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The benefits, Challenges, and Future of Blockchain and The Internet of Things

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Abstract

The Internet of Things (IoT) has expanded internet connectivity beyond computers and people to include most objects in our environment. The Internet of Things (IoT) can connect billions of items at once, which has the effect of improving the need for information sharing and ultimately enhancing our quality of life. Due to its centralized server/client approach, which limits the IoT's potential benefits, there are numerous obstacles to IoT adoption in the real world. For instance, the network's excessive number of IoT items can cause scalability and security problems. The server/client approach necessitates that all devices connect to and are authenticated by the server, creating a single point of failure. As a result, shifting the IoT system to a decentralized approach might be the best course of action. Blockchain is one of the most well-known decentralization technologies. The Blockchain is a potent technology that decentralizes administration and computation processes, which can address many IoT problems, particularly security. The benefits and difficulties of the integration of the blockchain with the IoT are highlighted in this paper's review. There is also a discussion of the potential research avenues for blockchain and IoT. We conclude that combining blockchain technology with IoT can result in a potent strategy that can significantly open the door for new business models and distributed applications.
Keywords: *Internet of Things, Internet of Things with Blockchain, Centralized, Decentralized.*

1. Introduction

A billion things can connect and interact at once thanks to the Internet of Things (IoT) [1]. It offers consumers several advantages that will alter how they engage with technology. Information about our environment can be gathered using a variety of inexpensive sensors and linked objects, allowing us to improve our way of life [2]. The idea of IoT is not brand-new. The Internet of Things has the potential to revolutionize the world, just as the Internet did, according to Ashton, the creator of the MIT Auto-Identification Center. possibly much more so. IoT is defined by the ITU as "a global infrastructure for the information society, allowing improved services by interconnecting (physical and virtual) things based on, existing and growing, interoperable information and communication technologies" later in 2005 [3]. IoT systems currently in use are designed using a centralized server/client architecture, necessitating the connection and server-based authentication of all devices [4]. This model would not be able to meet future IoT system expansion requirements. As a result, shifting the IoT system to a decentralized approach might be the best course of action. Blockchain is a well-known decentralization platform. A blockchain is a decentralized database of transactions that is shared among all network participants and contains all completed transactions. Distributed ledger refers to this distributed database [5].

The majority of network users must agree to verify each transaction before it can be recorded in the distributed ledger. The blockchain contains information about every transaction

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that has ever been made [6]. The most well-known application of blockchain technology is Bitcoin, a decentralized peer-to-peer digital currency. The advantages of combining blockchain and IoT are numerous [7]. The blockchain's decentralized model will be able to process trillions of transactions between IoT devices, which will significantly cut down on the costs of setting up and maintaining massive centralized data centers and spread out the demands for computation and storage across the trillions of IoT devices. Working with blockchain technology will also get rid of the centralized IoT architecture's single point of failure. Additionally, the combination of blockchain and IoT will enable peer-to-peer communication, file sharing, and autonomous coordination between IoT devices without the need for a centralized server-client approach [8].

This article presents an overview of integrating blockchain with the IoT system, including an analysis of the advantages brought about by the integration process and the difficulties faced during implementation [9]. The main objective of this research is to provide a thorough explanation of the advantages and difficulties that arise from combining blockchain with IoT so that readers may decide whether to pursue decentralization for the IoT or not [10]. The rest of this essay is structured as follows: Part III explores centralized IoT design, and Section II includes similar work examining the integration of blockchain with IoT applications. The blockchain technology and its structure are presented in Section IV; Section VI explains the blockchain's operation after Section V introduces its key qualities. Part VII introduces blockchain with IoT; Section VIII details the advantages of doing so; Section IX discusses issues with blockchain with IoT; Future research directions are covered in Section X, and Section XI is the conclusion [11].

2. Related Work

In a few papers, the integration of blockchain with IoT has been studied. To create a distributed network of devices, the IBM Autonomous Decentralized Peer-to-Peer Telemetry (ADEPT) project uses the blockchain [12]. Regarding the ADEPT project, other strategies are working to create a plan that would enable the fusion of all the various blockchain-based applications [13]. Additionally, Slock. introduced the first Ethereum-based IoT and Blockchain implementation. It is so-called Slocks to reflect real-world physical objects that can be controlled by the Blockchain. They make use of the Ethereum Computer, a piece of technology that extends Blockchain technology throughout the entire house, enabling users to accept payments directly and rent access to any compatible smart object [14]. Additionally, Dorri et al. investigated a smart home application as a representative case study for more extensive IoT applications to propose a new secure, private, and lightweight architecture for IoT based on blockchain technology that eliminates the overhead while maintaining the majority of its security and privacy benefits [15].

The suggested design is hierarchical and includes smart homes, an overlay network, and cloud storage that operate with blockchain to coordinate data exchanges and offer privacy and security. Blockchain has been proposed as a solution for numerous problems affecting the healthcare industry's IoT applications [16]. For instance, Gupta et al. has suggested a method for describing how Blockchain could facilitate the sharing of interoperable and secure electronic health records, with the ultimate owners being the patients. They have suggested a scenario in which the Blockchain would only be used to record metadata related to health and medical occurrences [17]. Therefore, to enable comprehensive health records, the Blockchain infrastructure would need to increase dramatically. So, although the actual records should be held in a separate universal health cloud, metadata like patient identity, visit ID, provider ID, payer ID, etc. can be preserved on a Blockchain [18]. In yet another study for Blockchain in Healthcare, existing medical records are represented using Ethereum's smart contracts. These contracts are kept in-house by individual network nodes. They have put up a "MedRec" approach to organize the copious amounts of data into three different sorts of contracts. Registrar Contract is the initial one. The public keys are naturally stored along with the participant's identification and any other necessary information [19]. Only accredited

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institutions are permitted to do this type of identification registration. The Patient-Provider Relationship Contract is the second contract. It is generated whenever one node maintains or stores data on behalf of another node. The primary application will be when a smart contract exists between the patient and the healthcare provider. The patient can locate her medical history with the help of the final one, the Summaries Contract. This agreement lists all prior and ongoing interactions with other nodes in the system [20].

3. IOT Architecture that is Centralized

In essence, the Internet of Things (IoT) involves the connectivity and communication of many objects [21]. These gadgets are made out of networking nodes, either servers or computers, that are linked to one another to share data. Every gadget has sensors that gather the information that can be communicated, saved, processed, and presented in a meaningful manner [22]. There are numerous IoT architectures that have gained widespread acceptance. Many experts and groups suggested various architectural designs. The ITU states that the IoT architecture is made up of four layers, as depicted in Fig.1 :

- Application layer
- Service support and application layer
- Network Layer
- Device layer

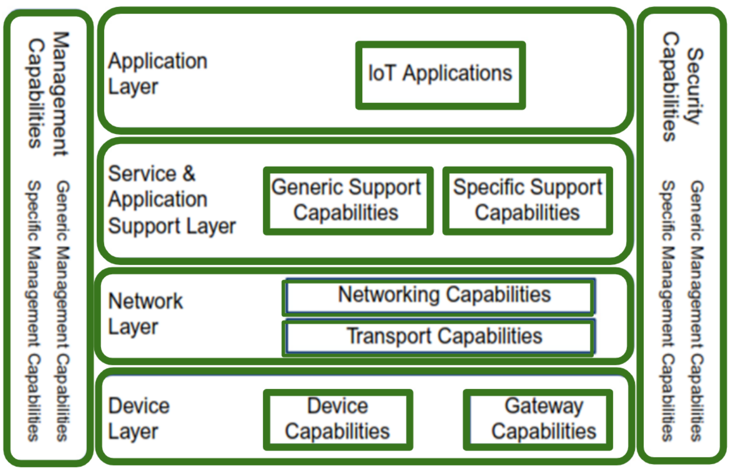

Fig.1. IoT Reference Model and Architecture

IoT applications are included in the application layer. IoT applications span a wide range of industries, including healthcare, smart cities, linked cars, smart energy, smart agriculture, etc. Common features that can be exploited by many IoT applications are included in the service support and application layer [23]. Devices used to build local and wide-area networks and provide Internet connectivity, such as routers, switches, gateways, and firewalls, are included in the network layer. Moreover, it permits communication between devices as well as communication with application platforms including PCs, remote controls, and cell phones [24]. The Open System Interconnection (OSI) model of the network architecture compares the device layer to the physical layer [25]. It is made up of mechanical components and object-controlling controllers. These items stand in for IoT entities such as a variety of endpoints that transmit and receive different types of data. For instance, sensors gather data about the environment around them [26]. The server/client model, which is the foundation of the current IoT architecture, is a centralized design. With this arrangement, all devices communicate with a centralized gateway rather than one another. The centralized architecture has been used for years to link a variety of computing devices, and it will continue to support

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small-scale IoT networks, but it won't be able to meet future demands to expand the IoT system. The number of IoT devices will skyrocket, resulting in a network capacity that is at least 1,000 times greater than it was in 2016 [27].

According to Cisco, there will be 20 billion IoT devices on the market by 2020. Costs will therefore rise exponentially as the volume of communication that must be handled increases. The server/client architecture will continue to be a vulnerability that might bring down the entire network, even if prices and communication issues are controlled [28]. The centralized model is additionally susceptible to data manipulation. Real-time data collection does not guarantee that the data will be used properly or for beneficial purposes [29]. For instance, if energy firms discovered that data analysis from smart meters will be the evidence, this might lead to expensive charges or legal action. This data will be edited or removed. Several of these problems could be resolved by the IoT using a decentralized method. Blockchain is a well-known decentralization method. Blockchain technology is covered in the next section [30].

5. Blockchain Technology

A secure, transparent, extremely resilient to outages, auditable method of recording transactions or any digital interaction is provided by blockchain technology. It will still be a few years before this technology is widely used in commerce because it is still in its infancy and is evolving quickly. To avoid disruptive surprises or missed opportunities, decision-makers across industries and corporate functions should pay notice right away and begin to research applications of this technology. The idea of Bitcoin was first suggested by Satoshi Nakamoto in 2008. By disseminating the widely read document "Bitcoin: A Peer-to-Peer Electronic Currency System," this was accomplished. The report made a recommendation for dispersing electronic transactions rather than keeping the exchange reliant on centralized organizations. Blockchain is defined in a variety of ways. A distributed database of records, or public ledger, of all executed transactions or digital events that have been exchanged among participating parties, is what the blockchain is described as, The consensus of a majority of the system's users verifies each transaction on the public ledger. Information cannot be deleted once it has been entered. Every transaction ever made is contained in a particular, verifiable record on the blockchain. As seen in Fig.1, a blockchain comprises two key components:

- Transactions: are the actions produced by system participants.
- Blocks: keep track of transactions and ensure that they are recorded in the proper order and are unaltered.

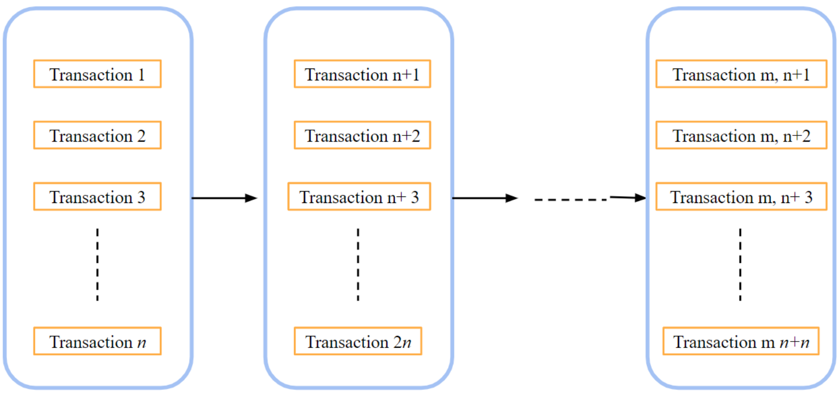

Figure 2. Blockchain Structure

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5.Specifications Of Blockchain

The IoT finds the blockchain to be very appealing for solving many of its problems due to its various features. As depicted in Fig. 2, among the qualities of blockchain are:

1. **Decentralization:** By utilizing the resources of all participating nodes and removing many-to-one traffic flows, the lack of centralized control assures scalability and robustness, which in turn reduces latency and resolves the single point of failure issue that arises in the centralized model.
2. **Anonymity:** Users' identities can be effectively hidden and kept private through the use of anonymity.
3. **Immutability:** One of the main benefits of blockchain is the ability to create immutable ledgers. Any centralized database that relies on confidence in a third party to maintain information integrity is susceptible to corruption. A transaction cannot be altered once agreed upon and documented.
4. **Increased Capacity:** One of the significant things about blockchain technology is that it can increase the capacity of an entire network. Having thousands of computers working together as a whole can have greater power than a few centralized servers.

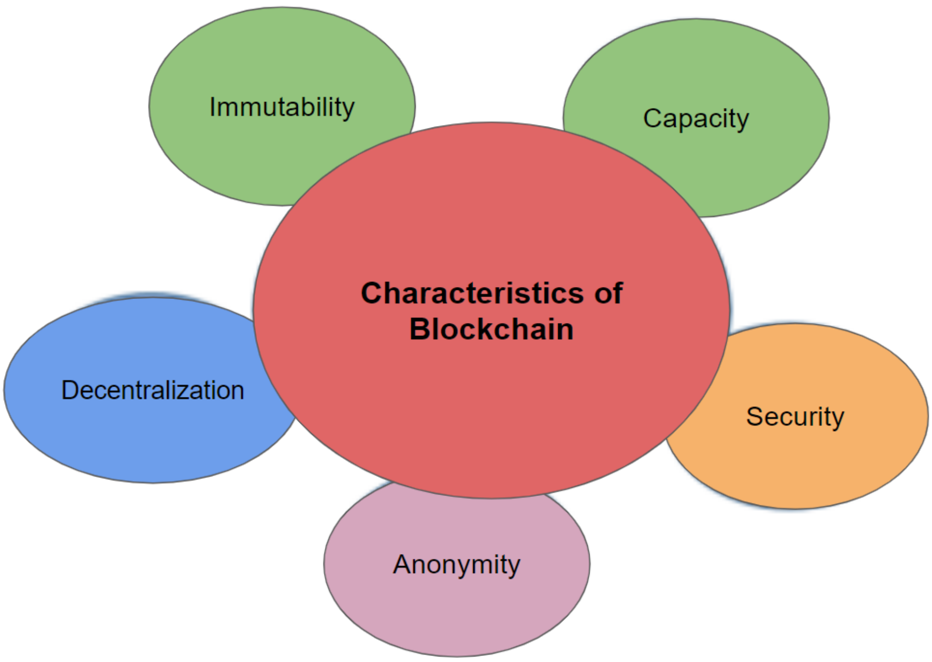

Figure 3. Characteristics of blockchain

5. **Greater Security:** Because there isn't a single point of failure that might bring down the entire network, blockchain offers superior security.

6. IoT and Blockchain

The Internet of Things (IoT) is a fascinating system that is still in development and offers countless advantages, but the current centralized IoT architecture, in which all devices are identified, verified, and connected through centralized servers, has many flaws. For many years, this architecture was used to connect a variety of computer devices, and it will continue to support small-scale IoT networks, but it won't be able to meet future demands to expand the IoT system. A table that contrasts blockchain and IoT is provided. Both technologies have several benefits that can be combined to produce better results. The IoT offers countless advantages, and a decentralized approach would address many challenges, including security. The installation and upkeep costs of building and maintaining massive centralized data centers will be greatly reduced by using a standardized peer-to-peer communication model to process the hundreds of billions of transactions between devices. This will also distribute the computation and storage requirements among the billions of devices that make up IoT networks. This will stop a network's failure in a single node from causing the network as a whole to collapse completely.

Table 1. Comparison between blockchain and IoT

Blockchain	IoT
Block mining takes a lot of time.	Calls for ow latency
Scalability with huge network is low	IoT is thought to have a lot of gadgets.
Improved security	IoT's biggest challenge is security.
Decentralized	Centralized
Requiring Resources	Limited Resources
Excessive bandwidth use	IoT devices have constrained resources and bandwidth.

The blockchain is ideally suited to serve as the basis for IoT solutions due to its decentralized, autonomous, and trustless characteristics. Enterprise IoT technologies have quickly emerged as one of the leading blockchain technology early adopters, which is not surprising. Yet developing peer-to-peer connectivity will have its own set of difficulties, particularly in terms of security. IoT security involves far more than just safeguarding private information. Hence, in order to prevent spoofing and theft, blockchain solutions will need to guarantee privacy and security in IoT networks and require participant validation and consent for transactions. The IoT's privacy and dependability problems are also thought to be largely resolved by blockchain technology. It can be used to keep track of billions of linked devices, allowing for the processing of transactions and coordination between devices, which enables manufacturers in the IoT sector to save a lot of money. Also, this decentralized strategy would get rid of single points of failure, making the platform on which devices run more resilient. Blockchain's encryption algorithms would increase the privacy of customer data. The blockchain can maintain an unchangeable record of the evolution of smart devices in an IoT network. With the help of this functionality, smart devices can operate independently of centralized control.

The blockchain will thus enable several IoT situations that were challenging or even impossible to achieve before. IoT solutions, for instance, can provide secure, trustless messaging between devices in an IoT network by utilizing the blockchain. According to this paradigm, the blockchain will treat device-to-device message exchanges similarly to how bitcoin network financial transactions are handled. Devices will use smart contracts to enable message exchanges, which will model the agreement between the two parties. The capacity to keep a properly decentralized, trusted ledger of all transactions occurring in a network is one of the most fascinating features of the blockchain. Without the need for a centralized model, this capacity is necessary to enable the numerous compliances and regulatory requirements of industrial IoT (IIoT) applications. To fully utilize the benefits of the blockchain, several sizable firms have begun to implement it with IoT devices. For instance, IBM and Samsung have created a platform called ADEPT (Autonomous Decentralized Peer-To-Peer Telemetry) that draws inspiration from the fundamental architecture of bitcoin to create a distributed network of devices or decentralized Internet of Things. The platform of ADEPT makes use of the three protocols BitTorrent (for file sharing), Ethereum (for smart contracts), and TeleHash (for peer-to-peer messaging).

7. How Does Blockchain Perform?

Although the blockchain is still in its infancy and is still being tested, it is seen as a ground-breaking answer to current technological problems including decentralization, identity, trust, data ownership, and data-driven decisions. In general, the blockchain functions as a database that organizes all transactions into blocks. As a new transaction is created, the sender broadcasts it to all other nodes in the network via the Peer-to-Peer communication channel. The exchange has not yet been validated and is currently fresh. Nodes accept transactions, verify them, and store the results in their ledger. By performing preset tests on the transaction's actions and structure, transaction validation is carried out. Miners are specialized node types that produce new blocks by including all or a portion of the available transactions from their transaction pool. The block is then mined, which entails locating the proof of work using varying data from the new block's header. A cryptographic hash that matches the specified difficulty target can be continuously calculated to find the proof of work. A lot of processing power is needed for mining, and special hardware is used by the miners. The miner who solves their block's problem first wins.

The new block in the chain is his candidate block. Since transactions are added to mining blocks as they come in, the most recent block in the blockchain is the one that contains the most recent transactions. A new block is time-stamped and transmitted to all network nodes when it is formed. Receiving the block, validating it, validating the transactions, and adding the block to his ledger are all steps that each node must take. It becomes a valid and irreversible portion of the blockchain when the majority of nodes accept the block. Every block also contains certain metadata and the previous block's hash value in addition to transactions. Each block therefore has a pointer to its parent block. This is how the blocks are connected to form the blockchain, which is a chain of blocks. Every member of the network has access to the distributed ledger and can examine its blocks and transactions. The users, however, maintain their anonymity since they just provide their public key as an address. The transactions are also encrypted. Transactions that are not legitimate are rejected and excluded from blocks. The proof of work for the associated block and all succeeding blocks must be calculated again if malicious attempts to modify the transactions are made. Unless the majority of the network's nodes are hostile, these computations are impossible.

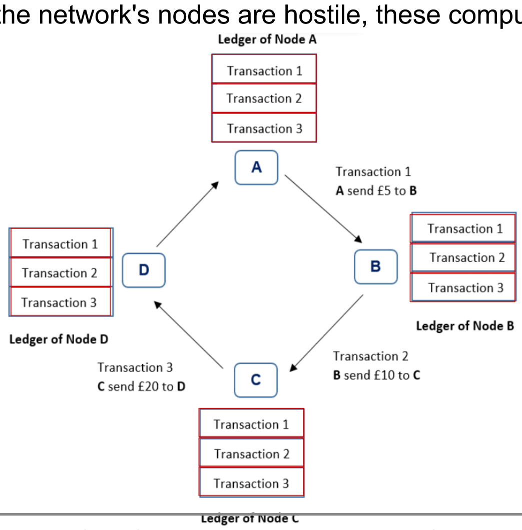

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Figure 4. Simple example of blockchain technology

The blockchain will be covered in this part with a straightforward example. Let's say that four nodes A, B, C, and D wish to send money using the blockchain because it is called Bitcoin. Decentralization is the concept that eliminates the need for an intermediary third party to facilitate money transfers between nodes. As a result, money would be sent directly to node B if node A decided to send it. As seen in Fig. 4, if node A wants to transfer node B £5, a transaction will be made and validated by every other node in the network before being added to the ledger. In addition, a transaction will be made and validated by all other nodes in the network for inclusion in the ledger if node B wants to give node D £10. The same thing will happen if node C tries to transmit node D £20. In a document known as a ledger, every transaction is linked together. The term "distributed ledger" refers to a ledger that is spread across all network nodes to ensure that each node has the same copy or version of the ledger.

8. Iot And Blockchain Difficulties

1. **Naming and Discovery:** Because the blockchain technology was not developed for the Internet of Things, nodes were not intended to be able to locate one another in the network. As an illustration, consider the Bitcoin application, in which some "senders'" IP addresses are stored within the Bitcoin client and used by nodes to create the network topology. This strategy won't work for the Internet of Things since IoT devices are always moving, which changes the topology continuously.
2. **Storage:** One of the key advantages of blockchain is that it does away with the need for a central server to keep track of device IDs and transaction data, but the ledger must still be kept on the nodes themselves. The distributed ledger will grow in size over time and as the number of network nodes rises. IoT devices, as was previously said, have relatively little computing power and storage space.
3. **Scalability:** Blockchain scalability difficulties could result in centralization, which is a concern for the future of cryptocurrencies. When the network's nodes grow in number, the blockchain scales poorly. Given that IoT networks are anticipated to include several nodes, this problem is critical.
4. **Processing Power and Time:** How much processing power and how long it takes to encrypt each object in a blockchain system. Different device types in IoT systems have highly varying computing capacities, thus not every one of them will be able to run the same encryption methods quickly enough.
5. **Lack of expertise:** Blockchain technology is still in its infancy. As a result, only a select few possess extensive understanding and expertise concerning the blockchain, particularly in banking. There is a general lack of comprehension of how the blockchain functions in other apps. There are IoT devices everywhere, but integrating them with IoT will be exceedingly challenging without widespread public awareness of the blockchain.
6. **Legal and compliance:** The blockchain is a new technology that will be able to connect individuals from many nations without enforcing any laws or regulations, which is a significant problem for both product makers and service providers. The main obstacle to the adoption of blockchain in many industries and applications will be this difficulty.

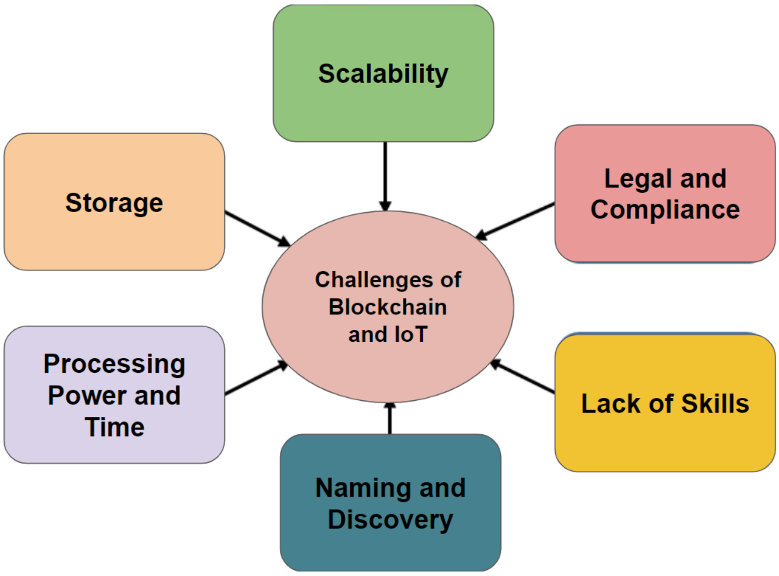

Fig 5. Blockchain and IoT challenges

9. Benefits of Integrating Iot and Blockchain

Using blockchain with IoT has numerous advantages, as illustrated in Fig 6. The following benefits can be summed up:

1. **Decentralization:** The vast majority of users must validate transactions before they can be approved and added to the distributed ledger. No single body has the power to sanction transactions or establish particular guidelines for their acceptance. As a result, there is a significant amount of trust involved because most network users must agree to validate transactions. As a result, the blockchain will offer an IoT device platform that is safe. eliminates the present centralized IoT architecture's single point of failure as well as centralized traffic flows.
2. **Anonymity:** To complete the transaction, both the buyer and the seller utilize anonymous, one-of-a-kind address numbers that protect their anonymity. Because it encourages the use of cryptocurrencies in the illicit online market, this function has drawn criticism. Nonetheless, it might be advantageous if utilized for other things, such as electoral voting systems.
3. **Immutability:** One of the key benefits of blockchain technology is the existence of an immutable ledger. The majority of the network nodes must confirm any modifications to the distributed ledger. As a result, it is difficult to change or delete the transactions. For IoT data, having an immutable ledger will improve security and privacy, which are the two biggest problems with this technology and any new technologies.
4. **Saving money:** The high infrastructure and maintenance costs associated with centralized architecture, sizable server farms, and networking equipment make existing IoT solutions expensive. When there are tens of billions of IoT devices, the volume of communications that must be handled will significantly increase those expenses.

5. **Speed:** A blockchain transaction can be executed at any time of the day and is instantly propagated across the network.
6. **Security:** With so many different types of devices in the Internet of Things, a safe network over untrusted parties is essential. Blockchain can provide this. In other words, in order to launch an assault, every IoT network node must be evil. With so many different types of devices in the Internet of Things, a safe network over untrusted parties is essential. Blockchain can provide this. In other words, in order to launch an assault, every IoT network node must be evil.
7. **Resilience:** Every node has a duplicate of the ledger, which records every transaction that has ever taken place in the network. Hence, the blockchain is more resistant to attack. The blockchain would continue to function even if one node were compromised thanks to all other nodes. Each IoT node having a copy of the data will reduce the requirement for information exchange. It does, however, raise fresh processing and storage problems.
8. **Publicity:** Because each participant has their own ledger, everyone can see every transaction and every block. Even though all parties may view the contents of the transaction, they are protected since they are encrypted with each participant's private key. The Internet of Things (IoT) is a dynamic system that allows all linked devices to exchange information while also preserving user privacy.

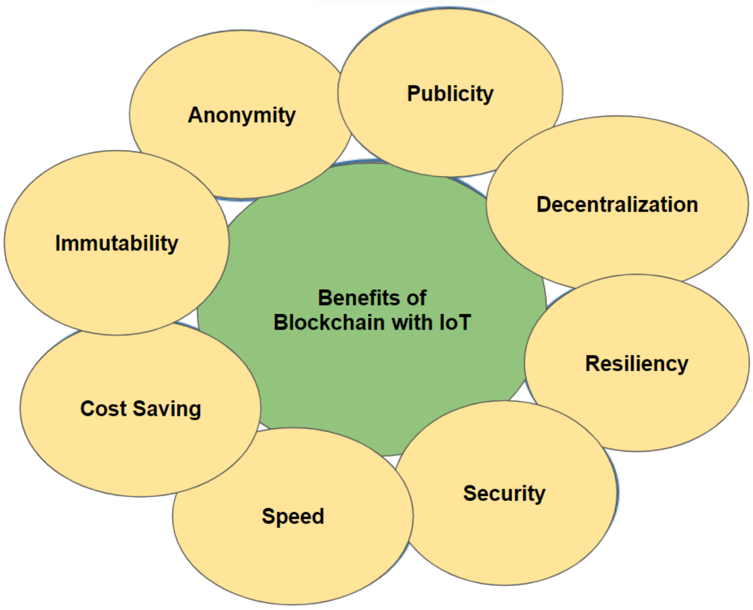

Figure 6. Benefits of integrating blockchain with IoT

10. Future Directions For Research

The idea of centralized authorities has evolved as a result of the blockchain. Opening new businesses and applications will begin with the integration of blockchain and IoT. Future research directions using blockchain and IoT are covered in this section. The following can be used to sum up this:

A. Security

Security is still the most difficult issue attracting researchers' and companies' attention for all new technologies. As it leverages the majority of participants' consent to confirm transactions, integrating blockchain with IoT can increase security by preventing spoofing and theft. IoT devices cannot process cryptographic algorithms due to their limited computational power and storage capacity. The security-related research issues that require attention are:

Q1: What is the best platform for IoT and blockchain integration?
Q2: How can a safe IoT system be provided given the limited capabilities of IoT devices?

B. IOTA

IOTA is a brand-new type of public and distributed ledger that makes use of the "Tangle" idea. A new data structure called The Tangle is built on a Directed Acyclic Graph. (DAG). IOTA offers fee-free, real-time, effective, secure, and lightweight transactions. It is a decentralized, open-source cryptocurrency created exclusively for the IoT.

IOTA might be more suitable for various IoT applications because it was created expressly for the IoT. It is, however, still being built. The IOTA-related research issues that require attention are:
Q1: Which decentralization technology blockchain or IOTA is best for the Internet of Things?
Q2: What are the principal difficulties with IOTA?

C. Smart Contracts

Scripts for smart contracts are kept on the blockchain. They are adaptable, which is why they are so strong. They can be programmed to use the data within a self-executing logical workflow of actions between parties, and they can encrypt and store data securely, restrict access to it to only the appropriate parties, and do all of this automatically. By converting business processes into computational processes, smart contracts significantly increase operational effectiveness. Smart contracts will offer an effective solution to increase the security and integrity of IoT data within IoT systems. The following research issues must be resolved in order to implement smart contracts in IoT systems:
Q1: Can the billions of IoT devices' billions of event functions be executed by smart contracts?
Q2: Because the Internet of Things is a dynamic system, how will the smart contract react to shifting environmental conditions?
Q3: What platform is best for integrating smart contracts into IoT systems?

D. Regulatory Laws

Regulatory laws are the processes developed by government bodies and local administrative organizations to specify the acceptable uses of a product or technology within a given nation or region. As previously said, blockchain is a novel technology without any established compliance standards. Regarding the legal and compliance challenges relating to blockchain, the following research question needs to be answered:
Q1: What international regulatory guidelines enable the optimum use of blockchain in the Internet of Things?

11.Conclusion

All homes in the universe are now included thanks to IoT technology. It can link commonplace items to the Internet. We can improve our quality of life by gathering a lot of data from the environment using inexpensive sensors. But several problems with the present server/client-based IoT architecture need to be solved, including scalability and security. Blockchain is one approach to addressing IoT problems. Blockchain offers a distributed peer-to-peer communication network that enables unreliable nodes to interact with one another in a verifiable way without the use of a third party. In this article, we outlined the advantages and difficulties of combining blockchain with IoT. Future research focuses were also a major topic of debate. In the end, we can say that combining blockchain and IoT has numerous benefits and solves many IoT problems, but it also creates new problems that need to be solved. More research is still required to fully examine the integration of blockchain and IoT.

References

[1] N. Sari, W. A. Gunawan, P. K. Sari, I. Zikri, and A. Syahputra, "Analisis Algoritma Bubble Sort Secara Ascending Dan Descending Serta Implementasinya Dengan Menggunakan Bahasa Pemrograman Java," *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 16–23, 2022.

[2] A. Argani and W. Taraka, "Pemanfaatan Teknologi Blockchain Untuk Mengoptimalkan Keamanan Sertifikat Pada Perguruan Tinggi," *ADI Bisnis Digit. Interdisiplin J.*, vol. 1, no. 1, pp. 10–21, Jun. 2020, doi: 10.34306/abdi.v1i1.121.

[3] U. Rahardja, Q. Aini, F. P. Oganda, and V. T. Devana, "Secure Framework Based on Blockchain for E-Learning During COVID-19," in *2021 9th International Conference on Cyber and IT Service Management (CITSM)*, 2021, pp. 1–7.

[4] F. P. Oganda, M. Hardini, and T. Ramadhan, "Pengaruh Penggunaan kontrak cerdas pada Cyberpreneurship Sebagai Media Pemasaran dalam Dunia Bisnis," *ADI Bisnis Digit. Interdisiplin J.*, vol. 2, no. 1, pp. 55–64, 2021.

[5] Y. Durachman, A. S. Bein, E. P. Harahap, T. Ramadhan, and F. P. Oganda, "Technological and Islamic environments: Selection from Literature Review Resources," *Int. J. Cyber IT Serv. Manag.*, vol. 1, no. 1, pp. 37–47, 2021.

[6] T. C. Husnadi, T. Marianti, and T. Ramadhan, "Determination of shareholders' welfare with financing quality as a moderating variable," *APTISI Trans. Manag.*, vol. 6, no. 2, pp. 191–208, 2022.

[7] T. Ramadhan, Q. Aini, S. Santoso, A. Badrianto, and R. Supriati, "Analysis of the potential context of Blockchain on the usability of Gamification with Game-Based Learning," *Int. J. Cyber IT Serv. Manag.*, vol. 1, no. 1, pp. 84–100, 2021.

[8] Q. Aini, U. Rahardja, A. H. Arribathi, and N. P. L. Santoso, "Penerapan Cloud Accounting dalam Menunjang Efektivitas Laporan Neraca pada Perguruan Tinggi," *Comput. Eng. Sci. Syst. J.*, vol. 4, no. 1, pp. 60–64, 2019.

[9] Q. Aini, W. Febriani, C. Lukita, S. Kosasi, and U. Rahardja, "New normal regulation with face recognition technology using attendx for student attendance algorithm," in *2022 International Conference on Science and Technology (ICOSTECH)*, 2022, pp. 1–7.

[10] U. Rahardja, "Skema Catatan Kesehatan menggunakan Teknologi Blockchain dalam Pendidikan," *J. MENTARI Manajemen, Pendidik. dan Teknol. Inf.*, vol. 1, no. 1, pp. 29–37, 2022.

[11] K. Kholil, K. Sulistyadi, and S. Arlan, "Strategies Of Food Safety Program Improvement To Prevent Food Poisioning Outbreak At Oil & Gas," *ADI J. Recent Innov. 1st Ed. Vol 1. No 1. Sept. 2019*, p. 46, 2020.

[12] A. Williams and E. Dolan, "Application of Blockchain Technology in e-LoA Technopreneurship Journal," *Aptisi Trans. Technopreneursh.*, vol. 2, no. 1, pp. 98–103, 2020.

[13] H. Henderi, S. R. Zuliana, and R. A. Pradana, "Periodic Data Analysis and Forecasting As An Overview of Future Management Economics," *Aptisi Trans. Manag.*, vol. 3, no. 1, pp. 73–83, 2019.

[14] S. B. Goyal, E. P. Harahap, and N. A. Santoso, "Analysis of Financial Technology Implementation on The Quality Of Banking Services in Indonesia: SWOT Analysis," *IAIC Trans. Sustain. Digit. Innov.*, vol. 4, no. 1, pp. 77–82, 2022.

[15] E. Retnaningtyas, E. Kartikawati, and D. Nilawati, "erma UPAYA PENINGKATAN PENGETAHUAN IBU HAMIL MELALUI EDUKASI MENGENAI KEBUTUHAN NUTRISI IBU HAMIL," *ADI Pengabdi. Kpd. Masy.*, vol. 2, no. 2, pp. 19–24, 2022.

[16] H. R. Widarti, N. C. E. Habiddin, A. B. Parlan, A. Ardyansyah, and D. A. Rokhim, "Development website of planning, writing, and publication of scientific articles based on Classroom Action Research (CAR) to increase teacher's pedagogical competence," *Improv. Assess. Eval. Strateg. Online Learn.*, pp. 37–43, 2022.

[17] R. Yunita, M. S. Shihab, D. Jonas, H. Haryani, and Y. A. Terah, "Analysis of The Effect of Servicescape and Service Quality on Customer Satisfaction at Post Shop Coffee Tofee in Bogor City," *Aptisi Trans. Technopreneursh.*, vol. 4, no. 1, pp. 66–74, 2022.

[18] L. A. Faza, P. M. Agustini, S. Maesaroh, A. C. Purnomo, and E. A. Nabila, “Motives For Purchase of Skin Care Product Users (Phenomenology Study on Women in DKI Jakarta),” *ADI J. Recent Innov.*, vol. 3, no. 2, pp. 139–152, 2022.
[19] U. Rahardja, “Meningkatkan Kualitas Sumber Daya Manusia Dengan Sistem Pengembangan Fundamental Agile,” *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 63–68, 2022.
[20] M. Budiarto, S. Maesaroh, M. Hardini, and A. Djajadi, “Future energy using blockchain systems,” in *2022 International Conference on Science and Technology (ICOSTECH)*, 2022, pp. 1–9.
[21] D. Apriliasari and B. A. P. Seno, “Inovasi Pemanfaatan Blockchain dalam Meningkatkan Keamanan Kekayaan Intelektual Pendidikan,” *J. MENTARI Manajemen, Pendidik. dan Teknol. Inf.*, vol. 1, no. 1, pp. 68–76, 2022.
[22] D. Apriani, T. Ramadhan, and E. Astriyani, “Kerja Lapangan Berbasis Website Untuk Sistem Informasi Manajemen Praktek (Studi Sistem Informasi Program Studi Kasus Merdeka Belajar Kampus Merdeka (MBKM) Universitas Raharja,” *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 24–29, 2022.
[23] P. Hendriyati, F. Agustin, U. Rahardja, and T. Ramadhan, “Management Information Systems on Integrated Student and Lecturer Data,” *APTISI Trans. Manag.*, vol. 6, no. 1, pp. 1–9, 2022.
[24] A. G. Prawiyogi, A. S. Anwar, M. Yusup, N. Lutfiani, and T. Ramadhan, “Pengembangan Program Studi Bisnis digital bagi pengusaha dengan perangkat lunak lean,” *ADI Bisnis Digit. Interdisiplin J.*, vol. 2, no. 2, pp. 52–59, 2021.
[25] D. Rifai, S. Fitri, and I. N. Ramadhan, “Perkembangan Ekonomi Digital Mengenai Perilaku Pengguna Media Sosial Dalam Melakukan Transaksi,” *ADI Bisnis Digit. Interdisiplin J.*, vol. 3, no. 1, pp. 49–52, 2022.
[26] N. Septiani, N. Lutfiani, F. P. Oganda, R. Salam, and V. T. Devana, “Blockchain technology in the public sector by leveraging the triumvirate of security,” in *2022 International Conference on Science and Technology (ICOSTECH)*, 2022, pp. 1–5.
[27] U. Rahardja, M. A. Ngad, S. Millah, E. P. Harahap, and Q. Aini, “Blockchain Application in Educational Certificates and Verification Compliant with General Data Protection Regulations,” in *2022 10th International Conference on Cyber and IT Service Management (CITSM)*, 2022, pp. 1–7.
[28] A. S. Bist, B. Rawat, U. Rahardja, Q. Aini, and A. G. Prawiyogi, “An Exhaustive Analysis of Stress on Faculty Members Engaged in Higher Education,” *IAIC Trans. Sustain. Digit. Innov.*, vol. 3, no. 2, pp. 126–135, 2022.
[29] B. Rawat, N. Mehra, A. S. Bist, M. Yusup, and Y. P. A. Sanjaya, “Quantum Computing and AI: Impacts & Possibilities,” *ADI J. Recent Innov.*, vol. 3, no. 2, pp. 202–207, 2022.
[30] S. Kosasi, U. Rahardja, N. Lutfiani, E. P. Harahap, and S. N. Sari, “Blockchain technology-emerging research themes opportunities in higher education,” in *2022 International Conference on Science and Technology (ICOSTECH)*, 2022, pp. 1–8.