An Empirical Analysis of using Blockchain Technology with Internet of Things and its Application

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Abstract. Blockchain technology uses the cryptographic technique to create expanding list of data records called blocks. Along with transaction and timestamp data, each block holds a hash value obtained using cryptographic technique. Blockchain gains importance for its decentralized data transaction and authorization without the need for third-party intervention. Although, it is mostly used in Finance sector these days, due to its inherent ability to protect data it can be applied to every field of computation especially in fields where data transaction is voluminous. Internet of Things (IoT) is one such area where it involves collection, transfer and processing of real time data from objects, humans and sensors to automate various tasks. Hence, this paper reviews the blockchain technology, and how it can be coupled with IoT to overcome the privacy and security issues. This paper first systematically introduces the concept of blockchain technology, its applications along with the need for IoT devices and its implementation. Finally, it discusses the blockchain based IoT (BIoT) its architecture, advantages, challenges in implementation.

Keywords: Blockchain, IoT, Review, BIoT, Applications

1   INTRODUCTION

Technological innovations take a quantum leap once in every few decades, which opens new horizons of innovation, techniques and applications. Blockchain technology and Internet of Things are such paradigms, which has already started proving its pivotal presence in many fields. The future of these emerging technologies is inevitably a major factor that would influence the human life for years to come. On one hand, Internet of Things is expanding at a faster rate [1] and there is a prediction [2] that by the year 2020 Internet of Things will surge our lives with more than 50 billion devices apart from the gadgets what we use in our daily life like laptops, tablets and smartphones. However, research [3] has pointed out that security issues like privacy, authorization, data management and access control as major pitfalls in the IoT implementation. Studies [1, 4, 5] have discussed that usage of blockchain technique in IoT applications can help overcome the impediments of security issues and privacy concerns.

This paper conducts a systematic review of using blockchain technology with Internet of Things along with the areas of application. The remaining section of the paper is structured as follows. Sect. 2, describes the blockchain technology, its basic functioning, types and applications. Sect. 3, introduces the Internet of Things, its application, future market trend and the various challenges in implementing IoT. Using blockchain with IoT and its architecture, advantages are discussed in Sect. 4. Sect. 5, deals with the challenges in implementing BIoT and gives an overview of widely used commercial BIoT products available in the market. Finally, in Sect. 6, concluding remarks are provided.

2   BLOCKCHAIN TECHNOLOGY AN OVERVIEW

2.1   Basic Functioning of Blockchain

Bahga and Madisetti [6] define blockchain as a collection linked transaction records generated by different actors in a network like consumers, suppliers, service provider etc., which is maintained in public ledger and a distributed environment. Blockchain works in a peer-to-peer network and hence doesn`t need a central authority to authorize or monitor the transactions [1]. An anonymous person named Satoshi Nakamoto in 2008 found the concept of blockchain for the operation of public transaction ledger of the crypto currency Bitcoin [7]. In 2013, second generation blockchain called Ethereum was introduced [1, 8].
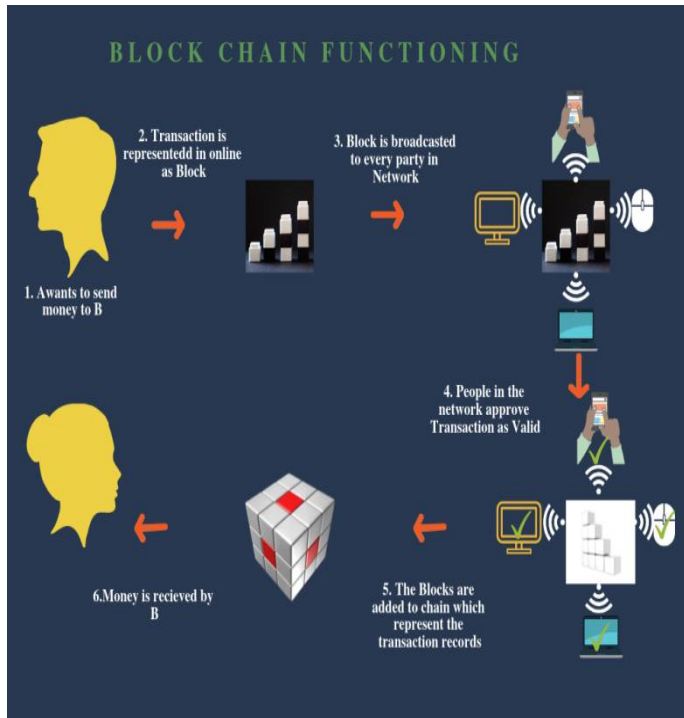
Fig. 1. Functioning of Blockchain

Fig. 2. Implementation of Blockchains

Ethereum allowed for the implementation of blockchain as executable unit using high-level programming languages [1, 9] for various applications. As all the transaction on the blockchain database is authorized by the participating users, trusted third party verification is not needed [6] and hence works in a decentralized environment. Fig. 1 shows the diagrammatic representation of the working of the blockchain. As an example, let us see a scenario in which 'A' wants to send money to 'B'. The transaction is represented as blocks through online. The block is broadcasted to all the associated parties in the network. People in the network approve the transaction as valid. The blocks are combined to form a chain of records, which represent the transaction history. Finally, the money is sent to 'B'.

How Blockchain Works. More like a traditional ledger a blockchain is a sequential list of blocks, which contains all the transactions records [8, 10]. Fig. 2 shows an example of a blockchain and the application of hash function to input data to obtain the hash value. The first block in any blockchain has no parent block and therefore it is called genesis. In Ethereum, the successive blocks are linked with one another using hash value.

Block. A block composed of the block header and the block body as shown in Fig 2. In general, the block header contains: (i) Block version: This specifies the set of validation rules to be followed [8,11].
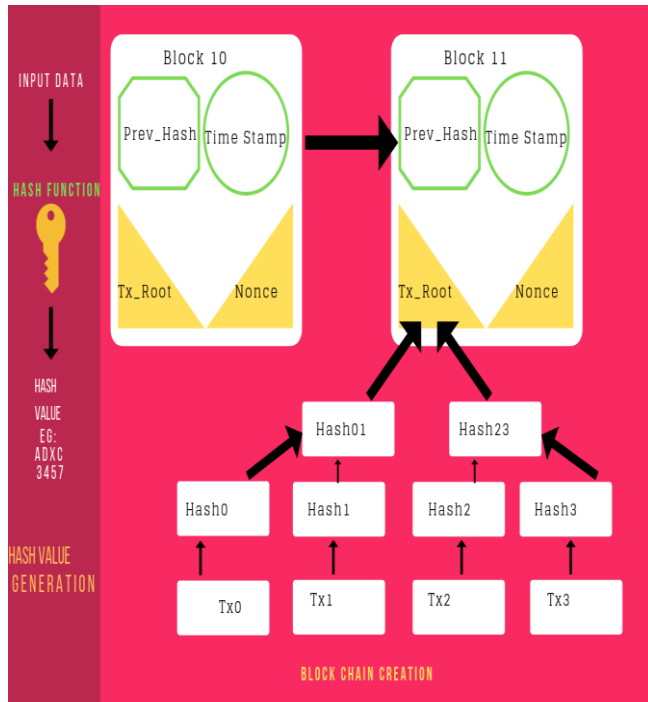
(ii) Merkle Tree Root Hash: This contains all the hash value associated transactions in the block [8, 10].

(iii) Timestamp: It holds the then current time up to seconds in Universal time during the block creation [8, 10].

(iv) Nonce: It is a 4-byte field, which initially has a value 0 and is incremented after the calculation of every hash function [1, 8, 11].

(v) Parent block hash: It is a 256-bit hash value, which links to the previous block in the block chain [8].

The body of the block contains the transactions and transaction counter, which is incremented for each transaction [8]. Size of the block and size of the individual transactions determines the maximum number of transactions a block can hold. The validation and authorization of the transactions in a block is carried out by using asymmetric cryptography techniques. As most of the transactions are vulnerable to security attacks the Digital Signature, technique using the asymmetric cryptography is applied to counter the security attacks [12, 8].

Digital Signature. Every user in the network has two keys, one private key and one public key [1, 8]. The private key is used to sign the transactions; it is a confidential key and hence not shared with anybody. The transactions signed digitally using private key is broadcasted to the whole network. Usually the digital signature works in two stages: signing stage and verification stage [8]. For example, 'A' wants to send a message to 'B'. In the signing stage, 'A' encrypts the data with the private key and sends the encrypted value along with the original data. In the verification stage, 'B' checks the validation of the received message using the public key of 'A'. This way receiver 'B' checks for the integrity, correctness and validity of the message received.

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2.2 Different Types of Blockchain

Blockchain can be divided in to three main categories viz. Public blockchain, Private blockchain and Consortium blockchain [8].

Public Blockchain. As the name suggests this type of blockchain is public and hence nobody controls the network. Anybody who is a part of network can read, write or verify the transactions in the decentralized environment. As there is no central authority, algorithm like *proof of work* or *proof of stake,* [8] are used to authenticate the transactions carried out. This type of blockchain is very transparent and anybody who participates in the network can view or evaluate anything at a particular point of time [8, 13]. Typical examples of this type of blockchain include Bitcoin, Litecoin, and Ethereum etc.

Private Blockchain. Though the working mechanism of private blockchain is similar to public blockchain, the main feature that distinguishes it from public block chain is the access control by a central agent [1]. Hence, it is more like a centralized data base system, where a central authority decides about giving access to other entities in the network [13]. This type of blockchain is privately owned by organizations. Though it is centralized and the rights are delegated through a trusted party what makes it effective is the usage of cryptographic techniques to carry out the transactions. Bankchain, Hyperledger are examples of private blockchain.

Consortium or Federated Blockchain. This type of blockchain ecosystem is characterized by the use of group companies in delegating the rights and formulating the standards. This is more like private blockchain, except for the inclusion of group of organizations or their representative individuals who take a collective decision to improvise the standard of the blockchain operation [14]. This group of organizations is called consortium or federation therefore this type of blockchain is also called federated blockchain. R3, EWF blockchains fall under this category.

2.3 Applications of Blockchain

However, blockchain technology was devised mainly for crypto currency this state of art technology due to its potential for extendibility, scalability and inclusiveness has been studied for applications in various fields. For instance, banking, smart contracts, distributed storage are some of the new areas where blockchain application is very useful. Studies have associated the advantages of using block chain in Human resource management [15], Smart governance [9], improving security in distributed system [16], E-Governance [4] and IoT [17]. Blockchain can be applied to any field where there is a need for decentralized, unsupervised transaction. Apart from providing authorization, blockchain provides privacy and security to the collected data.

2.4 Blockchain and Crypto Currencies

Blockchain is the enabling technology for the operation of crypto currency. Crypto currency is a digital asset, which uses the strong cryptographic algorithms for its operations such as asset transfer, control and audit [9]. As the functioning of crypto currencies uses a decentralized and distributed ledger, it is well supported by the blockchain concept. The process of verifying and validating various transactions and adding them to the digital ledger is called mining [6]. For carrying out this task successful miners are rewarded with crypto currency. The reward reduces the transaction fees through the generation of incentive by providing increased processing capacity of the network [16]. Some of the miners pool resources, by allowing their processing capacity to be shared over a network. They are rewarded based on their contribution in finding a probable block. When a proof-of-work is presented, a share is allotted to the mining pool members. Some of the major crypto currencies are Bitcoin, Ethereum, Litecoin, Stellar and Dogecoin [16].

3 Internet of Things An Introduction

3.1 Need for IoT Devices

Bagha defines Internet of Things as a network and interconnection of various devices such as vehicles, sensors, software that allows collection and transfer of data among themselves through which objects can be operated and monitored remotely [23]. The need for IoT is inevitable as it helps in automation of tasks in industries, home, parking, hospitals and many other fields [24]. IoT will have a strong presence in the future, because of its ability to do ubiquitous computing and control objects remotely through internet connection. The advantages IoT can provide are limitless; the application of IoT in various fields would change our working way and life style by optimizing resource utilization and saving time. IoT has already opened new possibilities for market, growth, and exchange of information among various entities.

3.2 IoT –Market Perspective

It is estimated that 1.9 billion smart homes will be shipped by the end of 2019 [18]. It is predicted that in the next few years the cloud based IoT business may give a global revenue of 490 billion US dollar [19]. Business giants like Google and Samsung are keen on providing IoT solutions to its customers, which is evident from the acquisition of Net Labs by Google and SmartThings by Samsung [20]. In near future IoT devices will have deeper percolation in manufacturing, industrial automation, business, wearable devices and healthcare [21]. Global growth of IoT is forecasted at 6.2 trillion US dollars with maximum revenue from health care by the end of 2025 [22].

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3.3 IoT in Various Domains

Internet of Things has started proving its efficiency in utilizing consumer households. Automated Door Bells, Smart Home, Smart Baby Monitoring, Tracking Energy Usage, Controlling Switches are some of the areas where IoT is being used widely and becoming affordable for usage. IoT has a strong presence in the industrial automation process, which could provide both monetary benefits and process optimization. The connected devices in IoT use sensors and the Internet to collect and transfer data among one another and with users, associating the physical and virtual worlds inside homes [25]. One of the main applications of IoT is in the medical field where critically ill patients can be monitored for vital signs even from a remote place. Other applications include movement tracking using GPS, tracking energy consumption at home, tracking the route of vehicles etc. [26].

3.4 Challenges in IoT Implementation

However, IoT provides many advantages it comes with the price of privacy risk [27]. The security and privacy risks in IoT need to be addressed to provide better solutions [28]. When the vulnerabilities in IoT environment are exploited, there will be a great loss in terms of authenticity, integrity, security and confidentiality [29]. While implementing IoT the privacy and security of the data must be the prime concern [30]. Providing appropriate notice and choice mechanism is also a challenge in IoT devices [31].

4 Blockchain and IoT Platform

4.1 Use of Blockchain Technology in IoT Devices

When the traditional client-server model is used in IoT environment, it can create problems in synchronization, security and privacy. To overcome these issues blockchain can be incorporated with the IoT systems [32]. Dorri et. al proposed that when blockchain is used with IoT, especially in Smart Home it resolved the security relates issues like confidentiality, integrity and availability [33]. Because of the decentralized mechanism when blockchain is used within IoT ecosystem it helps to handle configuration of devices, help in storage of sensor related data and enable micro payments in a secure way [34].

4.2 Advantages of Using Blockchain with IoT

Using blockchain with IoT has many inherent advantages [35]. Some of the major advantages are listed below.

Adaptability. The fusion of blockchain technology with IoT applications is compartively easy and does not require complicated intermediate blocks. The cross platform communication among devices with blockchain can be easily implemented with middle ware technologies [35].

Scalability. Even when the number of IoT devices or sensors in a network increases, it is easy to accommodate these devices with the extension of blockchian features [1].

Security. This is the prime motive behind the combination of blockchain and IoT technologies [7]. Researches have proved that blockchain provides solutions for security issues in IoT like Denial of Service (DoS) [33], Authorization [19], Identity management [28] and data protection [33].

Consistency. When the blockchain is used with IoT the data is throughout the system is consistent. Hence, it assures the integrity of the data. Blockchain can also be used in autonomous administrative IoT system or domains. Adhering to the blockchain rules every domain in the network can act independently to manage the IoT devices [17, 35].

4.3 Architectures for Blockchain IoT (BIoT)

Researches [36, 37] have devised blockchain based IoT lightweight architectures to reduce the communication induced overhead in the network. These architectures concentrated more on smart homes. This architecture was divided in to three layers: Home Layer, Network Layer and Cloud. The home layer has sensors, interconnected devices and storage system for locally collected data along with blockchain features. The network layer has provisions for connection of devices with the internet. Cloud is used for storage of the collected data. Li and Zhang proposed a multi-layered IoT architecture based on Blockchain [38]. As an improvement some changes were made in this architecture and the use of fog computing was proposed to attain better optimization [34]. A different architecture incorporating edge computing in the blockchain based IoT was proposed by [39]. Further research that is being carried to control the distributed automation control systems grounded on a distributed, hierarchical architecture, which is based on the IEC 61499 standard is described [1, 36].

4.4 Applications of BIoT

Blockchain can be used with many IoT applications that includes Health Care [30], Smart Home [25, 33, 34], Smart Contract [1], Smart City [20], Supply Chain [25], E-Governance [4]etc. Industrial automation is one of the major areas where BIoT finds its application. Some researchers have proposed the need for inclusion of Big Data with the BIoT solutions to control and effectively use the massive amounts of data collected in IoT ecosystem [40].

5 Implementation of BIoT

5.1 Different Consortium for BIoT

Reyna et. al found that the BIoT consortium are very less and opined that it is need of the hour to for consortiums for BIoT research to regulate the various factors affecting the implementation of BIoT [41].

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Chain of Things. It is a consortium, which is aimed to provide security for IoT applications using blockchain [42].

Trusted IoT alliance. It is an open source foundation formed to create, secure, cross-platform application which is easily scalable using blockchain in a trustworthy IoT ecosystem [43].

5.2   Commercial Products on BIoT

There are many commercial BIoT products available in the market [44]. Some of the important BIoT products with its purpose and area of applications are listed below.

Waltonchain. It is an application created with the combination of RFID and blockchain technology. It is used for data sharing in business environment with extreme transparency and provides a trustworthy IoT ecosystem.

Ambrosus. This application is centered on the food and pharmaceutical industries. It aims to optimize the supply chain by providing secure and seamless floe information among sensors, distributed ledger and servers, thus providing effecient transactions.

IoT Chain. IoT Chain (ITC) is designed as a lightweight Operating System using the blockchain, which allows the transaction using layered architecture, and allows the data storage in a decentralized environment also provides data protection.

Power Ledger. This is focused on the energy sector and provides an interoperable trading platform, which focuses exclusively on the energy sector applications.

Block Mesh. It is a platform, which concentrates on the communication among IoT devices. It supports the mesh-based devices connected in the IoT environment.

IoTeX. The focus of this product is on improving the privacy of the IoT applications using blockchain. It provides solutions for decentralized transactions on IoT devices.

5.3   Challenges of Implementing BIoT

Though there are many benefits in using blockchain with IoT, there are some challenges in the development and deployment of the BIoT applications [1]. Technical integration with relation to scalability, cryptographic algorithm overhead, standardized development of products is the foremost challenge [3]. Interoperability is another major challenge, which requires various amendments and consensus among all the stakeholders involved in the BIoT landscape. Legal compliance and government regulations will be a great challenge in developing BIoT applications [2, 27]. As new products will

be developed, real time testing to ferret out the possible malfunctioning will be an impediment [37].

CONCLUSION AND FUTURE SCOPE

This review presented the overview of blockchain technology with its functioning, and how it can be combined with Internet of Things to overcome security and privacy issues in the IoT environment. This review also discussed the architecture, challenges and applications of BIoT applications. As this state of art, technology is booming various other factors needs to be studied. For instance, the user perception of the BIoT applications, long-term effect of the process optimization in industries and the effect of government regulations in shaping the BIoT applications needs a thorough study. This work can be extended by narrowing down its area of research to Smart Homes. Smart homes are one of the promising areas of application of IoT. As discussed in this paper the security in the smart homes is one of the major bottlenecks, which limits its usage. Hence, in future this paper aims to provide innovative and novel system for smart homes using blockchain and IoT to overcome the existing issues.

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