BLOCKCHAIN-POWERED INTERNET OF THINGS: OVERVIEW, CURRENT PATTERNS, USES, AND UPCOMING DIFFICULTIES

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Abstract: Technological developments have always had an effect on our lives. A number of cutting-edge technologies offer revolutionary possibilities, chief among them the Internet of Things (IoT) and blockchain. Transaction data can be stored in a transparent, decentralized ledger called the blockchain. It offers the astonishing potential to develop unique designs for the majority of enterprise applications by efficiently establishing trust between nodes. Researchers became interested in blockchain when it initially emerged as a public network platform for trading anonymous crypto currencies like Bitcoin. A block is considered complete when it is connected to the one before it. A network of networked objects, the Internet of Things (IoT) can share data and be managed and controlled by special bit coins. This study examines the relationship between blockchain technology and the Internet of Things to learn more about how to improve device communication. Using the most advanced tools and techniques now available, the blockchain-enabled Internet of Things architecture presented in this article provides a helpful foundation for combining blockchain technology and the Internet of Things. The fundamentals of blockchain-based IoT, consensus methods, reviews, challenges, opportunities, applications, trends, and inter-node communication within an integrated framework are all covered in this article.

Keywords: Ethereum; smart contracts; the Internet of Things; privacy and security; proof of work.

1. INTRODUCTION

An important development in the way devices interact, transact, and communicate in decentralized ecosystems is the marriage of blockchain technology and the Internet of Things (IoT). Originally intended to serve as the foundational technology for crypto currencies, blockchain has developed into a flexible platform with significant implications for Internet of Things applications. A new era of innovation is being ushered in by the combination of blockchain technology with the Internet of Things (IoT), which offers connected device networks never before seen levels of security, efficiency, and autonomy. Originally intended to serve as the backbone of crypto currency, blockchain has developed into a strong framework that has the power to completely transform Internet of Things applications in a wide range of sectors. Fundamentally, blockchain makes it possible for IoT devices to securely communicate and do business with one another without the need for middlemen. Reliability and resilience are improved by this decentralized architecture, which is important for IoT networks. Blockchain addresses the inherent risks of centralized systems in Internet of Things deployments by utilizing consensus procedures and cryptographic hashes to guarantee data integrity and prevent tampering. IoT network procedures are automated using smart contracts, which are self-executing contracts with established rules encoded on the blockchain. This increases device trust, simplifies processes, and lessens the need for human intervention. Blockchain-powered IoT applications have transformative possibilities in a variety of industries, including supply chain management, smart city infrastructure, healthcare, and energy management. These applications improve transparency, optimize resource allocation, and open up new business opportunities. This overview attempts to give a thorough understanding of blockchain-powered

IoT, covering popular use cases, current trends, and issues that need to be resolved for long-term development. We aim to show the chances for innovation and cooperation across industries, paving the path for a safer, effective, and connected future by analyzing the connections between blockchain and IoT.

2. WHAT IS BLOCKCHAIN

Originally established as the foundation of crypto currencies, blockchain technology has developed into a flexible solution that has significant effects on the Internet of Things (IoT) ecosystem. To fully realize its revolutionary potential, it is essential to comprehend its purpose and role in this environment.

Key Ideas in Blockchain:

Decentralization: A decentralized network of nodes, each of which keeps a copy of the ledger, underpins blockchain technology. By doing away with the requirement for a central authority, this decentralized design promotes trust and lowers the number of single points of failure in Internet of Things environments.

Immutable Ledger: A Blockchain's transaction records are unchangeable and impervious to tampering. Data integrity and transparency amongst IoT devices are ensured by the cryptographic hash of each block in the chain.

Consensus Mechanisms: To validate transactions and reach a consensus among nodes, blockchain networks rely on consensus algorithms. Consensus techniques like Proof-of-Work (PoW), Proof-of-Stake (PoS), and others guarantee the security of transactions and data integrity in Internet of Things applications.

Smart contracts are self-executing agreements that have pre-established guidelines inscribed in them. By automating procedures and transactions, these contracts allow for safe, transparent, and middleman-free interactions between IoT devices.

Benefits of Blockchain Technology for IoT

Enhanced Security Blockchain ensures data integrity and confidentiality by reducing the risks of data breaches and unauthorized access in Internet of Things networks through its cryptographic algorithms and decentralized architecture.

Transparency and Traceability: Supply chains and other industries benefit from increased accountability and audit ability due to the transparent nature of blockchain, which enables stakeholders to track the beginning and path of IoT data and transactions.

Operational Efficiency: Smart contract automation speeds up transactions in IoT ecosystems and lowers administrative overhead, improving efficiency and saving money.

Interoperability: By offering a standard framework for safe data transmission and communication, blockchain can help promote interoperability across various IoT platforms and devices.

Blockchain technology has the potential to completely transform IoT applications in a variety of industries. Blockchain-powered Internet of Things solutions have the potential to unleash previously unheard-of possibilities for creativity and cooperation in the digital age by resolving security issues, improving operational effectiveness, and opening up new business models. The potential of these technologies to transform sectors and generate new value propositions is a driving force behind technological advancement and strategic investment, even as they continue to mature.

3. Consensus Algorithms

In computer science, a consensus algorithm is a procedure used to get disparate processes or systems to agree on a single data value. The goal of these algorithms is to provide reliability in a network with several nodes or users. Resolving this difficulty, sometimes referred to as the consensus problem, is

crucial for distributed computing and multi-agent systems, such the blockchain networks used by crypto currencies

Consensus algorithm operation

Large-scale fault-tolerant systems depend on consensus algorithms because they allow a collection of distributed or replicated machines or servers to cooperate coherently and reach a consensus regarding the state of the system even in the event of failures or outages. The algorithm establishes a threshold, or the minimum number of member machines required to come to a consensus, in order to accomplish this. Consensus methods presume that only a percentage of the nodes will reply and that some processes and systems will be inaccessible while they solve a consensus challenge. They also anticipate that there will be some transmission loss. Nevertheless, the accessible nodes must respond. For instance, in order to reach consensus or agreement on something, an algorithm might need that at least 51% of nodes reply.

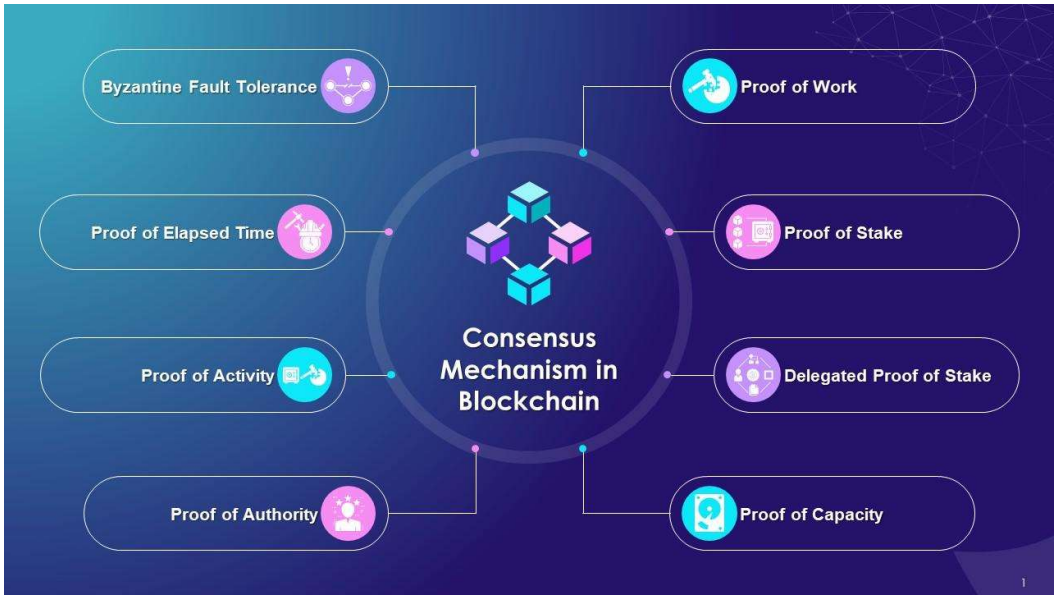

Fig 1: Consensus Mechanism in Blockchain

These algorithms underpin a wide range of digital and computational systems in the real world, apart from blockchain and crypto currencies, such as: state machine replication, Google Page Rank, load balancing, intelligent power grids, clock synchronization, and drone control, among other uses.

Consensus algorithm types

Now let's investigate the various kinds of consensus algorithms.

1. Evidence of Work

Among the earliest kinds of consensus algorithms is the proof-of-work (PoW) algorithm. The main principle behind Proof of Work (PoW), which was first proposed in 1993 and reintroduced by Bitcoin founder Satoshi Nakamoto in 2008, is for nodes to solve challenging mathematical puzzles and make as many guesses as they can in the shortest amount of time. Blockchain's for crypto currencies that use the Proof-of-Work (PoW) algorithm require miners, also called valuators or participant nodes, to demonstrate that the work they have completed and submitted entitles them to add new transactions to the blockchain. They have to figure out a cryptographic hash of a specific block in order to solve a challenging mathematical puzzle.

2. Postponed Work proofing

The Proof of Work consensus technique has been tweaked to create Delayed Proof of Work (dPoW). By taking periodic photos of itself and writing them into a network block as part of the notarization process, the blockchain network achieves consensus in this way. This procedure aids in generating a blockchain backup of the complete system. Since consensus isn't reached on new blocks using dPoW, it isn't technically a consensus algorithm. Instead, it's a security feature that guards against a 51% assault, which could seriously disrupt a blockchain network by giving one party control over most of the hash rate. Because the dPoW resets the network's consensus rules, this is made possible.

3. Evidence of Stake

An alternative to proof of work (PoW) is called proof of stake (PoS). PoS mining requires less sophisticated gear and software than PoW mining because it does not require solving intricate computational issues. Crypto valuators', on the other hand, stake or lock away some of their currency in a wallet. If they find a block that can be added to the blockchain, they subsequently validate the block. Based on the blocks that are put to the blockchain, valuators' receive a reward or an increase in stake that is proportionate to their wagers. The algorithm uses less computing power than PoW because it is incentive-based.

4. Assignment of Proof of Stake

One more effective and democratic kind of proof of stake is called delegated proof of stake, or DPoS. To reach consensus during the generation and validation of blocks, this algorithm is based on a voting system in which witnesses or delegates cast their votes for the valuators' they like. Delegates support the upkeep of the blockchain network's integrity, dependability, and transparency in addition to confirming transactions. Each delegate has a voting power equal to the quantity of coins they own. Transaction fees are used to compensate them for their efforts and are distributed to the corresponding electors.

5. Authority Verification

The power-hungry and less scalable Proof of Work (PoW) algorithm is replaced by the more effective and scalable Proof of Authority (PoA) consensus process. Moreover, PoA is a more secure system than PoS since block valuators' stake their identities and reputations rather than currency. A PoA-based blockchain network is essentially protected by a small number of validating nodes. These nodes are reliable individuals who have been pre-approved and randomly selected to validate transactions and blocks. By serving as system moderators, these users contribute to the development of a more scalable mechanism than PoW.

6. Burn Proof

PoW and PoS algorithms are being examined with Proof of Burn (PoB) as a potential sustainable replacement. PoB and PoW are similar, but PoB uses a lot less computing power. This is true because hardware or processing power are not needed for the Blockchain's block validation procedure. Rather, in order to reach consensus, miners "burn" or invest money in the network. To make coins unusable, they are delivered to an address from which they cannot be reclaimed. This grants the miners the authority to create new coins and approve fresh transactions on the network, proving their dedication to the system. An individual miner's odds of being the next block valuators' rise with the amount of Bitcoin they burn.

7. PoW/PoS hybrid consensus

PoW and PoS algorithms' shortcomings are balanced by a hybrid PoW/PoS technique. PoW miners first add new blocks to a blockchain by creating new ones. PoS miners cast votes to approve or disapprove the blocks after they are generated. They stake some of their tokens as part of the PoS algorithm during the process. However, unlike PoS, this hybrid algorithm does not look at the overall number of votes. Rather, a random five-vote process is used to assess the new block's effectiveness.

Consensus is reached and the block is uploaded to the blockchain if three of the five votes are in favor. A proportionate 60% of the rewards go to PoW miners, 30% go to PoS miners, and 10% goes to other miners.

4. Blockchain–IoT Layered Architecture

The most transformative technology to emerge in the last ten years is blockchain. The financial markets are the most likely to be affected. A few businesses using technology are healthcare, medicines, insurance, smart properties, cars, and even government agencies. But the most successful use of the technology to date is Bitcoin: A Peer-to-Peer Electronic Cash System, which is also the first application of blockchain technology. It follows that understanding the creation and operation of the Bitcoin System is the first step towards understanding blockchain technology. In essence, a blockchain is an ever-growing digital list of data entries. This kind of list is composed of multiple data blocks that are stored in a certain sequence, linked together, and secured using cryptographic proofs. The article's main discussion point is the blockchain ecosystem's tiered architecture.

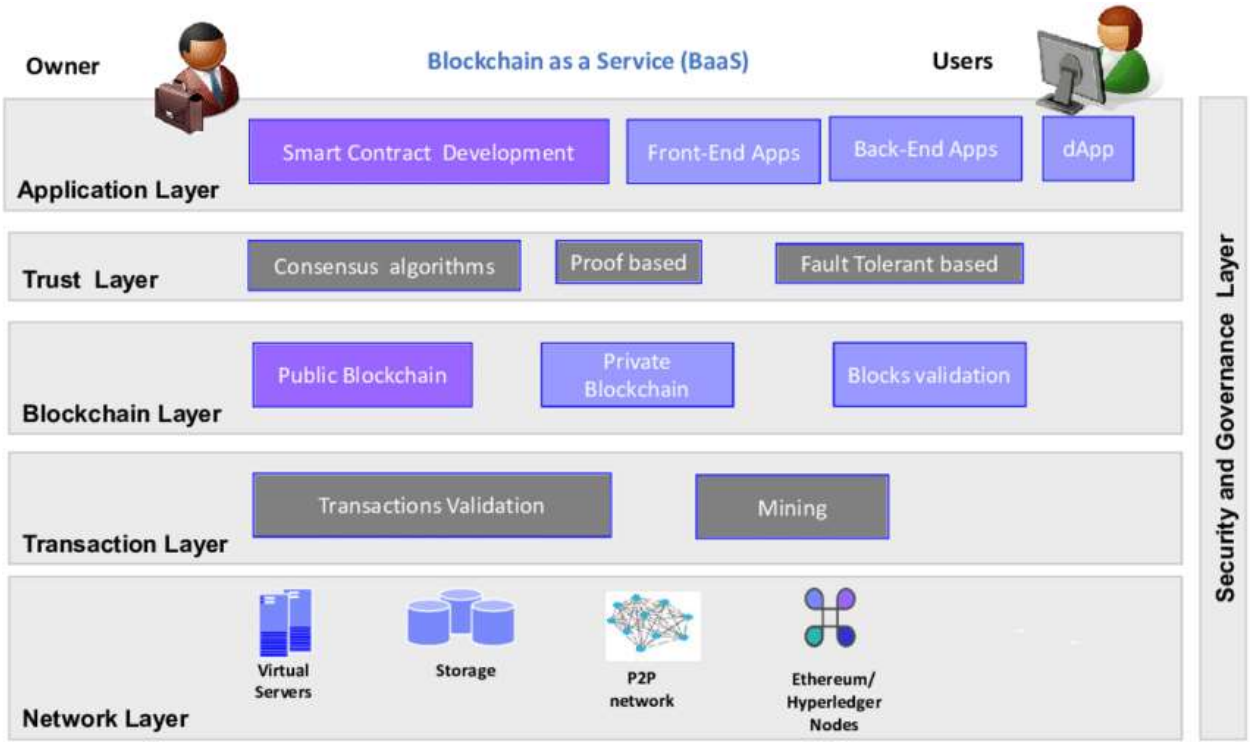

Fig 2: Blockchain Layer

Within the context of blockchain technology, an ecosystem is a group of interconnected parts that create a distinct habitat. Ecosystems built on blockchain consist of a group of dispersed nodes that replicate immutable transactions. As seen in the graphic below, the blockchain (also known as digital ledger) technology is based on a tiered architecture.

Blockchain Layer Types According to Experts

However, blockchain technology layers can also be classified into the following other categories:
Layer 0; Layers 1 and 2; and 3

1. The Layer 0
   Layer-0, which consists of the connections, hardware, protocols, and other components that make up a blockchain ecosystem, acts as the network architecture for the blockchain. This layer could be referred to as a "network of blockchain."

Layer 0 not only permits inter-chain communication, but it also facilitates inter-chain operability. It provides an essential basis to address layer scaling problems in the future. Layer 0 often uses a native coin to promote engagement and development.

Layer 0 contains the Polkadot, Avalanche, Cardano, and Cosmos designs.

2. First Layer

Most of the work that maintains the fundamental features of a blockchain network, including consensus, programming languages, protocols, limits, and dispute resolution, is carried out at Layer 1. The blockchain itself is represented by the first layer.

Many times, scalability problems arise from the sheer number of jobs this layer has to handle. As more users join a blockchain, the computational power required to solve and add blocks to the blockchain increases, leading to higher fees and longer processing times

The scalability problem is somewhat lessened by employing improved consensus techniques like proof-of-stake and the advent of sharding (the partitioning of computing processes into smaller sections). But history has shown that they are insufficient.

Examples of Layer 1 systems are Bitcoin, Solana, Ethereum, and the Binance Smart Chain.

3. Second Layer

The blockchain needs more processing power in order to function more productively. However, the requirement for extra nodes causes congestion in the network. A Blockchain's decentralized character cannot be maintained without more nodes; however changes to scalability, decentralization, or throughput will affect the other layer 1 parameters.

This means that expanding layer 1 would require shifting all processing to layer 2, which is a layer that is added on top of layer 1. This is made feasible by permitting the incorporation of layer 1 solutions from outside sources.

A new network named Layer-2 is responsible for redesigning Layer-1 and managing all transactional validations. Layer 2 sits atop Layer 1 in the blockchain ecosystem and interacts with it.

4. Layer Three
The blockchain ecosystem's top layer is also the one that is visible to the unaided eye. In due course, users will interact using Layer 3 protocol user interfaces. When interacting with L1 and L2, this layer aims to provide simplicity and ease.

In addition to user interfaces (UI), L3 provides intra- and inter-chain operability, which includes staking applications, liquidity provisioning, and decentralized exchanges. Decentralized apps (dApps) are a type of layer 3 interface that enable the usage of blockchain technology in real-world scenarios.

Other instances include wallet providers, Compound and Aave-style liquidity management protocols, and decentralized crypto currency exchanges like Pancake Swap and Uniswap, like Binance and Coin base.

5. Roles of Blockchain in IoT

The Internet of Things (IoT) facilitates information sharing across linked physical objects in a heterogeneous network [18]. One could categorize the IoT into the sections that follow.

1. Physical Things: Every linked object in the network has a unique ID thanks to the Internet of Things. Other IoT nodes can share data with the actual objects.

2. Gateways: These are the devices that operate between the cloud and physical objects to guarantee that a connection is made and that the network is secure.

3. Networking: it determines the quickest path between IoT nodes and controls data flow.

4. Cloud: Data is computed and stored there.

The BC is a series of cryptographically-verified blocks of transactions that are stored by the linked device in a network. The digital ledger, which is accessible to the public, houses the block data. Secure communication within an IoT network is provided by the BC. A blockchain might have distinct qualities and operate as a private, public, or consortium. The distinctions between all types of blockchain are shown in the following table.

6. Current Trends in BC-IoT Development

Now Blockchain is a distributed ledger system that is decentralizing and starting to replace nearly every application in the banking, finance, agriculture, and transportation sectors, among others. When this technology is integrated with other technologies, such as cloud computing, machine learning, or the Internet of Things, such improvements become feasible. This article performs an extensive review of the literature regarding blockchain-enabled IoT-based applications across several industries. Examining the current state of blockchain-based Internet of Things systems and applications is the aim, as is showcasing how unique features of this technology might revolutionize industry practices. Blockchain attracted a lot of interest because of its security mechanism, which sends transactions between several entities without the need for a third party and verifies the accuracy of the information. There might not have been a systematic study to look at and assess blockchain from many perspectives, despite the fact that many analysts believe that Blockchain's privacy and security features are the answer to many issues in today's inherently unsecure internet [81]. Less than ten years prior, in 2009, blockchain made its debut. The world experienced a swift transformation as a result of this remarkable invention. Blockchain is starting to find its way into the scientific, medical, and retail sectors of the professional worlds.

Network Federated

One of the most important and effective blockchain developments in recent years is federated blockchain technology. This is an improved approach to the fundamental blockchain foundation, which makes it ideal for a range of pertinent applications. Experts predict that because federated blockchain offers a more customizable view of private blockchain, its popularity may increase. With a few minor exceptions, federated blockchain are similar to private blockchain in most respects. These blockchain offer more transaction privacy and are faster (more scalable). Examples of federated blockchain are Corda, EWF (energy), B3i (insurance), R3 (banking), and others.

As a Service: Blockchain (BaaS)

Blockchain-assisted applications are run on cloud-based systems created and maintained by third parties, a practice known as BaaS. Amazon and Microsoft are also adopting the BaaS trend. Numerous entrepreneurs and enterprises are now integrating this recent blockchain movement. However, while developing, maintaining, and overseeing a novel blockchain approach, such future blockchain trends could not be feasible. It's a blockchain-powered cloud-based solution that lets users create online services. These digital goods could be apps, smart contracts, or other services that run outside of the network built on blockchain technology.

Interoperability of Blockchain

The exchange of data and other content between various blockchain networks and infrastructures is referred to as interoperability. This feature allowed the public to quickly access data that was stored across many blockchain [82,83]. It makes it possible for users to swiftly and simply move money between blockchain. Other features like cross-chain transactions are also added using this functionality. By building multi-token wallet services, it may also enhance multi-token transactions.

Contracts Ricardian

The purpose of the Ricardian contract was to locate a legitimate legal document that was electronically connected to a crucial element. The Ricardian contract arranges all of the terms of the legal agreement in

a way that the software can follow. Therefore, because of cryptographic verification, it serves as both a secure network and a legal contract that is electronically integrated into digital infrastructure. It is not the same as a smart contract. One kind of digital agreement that was previously agreed upon and is automatically executable is called a smart contract. Conversely, the Ricardian contract serves as an agreement model to document the goals of an agreement and any associated conduct before the agreement is carried out. Similarly, Ricardian contracts could

Blockchain's that are Hybrid

The future of blockchain technology suggests utilizing a more suitable ratio of public and private blockchain technologies. This technology might be summarized as the blockchain. Because verifying procedures are made quick and easy by the network's well-known nodes, the exchange rate is somewhat lower. Because the hybrid blockchain is a closed ecosystem, network security is enhanced by all evidence. This prevents over 50% of attacks as well because thieves are unable to access the blockchain system. The rules are updateable by the user as needed. Maintaining task secrecy when interacting with the outside world also helps.

Social Media

Blockchain technology in social networks could solve issues including contentious arguments, privacy infringement, information manipulation, and material importance. As a result, social media architecture is incorporating blockchain, a new technological trend. Social networks employ tokens. Media businesses are thus offered financial incentives to provide content and raise network productivity. On platforms like the blockchain, token exchanges are completed, nearly immediate, and fee-free.

7. Challenges

Flexibility

Blockchain is susceptible to blocking due to the volume of transactions it processes. As of July 10, 2022, Bit coin's storage capacity exceeded 406 GB [89]. When IoT joins blockchain, weight can be far more important than the greatest blockchain.

Storage

The provided ledger will be stored on all IoT devices. But when its storage capacity increases, it will become harder to work with and weigh a lot more than any other connected instrument.

Insufficient Capabilities

Unbeknownst to most researchers, blockchain technology is becoming more and more common. Additionally, it's an endeavor to educate people on almost all technologies.

Investigating and Combining

IoT applications are not meant for blockchain technology. Within the blockchain and IoT networks, it can be difficult for related devices to find another tool. IoT nodes may therefore identify and integrate blockchain and other nodes, and they can also access all other nodes.

Private Information

Every device that is linked can access the shared ledger. Real-time ledger transaction viewing is possible with these devices. Thus, it is challenging to ensure privacy in an embedded system [90].

Communication

Blockchain technology can exist in a public, private, or consortium setting. Thus, a blockchain IoT agreement also governs the connection between public and private blockchain.

8. Applications

The accessibility and safety of linked materials are issues that the modern internet addresses. These resources might be encrypted on a blockchain, or network-to-network chain, where users are aware of each other's transactions. It may protect company relationships and prevent fraud since it streamlines operations, expedites workflow, removes errors, and saves data. People's lives will be completely changed by distributed blockchain technology, which will enable them to vote, rent a car, perform trades or manage money via phones, and even authenticate themselves.

Intelligent Equipment

Wireless connectivity allows smart devices to provide users with unparalleled information and control. For example, a code linked to your gadget can connect to the internet and alert you if your washing machine breaks down. These notifications keep the gadgets operating at optimal efficiency, saving them money on energy costs and enabling you to keep an eye on them while commuting to work. Using the blockchain to access these devices would protect the assets and facilitate information sharing.

Sensors for the Logistics Network

A sensor is an apparatus that is used to identify and react to a certain type of input obtained from physical infrastructure. Critical information can be obtained from changes in light, wind, movement, humidity, strain, or any other environmental factor.

The Contract for Smart Contracts

Over time, the smart contract has developed into a digital device that can electronically promote, verify, or carry out the setup and implementation of an agreement. Reliable transactions can be carried out with smart contracts without requiring the assistance of other vendors.

Monitoring Prescription Drug Usage

According to the release, blockchain could enhance the patient experience by enabling them to instantly ascertain whether a prescription is fake by scanning a barcode. Additionally, its ingenuity could decide when to gather and move medications throughout the manufacturing process at the necessary temperature adjustments.

Music by Blockchain

Blockchain technology might be useful in the music industry in some circumstances. It might make more content available or use special edition electronic releases to reward watchers and split profits. But it's unfair to use it for a music service, and it's untrue to say that it addresses any of the most important problems that musicians face.

Identification via Blockchain

These days, identity verification plays a significant role in our everyday lives. Identity checks are required when traveling abroad, buying a new car, and enrolling in college. Authorization for mobile devices is also required when creating a new social media account. It might not always be possible or even practical to bring personal belongings. This is where the effective confidentiality control of the blockchain is useful.

Information Sharing

Enhancing the effectiveness of data interchange between producers, shipping companies, distributors, governments, suppliers, fulfillment centers, and customers is the main goal of blockchain technology. Blockchain technology will lessen the impact of contaminated items by enabling the company to track the cause of degradation much more rapidly. Blockchain’s can provide end-to-end information traceability,

the best capacity to investigate the history of the goods, and real-time position and condition with regard to consumer refunds.

Land Registration, Real Estate Registration, and Property Registration

Blockchain's have the potential to significantly change the real estate industry, from title management to property purchasing. It has the power to completely alter the dynamic between taxpayers and tax authorities as well as the way tax payments, returns, and data management are done. Blockchain technology can simplify exchange, transaction, and property registration procedures while upending and restructuring the financial industry.

In an Adverse Circumstance (COVID-19)

The COVID-19 epidemic highlights how interconnected the world is. This also draws attention to a complicated reality: when we need quick, coordinated action or collaboration, a lot of vital information gets stuck in protected information storage facilities and reputation systems. The most challenging problems facing us between 2019 and 22 are resolved with the help of the blockchain-IoT integrated solutions.

9. Conclusions

The blockchain architecture, which included peer-to-peer networks, shared key encryption, and hash-based proof of work, was a crucial part of this decentralization approach. Existing IoT solutions are hampered by their complexity, limited interoperability, resource limitations, privacy and security issues, and vulnerabilities. Blockchain technology's quick development offers answers to issues with improved connectivity, privacy, security, stability, and transparency. In this post, academics explore the relationship between blockchain technology and the Internet of Things. They also gave literature reviews and had a discussion on blockchain and IoT. We talk about the problems and uses of creating a reliable and compatible communication infrastructure for blockchain technology and the Internet of Things. The present blockchain tendencies are examined in this article. The pros and cons of the combined strategy are examined, along with the integration of blockchain and Internet of Things architecture.

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