Blockchain Technology: A Driving Force in Smart Cities Development

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ABSTRACT

Smart Cities are well planned, designed, and established keeping in mind the growing need of citizens in search of better livelihood. Technology has played a big role in equipping Smart Cities to offer better facilities to its citizens in terms of better living comfort, better atmosphere, better surrounding, better medical facilities, and most importantly ease of doing business, office, and day to day activities. While doing so, IT Infrastructure and online transactions have influenced all the operational processes of Smart Cities and almost acting as its backbone. Obviously, any adverse impact on online transactions can create chaos in Smart City operations. To address this concern, a safe and reliable online transaction is a must. In this paper, we have discussed Blockchain Technology-based solutions for Smart Cities and their potential impact on Smart Cities Development. We specifically tried to address the concern of how Smart City online operational processes for various applications can be made reliable and safe by using Blockchain Technology and how this technology can benefit Smart Cities overall development. Based on the comprehensive research and detailed literature review, we proposed Blockchain Technology based secure framework for Smart Cities. We also identified various applications and process areas that can be highly benefited by using Blockchain Technology and can make these applications smarter and more reliable and fit for use for any Smart City.

Keywords: Blockchain, Smart city, Smart contracts, Secure framework, Distributed ledger

1. INTRODUCTION:

Blockchain Technology is the most advanced, complex, and bit difficult to understand in the first place. It has gained significant popularity over the past few years and most businesses started using Blockchain technology in their business transactions. In a simple language Blockchain is nothing but Blocks of Chain. Now it is important to understand what these Blocks do and how they are connected in a Chain. Blockchain Technology can be defined as a decentralized and distributed database of encrypted records. Blockchain is sometimes referred to as Distributed Ledger Technology (DLT). Blockchain makes the history of any digital asset unalterable and transparent by using decentralization and cryptographic hashing. Blockchain can be considered as the technology framework which allows the scalability of trust via technology for combining public information with a system of control and checks in place to maintain integrity, data accuracy, and availability to create trust among users [1]. In a simplified manner, it can be explained as follows

- It is a data structure where each block is linked with another block in a time-stamped chronological order.
- It is an append-only decentralized transactional database, allowing full real-time access. It is not a replacement to the conventional databases.
- In the data structure, every node keeps a copy of all the transactions that happened in the past which are cryptographically secured.
- All information once stored on the ledger can be verified and auditable at any time but cannot be editable under any circumstances.

- The whole data structure is highly fault-tolerant and reliable since there is no Single-point-of-failure.

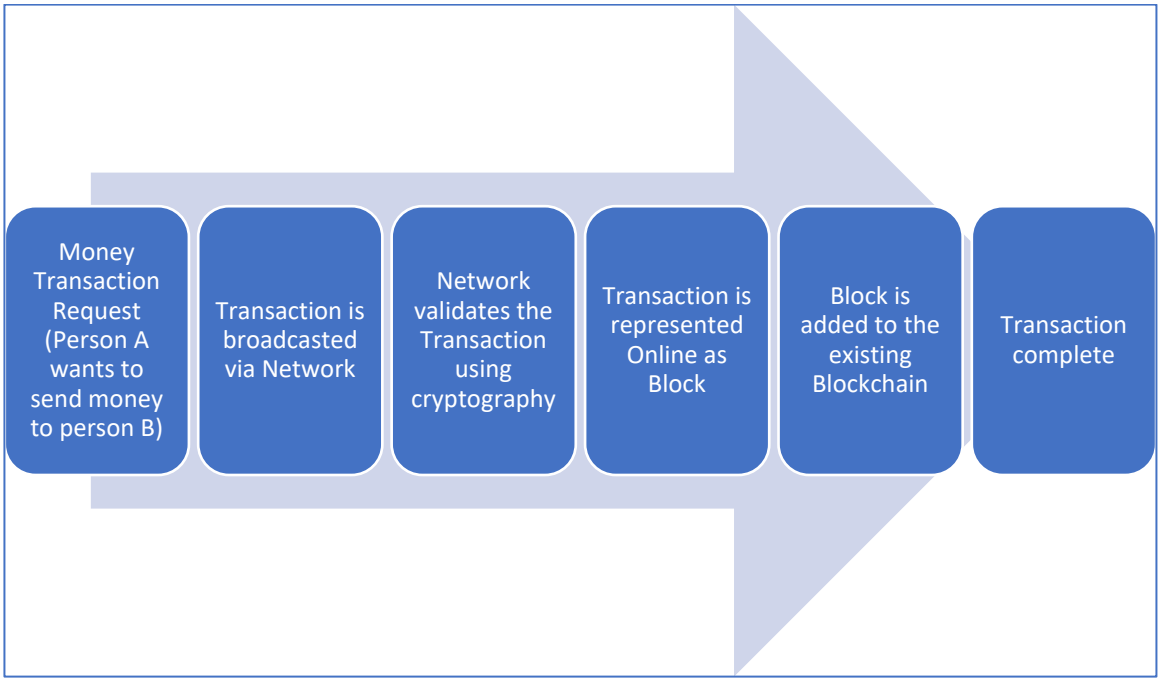

Fig. 1: Blockchain Six Steps Financial Transaction Process

The typical sequence of events that took place during the financial transaction using Blockchain Technology is represented in figure 1 above. Blockchain Technology assures safe and reliable online transactions without the need for third-party intervention. This is advantageous over traditional online transaction system, making it more popular in conducting online business activities and that is why many online transactions in Smart Cities readily make use of Blockchain-based solutions.

2. PROBLEM STATEMENT:

Smart Cities are rapidly changing the concept of "better living" by offering a "smart living" facility. To do so, Smart Cities extensively relies on the deployment of information and communication technologies that facilitates storing online data records and online transactions in doing much administration, business and office activities sitting at the comfort of their home or from anywhere which allows one to connect to the internet. Just imagine, what will happen if the online transactions, fail to record transactions with the right data elements? Or if someone alters the recorded data of a transaction to commit fraud. Be it a financial transaction, land registrations, online insurance data, patient's medical history, or student's academic transcripts, any alterations with such critical data record can permanently damage the stakeholder's reputation and may put them in huge financial loss which may be extremely difficult to recover. Also, such online data alterations or failed online transactions related to Smart Cities not only affects the individuals but also the organizations and administrations of whole Smart City. If we ensure safe and reliable online transactions and storing and retrieving online records without any unwanted alterations, then any fraudulent activities or cyber fraud can be safely avoided. Blockchain Technology is a revolutionary and novel technology that facilitates a distributed ledger to create append-only immutable databases with a unique identification number to trace the transactions made. This paper is exploring Blockchain Technology based solutions to address the above stated concerns of Smart Cities.

3. RESEARCH OBJECTIVES:

The main objective of this research is to study Blockchain Technology and propose the blockchain based secure framework which can be used in various applications of Smart Cities to conduct safe and reliable online transactions. The other objectives also involve analysing Blockchain Technology and identifying any limitations and constraints of Blockchain Technology in using with Smart Cities existing IT infrastructure and framework.

4. METHODOLOGY:

A systematic literature review is a backbone behind identifying various applications in Smart Cities where Blockchain Technology is either proposed or rigorously applied. We focused on research papers from reputed national and international journals which were mostly UGC-approved Research Journals, Scopus Indexed Journals, IEEE Journals, WOS Database Journals, reputed websites blogs, and or high impact factor multidisciplinary national/international journals. The relevant papers and research articles were identified through the online search by using specific keywords, titles, and or exploring the abstract. We also visited websites of reputed organizations that are conducting research on Smart Cities Technologies and or offering their services for setting up or operating and maintaining Smart Cities worldwide. An algorithm based on a combination of query and Boolean operator ("Smart City" AND "Blockchain Technology", "Smart Cit*" AND "Blockch*", with produced results refined based on Document Type such as "Journal Paper", "Book Chapter", "Blog", "Review Paper" and time coverage of mostly last 10 Years documents or articles") was employed to identify relevant Research Articles and or Journal Papers, Book Chapters and or websites blogs. Apart from this, we also interacted with industry professionals and researchers who are either prime stakeholders while delivering services for Smart Cities or conducting research on Blockchain Technology for Smart Cities Applications.

5. RELATED WORKS:

There are a lot of research papers available on Blockchain Technology elaborating its components, architecture, its various applications in different domains, and new focus areas where Blockchain Technology can be utilized. A systematic review of most such papers can provide great details of technology trends, application domain areas, challenges, and limitations in the deployment of Blockchain Technology. In the present research paper, the literature review of some selected research papers, book chapters, online blogs, and white papers, is carried out, to understand Blockchain Technology details and its applications.

Blockchain Technology brought serious disruption and revolutionary change to the traditional business processes which basically depends upon centralised architecture and trusted third parties applications to carry out on line transactions, can operate in a decentralized manner with the help of blockchain technology with the same level of certainty [2]. Many times people think that Blockchain technology is only the basis of the crypto currency Bitcoin, but in reality it is not limited to that, Blockchain technology allows carrying out verifications and secure transactions on the internet and can be utilized as an excellent tool for management of Smart Cities [3]. Sun et al. in their paper [4], Blockchain-based sharing services: What blockchain technology can contribute to smart cities, have discussed the conceptual framework of Smart Cities based on three factors human, technology and organisation and using this triangle framework, also discussed the set of fundamental factors that makes a city smarter from a sharing economy perspective. The authors have highlighted various features of blockchain technology which can contribute to smart city development through sharing services. PWC Report [5] of year 2020 on Blockchain to make Cities Smarter has stressed that Blockchain Technology is an emerging tool for governments of many countries across the globe, to redefine the transaction framework for information exchange. The report provided elaborated information on the various urban challenges tackled through smart cities and how blockchain technology can transform the smart cities to make it more efficient and smarter. It has also highlighted that applications which has issues related to inefficiency, corruption, lack of transparency and data security can be very well based on Blockchain Technology for a positive impact. Blockchain Technology has started many and many applications across Smart Cities and Urban Management and Town Planning domain. Smart cities are highly complex and highly interconnected, or in other words, a truly smart city cannot function without digital infrastructures that physically link together dispersed sensors, devices and machines that make up public systems and services, so they can exchange information in real time [6]. Horst Treiblmaier and Abderahman Rejeb in their paper [7]: Blockchain as a Driver for Smart City Development: Application Fields and a Comprehensive Research Agenda, have discussed the Blockchain Technology concepts and its applications for Smart Cities. The authors identified and discussed nine application fields of Smart Cities such as healthcare, logistics and supply chains, mobility, energy, administration and services, e-voting, factory, home and education, which can be based on Blockchain Technology and can offer better services in making cities more smarter. Kamanashis Biswas and Vallipuram Muthukkumarasamy in their paper [8], Securing Smart Cities Using Blockchain Technology, have stated that Blockchain Technology using its distributed ledger form of storing and securing information can offer better solution to integrate and manage physical, social and business infrastructure of Smart Cities. They have proposed the Blockchain Technology

based Security Framework making use of IOT components, Cloud Computing Platforms and interconnected networks for Smart Cities. The authors have argued that Blockchain Technology based solutions are very safe and secure since if any attacker intentionally wanted to do any wrongdoings with such systems, then the attacker will have to compromise around 51% of system components to surpass the hashing power of the target network, thus it is logically and practically impossible to launch a successful attack against the Blockchain System. Carmen Rotuna, Alexandru Gheorghita et al in their paper [9]: Smart City Ecosystem Using Blockchain Technology have clarified that Blockchain Technology can be very useful in having Smart Cities systematically organised and more transparent in resource management. Authors have proposed a Smart City ecosystem model based on Self Sovereign Identity authentication and smart contracts between various entities, administration services and smart city residents. Authors have also confirmed that the results of their study can be a very good starting point for development of Blockchain based platform for communications and transactions in the public sector Blockchain Technology is also widely used for applications from other domains. Sara Rouhani et al [10], have specified in their research paper MediChainM: A Secure Decentralized Medical Data Asset Management System, that how a Blockchain technology can be successfully used to develop and implement a secure medical data asset management system. Nagothu Deeraj, Xu Ronghua et al [11], in their paper "A Microservice-enabled Architecture for Smart Surveillance using Blockchain Technology" have proposed a new architecture for Smart Surveillance Applications based on microservice using Blockchain Technology. Authors have clarified that traditional surveillance systems based on monolithic architecture to carry out lower level operations such as monitoring, and recording are typically not scalable to meet the extended requirements of advanced video streaming and safe data analytics and transactions of modern surveillance System. Authors have claimed that with their novel microservice architecture with Blockchain Technology a secure smart surveillance systems, using various independent microservices can not only isolate the video feed from different sectors but can also improves the system robustness and availability by decentralizing the operation using Blockchain Technology which can ultimately provide tamper proof of data in the trustless network environment. It is not that deployment of Blockchain Technology do not pose any challenges with the existing Applications. In fact, if the design framework doesn't meet the IT Infrastructure requirement for running Blockchain, it is not possible to get full advantage of using Blockchain Technology. Shuling Li, in the research paper [12] has discussed the storage space requirements related challenges for the applications when applying blockchain technology to the IIoT infrastructure. To address this issue, author proposed a hierarchical blockchain storage structure where the majority of the blockchain is stored in the clouds, while the most recent blocks are stored in the overlay network of the individual IIoT networks.
While Blockchain applications are being widely deployed in Smart Cities and Urban Management applications, there is enough room to fine tune and customized the Blockchain Technology components so that it can be used and deployed for other domains and services as well. based on various research papers survey and review it is confirmed that Blockchain Technology offers scalable and robust solutions to suit requirements of wider applications but at the same time to take advantage of full capacity and potential of Blockchain Technology, a more robust and high performance IT infrastructure is also needed to run such applications. As Blockchain Technology becomes more mature, it is expected that their applications and solutions can be deployed in many more industries and domains.

6. BLOCKCHAIN TECHNOLOGY – DEEP DIVING:

Blockchain technology though complex, is always considered as safe and reliable since the goal of using Blockchain Technology is to increase transparency into digital trade transactions and eliminate the time spent on exchanging documents for verification. Implementing Blockchain Technology can reduce the bottlenecks in trade financing by facilitating a platform for all parties to observe the transfer of goods.

6.1 Main Elements of Blockchain Technology

The main technology elements for Blockchain are as follows.
(1) Distributed Network
(2) Cryptographic Algorithms
(3) Blockchain Protocols

(1) Distributed Network

In order to achieve outcome in a coordinated fashion, Blockchain uses distributed network where two or more nodes work with each other. It should be noted that all users on the Blockchain are peers or typically

nodes who maintain their own ledger. In distributed network architecture, transaction data is transmitted peer to peer. Note that faster transaction process makes the validation process also faster which directly results into faster transfer of digital assets.

(2) Cryptographic Algorithms

Cryptographic Algorithms used to encrypt Blockchain data. Everything stored in Blockchain is encrypted to ensure absolute data security. Cryptographic algorithms are complex mathematical algorithms, such algorithms, e.g. Secure Hashing Algorithm (SHA-256) are hard to detect and almost impossible to manipulate. All the transaction data is digitally signed by using Cryptographic algorithms.

(3) Blockchain Protocols

Blockchain Protocol is a set of rules and procedures used to manage Blockchain. Protocols are used to ensure that different aspect of the platform work as intended. Various protocols are used for various specific applications based on their suitability. Some of the protocols are open source protocols whereas some protocols are scalable private permissioned network. Following are popular protocols of Blockchain.

- Hyperledger: Opensource protocol managed by Linux foundation
- Quorum: Opensource Enterprise Blockchain Protocol
- Corda: Enterprise Protocol suitable for Banking and Finance Applications
- Enterprise Ethereum: Scalable private permissioned network

6.2 Blockchain Components

Blockchain consists of following 3 essential components [13], let us go through details of every component

(1) Blocks
(2) Nodes
(3) Miners

(1) Blocks

Blockchain consists of multiple blocks and the first block when created, it basically starts the chain. Each Block has following components.

- Data: This data is basically transactional data and it contains with in the block. Since Blockchain needs to be transparent, every action in the ledger requires easy view and verification. Each participant is given a unique alphanumeric identification number that shows their transactions in the form of data.
- Nonce: This is a 32-bit whole number which basically gets randomly generated when blocks get created. Nonce is also then generates a block header hash
- Hash: It is a block header hash which is basically 256-bit number attached with nonce. It always starts with number of zeroes

Note that the chain is started with creating first block, and nonce of that block creates the cryptographic hash. The block contains data which is permanently tied to nonce and hash and is considered signed. Note that this data subsequently cannot be edited and treated as good as recorded transaction.

(2) Nodes

As stated above, the whole Blockchain Technology relying upon decentralization mechanism. This ensures that no component of IT Infrastructure or Computer or any Organization can own the chain. Note that the blocks of Blockchain are connected via the nodes. Nodes can be any kind of electronic device that maintains copies of the blockchain and keeps the network functioning. Every node has its own copy of the Blockchain, and the network must algorithmically approve any newly mined block for the chain to be updated, trusted and verified.

(3) Miners

Miners plays a very important role of creating new blocks in Blockchain. And, this process of creating new Blocks is called as mining. As we know that each Block has its unique id that is nonce, its own hash and also the hash of the previous block in the chain, it should be noted that this makes mining process not the easy one, this is very true specifically for large Blockchain. Since Nonce is 32-bit number and Hash is 256 Bits number, it is very difficult to find out right Hash-Nonce combination that must be mined, out of nearly 4 Billion combinations. This is the reason that through computer program and using right algorithms only it is possible to identify correct nonce that generates an accepted hash. When it happens, miners have said

to get Golden Nonce and their block gets added to Blockchain. Now in case any change is required in the existing block of chain then it is extremely difficult since such change requires re-mining not to that alone block but to all the blocks which are added to the chain later after that block. That is why getting Golden Nonce requires enormous amount of computing power and time and thus who receives it gets financially rewarded as well. Thus, manipulating Blockchain Technology is extremely difficult.

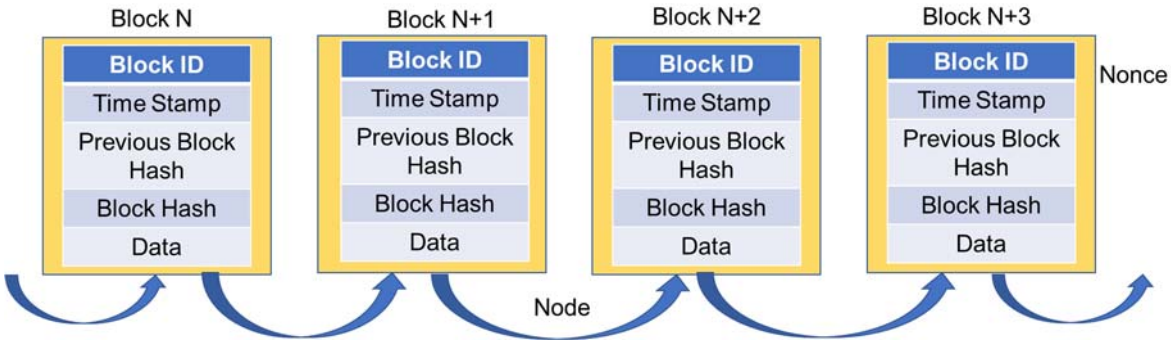

Fig. 2: Typical Blockchain Representation

Refer figure 2 which has represented the Blockchain and its components. The Blockchain has presented that digital money is transferred from one person to other without involving third parties. Such transactions are safe, reliable and transparent. This is basically the power of using Blockchain technology.

Having explored the Blockchain Technology, its components and functioning, it is necessary to understand the attributes of Blockchain and its advantages to explore its full potential which makes this technology unique. Blockchain Technology has following basic attributes.

Table 1: Blockchain Technology Attributes

Sr. No.	Blockchain Attribute	Description
1.	Shared Ledger	It is an append-only distributed system of records shared across the business network, making it robust system by eliminating a 'single point of failure'.
2.	Consensus	A transaction is committed only when all stakeholders agree to a network verified transaction.
3.	Provenance	All the modification history of the record is available
4.	Immutability	Records are not editable and cannot be tampered with once added to the shared ledger. Only way to alter the data is to add new valid record in the blockchain
5.	Firmness	Once the transaction is completed over a blockchain, it cannot be reverted.
6.	Smart Contracts	Code is built within a blockchain that computers/nodes execute based on an event or condition according to the terms of a contract or an agreement., and thus it can be auto executed,

Blockchain technology offers numerous advantages to carry out safe and reliable online transaction. Refer figure 3 which has presented Blockchain Technology advantages which includes. but not limited to online transaction security through encryption, accidental and intentional alteration proof through immutation, safe, and agreed alterations through consensus mechanism, programmable according to requirements, audit compatible because of transparent process and absolutely safe and reliable data transactions by having distributed ledger database.

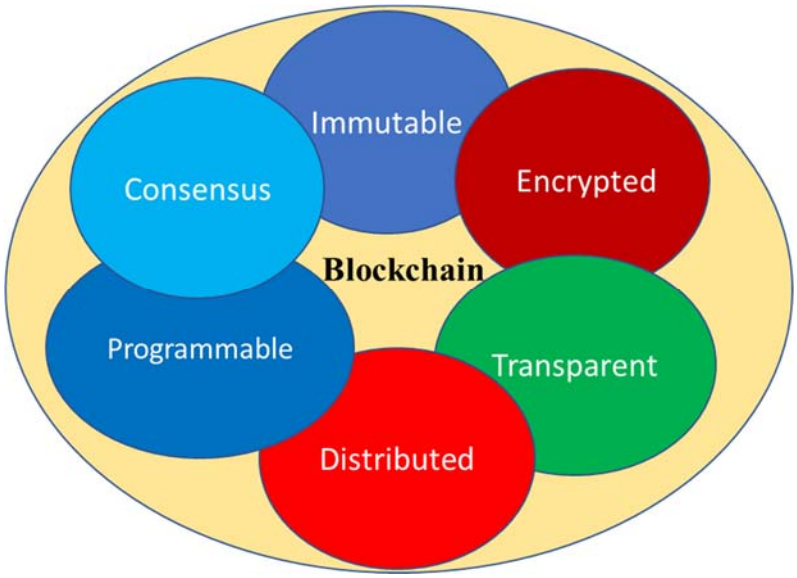

Fig. 3: Advantages of Blockchain Technology

7. BLOCKCHAIN DEVELOPMENT TOOLS:

Blockchain Technology is complex and needs specialised tools and training for development purpose. Refer Table-1 below, which has stated and described some of the top development tools for developing Blockchain Technology based Applications.

Table 2: Blockchain Development Tools

Sr. No.	Blockchain Dev. Tool	Description
1.	Solidity	It is object-oriented programming language, similar to Java and commonly used to develop smart contracts and Ethereum-based applications. It is the runtime environment in Ethereum.
2.	Geth	It is a program which acts as the node of the Ethereum blockchain and available on platforms such as Windows and Linux. It uses the Go programming language and allows the user to transfer tokens between addresses, explore block history and creation and execution of smart contracts through the Ethereum Virtual Machine.
3.	Remix	It is an open source compiler used for deploying, testing, and debugging of smart contracts. It connects to the Blockchain using Metamask. It is written in Javascript so that it can be accessed via any modern browser. Remix can be used for writing, testing, debugging, and deploying smart contracts written in Solidity [14].
4.	Mist	It is developed by the creators of Ethereum, as an official Ethereum wallet and used for deploying smart contracts. It is a full node wallet used to store Ether tokens. To make use of it, one must download the entire Ethereum blockchain.
5.	Solium	It is a basically a vulnerability assessment tool used to check vulnerabilities in the code. It helps in fixing security issues, if any, in the code.
6.	Parity	Parity facilitates a secure way to interact with the blockchain. It is developed in Rust programming language. It can be directly integrated into a web browser and allows access to basic wallet functions and Ether.
7.	DApp Board	It is a web-based analytics service and acts as an analytical Ethereum blockchain explorer and as an analytical platform

		for Ethereum smart contracts. It monitors and analyse activities of smart contracts on the Ethereum blockchain.
8.	Truffle	It is a development suite for building smart contracts which simplifies blockchain development to enable developers build decentralized applications quickly and easily. It allows network management of public and private networks and built-in smart contract compilation, deployment, and linking.
9.	Embark	It is a developer framework which enables one to create new smart contracts which can be then made available in the JS Code. It also helps in creating and deploying DApps. In case of Contract updating, Embark automatically modifies the contract and related DApps.
10.	Blockchain Testnet	A Blockchain Testnet allows one to quickly test dApps for bugs and errors before making them go live. Each blockchain solution has its unique Testnet. There are three types of Blockchain Testnet – Public Test, Private Test, and GanacheCLI. Blockchain Testnet facilitate cost effective testing.

8. BLOCKCHAIN BASED SECURE FRAMEWORK FOR SMART CITIES:

Smart cities need appropriate and highly compatible technological ecosystems to be functional and develop successfully. Otherwise, they will become isolated, with systems that are unable to communicate with each other because they speak different languages [15]. With the literature review of various research papers, it is observed that Blockchain Technology started being widely deployed in Smart City Services, however the main issue observed is the development time and modifications required to suit the model to different services. Also interacting with the professionals dealing with such issues, one thing most of the professionals agreed for is to have some simple design architecture which can suit to most of the application areas and services of Smart Cities with minimum modifications. Keeping in mind this objective, we started developing modular architecture based on Blockchain Technology, which can be applied to any Services of Smart Cities with modifications to any specific module keeping rest of the architecture intact.

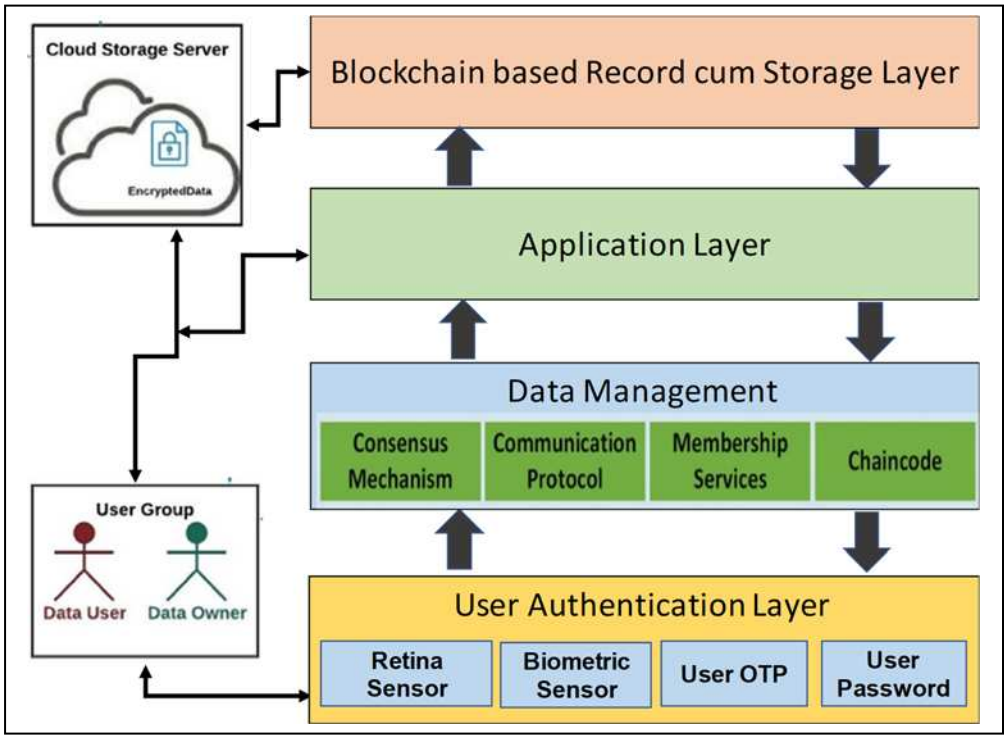

Fig. 4: Blockchain based generic Secure Architecture

The solution to deal such kind of requirement is to have design framework which can have application specific module separate from the common functional modules. Application Specific Module can deal with Application specific functionality such as Application relevant dashboard, Application relevant Data process, algorithms implementations and relevant user actions processing. Whereas common functionalities can include processing of common User Dashboard, User Authentication, Communication Protocols with Cloud Server and backend database etc. Refer figure 4 which has presented a generic Security Framework based on Blockchain Technology for Smart City and Urban management domain. Note that this Security Framework is modular and has been developed keeping in mind its adaptability for any services of Smart Cities with minimum fine tuning and modifications. The proposed Secure Architecture is generic one and designed keeping in mind the flexibility to adapt to any specific Application for Smart City. As shown in figure 4, the Architecture is modular and contains 4 layers namely

(1) User Authentication Layer
(2) Data Management,
(3) Application Layer,
(4) Blockchain based Record cum Storage Layer.

Note that the Application based on this Secure Framework allows user interaction with the Application Service through an inbuilt authenticated mechanism. The Service can be hosted locally with on-premise Server or any cloud platform and the user can connect to the service with either dedicated Client Application or through a secure web browser over HTTPS. Let us briefly explore each layer of secure framework.

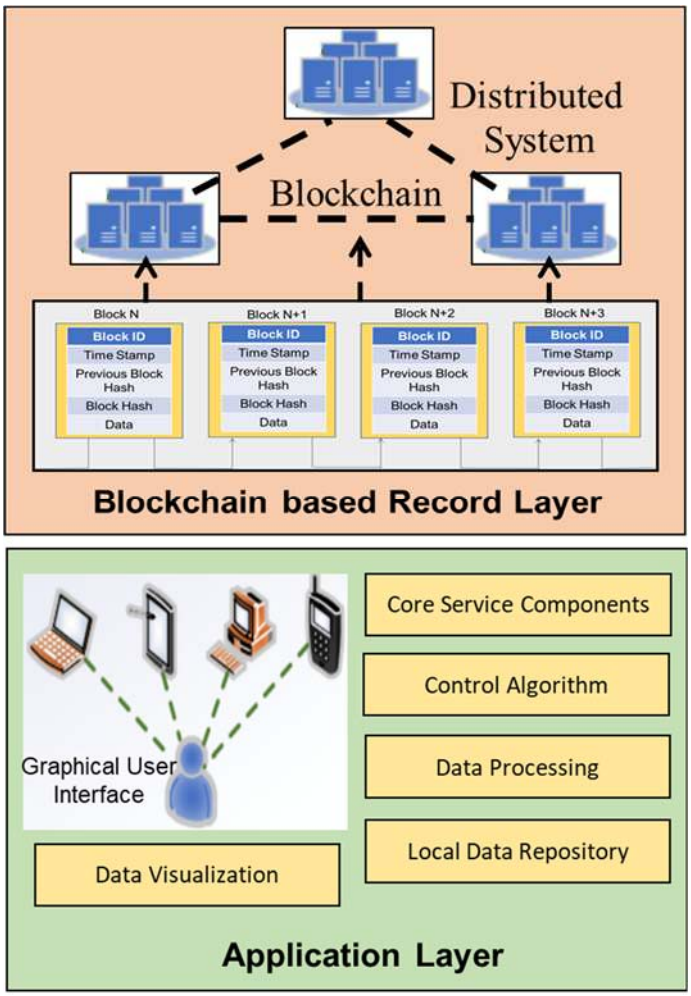

Fig. 5: Exploded view of Record Layer and Application Layer

(1) User Authentication Layer

This layer ensures only authenticated users are allowed to access the intended application. The user authentication can be carried out through various ways and means. i.e. by using biometric thumb impression sensors or by scanning eye retina through retina scanners. Also, an economical means of using one-time password sent over user registered mobile number and or by entering the registered password with the

Application, User can get access of the application. Note that it is recommended to use two level authentication such as Biometric Thumb impression validation or Retina Scanning validation along with OTP or User Password. The Authentication mechanism and number of authentication levels can be user configurable. Note that User need to connect the sensors with the Laptop or Desktop installed with client application or through which the application is going to be accessed over web.

(2) Data Management Layer

This layer is responsible for data handling related activities. It sets the rules to allow the data alterations in accordance with agreed rules and regulations knows as consensus. This layer carries out data parsing for the user transacted data, data encryption and packaging cum arranging the data to generate the transaction block. It also maintains user cache data to faster transactions. Data management layer basically coordinates user actions between Application and Blockchain layer.

(3) Application Layer

This layer is like brain of Security Architecture. Application Layer basically segregates various activities as per the required services and also responsible for the underlying implementation technologies to connect each layer. This layer can be configurable to suit service level requirements for most of the application services offered by Smart Cities. Such applications can be Secure Online transactions, Online Insurance, Electronic Medical Record for Smart City residents, Smart City Governance Service, Smart Virtual Learning and performance evaluation, Smart Library Database, Smart Factory, Smart Public Transportation service and so on. Please refer figure 5 which has presented detailed view of Application Layer components. As required by the individual Service the Application layer components such as Data Processing using specific algorithms, User Dashboard, Service Data Repository, user interface for various kind of user privileges etc. can be configured. Application Layer interacts with Blockchain Layer to read write user transactions and application relevant data.

(4) Blockchain based record cum storage Layer

This layer is like a heart of the overall Secured Architecture Framework and key element with respect to safe and secure operation. It offers the capability to Application Service to securely store, read and write the encrypted data transactions, which are tamperproof and compliant to stringent cybersecurity requirements. Since the data is stored in distributed ledger form, it requires synchronising at regular interval and while updating the block record.

It should be noted that the secured architecture framework based on Blockchain Technology, can run and process thousands of data transactions safely over LAN and WAN environment and to utilize its full processing capability can need powerful IT infrastructure including high speed Server and Client machines and Gigabit speed internet. Since Smart City services, already runs on powerful IT infrastructure, the proposed secure architecture framework can easily be deployed on the existing IT infrastructure of any Smart City.

9. USE OF BLOCKCHAIN TECHNOLOGY IN SMART CITIES DEVELOPMENT:

Having explored the Blockchain Technology, its components and functioning, let us see how Blockchain Technology is redefining Smart Cities development and facilitating wellbeing of Smart City residents. Smart City is a place where traditional information networks are replaced with digital services offering more flexibility, more efficient and more sustainable by making the best use of available technologies such as digital and information communication technologies, to improve the overall operations and provide benefits to its residents [15]. However, since there is no standard and the requirements are different in each city, the technology infrastructure is left up to each city and that has the potential to cause some challenges. That is where Blockchain can play a role. Blockchain can connect these technologies together [16]. Since, Blockchain Technology provides faster, secure and better experience in digital transactions, it can be used as an excellent instrument to rule out corruption and inefficiency in managing and operating Smart Cities operations and digital transactions. This very advantage of Blockchain Technology makes Blockchain as preferred choice, in comparison with conventional less secure online services, while carrying out multiple services across Smart Cities operations and management. Smart cities worldwide are using blockchain as the foundation of plans to enhance urban living. Dubai is on path of becoming global leader in the smart economy is banking on Blockchain Technology as the first blockchain-powered government, and Moscow,

which recently became the first city to use blockchain in an e-voting system designed to eliminate corruption and voter fraud [17]. With the help of proposed Secured Architecture Framework, it is possible to build the application specific functionality over the application layer and use the overall model to suit the specific application service of Smart City. Some of the examples of such services [18-31] are as follows.

Fig. 6: Blockchain Applications Portfolio in Smart Cities

9.1 Online Financial Transactions

Blockchain powered Applications being absolutely safe and secure while carrying out online digital transactions can be used to send and receive payments. Such solutions can be ideal for organisations with remotely operating employees. In similar way, Smart City based small business owners can also use Blockchain powered Applications to send and receive money securely without paying any transaction fees to third parties and intermediaries.

9.2 Insurance

Insurance Industry transactions are known to be worst affected by online frauds and easy targets for cheating and carrying out fraudulent activities. Due to this Insurance business, though one time very flourishing business, today is considered risky and unstable. Blockchain applications, since offering highest security and safe online transactions, Smart City based Insurance Services are frequently using Blockchain Technology in tracking and managing digital identities with the help of cryptographic digital signatures instead of less secure conventional password-based systems.

9.3 Supply Chain Management

Smart City Organizations can use Blockchain powered Smart Contracts for managing supply chain related operations across the city and a region effortlessly and securely. Such Supply Chain activities can be well applicable to right from the agriculture industry to automotive, or any logistics organisation where Blockchain based Applications can bring better transparency between producer and consumers.

9.4 Environment Management

One of the biggest challenges faced by Smart Cities to control Carbon footprint across the City and maintain a healthy environment. Due to technological advances, Smart Cities needs to manage a tremendous amount of generated electronic waste, and thereby increased Carbon Footprint. Blockchain Technology can assist Smart Cities in controlling the environment under check. Blockchain powered Applications can assist Smart Cities services in measuring and analysing the Carbon footprint from various sources and due to Blockchain Technology such environmental data records cannot be tampered with and can be treated as accurate sources of data for a better analysis and results.

9.5 Health Records

Smart Cities are determined to provide better health care facilities to its residents. While providing better healthcare facilities, one of the challenges faced by Smart City to maintain accurate health record of each stakeholder. Blockchain Applications can assist Smart City Services in maintaining accurate and tamperproof Medical Records of its users. Blockchain technology's use of decentralised ledger can facilitate the sharing of patients EMR data across hospitals and doctors seamlessly and accurately without worrying for any attempt to alter the medical record. This will also help in processing medical insurance claims from patients hassle-free.

9.6 Energy Trading Solutions

Blockchain based point to point energy trading solutions can offer better support to stakeholders to use and better manage energy sources such as solar power, Wind Energy, and other alternative sustainable energy sources. While doing so, Blockchain Technology ensures eliminating middlemen and third parties and facilitates individuals to generate, buy, sell, and trade energy. Since Blockchain Technology can also integrate with IoT based Sensors, the whole energy management process can be better controlled and analysed without any issue to the stakeholders.

9.7 Identity Management

Correctly managing and identifying Smart City residents due to ever increasing population of Smart City citizens is a big challenge for Smart Cities. Blockchain Technology facilitates an easy and safe mechanisms to store, verify and retrieve identities from the decentralised identity management solutions. Such Solutions not only assists in storing the identity data but also in preventing identity thefts and other such fraudulent activities.

9.8 Governance

For effective administration and governance of Smart Cities, effective and reliable solution is needed. Blockchain can assist Smart Cities in providing better governance by using Smart Contracts which can be deployed across a range of operation and activities. Blockchain Technologies can be deployed to make entire system smooth while conducting various activities right from conducting transparent voting to automating bureaucratic processes, tangible and intangible Assets management, filing taxes, tracking ownership and so on.

10. CONCLUSIONS :

Blockchain Technology is complex and powerful technology and is going to shape the world with its enormous power of accuracy, assurance of safe transactions, and operating reliability. Due to such advantages, Blockchain applications are very effectively getting utilised in solving real life problems and challenges in Smart Cities Development. Blockchain powered Applications are finding their way across large sectors such as Insurance, Governance, Supply Chain Management eHealth Records, and so on. Looking at the way Blockchain is slowly and steadily capturing a wide variety of application areas, there is no doubt that Blockchain has come to rule the world and is going to stay there for a longer time as the top preferred technology in digital transactions.

11. FUTURE WORK :

In the present paper, the secured architecture based on Blockchain Technology is proposed for various services of Smart Cities. Due to time and finance constraints, the architecture model could not be implemented and tested. However, looking at the enormous strengths of Blockchain Technology and its wide range of possible applications for maintaining and operating services with Smart Cities, in the future, I will go ahead and implement this framework and will also try to make the possible enhancements wherever possible. I also would like to evaluate the secure architecture based on its performance, operation speed, its flexibility to adapt to specific Service of Smart City, its cybersecurity compliance, and its limitations if any.

REFERENCES :

[1] Yaga, Dylan., Mell, Peter., Roby, Nik., Scarfone, Karen. (2019). Blockchain Technology Overview. *NISTIR, 8202*, 1-17.

[2] Casino, Fran (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Elsevier, Telematics and Informatics*, *36*(1), 55-81.

[3] Blockchain technology at the service of urban management. https://www.iberdrola.com/innovation/blockchain-for-smart-cities-urban-management. Accessed on 16/12/2020.

[4] Sun, J. et al. (2016). Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financial Innovation, 2*(26), 1-9.

[5] Blockchain: The next innovation to make our cities smarter. http://ficci.in/spdocument/22934/Blockchain.pdf. Accessed on 16/12/2020.

[6] Aldoma, C. (2019). Blockchain and Smart Cities - Innovation & Technology Blog. https://www.e-zigurat.com/innovation-school/blog/blockchain-and-smart-cities/. Accessed on 16/12/2020.

[7] Treiblmaier, Horst., Rejeb, Abderahman., Strebinger, Andreas (2020). Blockchain as a Driver for Smart City Development: Application Fields and a Comprehensive Research Agenda. MDPI, *Smart Cities*, *3*(3), 853-872.

[8] Biswas, Kamanashis., Vallipuram M. (2016). Securing Smart Cities Using Blockchain Technology. Proceedings of IEEE 14th International Conference on Smart City, 1392-1393.

[9] Zamfiroiu, Alin., Rotuna, Carmen., et al. (2019). Smart City Ecosystem Using Blockchain Technology. *Informatica Economica*, *23*(4), 41-50.

[10] Rouhani, Sara., Butterworth, Luka., et al. (2018). MediChain: A Secure Decentralized Medical Data, Asset Management System. *Proceedings of IEEE International Conference on Internet of Things (iThings)*, 1-6.

[11] Nagothu, Deeraj., Xu, Ronghua., et al. (2018). A Microservice-enabled Architecture for Smart Surveillance using Blockchain Technology. Proceedings of IEEE International Smart Cities Conference (ISC2), 1-4.

[12] Shuling, Li. (2018). Application of Blockchain Technology in Smart City Infrastructure. Proceedings of IEEE International Conference on Smart Internet of Things (SmartIoT), 2761-2766.

[13] Gupta, Manav. (2020). Blockchain for dummies. 3rd IBM Limited Edition. John Wiley & Sons. *Taking a Look at How Blockchain Works*, 13-18.

[14] 10 Most Used Blockchain tools in 2020 For Blockchain Development. https://www.upgrad.com/blog/top-blockchain-tools/. Accessed on 16/12/2020.

[15] Gade, D. (2019). Introduction to Smart Cities and Selected Literature Review. *International Journal of Advance and Innovative Research, 6*(2), Part 4, 7-15.

[16] Gupta, Shekar. (2020). Using Blockchain in Smart Cities. https://meetingoftheminds.org/using-blockchain-in-smart-cities-29319. Accessed on 17/12/20.

[17] Sergio. (2018). 10 Ways Blockchain Is Revolutionizing Smart Cities. https://medium.com/smartcityworld/10-ways-blockchain-is-revolutionizing-smart-cities-595046ba05b1. Accessed on 18/12/20.

[18] Lopes, L. (2019). Blockchain's role in developing smart cities. https://theblockchainland.com/2019/03/05/blockchain-role-developing-smart-cities/. Accessed on 18/12/20.

[19] Wan, J., et al. (2019). A Blockchain Based Solution for Enhancing Security and Privacy in Smart Factory. *IEEE Transactions on Industrial Informatics*, *15*(6), 3652-3660.

[20] Wang, Gang, et al. (2019). ChainSplitter: Towards Blockchain-based Industrial IoT Architecture for Supporting Hierarchical Storage, Proceeding of IEEE International Conference on Blockchain (Blockchain), 1-10.

[21] Zamfiroiu, Alin., Rotuna, Carmen., et al. (2019). Smart City Ecosystem Using Blockchain Technology. *Informatica Economica*, *23*(4), 41-50.

[22] Zorzo, Avelino., Dorri, Ali., et al. (2018). SpeedyChain: A framework for decoupling data from blockchain for smart cities. *Proceedings of 15th EAI International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services*, 145-154.

[23] Khan, Z., et al. (2020). Securing Smart Cities through Blockchain Technology: Architecture, Requirements, and Challenges. *IEEE Network*, *34*(1), 8-14.

[24] Xie, J., Tang, H., Huang, T., Yu, F. R., Xie, R., Liu, J., & Liu, Y. (2019). A survey of blockchain technology applied to smart cities: Research issues and challenges. *IEEE Communications Surveys & Tutorials*, *21*(3), 2794-2830.

[25] Nam, K., Dutt, C. S., Chathoth, P., & Khan, M. S. (2019). Blockchain technology for smart city and smart tourism: latest trends and challenges. *Asia Pacific Journal of Tourism Research*, *24*(1), 1-15.

[26] Matteo, S., et al. (2017). CitySense: blockchain-oriented smart cities. Proceedings of the XP2017 Scientific Workshops, 1-5.

[27] Jo, J. H., Sharma, P. K., Sicato, J. C. S., & Park, J. H. (2019). Emerging Technologies for Sustainable Smart City Network Security: Issues, Challenges, and Countermeasures. *Journal of Information Processing Systems*, *15*(4), 765-784.

[28] Bhuvana, R., Madhushree, L. M., & Aithal, P. S. (2020). Blockchain as a Disruptive Technology in Healthcare and Financial Services-A Review based Analysis on Current Implementations. *International Journal of Applied Engineering and Management Letters (IJAEML)*, *4*(1), 142-155.

[29] Bhuvana, R., & Aithal, P. S. (2020). RBI Distributed Ledger Technology and Blockchain-A Future of Decentralized India. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *5*(1), 227-237.

[30] Bhuvana, R., & Aithal, P. S. (2020). Blockchain based Service: A Case Study on IBM Blockchain Services & Hyperledger Fabric. *International Journal of Case Studies in Business, IT, and Education (IJCSBE)*, *4*(1), 94-102.

[31] Aithal, P. S., & Aithal, S. (2019, October). Digital Service Innovation Using ICCT Underlying Technologies. In *Proceedings of International Conference on Emerging Trends in Management, IT and Education* (Vol. 1, No. 1, pp. 33-63).

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