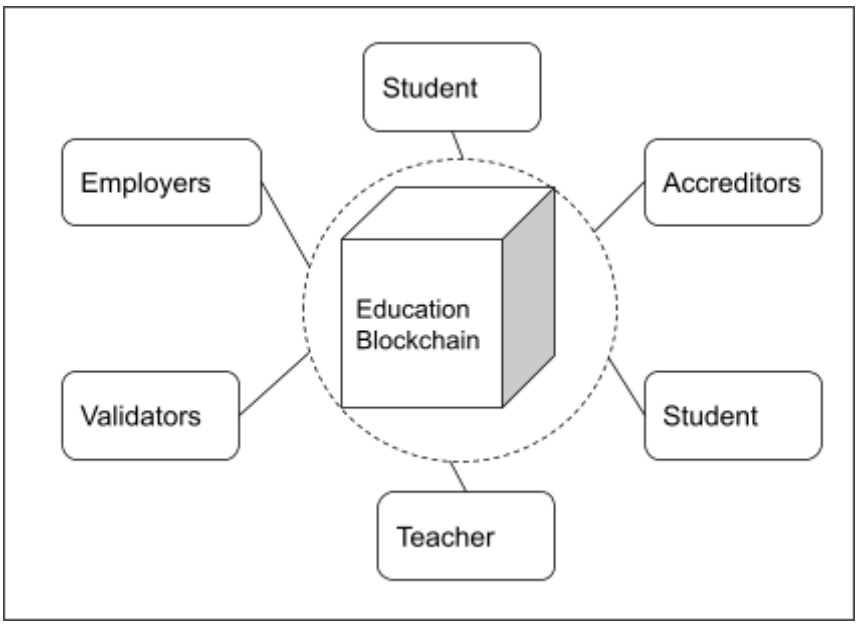

Figure 7 : Education Blockchain

Student records, faculty records, educational certificates, etc., are key assets in the education domain. Their authenticity is primary to ensure good practices of human resource development and employment. These records are shared with multiple stakeholders and it is imperative to ensure that they are trustworthy. The provenance of these records also needs to be determined accurately. Student records, faculty records and educational certificates are maintained with the application of blockchain technology as shown in figure 7. Blockchain simplifies certificate attestation and verification. The emphasis on credit based vocational courses, value added courses etc that are interdisciplinary & multidisciplinary in nature has been suggested by National Education Policy. The use of blockchain technology ensures the verification and validation of credits earned for the growth of employees.

Finance

Traditional financial systems, like banks and stock exchanges, use blockchain services to manage online payments, accounts, and market trading. By adopting blockchain, these companies solve several challenges, including batch processing and manual reconciliation of several thousand financial transactions. Blockchain digitises the entire trade finance lifecycle with increased security and efficiency. It enables more transparent governance, decreased processing times, lower capital requirements and reduced risks of fraud, human error, and overall counterparty risk.

Public Safety

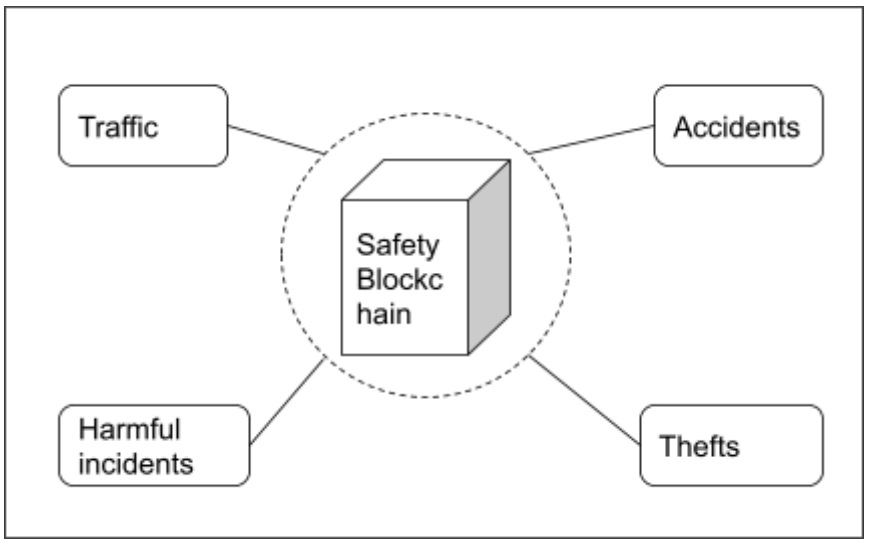

Figure 8 : Public safety Blockchain

Public safety is a basic need of any smart city. It has several domains ranging from natural disasters to man made disasters. Amongst these, a smart city does good work with the promotion of road safety by recording accidents, identifying accident prone spots, and taking corrective action. Figure 8 shows the blockchain technology records these facts for the interest of the public. These records are accessed and corroborated not only for their statistical inferences but also for the analytical deductions. The traffic congestion records also assist in better planning and coordination for a faster commute.

Agriculture

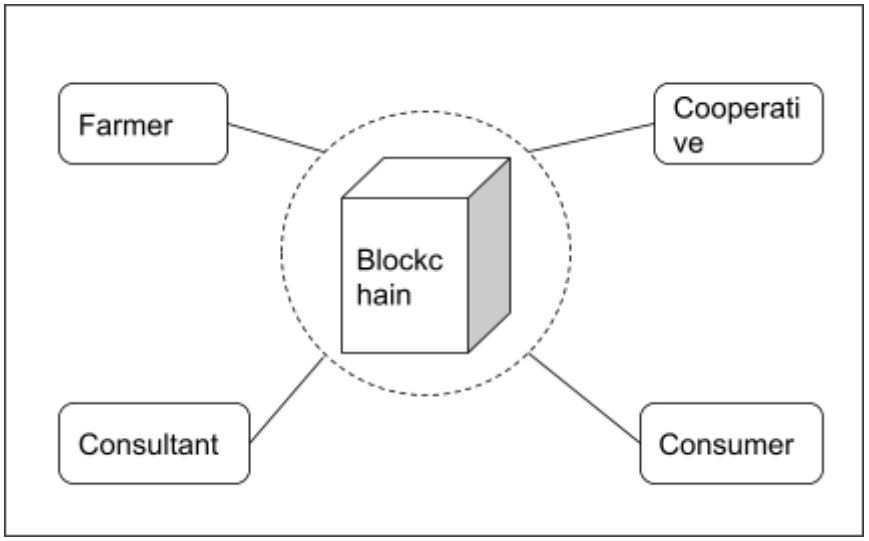

Figure 9 : Agriculture Blockchain

A smart city emphasises on smart use of agricultural resources through blockchain technology that assists in crops to be harvested depending on soil and weather conditions, connecting the farmer and consumer, transparency in agriculture related administration, simplifying processes, trustworthy provenance in supply chain etc.

Other applications include the use of blockchain technology to record and manage agricultural land records as well as agriculture insurance, local farmer market etc.

Environment

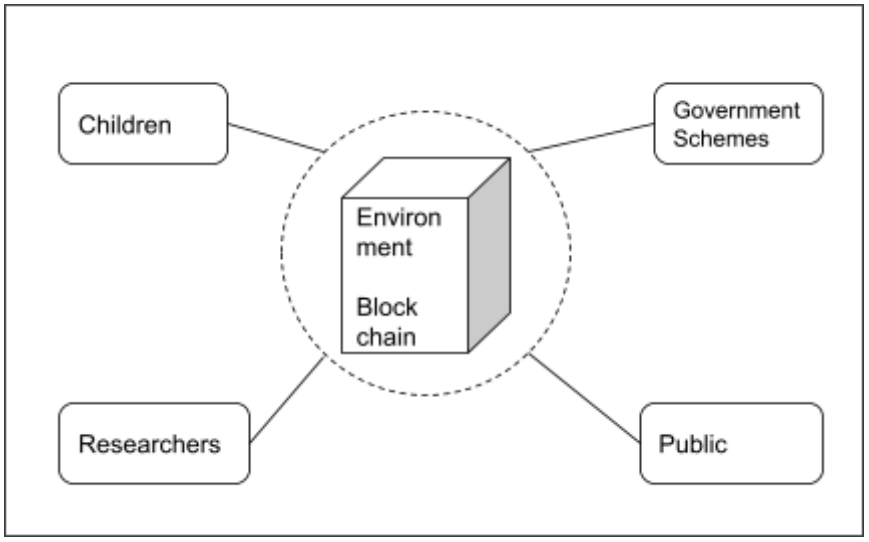

Figure 10 : Environment Blockchain

It is making a splash in the news these days. The prime requirement of a Smart City is a clean environment and a reduced carbon footprint. Measurement and initiatives for ensuring a clean and healthy environment has been possible through blockchain technology which boosts green environment by providing a tree registry where number and types of trees is recorded on the distributed ledger technology as shown in figure 10. This technology is also used for the recording of air, water, and noise quality of a smart city to propose ways and means to reduce pollution. The young generation gets awareness on these issues and efforts needed to promote a clean green environment.

Energy and waste management

A smart city works for efficient energy utilisation and waste management. A blockchain technology is deployed to create a marketplace for electric power supply where microgeneration of electricity through home power generation using solar energy has started supplementing traditional power supply and promoting the use of renewable energy sources. Using smart metres, a record of produced and consumed electricity for each user in the grid is maintained on a blockchain with credits /currency allocated to the user and credits redeemed for power consumption. Moreover, with new electric vehicles in the market, blockchain technology will assist in their management and provide a great payback. Also, the segregation of waste into its different types at the source itself; gets recorded on the blockchain for its management and disposal to assign brownie points to buildings or housing societies and thereby promoting a clean environment.

Citizen Services

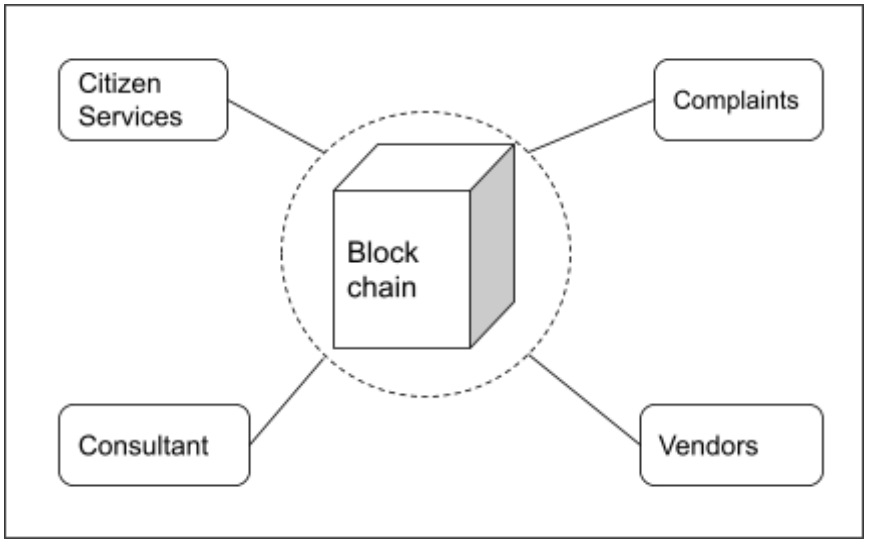

Figure 11 : Citizen services Blockchain

A smart city caters to the needs of the citizens who consume the services like birth / death / housing registration, taxes, complaints, Municipal Permits, NOCs (No Objection Certificate), clearances etc. People suffer in procuring these various documents as there is lack of coordination and traceability between the issuing authorities. These processes are simplified through the application of blockchain technology (figure 11) to create distributed citizen registration platforms that register vital events such as births and deaths on a blockchain. This helps citizen records tamper-proof, resilient, secure and private, thus providing wide-ranging benefits for a variety of stakeholders. Services such as transportation, connectivity, recreational activities, parks, shopping areas etc are all better managed with the use of the distributed ledger technology that provides recording of all such transactions in the public domain.

Defence

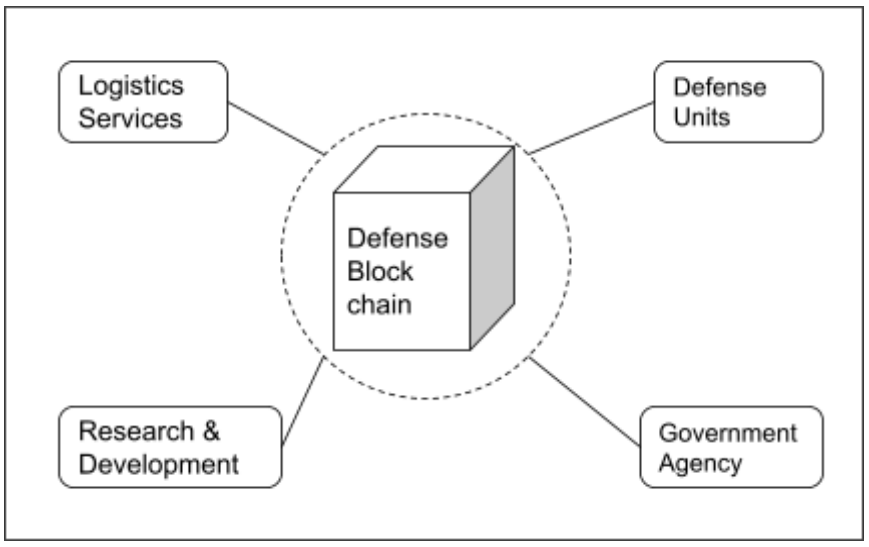

Figure 12 : Defense Blockchain

The information related to the defence system of any country is very important. For this reason, it is kept at distinct locations to prevent unauthorised access and modification and thereby ensure security. Blockchain technology is leveraged to provide consensus-based access for providing secure systems integral to smart cities (figure 12) where internal and external threats have to be dealt with. The blockchain technology provides security and uniformity to smart infrastructure, important physical installations, any types of attack etc.

Governance

Government departments have functional interdependence but operate in silos, which impacts the availability of services and deteriorates citizen experience. Blockchain technology addresses these concerns by increasing efficiency and transparency. The linking file and data movement between departments through a blockchain increases visibility into the process and ensures that the data/file moves forward in real time. The crucial activity i.e. voting also is a transaction that takes place through the ballot system where the results are kept on the public domain. The blockchain technology facilitates the system for elections related to governments, companies, cooperatives, universities. etc.

Employment

The educational institutes are working for the promotion of skill based educational programs that promote interdisciplinary education. Students earn credits for the courses they undertake and the authentication of credits has been made possible with the national digilocker service in India. The uploaded documents are in public domain and secure through the distributed ledger technology. This brings the employer and employee on a common platform for a given skill. Such a skill

repository has a wide-ranging benefit for skilled resources and entities seeking their contribution.

In short, the nature and number of blockchain applications is forever progressive and incremental for realising the true meaning of blockchain enabled secured smart city transactions. The efforts of people at strategic level, planning level and operational level continue to see the advancement that is brought about in the society.

IX. Acknowledgment

Writing this chapter was a challenge and was taken up due to the wonderful words mentioned in the email inviting all authors to contribute for the purpose of a book and my daughter, Manasi, who prodded me on for taking up the writing work.

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