Blockchain in IoT Networks for Precision Agriculture

Rashi Tanwar, Yogesh Chhabra, Punam Rattan, and Sita Rani

Abstract With the increase in research and development in communication technology, it is predicted that more and more number of sensing devices will be added in various sectors by application of IoT. Therefore, there is an immediate need of replacing the traditional methods of storing, sorting and sharing of data that has been collected from various sensing devices (Chiang and Zhang in IEEE Internet Things J 3:854–864, 2016), (Lee et al. in Comput Electron Agric 74:2–33, 2010). This will help in making data more transparent, reliable, decentralised and immutable. This has led to the integration of blockchain into IoT systems. The upcoming section gives a vivid picture about the basic concept and feature of blockchain technology and thereby detecting various advantages of integration of blockchain into IoT.

Keywords Internet of Things · Blockchain · Ledger · Precision agriculture · Smart contract

1 Introduction

Blockchain theory was invented by Satoshi Nakamoto in the year 2008 in context to Bitcoin transactions for making these transactions independently auditable, verifiable and transparent [3]. Blockchain is defined as a "decentralised distributed Ledger for sorting timestamp transactions between many computers in a peer-to-peer network". The designing of blockchain basically can be summarised as stacking of records which are formally known as blocks (Fig. 1).

R. Tanwar · Y. Chhabra
CT University, Ludhiana, Punjab, India
e-mail: Dryogeshchhabra3012@ctuniversity.in

P. Rattan (✉)
School of Computer Applications, Lovely Professional University, Phagwara, India
e-mail: punamrattan@gmail.com

S. Rani
Department of Comuter Science and Engineering, Gulzar Group of Institutions, Khanna, Punjab, India

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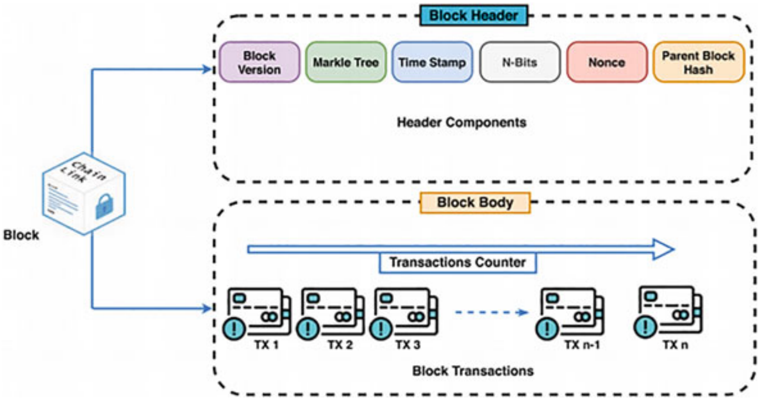

Fig. 1 A typical block design

The blocks contain a peculiars hash value which is the unique identification of the block and the first block in the chain is known as Genesis Block [4]. The blocks are connected to each other through cryptographic methods. Furthermore specifically, each block must contain a set of confirm transactions, a timestamp and a hash code of the last block. A single block unit consists of block header and block body. A P2P network and a public time stamping server autonomously controls this blockchain ledger making the entire block steam system transparent and decentralised for tracing and securing transaction workflows [5].

1.1 Features of Blockchain

The four main feature of blockchain system is summarised below.

1.1.1 Decentralisation

The use of ledger based on P2P network makes the system transparent and decentralised [6]. It makes additions and verification of block transactions in such a way that all nodes function altogether in a peer-to-peer fashion in the blockchain-based communication process.

1.1.2 Anonymity

Participants willing to communicate through a blockchain communication system need not reveal their real identity as they can communicate with a virtual identity code [7]. However, this feature of blockchain is one of the major security and privacy concerns related to blockchain transactions.

1.1.3 Persistency

The decentralisation of transaction through blockchain also adds to its persistent nature [4]. Persistency refers to the fact that in a blockchain system any identified transaction which is added to the block once cannot be rolled back. It also features the identification of invalid transactions immediately.

1.1.4 Auditability

The tracking of transactions that makes the blockchain system persistence also adds to the auditability feature [8]. The secure linking of one block to the previous block makes the blockchain system easy to be verified and tracked.

2 Review of Literature

2.1 Integration of Blockchain and IoT

Integration of IoT with blockchain is a revolutionary change that is expected to happen in various domains. The application of the distributed ledger-based P2P system across various heterogeneous IoT networks have attracted many researches to focus on this aspect [9]. It is estimated that the integration of blockchain into IoT-based environments will enhance the economic value of IoT by 176 billion dollars in 2025 which is further expected to raise up to 23 trillion dollar in 2030 [10]. The integration of blockchain distributed ledger in the IoT devices will play a major role in determining how the IoT devices will be linked together for further ease of collecting sorting and storing data [11]. It will also facilitate cost reduction, trust building and accelerating transactions. This has therefore led to identification of various design patterns by the researchers for integration of blockchain in IoT. Thereof the majorly identified design patterns in this context are discussed below

i. **IoT to IoT design pattern:** In this design pattern, the major communication process occurs outside the blockchain as the blockchain only helps in storing data in the IoT devices [12].
ii. **IoT to blockchain design pattern:** This design pattern has blockchain in a bit more integrated manner. The block chin here functions for storing of data along with monitoring and managing transactions [13]. Therefore, this design pattern allows IoT transactions to go through blockchain making it highly appreciated because of the guaranteed traceability empowered by blockchain in the IoT

network. Furthermore, it also is extremely helpful in establishing successful transactions between a variety of IoT devices in varying domains.

iii. **Hybrid design approach:** This design approach is amalgamation of mission of IoT with high throughput data analysis techniques such as artificial intelligence, fog computing along with blockchain [14]. In this approach transmission of data to the cloud is not required as data manipulation occurs in the IoT device itself. Artificial intelligence helps in critical decision-making by the IoT devices [1] and the blockchain provides secure links for the edge computing approach [15]. However, the use of only artificial intelligence and blockchain in the IoT network requires a huge volume of data transmission in a secure and reliable manner. This limitation could be sorted by the use of fog computing as it helps in reduction of the bandwidth amount and thereby hastening the blockchain mining operation [16].

2.2 Blockchain Mediated IoT Networks in Precision Agriculture

As stated in the above sections, it is quite evident that the integration of blockchain in the IoT network enhances the overall efficacy of the agricultural IoT networks [17]. The same has been witnessed in case of IoT-based precision agriculture. Blockchain has introduced many new opportunities in the IoT-based smart precision agriculture systems. Therefore, the current times have seen a boom in literature that has defined many applications of blockchain mediated IoT networks for precision agriculture. This integration provides the following advantages in agricultural sector.

i. The distributed ledger system helps in building a secure and smart connection between various IoT devices thus enhancing IoT network security [18].
ii. Blockchain is able to extend the address space for the IoT networks thereby enhancing the scalability of IoT networks for agricultural usage [19].
iii. Blockchain helps in keeping a track on the end-to-end process by generating unique identities and managing access to agricultural IoT devices. This also helps in building data transparency [20].
iv. Blockchain can enhance performance of IoT devices by defining communication rules between sensors that are embedded in the agricultural IoT devices such as humidity sensors or sensors for different soil parameters [21].
v. As the devices are registered with a unique code in the blockchain system, the integration of blockchain into IoT helps in making the IoT transactions more authentic by developing authorization of IoT systems [22].
vi. Integration of blockchain to the IoT networks helps in making the communication process a bit more precise by decreasing the network complexity due to the decentralised network system provided by blockchain [23].
vii. Blockchain also helps in enhancing the data storage ability of IoT devices as large volume of agricultural data could be stored in blockchain-based storage

systems that will also help in analysis and manipulation of data in the real time in a secure manner [9].

The aforementioned advantages of integration of blockchain in IoT have also received research attention. However, bibliometric analysis of literature in this domain depicts a neonatal stage of research contribution in the SCOPUS database starting from 2016 (Fig. 2).

The major research work that could be traced from the literature in terms of smart agriculture through integration of both the communication technology could be categorised into four sub-applications namely food safety, farm overseeing, land registration, supply chain. The bibliometric trend in research depicts the following contribution of research under each of the above-mentioned subdomain Fig. 3.

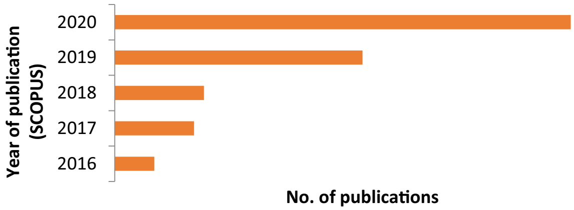

Fig. 2 Bibliometric trend of literature published in SCOPUS under applications of blockchain-based IoT in agriculture

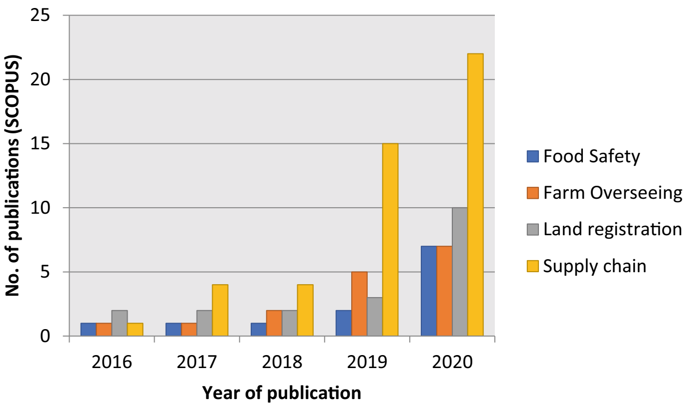

Fig. 3 Research contribution in various subdomains of blockchain-based IoT applications in agriculture

Table 1 Some Prominent studies on the proposed application of the blockchain-based IoT system on food safety

Authors	Proposed application of the blockchain-based IoT system by researchers
Iqbal and Batt (2020)	Ensuring safe farming by deploying sensors to detect and repel animal attack in fields by producing human-safe ultrasonic sound waves [24]
Lin et a. (2019)	Blockchain system for preventing food data tampering [25]
Lin et al. (2018)	Food tracking technique based on IOT and blockchain [26]
Tse et al. (2017)	Blockchain use cases in securing food supply chain process [27]
Tian (2016)	Tracking system for an agri-food supply chain in China [28]

Table 2 Some Prominent studies on the proposed application of the blockchain-based IoT system on farm overseeing

Authors	Proposed application of the blockchain-based IoT system
Pincheira et al. (2021)	Improving IoT sensor-based irrigation system [30]
De Clercq et al. (2018)	Future farming tech. in agriculture 4.0 [31]
Lin et al. (2017)	Monitoring system for water distributions [32]
Patil et al. (2017)	Tracing system for securing sensor communications in the farms [33]

2.3 Proposed Application of the Blockchain-Based IoT System by Researchers

The following are the applications proposed by various researchers in the field of Food Safety (Table 1).

2.4 Blockchain and Farm Overseeing

This application includes fabricating blockchain mediated IoT devices with sensors like humidity, temperature, crop maturity sensors, light, etc. in order to help farmer record and utilise data for better farming opportunities [29] (Table 2).

2.5 Blockchain and Land Registration

"It can be defined as the process of determining, recording and sharing transactional information about rights, value, and use of land pieces" [34] (Table 3).

Table 3 Some Prominent studies on the proposed application of the blockchain-based IoT system on land registration

Authors	Proposed application of the blockchain-based IoT system
Barbieri and Gassen (2017)	A Blockchain model for managing digital land registry [35]
Vos et al. (2017)	Analysis model for applying blockchain in Land Administration [36]
Anand et al. (2016)	Blockchain system for managing land admiration activities [34]
Chavez-Dreyfuss (2016)	"Proof of concept": a blockchain in the Swedish land registry [37]

2.6 Block chain and Supply Chain

This application aims at monitoring food at every point in the supply chain thus enhancing the transparency of the supply chain processes [38] (Table 4).

Table 4 Some Prominent studies on the proposed application of the blockchain-based IoT system on supply chain

Authors	Proposed application of the blockchain-based IT system
Nihit Choudhary (2020)	Contract Farming Through Blockchain Technology Using Smart Contracts [39]
Ronaghi (2020)	Improving supply chain transparency with less human intervention [40]
Dujak and Sajter (2019)	Blockchain application in supply chain and logistics [41]
Lin et al. (2018)	Enhancing the traceability of food in various stages of supply chain by reducing human intervention in verification of food in each step of supply chain [26]
Caro et al. (2018)	AgriBlockIoT mechanism for managing Agri-Food supply chain [42]
Li and Wang (2018)	Monitor system for agricultural products [15]
Platform with duplicated and shared bookkeeping (2018)	Provenance system for supply chain trust [43]
Leng et al. (2018)	Double Blockchain chain system for securing public transactions [44]
Toyoda et al. (2017)	Blockchain system for the Post Supply Chain [45]
Chen et al. (2017)	Supply Chain system for Quality Management [46]
Lu and Xu (2017)	Monitoring system the product origins in supply chains [47]
Xie et al. (2017)	Secure blockchain system for tracking products [48]

3 Research Gaps and Future Scope

3.1 Research Gaps

i. IoT network used for various applications in smart agriculture has many lacunas such as security and privacy threats, lack of authentication and authorisation, lack of interoperability, lack of scalability and reliability, quality of service, etc. [49].
ii. Numerous IoT devices are connected in the IoT-based smart agriculture networks; therefore, a huge volume of data with high level of throughput is required for proper functioning of the IoT networks in a harmonised manner which is another challenging issue [39].
iii. IoT sensors which are installed in various agricultural devices and machines like tractors, greenhouses emit a lot of data which is a cause of data loss at times. This also marks for another challenge for adaptation of IoT in smart agriculture [18].
iv. To implement smart contract with right condition in agriculture is a big challenge in blockchain technology [49].
v. Lack of unifying requirements is another big issue. Current systems do not support rapid and reliable response to trace data in case of food chain and analysis of data can be difficult in case of decision-making [50].

3.2 Future Scope

i. To overcome the lacunas of IoT network such as security and privacy threats, lack of authentication and authorisation, lack of interoperability, lack of scalability and reliability, quality of service, etc. blockchain technology will be integrated with IoT [49].
ii. Practical implementation of Smart Contract in Agriculture field using these two technologies has not been developed yet. So, a new model can be developed for smart contract using blockchain and IoT [40].
iii. As consumer preference shifting rapidly, they demand relevant and reliable information according to their need. So in case to provide data on time there is a need of secure network which is possible by IoT and blockchain [9].
iv. Smart Contract can also be used as an automated warning code for a system, in case of finding problems and process them in time by law-executors [35].

4 Conclusion

As a conclusion it is observed that Integration of blockchain and IoT helps in building an ecological, trusted, open and self-organised smart agriculture system.

The proposed methods discussed above tried to use IoT devices instead of manual recording and verification, which reduces the human intervention to the system effectively. Some of the prominent studies related to different applications of blockchain and IoT are described and at last future scope of IoT and blockchain is discussed in the paper.

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