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Integrating Blockchain and Cloud to Create Innovative IoT Architecture

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Abstract- The emergence of blockchain, cloud computing, and the Internet of Things (IoT) as a continuous worldview is transformational for the state-of-the-art computerized biological system. IoT systems with expanding reach are the generat massive amounts of data that appear to be properly managed if they are safe, adaptable, and skilled. Despite its versatility and abundance of resources, cloud computing frequently lacks the security that the Internet of Things demands, leaving the devices open to cyber threats. By enhancing the information intelligence, security, and dependability of IoT systems, blockchain technology, with its decentralized and impenetrable record, could close these security gaps. The goal of this research is to see how blockchain technology and cloud computing can be combined [2]. The main issues of scalability, latency, and security can be fully addressed by combining blockchain technology with cloud computing for Internet of Things applications. Blockchain's decentralized management, transparency, and data immutability can greatly reduce the risks associated with single points of failure in centralized cloud systems. In the meantime, real-time processing of streams of Internet of Things data at scale can be made possible by cloud computing's vast processing and storage capacity, which may exceed blockchain's computational limits. Strong networks of IoT devices that can support vital applications in the management of supply chains, smart cities, healthcare, and other fields may result from this collaboration. In order to successfully balance cost, performance, and security, future study must concentrate on maximizing the integration of these technologies

Keywords- Blockchain technology, Internet of Things (IoT) ,Blockchain-based Internet of Things (BIoT), Cloud Computing

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I.INTRODUCTION

It's challenging to envision a world without the Internet, given its deep integration into both our personal and professional lives. The Internet has become indispensable, and numerous devices such as smartphones, sensors, and mobile computers have become integral parts of daily life. These smart objects, along with various Internet of Things (IoT) technologies, have had a profound impact on the evolution of information and communication technology (ICT) and enterprise systems. It's challenging to envision a world without the Internet, given its deep integration into both our personal and professional lives[1]. The Internet has become indispensable, and numerous devices such as smartphones, sensors, and mobile computers have become integral parts of daily life. These smart

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objects, along with various Internet of Things (IoT) technologies, have had a profound impact on the evolution of information and communication technology (ICT) and enterprise systems. However, the integration of blockchain presents significant challenges, primarily due to high energy consumption and substantial computational resources required, which conflict with the resource constrained nature of most IoT devices. In its early stages, the Internet was primarily known as the "Internet of Computers," evolving later into the "Internet of People." With rapid advances in ICT, it has now progressed to the "Internet of Things‖[3]. The concept of connectivity has broadened from —any-time, any-place, for any-one‖ to now include —any-time, any-place, for anything. —This paradigm shift involves connecting various mechanism and secured by means of cryptographic algorithms The concept of Furthermore, improvements in statistics and opportunity IoT have created new opportunities anything ties for industrial ,consumer and commercial The development of IoT technology has become an important focus in ICT innovation and economic strategies worldwide[6]. It positions lot as one of most important Facilities technologies of the future. The main goal is to facilitate smooth Interaction and integration between the physical and digital worlds each expected to enable advanced communication and intelligent operation is between devices, system services. It represents a new revolution in communication technology. Which almost every object From household appliance to industrial machinery it has been designated as unique, Identifiers [4]. As a core pillar of the future Internet, IoT is expected to enable superior communication and clever. operation amongst gadgets, structures, and offerings. This is representing a brand-new revolution in verbal exchange generation, in which nearly every item, from household objects to business machinery, is assigned a unique identifier, permitting them to attach and alternate records. While there's no universally agreed-upon definition of IoT, its impact is clear throughout various sectors[11]. Researchers and marketers alike are exploring the capacity of IoT to provide revolutionary services throughout a wide range of packages, from healthcare advancements to responses to international challenges like COVID-19. With nearly 25 billion IoT devices already in use, the quantity is projected to reach 50 billion by way of 2025 ,underscoring the widespread and developing haven impact on of IoT technologies. It's quite hard to imagine a world without the Internet, the internet as so deeply pervasive in personal and professional life, now part of professional life, now part of every device-like smartphone, sensors, and mobile computers. [5]. These intelligent objects, along with different kinds of IoT-related technologies, greatly affected the development of both ICT and enterprise systems. Nobody can even imagine life today without the internet; its penetration runs incredibly deep into our personal and professional life. [6]. The Internet, one cannot envision or conceptualize its nonexistence and thousands of devices, including smartphones, sensors, and mobile computers. Coupled with several technologies that comprised the Internet of Things, these smart objects and intelligent items have transformed the information and communication technology or ICT and enterprise systems. However, blockchain integration faces serious challenges mainly in terms of high energy consumption and significant computational needs which are at variance with the resource-constrained nature of most IoT devices[9]. As an early development, the Internet was mainly referred to as the "Internet of Computers[6], —It positions lot as one of most important Facilities technologies of the future. The focus is on seamless Interaction and integration between the physical and digital worlds each of which is supposed to enable advanced communication and intelligent operation that is between devices, system services[13]. This is a novel revolution in the world of communication technology. In nearly every object From the household appliance to industrial machinery has been assigned as unique, Identifiers. As a core pillar of the future Internet, IoT is expected to enable superior communication and clever. operation amongst gadgets, structures, and offerings. This is representing a brand-new revolution in verbal exchange generation, in which nearly every item, from household objects to business machinery, is assigned a unique identifier, permitting them to attach and alternate records[2].

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II. ROLE OF BLOCKCHAIN IN IOT

Blockchain is increasingly more incorporating current technology which includes AI IoT, and cloud computing. Industries are leveraging the mixture of blockchain with IoT to facilitate stable and trustworthy transactions. With billons of gadgets connected to IoT, the capability for this integration is vast[9]. According to Cisco, the number of networked devices worldwide was projected to upward push from 17.1 billion in 2016 to 27.1 billion through 2021. Similarly, a forecast expected the wide variety of connected devices the use of these communication technologies might develop from 780 million in 2016 to three. Three billion with the aid of 2021[11]. Recent studies highlight the advantages and demanding situations of mixing IoT with blockchain. One takes a look at demonstrates that integrating blockchain with off-blockchain solutions secures private information without counting on depended on 1/3 parties. The idea of the Bitcoin blockchain has been applied to protect IoT gadgets via a evidence-of-idea protocol. Additionally, the Fair Access framework introduces new transaction kinds for granting, obtaining, delegating, and revoking get admission to. This framework is primarily based on concepts like consumer-pushed transparency, equity via blockchain, a allotted structure, and great-grained manipulate.

III. ROLE OF CLOUD COMPUTING IN IOT

When IoT and cloud computing come together It will create a new paradigm called the Cloud of Things. IoT enables better communication via extensive networks and devices with the outside world, particularly the internet [7]. Cloud computing now provides scalable network access that adapts to neediest typically involves many distributed devices with limited data storage capacity[4]. This often faces performance-related challenges. reliability privacy and safety Cloud computing complements the IoT by providing nearly unlimited storage capacity and computational power. Along with a flexible and robust environment for combining data from different sources, connectivity addresses many of the challenges facing IoT[21]. The cloud-based Internet of Things (CloudIoT) enables intelligent, efficient and economical deployment of software, data and infrastructure. Although IoT and cloud computing are different The cloud-based Internet of Things (CloudIoT) enables intelligent, efficient and economical deployment of software, data and infrastructure. Although IoT and cloud computing are different technologies, different The cloud-based Internet of Things (CloudIoT) enables intelligent, efficient and economical deployment of software, data and infrastructure. Although IoT and clo cvfr56tud computing technologies is different[6].

IV. INTEGRATION OF BLOCKCHAIN AND CLOUD FOR IOT

Various advanced technological advances, such as cloud computing, the Internet of Things, and artificial intelligence, are being integrated with blockchain technology. Industries have started adopting the technology in conjunction with advanced technologies, such as the Internet of Things (IoT) to enhance the security and credibility of the existing systems. The scope of connectivity is beyond limits as millions of devices are included in the Internet of Things network. Cisco forecasted that the total of connected devices worldwide would grow from 17.1 billion in 2016 to 27.1 billion by 2021[7].In addition, it was expected that several devices using these technologies would rise from 780 million ten years agog to 3.3 billion five years into the future. IoT and blockchain have also been reviewed by some of the recent research works just examining the merits and demerits of the combination of the two[6]. Research indicates that protection of end-user data can be improved using blockchain incorporated into off-blockchain solutions mitigating the use of trust third parties. In another instance, there has been a proposed protocoled which protects IoT devices based on the principles of the Bitcoin blockchain concept The Fair New transaction types are introduced by the Access Framework that manage access rights, such as granting, obtaining, delegating, and revoking

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access. This framework is grounded in principles fine-grained control, distributed architecture, blockchain-based fairness, and user-driven transparency. The Fair Access system is modelled after the OM-AM Framework, which consists of four layers: Objective, Model, Architecture, and Mechanism.

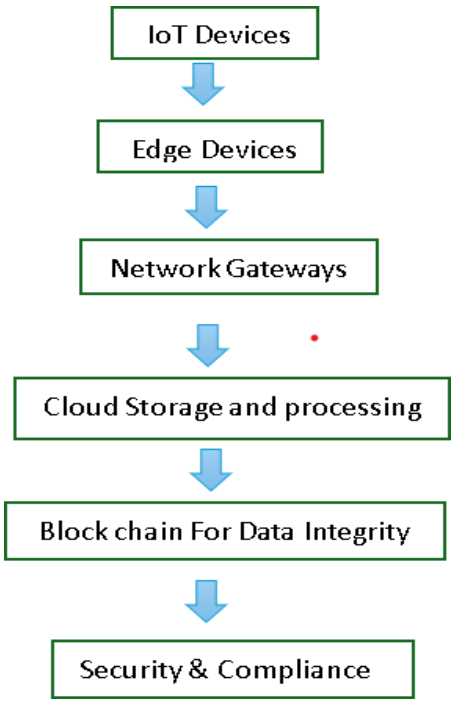

Figure 1 Flow Chart Of Integration IoT with Blockchain and cloud

In Figure 1 Flowchart will show how data flows from IoT devices to the cloud, where blockchain adds security and transparency, before reaching end-users or automated processes In one regard, lack of appropriate resources in IoT can be alleviated by the ever-expanding use of Cloud where its resources are available abundantly and such aspects as storage, computational abilities as well as power are not limitations. To be precise, the Cloud is manageable for the implementation of IoT services and exploitation of good software from the data collected from different IoT devices. In contrast, it is aimed at the objects that are occupied with Cloud computing whereby the services are enhanced, and the level offered is more interactive and engaging in a typical scenario. As it is shown in many papers, the synergy between the Cloud and the Internet of Things encourages the emerging of the CloudIoT concept. Thus, within this structure, the Cloud is placed in between the IoT devices and their software, acting mainly to conceal the intricacies, and perform only the indispensable actions. This integration is predicted to influence the subsequent development of software, giving rise to new possible obstacles about data collection, processing as well as transmission, especially in case of multi cloud systems[4]. Future application development will be impacted by this framework since data collection, processing, and transmission will present new difficulties that must be overcome in a multi-cloud setting. [2].This section outlines the advantages of incorporating IoT within Cloud technology as detailed below.

Storage Resources: Iot Involves Many Information Sources

Things that produce vast amounts of semi-structured or unstructured data, aligning with the characteristics of Big Data (volume, variety, velocity)[12]. The most effective way to manage this data is to provide nearly limitless and inexpensive storage space on demand [10]. Opportunities for data aggregation, integration, and sharing with external parties are made possible by CloudIoT. While allowing data to managed uniformly via standard API, secured with top-tier protection, and accessed from anywhere.

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Communication:
Cloud-based IoT enables application and data sharing through connected IoT devices, allowing for automated and low-cost data distribution and collection. The Cloud facilitates dynamic monitoring, remote control of objects, and real-time data access. Although Cloud improves IoT interconnection, limitations may arise when transferring vast amounts of data from IoT devices to the Cloud[11].

Scope: With billions of connected devices generating a wealth of data, we are moving towards the "Internet of Everything" (IoE), where CloudIoT provides new services and software by bridging real-world objects with Cloud infrastructure. This opens a variety of real-world scenarios and new service opportunities for businesses and users alike.

V. CHALLENGES WHILE INTEGRATING BLOCKCHAIN AND CLOUD WITH IOT

The merging of blockchain and IoT holds the potential to revolutionize many aspects of daily life[8].However, this combination also faces several technical and operational challenges. The key obstacles in combining blockchain with IoT, provides a mapping of these challenges, their potential solutions, and relevant references. In this section, the major challenges and limitations are explained.

1. Energy Efficiency
Energy efficiency is a crucial consideration when constructing Blockchain-IoT architectures since IoT devices frequently run on batteries.. On the other hand, most blockchain architectures are energy intensive. The two main factors contributing to blockchain's high energy consumption are:

- **Consensus Algorithms:** Protocols like Proof of Work require significant computational power, resulting in enormous energy waste, especially for solving cryptographic puzzles (mining).
- **P2P Communication:** IoT devices must remain power on during peer-to-peer (P2P) communication, which further consumes energy.

Several energy-efficient P2P protocols have been proposed to address this issue. Ball et al. suggested using the energy consumed in PoW for more productive activities. Additionally, consensus algorithms like Proof of Stake (PoS) and Practical Byzantine Fault Tolerance (PBFT) have been introduced to reduce energy consumption in blockchain systems[9]. In P2P communication, energy is consumed with every blockchain update, but by utilizing "mini blockchains," which enable direct interactions between IoT nodes and the blockchain without involving the entire chain, the number of updates (and thus energy consumption) can be minimized. Furthermore, fast hashing algorithms like X11, Script, and Blake-256 have been introduced to improve energy efficiency in blockchain.

2. Privacy
In blockchain systems, public keys are used to identify all users, which inadvertently compromises anonymity. Since all transactions between nodes are visible on the blockchain, third parties can potentially interpret these transactions and uncover the identities of participants. To address this lack of anonymity, Qin et al. proposed a solution combining Ethereum, which allows private transactions while preserving user anonymity during activities such as voting, payments, and blind auctions.

Identity management is another significant challenge in BIoT. If a node has authority for identity verification, it may also possess the power to block other nodes. Permissioned blockchains, which can manage multiple IoT nodes, offer a potential solution to this problem. They provide a distributed method to identity management and rotate asymmetric keys to thwart assaults. Participating nodes create keys, and the system uses a Device Group Membership (DGM) mechanism—which groups devices owned by the same user—to verify user identities. In this scenario, the blockchain can identify the user group to which a transaction belongs whenever it is completed. In public blockchains, to

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mitigate privacy concerns, a user (sender) should only be aware of the address of the user (receiver) they are interacting with, rather than having access to the addresses of all nodes in the blockchain. However, if participants change their address with each transaction, it could increase blockchain complexity[25]. In private blockchains, solutions like Multichain ensure privacy by allowing selected participants to monitor the blockchain. Integrating IoT with cloud technologies brings numerous benefits, but it also comes with significant data privacy concerns at every stage. It begins with IoT devices collecting data, often sensitive, which can sometimes happen without the user's full knowledge or consent. When this data is transmitted to the cloud, there's a risk of interception if proper encryption or secure protocols aren't in place. Once the data reaches cloud storage, it's vulnerable to breaches if the systems lack strong security measures.

During processing, data might be analysed in ways that go beyond its intended purpose, increasing the chances of misuse or exposure.

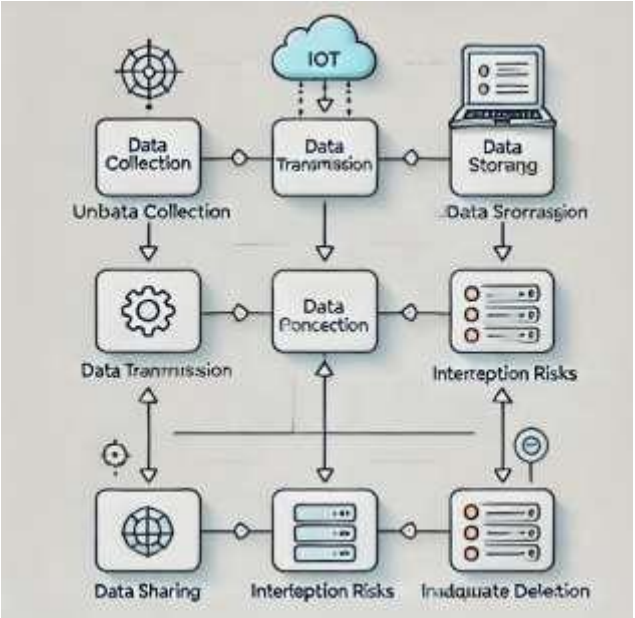

Figure 2 Possible of Data breach Integrating Cloud and IoT

3. Possible Privacy Breaching

One of the best things about blockchain is that it integrates quite well private and public key pairs ensuring data privacy. This form of encryption yet may not be fool proof in some occasions[16]. It was also noted that due to learning and inferring many transactions made by one user, this user could be identified. Moreover, putting all the information onto a block chain to eradicate any chances of possible privacy violation could be more worrisome.

4. Resource Allocation

Resource allocation would be a problem when IoTs of completely distinct and unexpected entities would be requesting resources in a cloud. It would be very difficult to estimate how much of a particular resource an entity or an IoT may use. Resource allocation must be mapped according to the type, quantity, and frequency of data generated by the sensor, its intended application, and other factors. It can also be helpful to send a sample packet from the just joined node. Introducing a middleware that can handle complete management of resources, such as Broker or Fog, is one way to solve the problem. The middleware can be used to construct resource management methods, and all underlying devices are managed appropriately. Devices will be able to communicate with the cloud through CoT. Thus, a middleware layer can also be used to manage cloud resources.

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5. Location of Data Storage

The location of data storage plays a crucial role in delivering services that are sensitive to latency or jitter . Time-sensitive data, such as video, should be stored in a physical location as close as possible to the user to reduce delays. For multimedia content, it is essential to allocate the nearest available virtual storage server to ensure minimal latency. provides an example of this scenario[25].

6 Use Case of Integrating IoT and Blockchain With Cloud Computing

Supply Chain Management

Two important areas for the implementation of blockchain-based automotive supply chain management are outgoing distribution services to importers and dealers and incoming logistics services to the plant.

Incoming Logistics Service

Ensuring timely delivery of parts and maintaining optimal inventory levels are critical priorities for manufacturing plants. This can be achieved through effective coordination between third-party logistics providers, transportation companies, and multiple tiers of suppliers[15]. The coordination process can be significantly enhanced by utilizing an IoT-integrated blockchain system. This system employs smart IoT sensors and devices that track the location, quantity, and other relevant data of parts in real time. The enhanced system offers several benefits to the manufacturing plant, including more accurate production scheduling, improved material and information flow, and better tracking of goods. For suppliers, the system reduces the likelihood of incorrect orders, lowers warehousing costs, optimizes inventory levels, and improves inventory turnover rates[24].

Outgoing Distribution Service

On the other side, the timely distribution of vehicles to dealers and importers is a key priority for manufacturing plants. This requires effective coordination with third-party logistics and transportation companies. By leveraging an IoT-integrated blockchain system, which employs IoT sensors and smart devices, the location of vehicles and other important information can be

Wireless Sensors Networks (WSNs) IoT-based System Stacked in Real Time

This improved system provides several benefits to the manufacturing plant, such as enhanced just-in-time logistics, fewer damaged vehicles, and better inventory control. For dealers and importers, the system leads to reduced lead times for build-to-order vehicles and decreased warehousing costs. This component envelops remote sensor systems that shape IoT frameworks planned to screen and track the development, transportation, and taking care of raw materials, semi-finished items, and wrapped up merchandise over the whole supply chain. The handle ranges from numerous providers (Factory, supplier1,... provider n), through the unique hardware producer (OEM), different merchants (distributor1, distributor2, ... distributor n), and eventually to the conclusion client. These highlights change over conventional criticism signals into noteworthy, computerized experiences, empowering enhancements in operational costs, execution, and client fulfilment. IoT sensors inside the supply chain are categorized based on the physical properties they screen, counting temperature, nearness, infrared (IR) signals, weight, smoke, gas, touch, colour, stickiness, and weight. They are utilized to identify changes in light, warm, movement, moisture, weight, or other natural conditions. Furthermore, IoT sensors offer real-time data on stock levels in warehouses and on shelves, as well as tracking information about product locations and the conditions of transportation. Data gathered by these sensors is transmitted to a cloud-based blockchain consortium management system. This transmission leverages various standards and technologies, such as Radio Frequency Identification (RFID) tags, Wi-Fi, GPRS, GPS satellites, and others

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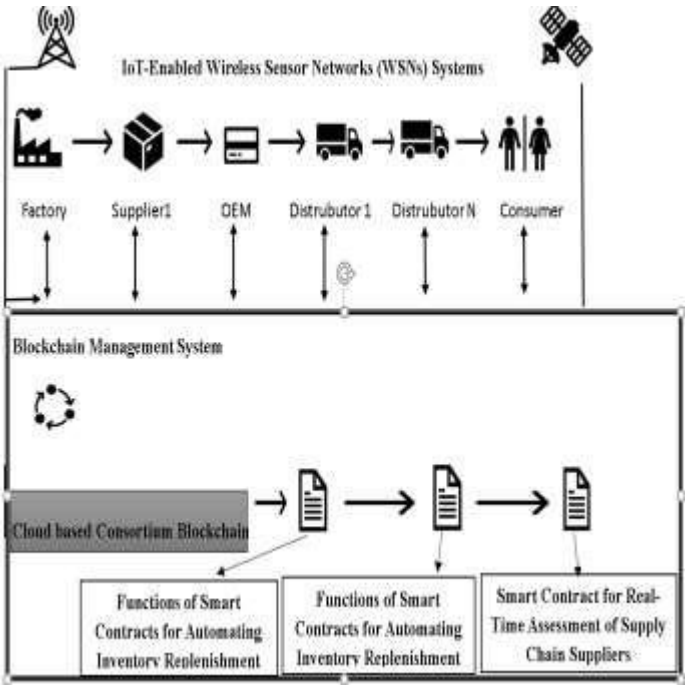

Figure 3 Integrated IoT based Blockchain Model for Supply Chain Management

2. IoT and Blockchain based Supply-Chain Management In Pharmaceutical Industry

The traditional pharmaceutical supply chain has major issues with tracking fake drugs and ensuring drug quality because it lacks transparency. But, by using a system that combines the Internet of Things (IoT) with blockchain technology, we can give each pharmaceutical product a unique tag, like a Global Trade Item Number (GTIN), an expiration date, and a serial number[10]. These tags are visible to everyone in the supply chain, making it easier to see what's happening at every step of the drug's journey. In this improved system, each drug package is seen as a digital item, giving companies full visibility from when it's made, stored, transported, and finally delivered to the customer. IoT devices in the supply chain keep track of real-time conditions, like temperature and humidity, to make sure everything is within the right environment[15]. If anything, unusual happens, the blockchain system quickly alerts everyone.

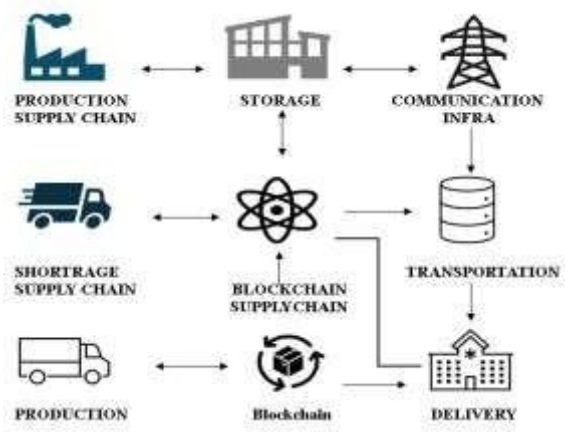

Figure 3 Blockchain based pharma supply chain System

This graph Fig 3 exhibits the integration of IoT and Blockchain in a pharmaceutical supply chain, guaranteeing proficiency, straightforward forwardness, and security. The handle starts at the plant, where drugs are created and observed by IoT sensors for quality confirmation. After generation, the

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drugs are put away in stockrooms where IoT gadgets track stock levels and natural conditions, with information recorded permanently on the blockchain. Amid transportation, IoT-enabled trucks screen basic parameters like temperature and area, guaranteeing secure conveyance. The IoT Communication Hub (Cable Tower) plays a pivotal part by empowering real-time information transmission between IoT gadgets and the blockchain, guaranteeing perceivability and secure information trade. In case of inadequate or terminated items, the turn around coordination's prepare encourages secure returns or transfer. At long last, the drugs are conveyed to clinics or drug stores, with blockchain confirming realness and avoiding fake drugs from entering the supply chain

3. Integration of Cloud Computing and a IoT(Cloud) in Smart Grids

Smart grids are the future of energy systems, using IoT and cloud computing to manage energy produ-ction, distribution, and usage more efficiently. Cloud computing provides the necessary storage and processing power to handle the large amounts of data from IoT devices, which is crucial for real-time monitoring and automated decisions in modern smart grids.[3]

4. There are four main types of Cloud Computing used in Smart Grids

- **Public Cloud:** Used to make facilitiesmanaged by the cloud provider available to smart grid users and subscribers via the Internet
- **Private Cloud:** Dedicated to grid operators, ensuring greater cybersecurity and customization .
- **Hybrid Cloud:** Combines multiple cloud types, transferring data between private and public clients implementation. to enable flexible
- **Community Cloud:** Designed for groups of clients with shared interests, such as energy companies. It is economical since the Generation Layer: IoT enables optimized operation and secure integration of renewable energy sources. It aids in accurate forecasting and predictive maintenance of power generation resources, supporting cooperative energy storage and grid-scale management[23].
- **Transmission Layer:** IoT ensures secure operation by providing real-time fault detection and quicker maintenance. The integration of sensors at this level contributes to the reliable operation of transmission lines[8].
- **Distribution Layer:** IoT facilitates communication across a vast network of interconnected components, enabling the management of electric vehicles, virtual power plants, and active distribution networks.

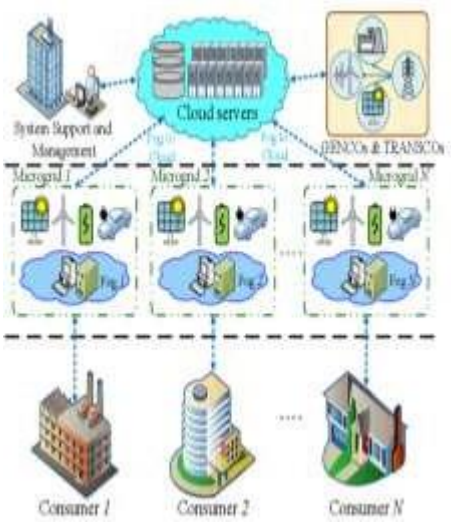

Figure 4 Deployment of Cloud IoT in the smart grid environment[19]

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Cloud computing complements this IoT facilitiesby providing essential computational power for data analytics and big data processing. With cloud enabled IoT, smart grids benefit from enhanced demand response capabilities, optimized grid operations, and better integration of renewable energy sources. However, challenges remain, including the need for IoT-enabled devices, uniform standards, cybersecurity, and interoperability among components[22].

VII. CONCLUSION

The convergence of blockchain, cloud computing, and IoT technologies represents a transformative approach to addressing the challenges and unlocking the potential within IoT ecosystems. Blockchain enhances data security, transparency, and immutability, resolving many of the longstanding issues surrounding data integrity and trust in IoT networks. When coupled with the scalable facilitiesof cloud computing, IoT devices benefit from an efficient and resilient environment capable of managing vast amounts of data generated by billions of interconnected devices[14].

In conclusion, the integration of blockchain with cloud and IoT is a promising model for the next generation of intelligent systems. As technology advances, addressing these challenges will help pave the way for a more secure, efficient, and decentralized IoT ecosystem, enabling a future of connected devices that are trusted, scalable, and optimized for performance

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