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Survey on Applications of Blockchain in E-Governance

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Abstract
Block chain is a distributed ledger that offers secure and immutable storage. E–governance allows exchange of information between government and citizens or organizations through latest information and communication technologies. The E governance services facilitate efficient and fast access of services; on the other hand it raises potential risks of breaching into privacy and Security. Blockchain based e-governance system offers secure and transparent services without intermediary. This paper investigates the scope and challenges of adopting blockchain technology as a platform for E-Governance.

Key-words: Blockchain, E-governance, Smart Contract, Consensus, Privacy, Security, Distributed Ledger.

1. Introduction

The rapid growth of Internet technology drives integration of IT into business and public administration services. E-governance uses Information and communication technology to effectively deliver government services and Information to citizens and to increase their participation in democratic process (Fang & Zhiyuan, 2002). E-governance system utilizes web based platform for delivery of services. Online access to services eliminates the traditional procedures and formalities to access government services. E-governance provides rapid provisioning of services to broad public and easy access of services to end users. It brings transparency in government procedures and increases the interaction between citizen and governments. As a result more and more countries are embracing E governance technologies and the recent survey conducted by United Nations revealed

that 193 countries actively deploying E-governances applications (U.N E-government Knowledge base, 2018).

Transition to E-governance systems raises challenges to the privacy and security of sensitive data of citizen and organizations. E-governance system demands storage and exchange of data in digital form. Government maintains huge data centers for storing sensitive information such as identity, income, medical records, assets etc. People entrust the government to ensure the security of data. E-governance Information systems are to be coupled with proper security mechanisms to ensure confidentiality, integrity and availability of data. The pitfall in the design and implementation of security mechanism often causes data leakage. This can disrupt the trust and confidence of users on E-governance system.

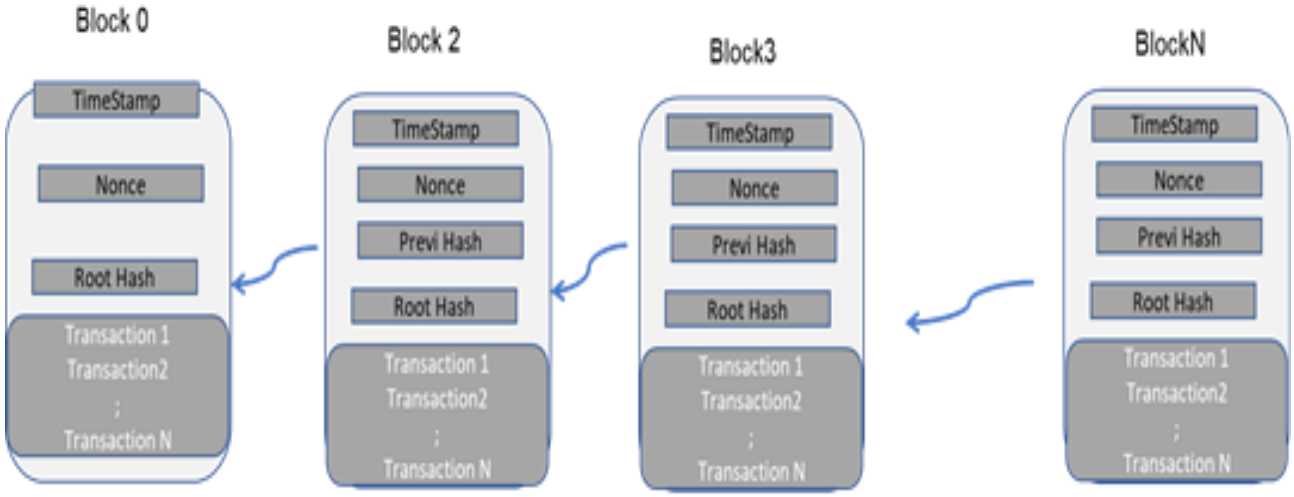
Blockchain is emerged as trust building protocol of internet. Block chain is an immutable record of transaction maintained by a set of decentralized and distributed nodes (Peck, 2017). The first blockchain, Bitcoin Blockchain, was introduced by Satoshi Nakamoto (2008) as a secure platform for enabling peer – peer transaction of crypto currency Bitcoin. Even though specifically crafted for recording Bitcoin transactions, the Bitcoin blockchain demonstrated how to perform an asset transfer securely without intermediary. The next revolutionary step in the history of blockchain was the introduction of programmable public block chain: Ethereum by Vitalik Buterin (2013). Ethereum introduced the concept of smart contracts, the code fragments that can be deployed and executed on block chain platform. The capability to represent complex business operations as smart contract accelerates the adoption of block chain technology to diverse application areas. The decentralized, distributed architecture and cryptographically secured transaction execution makes it as prime choice for deploying secure applications especially in E governance sector. Now a day's many countries around the globe uses blockchain technology for providing services like e-voting, digital ID, health record management, land registration, education and banking (Myung San, 2018).

The objective of this paper is to conduct an in depth study of adoption of block chain technology in E-governance services and understand the scope and challenges. The paper is organized as follows: Section II explain the architectural components and characteristics of blockchain. Section III, brief out potential use cases of blockchain in various public sectors. Section IV presents the key benefits derived from blockchain adoption and Section V list out the factors limiting the wider adoption of blockchain. Finally, Section VI concludes the paper.

2. Blockchain

The Blockchain is structured as linked list of blocks where each block holds a shared public ledger that automatically record all confirmed transactions occurred over the whole network. The ledger is structured as a linked list of blocks, where each block maintains a list of transactions. The transaction represents the creation or transfer of digital assets. The nodes of block chain runs on computers provided by volunteers around the world. This decentralized architecture makes blockchain immune to network attacks.

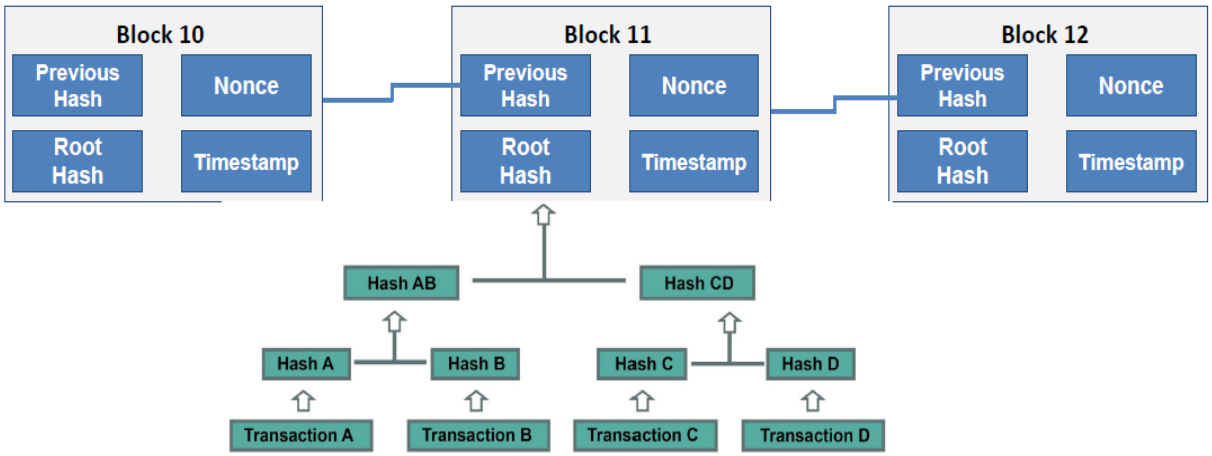
Figure 1 - Structure of Blockchain



Blockchain is a meta-technology (Mougayar, 2016), built around cryptographic techniques and distributed computing methods to ensure the security and integrity of transactions.

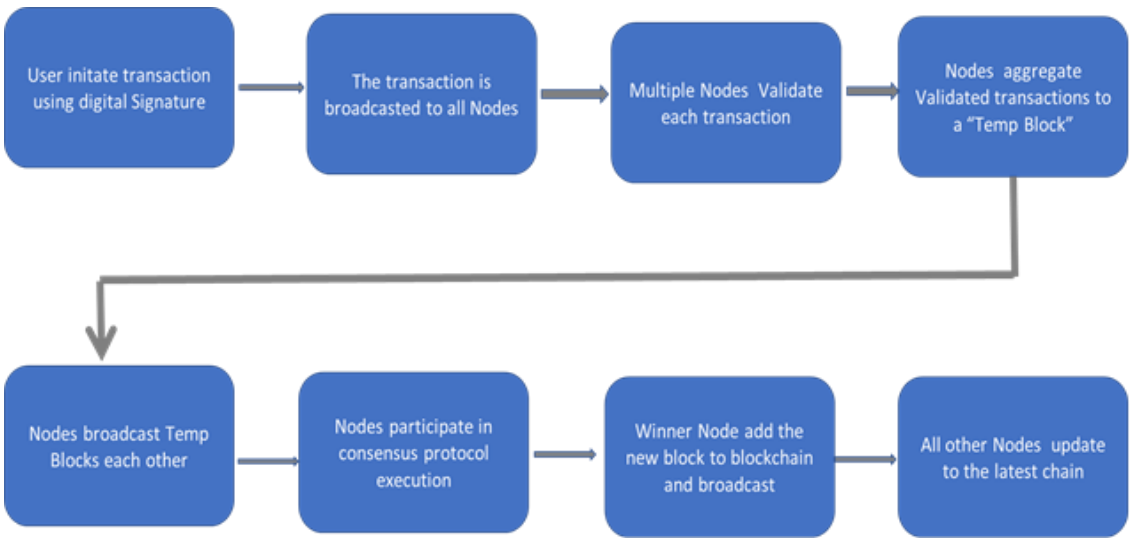
The transactions in block chain are encrypted using asymmetric cryptographic techniques hence ensures confidentiality and privacy. The blockchain is structured as a linked list of blocks as shown in fig 1. Each block in a blockchain holds the block address (block hash computed using SHA256) of predecessor block. Also the Root hash field in block header records the cryptographic hash (SHA256) of all transactions in block computed using Merkle tree method (V. Buterin, 2013) as in fig2.The root hash and previous block hash together ensures the immutability of transactions in a block chain.

Figure 2 - Merkle Tree Root Hash of Transactions in Blocks



Another integral component ensuring the integrity of blockchain is consensus protocols. Block chain is a distributed ledger which is shared by all the nodes in a decentralized network. Transaction verification and addition of new blocks needs agreements among nodes and this is achieved using distributed consensus protocols. The consensus protocols ensure the participation of majority/all the nodes in the network to decide on the addition of a new block. Upon successful consensus the new block is added to block chain and every node update to latest form of ledger. The consensus protocol ensures that the compromise/failure of individual system does not affect the integrity of block chain. Proof of Work (PoW), Proof of Stake (PoS), Practical Byzantine Fault Tolerance (PBFT) etc is the common consensus protocols used in blockchain platform (Zhang & J-H Lee, 2020). Figure 3 explain the various steps in the execution of a transaction in a block chain platform.

Figure 3 - Transaction Execution in Blockchain



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Smart contracts are yet another component that enhances the capability of blockchain for business applications. Smart contract is an agreement between two or more parties expressed in the form of a computer program that can be automatically executed on blockchain platform when the pre-coded conditions are met (Nawari, S Ravindran ,2019). Smart contract allows parties to define the rules and penalties around an agreement as a set of executable instructions and automatically execute transactions when conditions are triggered. The tamper proof architecture of blockchain provides a secure platform for deploying and executing smart contracts. This eliminates the need of manual intervention as well as third parties for the verification and enforcement of contractual terms. Various business operations can be deployed as smart contracts on blockchain and can ensure fast and secure execution.

The decentralized storage, consensus based transaction verification, encrypted transactions and automated processing through smart contracts altogether bestowed blockchain as a Trust Machine (De Filippi et al., 2020). The blockchain platform itself acts as a secure tamper-proof database and hence the applications deployed on blockchain inherently possess the following characteristics:

• *Decentralized :-*	The ledger is shared by a distributed network of nodes that are not under the control of a single organization. Thus the system is immune to partiality or control of a single authority.
• *Immutable :-*	The content of the ledger cannot be altered. The cryptographically linked block structure and consensuses protocol together ensures immutability.
• *Reliability:-*	Blockchain represent a single version of truth shared among multiple parties. Consensus protocols ensure the integrity of blockchain content. Compromise by minority of nodes cannot disturb the structure of blockchain.
• *Availability:-*	The records are replicated in multiple nodes and thus blockchain ensures high availability of data.
• *Transparency:-*	Blockchain records every transaction permanently. The transaction records can be viewed by stakeholders at any time by referring the transaction id.
• *Verifiability:-*	Blockchain transactions are facilitated through asymmetric cryptographic protocols. Entities possessing valid crypto keys are only be allowed to transact on blockchain platform. The transactions in blockchain are digitally signed and hence it's verifiable.
• *Anonymity:-*	Even though the transaction records accessible to all, the transactions are recorded in encrypted format. The content of transaction is visible only to the participating entities of a transaction.
• *Automation:-*	Smart contract enable automatic execution of transaction when triggered with specific conditions.

The extent to which a blockchain exhibits these characteristics depends on the deployment model. According to mode of deployment blockchain are categorized to: *public, private and consortium blockchain* [5].

Public blockchain: - Public blockchain allow anyone to participate in transaction execution and verification. Here a set of volunteering computers around the world act as decentralized public network. The consensus protocol ensures the integrity of the ledger content. Public blockchain are "fully decentralized" and offers the highest level of security. Etheruem and Bitcoin blockchain are example of public blockchain.

Consortium Blockchain: - A blockchain constituted and maintained jointly by multiple organization (stake holders) for cross organizational business and data transfer. The transaction and consensus execution rights are limited to permissioned nodes. Some consortium systems allow public to view the records. Consortium blockchain are "partially decentralized" and offers a secure platform for multi-organizational business. Hyper ledger technologies are generally preferred consortium blockchain.

Private Blockchain:- It's a permissioned blockchain operates in a closed network set up by an organization. The organization decides who can write and read from blockchain. Mainly used for database management and auditing.

The choice of blockchain depends on the business requirements and the features that offer. Table [1] summarizes the comparison of these three blockchain models (Zheng et al., 2018).

Table 1 - Comparison of Public, Private and Consortium Blockchain (Zheng et al., 2018).

Property	**Public Blockchain**	**Consortium Blockchain**	**Private Blockchain**
Centralized	No	Partial	Yes
Immutability	Highly Immutable	Can be Tampered	Easily tamperable
Consensus Method	Permissionless	Permissioned	Permissioned
Consensus determination	All miners	Selected Set of nodes	One organization
Read Permission	Public	Could be public or restricted	Could be public or restricted

3. Blockchain in E-Governance

Government authorities are responsible for managing and holding many official records of both citizens and/or enterprises. Individuals have to entrust government to ensure security and privacy of these documents. Blockchain enabled applications can transform the way of management of these documents through disintermediation, secure and immutable record keeping (Reijers et al.,

2016). Block chain can make public services more efficient and corruption free through automation and accountability. Block chain enabled governance aims at providing the public services in a decentralized and efficient way while maintaining the same validity. This section analyzes the blockchain use cases in different sectors of public life. Table [2] list out some of the public sector domains where the blockchain based platforms are highly adopted and the remainder of this section discusses the potential use cases of blockchain in these domains.

Table 2 - E-governance Sectors and Sample Use Cases

E-Governance Sector	**Applications**
Public Administration	-- E-voting, Digital Identity
Healthcare	--Management of Health care records, Pharmaceutical Supply Chain
Agriculture	--Food-Agriculture Supply chain, Agriculture marketplace
Education	--Certificate management, Reward-reputation system
Energy Distribution	--Smart grid management, Peer-Peer Energy market, Electric Vehicle Charging

Public Administration Applications

Establishing transparent and secure voting system is a challenge to any democratic system. Setting up and conducting voting process using Electronic voting machines(EVM) and paper based ballots requires huge time and resources'-voting has been considered as a promising method for many organizations, as that speed up voting processes, simplify and reduce the cost of elections. However, existing e-voting systems rely on centralized authorities that can threat the trust and confidentiality of voting system. Blockchain based e –voting solutions are promising in this context. The West African country Sierra Leone pioneered in utilizing blockchain technology for conducting a public election. They conducted a pilot study jointly with Agora (2017), a block chain based platform for digital voting. It uses a permissioned blockchain called Bulletin boards to record and store votes. The bulletin board consists of write-permissioned nodes operated by Agora to record votes of individuals, witness nodes operated by third parties and read-only nodes accessible to all users for verification of votes. The periodic snapshot of bulletin board is recorded on Bitcoin blockchain. Open Vote Network (Patrick et al., 2017) another distinguishing e-voting application built on Etheruem blockchain. Every user possesses two cryptographic keys for verifying identity and to record vote. The final vote is computed from all submitted votes and made available through publicly accessible functions. Even many other blockchain based e-voting methods are available in literature, but all these technologies are confined to electoral process in small-medium level organization.

Another threat area in public administration is the issue and management of Digital Ids of citizens. Individual possess multiple digital Ids like passports, electoral Id, health card, pan card etc. to avail services from varying sectors. Identity information's are stored in centralized databases under the control of government or sometimes third party service providers. These databases are vulnerable to cyber attacks and often lead to identity theft. The individuals have limited control on the storage and access of their data. Blockchain based Identity management system are found effective to address these issues (El Haddouti and El Kettani, 2019). Blockchain facilitates self-sovereign identity where the individual have the complete ownership of their identity (Naik and Jenkins, 2020).An individual can control access to the identity and can decide how much information is to be disclosed. The Digital ID & Authentication Council of Canada (DIACC) is progressing with the development of blockchain based Canadian digital identification ecosystem (Wolfond, 2017). Bitnation, a blockchain initiative founded by Susanne Tarkows explores the capacity of blockchain to solve migrant issues and issues emergence Ids for refugees.

Applications in Education

Education sector has many potential use cases for utilizing Blockchain technology. Meng & Zhigang (2018) propose blockchain-based educational records verification system. The universities issue digitally signed certificates through a blockchain platform. The students can share the certificate with companies/other institution and the verification can be performed by tracking the transaction recording the issue of certificate. Along with elevated security the system provides self-verifiability and transparency. Blockchain based educational reward and reputation system (Sharples and Dominguez, 2016) used "learning is earning "method. This system uses a crypto currency Kudo for crediting academic achievements of students.

Applications in HealthCare

Blockchain has wide range of applications in healthcare like secure storage and sharing of electronic medical records, medical supply and drug traceability, biomedical research; remote patient monitoring etc (Agbo et al., 2019). Advancement in digital technologies has influenced the mode of operation of health care service and corresponding data storage. Hospital automation and increasing popularity of online patient consultation etc. transformed the way of storage and access of Electronic Health Records (EHR). Sharing health records of an individual between hospitals and ensuring their

validity is often a difficult process. The majority of blockchain applications in healthcare sector are deployed for addressing this issue. All these methods propose a blockchain based storage of healthcare records where an individual have the privilege to share his details whenever needed. The government of Estonia has enabled all healthcare services to its citizen through blockchain technology developed by Guardtime (Mettler, 2016). MeDShare (Xia et al., 2017) and MedBlock (Fan et al., 2018) are some other blockchain based applications to manage the storage and access of EHR by different stake holders like hospitals, insurance companies, researchers etc.

Blockchain technology is utilized in Pharmaceutical Supply chain Management (Bocek et al., 2017) to ensure the quality of transportation of drugs from manufacture to end points and to identify substandard/fraud drugs. One another use case of blockchain in healthcare is to ensure integrity and accuracy of clinical trials by researchers (Shae and Tsai, 2017). The clinical trial reports are automatically fed into a blockchain system which offers tamper-proof storage. The blockchain system prevents falsification or modification of data at a later stage of clinical trial in order to establish the success of the trial. The data owners can share the data for peer verification and can provide transparency in the system.

Applications in Agriculture

The use cases of blockchain in agriculture is mainly on three categories: food and agriculture supply chain, agribusiness and agrifinance (Kim and Laskowski, 2018). The blockchain based supply chain applications offers provenance tracking across various stages of agricultural products and eliminate the cases of food fraud and contaminated from. The Wallmart-IBM food ecosystem (Popper and Lohr, 2017) and Agriledger (2017) comes under this sector. The Farmshare (William E. Bodell, 2015) is a blockchain based platform for creating local communities and virtual markets, where the formers can trade directly with customers and can avoid exploitation by intermediaries. The platform uses a native currency farm share token for trading. The agri-supply chain platform Agridigital (2017) extends its service to commodity transaction. The system automates all the process in commodity transfer which includes buyer and seller verification, quality assurance and transportation.

Applications in Energy Sector

The evolution of local- small scale renewable energy generations challenges the capability of traditional centralized energy management systems. The distributed energy resources and integration

of IOT technologies for metering energy production and consumption demands a decentralized platform for managing and trading energy, which lead to the wide adoption of blockchain technology in energy sector. The prime use cases of blockchain in energy sector are: Smart grid management, peer-peer energy trading, decentralized energy markets-vehicle charging and certification of energy products (Bao, 2020).

The Brooklyn Microgrid project is reported as the first blockchain based platform for peer-peer energy trading (Mengelkamp et al., 2018). The platform allows creating virtual market place for trading energy within local community consists of prosumers and consumers. The system provides real time statistics of energy production and consumption, negotiation and automated trading through smart meters. In 2018 the Chilean National Energy Commission (CNE) announced a blockchain projectto track information related to the national electricity such as installed capacity, medium-micro scale energy generation capacity, average market prices, marginal costs, hydrocarbon price etc (Cointelegraph, 2018). The system utilizes Etheruem blockchain to record the data and transactions. The increasing popularity of electric vehicles demands a charging infrastructure with distributed charging piles with automated transaction capabilities. Huang et al. (2018) proposed a blockchain based framework for secure transaction for Electric Vehicle charging. Juice Net (Su et al., 2018) a peer-peer charging network in North America use blockchain platform use the concept of sharing and charging. The system maintains a distributed network of charging stations, including home charging points, in which the users credited when others use the charging location they shared.

4. Benefits from Blockchain

This section analyzes the top benefits associated with blockchain over traditional centralized application platforms. Blockchain offers trusted record keeping mechanism through cryptographic and distributed computing platforms. The decentralized and immutable storage structure along with transparent access monitoring capacity makes blockchain suitable for data management applications. The prime reason behind the adoption of blockchain technology is security. Other factors include decentralized governance, verifiability, transparency and capability for automation. Table-3 summarizes the key benefits the particular use cases derived from blockchain platforms.

Table - 3 Benefits Derived from Blockchain based Application over Traditional System

Application	Traditional System (Constraints)	Blockchain Based platform (Benefits)
E voting	• Lack of Trust due to Centralized architecture. • Time consuming and Labor intensive task	• Decentralized storage and verification process enhance trust • Increased Transparency • Reduced cost and labor
Digital Identity	• Centralized data store vulnerable to data leakage • Difficulty in Verification • Less privilege to user in access control	• Decentralized and immutable storage • User centric storage and access control • Verifiability without disclosing confidential information
Electronic Health Record Keeping	• Difficulty in integrating information from multiple databases • Difficult to ensure authenticity and integrity	• Decentralized storage system with multiple stakeholders • Cryptographic and Consensus protocols ensures authenticity and integrity
Pharmaceutical Supply Chain	• Limited access privileges to users • Difficult to streamline the processing and integration of information from multiple sources • Transaction verification and settlement is time consuming • Lack of traceability	• User centric access control • Streamline operations through a decentralized platform with access to multiple stakeholders • Smart contract enabled automatic transaction execution and settlement • Improved traceability
Food-Agri Supply Chains	• Lack of interoperability between the participants of supply chain • Centralized storage of information lack in integrity and transparency of data • Transaction verification and settlement need is time consuming	• Decentralized data store accessible to stakeholders and integrity ensured through consensus protocols • Smart contract enabled automatic transaction execution and settlement
Agriculture marketplace	• Presence of intermediaries - Difficulty to establish trust between transacting parties • Difficulty in verification of transaction records	• Disintermediation • Provenance Tracking, disintermediation • Peer to peer transaction and immutable record keeping
Certificate Management	• Difficulty in integrating information from databases under multiple authorities • Time consumed verification process	• Decentralized platform with immutable storage mechanism • Provenance verification is easy
Academic reward-reputation system	• Difficult to ensure correctness and transparency of rewarding system • Difficulty in verification of data	• Ownership and access privilege rights granted to individuals • Automated crediting and rewarding mechanism through cryptocoin • Verification of data through shared ledger
Smart grid management	• Difficulty to incorporate Distributed Energy Resources • Hard to trace and verify data and transactions	• Distributed ledger with decentralized authority • Digitally signed transaction • All transactions are visible to stakeholders
Peer-Peer energy Trading	• Difficult to ensure trust between transacting parties • Time consumption in verification and settlement of transactions	• Trusted platform for peer to peer transactions • Disintermediation and support direct negotiation between buyer and seller • Smart contract enabled automatic transaction verification

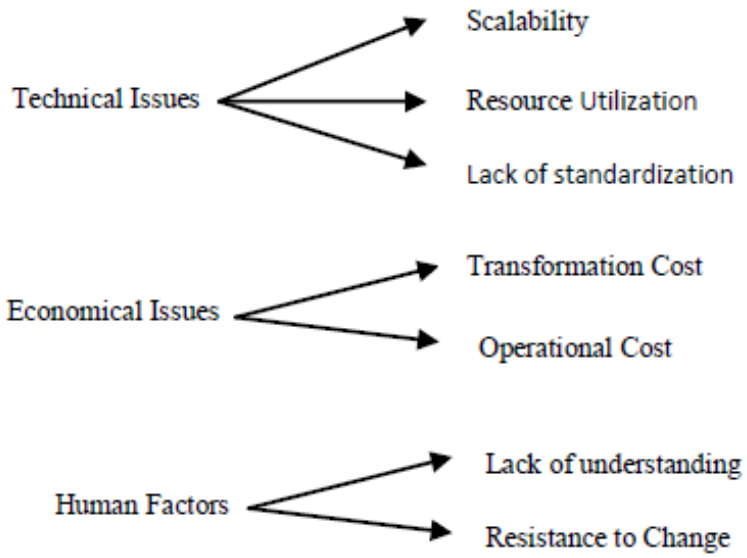
The cryptographic protocol in blockchain ensures the authenticity and integrity of data. Transactions are recorded in write-only manners which contribute to trust and transparency of transactions. Consensus protocols ensures the integrity of data in distributed storage and act as the backbone for ensuring fault tolerance. This eliminates the need of third parties for transaction verification.

Another driving feature that attracts industry and business towards blockchain is the capability of automation through smart contracts. Business logic expressed as smart contracts facilitates automatic execution and management of workflows up on this trusted platform. Thus business can be benefitted with increased efficiency and reduces the time and cost of business operations.

5. Blockchain Limitations

Literature related to block chain application revealed concerns about the limitations of block chain technology on various application domains. As shown in figure-4 the factors that restrain the wider adoption of blockchain is mainly categorized into three: Technical issues, Economical and Human Factors.

Figure 4 - Limitations of Blockchain



Technical challenges pertaining to block chain are primarily associated to the architectural elements of blockchain itself. The authors of (Zheng et al., 2018) cited Scalability, Resource utilization, Interoperability as the top limitations.

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The major hindrance for adoption of blockchain technology is Scalability (Schatsky et al., 2018). The initial design of blockchain was not drafted for wide scale use and adaptation, and the current blockchain technologies are not suited for high frequency transactions. According to the operating principle of blockchain transaction, validation needs consensus of all nodes in the network, and as the number of transaction increases the time to reach consensus also increases. The typical processing speed of Bitcoin network is 3-7 TSP and that of Etheruem is 10-20 TSP only. Blockchain designers are exploring new consensus protocols and technologies for improving transaction processing time. *Off-chain* recording and *sharding* are some solutions for accelerating transaction execution. Huge resource utilization and power consumption is another area for improvement. The distributed consensus protocols like Proof of Work and Proof of Stake needs the participation of every node in the network to reach consensus and demands high computing power.

Lack of standardization is another barrier to the adoption of blockchain (Imran,2018) No standard protocols are defined to facilitate the integration with existing system and even the communication between two blockchain platforms is quiet difficult. Standardization could enhance interoperability and data exchange between different blockchain platforms. In order to set up standards for blockchain platform a technical committee ISO/TC 307 has already been constituted.

Considering the economical aspects, the migration from legacy system to blockchain platform needs significant investments and effort (Schatsky et al., 2018). Huge upfront investment is required for setting up a blockchain platform. Also Blockchain is not a suitable choice for applications that requires frequent updates on data, as every update is to be approved through consensus protocol and the execution is costly. Proper investigation of business benefits expected from blockchain integration and cost of installation and operations to be performed before jumping into implementation. Leading cloud providers are now offering Block chain as a Service, and allow customers to choose a plan suitable to their scope and budget.

In addition to these technical issues there exist barriers related to human elements and corporate culture. The migration to block chain technology demands updating of business process which the corporate are reluctant to initiate. Lack of understanding of the technological aspects and misconception are other factors restraining adoption of blockchain to business and industry.

6. Conclusion

Even though blockchain was introduced as a technology for enabling crypto currency, presently it’s widely adopted by many other application domains. The decentralized architecture and

inherent security property enhances the diffusion of block chain into diverse domains. These studies focused on the application of blockchain in E government sector and elaborate how block chain technology is interfaced to provide secure and transparent services to public. The study explored the potential characteristics and challenges associated with block chain based E governance applications. Identification of specific requirements for individual application domain enables the stakeholders to choose the proper blockchain platform. The factors limiting the wider acceptance of blockchain are also identified. Further researches and technical advancement in blockchain will help to rollout more and more e-governance applications on blockchain platform.

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