BLOCKCHAIN-ENABLED INTERNET OF THINGS APPLICATIONS IN HEALTHCARE: CURRENT PRACTICES AND FUTURE DIRECTIONS

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FOREWORD

In the healthcare field, the combination of blockchain technology and the Internet of Things (IoT) has brought about a wave of innovation and change. The collaboration between these technologies shows the potential to transform how healthcare services are provided, managed, and safeguarded. As we dive into the contents of this revised book titled "Blockchain-Enabled Internet of Things Applications in Healthcare: Current Practices and Future Directions", we set out to explore and uncover the possibilities of this duo.

This publication serves as a handbook that sheds light on the state of blockchain-powered applications in the healthcare sector, providing valuable perspectives on the potential future directions that this integration may take. By presenting insights from industry experts, readers will gain a view of the uses, challenges, and opportunities at the intersection of blockchain, IoT, and healthcare.

From bolstering data security and privacy to facilitating communication among healthcare systems, the sections featured in this book provide a perspective on the innovative solutions shaping the healthcare sector. By utilizing the characteristics of blockchain in conjunction with the interconnected nature of devices, healthcare stakeholders are empowered to improve effectiveness, enhance results, and propel innovation to unprecedented levels.

As we delve into the world of telemedicine, patient monitoring, supply chain management, and more, the insights shared in this book will spark inspiration and fuel curiosity. This book will pave the way for a future where healthcare prioritizes patients, relies on data, and embraces technology. I want to applaud the editors, authors and contributors for their input to this collection. I am confident that this book will be a source of knowledge for academics, researchers, practitioners, and enthusiasts.

Let’s embark on this adventure together as we delve into the world of healthcare applications powered by blockchain technology. Envision a future where innovation knows no bounds. May this book motivate you to embrace technology’s potential in healthcare and drive change for all.

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PREFACE

In the changing world of healthcare technology, the combination of the Internet of Things (IoT), blockchain, and smart healthcare has transformed how we view and provide healthcare services. This publication seeks to clarify these concepts and their practical applications in the healthcare industry for readers from different backgrounds. We begin by outlining terms such as IoT, blockchain, and smart healthcare to ensure a grasp of the technologies discussed throughout the book. Real-life examples are included to demonstrate the uses of IoT and blockchain in healthcare, highlighting both the advantages and difficulties faced by industry players.

The ethical aspects related to healthcare data, such as consent and data security, are explored to underscore the significance of upholding standards in this digital age of healthcare. Insights into trends and future pathways in IoT blockchain and healthcare are shared to provide a glimpse into where the industry is heading and potential advancements. Recognition of research in this field is acknowledged, along with a discussion on how this publication contributes to enhancing knowledge about IoT, blockchain, and healthcare.

An overview of security measures like authentication and authorization in IoT systems is presented to underscore their importance in fortifying against potential cybersecurity risks. In this book, you will find in-depth discussions about how blockchain technologies are incorporated into IoT healthcare systems. It also delves into the methods that safeguard data privacy and confidentiality.

The book sheds light on the hurdles and possibilities in the healthcare industry, demonstrating how IoT and blockchain are revolutionizing healthcare services and patient supervision.

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CHAPTER 1

Intelligent IoT Healthcare Applications Powered by Blockchain Technology

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Abstract: The fusion of artificial intelligence (AI) with the Internet of Things (IoT) marks a significant advancement in enhancing conventional healthcare systems across various domains, such as monitoring vital signs and patient behaviors. IoT sensors collect extensive information, which is then processed by AI platforms for informed decision-making. However, the pivotal challenges of privacy and security loom large, demanding robust protective measures for patient data against unauthorized access.

While access control has conventionally been employed to address these concerns, a more effective solution lies in leveraging blockchain technology. Consequently, the integration of IoT-based healthcare monitoring with blockchain emerges as a compelling technological innovation, offering a promising avenue to alleviate security and privacy apprehensions associated with data collection. This chapter introduces an architectural framework designed to gather, store, analyze, facilitate intelligent decision-making, and safeguard data using blockchain technology.

The proposed architecture harnesses the computational power derived from the synergy of IoT, blockchain, and artificial intelligence. It represents a versatile solution applicable across a broad spectrum of healthcare optimization initiatives, showcasing the potential to revolutionize and optimize healthcare systems.

The purpose of this study is to harness the power of artificial intelligence, IoT, and blockchain technology in making a system capable of enhancing the healthcare system. Further, the study presents an architecture that, if implemented, can help optimize the healthcare systems.

An architecture-based approach with AI, IoT, and blockchain techniques will be followed in designing architecture that can solve the integrated issues of data privacy and security that occur in healthcare systems.

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A systematic architecture will be generated to tackle the healthcare industry problem. Systematic study and architecture will serve as a platform for new research and application development.

Keywords: Artificial intelligence, Blockchain technology in healthcare, Decentralized healthcare, Data security, Digital health records, Healthcare data management, Healthcare blockchain integration, Healthcare applications, Intelligent healthcare, IoT in healthcare, Integration of AI in healthcare systems, Medical IoT devices, Remote patient monitoring, Real-time health analytics, Smart health monitoring, Smart hospitals, Telemedicine.

INTRODUCTION

An overview of the healthcare records from the past century clearly illustrates the remarkable evolution of healthcare systems. Key milestones include the development of antibiotics, anesthesia, vaccines, insulins, and significant advancements in medical technology and diagnostic tools. The progress in medical technology has greatly improved the accuracy and speed of diagnoses, with notable contributions such as X-rays, magnetic resonance imaging, computed tomography, electrocardiograms, ultrasound imaging, and patient monitor systems.

One groundbreaking innovation in medical technology that holds transformative potential is the integration of Internet of Things (IoT) devices into healthcare. In the healthcare context, IoT devices encompass wearable or implanted internet-connected devices designed to monitor specific health parameters [1]. These devices play a crucial role in various aspects, including glucose monitoring, hygiene monitoring, and tracking mood or depression. While IoT devices find applications in diverse domains, for the sake of clarity in this chapter, we recommend readers to associate them specifically with healthcare systems.

The core objective of any IoT device is to provide timely medical assistance. To satisfy this objective, a typical IoT device should have or facilitate 3 functionalities: data collection, data transmission, and data storage. Fig. (**1**) represents the intermixing of these functionalities, where an IoT device is responsible and engineered to collect the data from the patient, it needs to relate to a network, and lastly, it transfers data *via* a network to the IoT cloud managed by the respective healthcare service provider.

Fig. (1). Basic functionalities of or supported by IoT devices.

The data stored in the cloud is used for data analysis, whereby the healthcare providers can make decisions based on the reports. Fig. (**2**) introduces the data analysis components of previous functionalities.

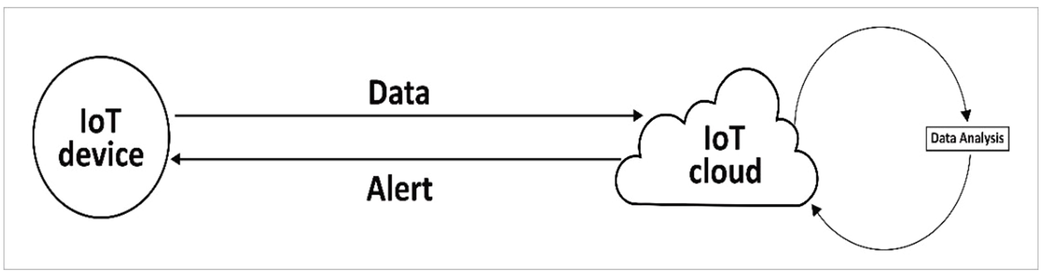

Fig. (2). Basic functionalities of or supported by IoT devices with data analysis components.

With recent advancements in artificial intelligence (AI) technology, the data store can be used to train machine learning (ML) algorithms so that the data can be used for intelligent decision-making. Fig. (**3**) shows the AI component in action.

Fig. (3). Basic functionalities, data analysis component, and AI component.

IoT devices, although effective if not designed and implemented carefully, are vulnerable to cyberattacks and can pose serious threats to the person. The data needs to be transmitted and stored in a secure manner. The analysis and reporting, if done incorrectly or late, can also pose a threat to the person. But if we can use cryptographic techniques to transmit the data, blockchain technologies to store the

CHAPTER 2

Blockchain-Powered IoT Innovations in Healthcare

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Abstract: The convergence of blockchain technology and the Internet of Things (IoT) has become a transformative catalyst in healthcare. "Blockchain-Powered IoT Innovations in Healthcare", a chapter in this book, explores the dynamic interplay between these technologies and their far-reaching impact on healthcare systems. This chapter commences with an introduction to blockchain and IoT, emphasizing their relevance within the healthcare domain. It underscores blockchain's pivotal role in fortifying patient data security, addressing privacy concerns, and rectifying vulnerabilities in healthcare data management and highlights the diverse applications of IoT devices in healthcare, including wearables, remote patient monitoring, and smart hospital equipment. It also addresses how blockchain facilitates secure cross-platform data sharing while preserving data integrity and confidentiality. The implementation of smart contracts in healthcare is explored, showcasing their influence on patient empowerment, data transparency, and the management of clinical trials. The chapter also illustrates how blockchain technology enhances supply chain management and ensures drug traceability, countering the proliferation of counterfeit medications. A comprehensive discussion on patient empowerment and data control reveals how blockchain is revolutionizing patient engagement and informed decision-making. The chapter analyzes the intricate landscape of legal and regulatory aspects, offering guidance on compliance and potential legal implications of blockchain adoption in healthcare. In conclusion, the chapter addresses the challenges, future prospects, and emerging trends in the field of healthcare. It serves as an essential resource for healthcare professionals, researchers, policymakers, and technology enthusiasts navigating the intersection of blockchain and IoT in the ever-evolving realm of healthcare.

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Keywords: Blockchain, Counterfeit medications, Clinical trials, Data security, Data interoperability, Drug traceability, Emerging trends, Healthcare, Internet of Things (IoT), Informed decision-making, Legal considerations, Medical research, Privacy, Patient engagement, Patient empowerment, Regulatory compliance, Remote patient monitoring, Smart hospital equipment, Smart contracts, Wearables.

INTRODUCTION

The convergence of blockchain technology along with the Internet of Things (IoT) has steered a new era of possibilities for the healthcare industry. “Blockchain-Powered IoT Innovations in Healthcare”, a chapter in the book exploring this transformative interplay, begins by establishing the fundamental concepts of blockchain and IoT and their relevance within the healthcare domain. Blockchain, a distributed record technology, is a distributed and tamper-resistant database that registers and verifies transactions. It has gained significant traction across various industries due to its skill to improve security and transparency. In healthcare, the starter of blockchain expertise is paramount in addressing the numerous problems related to data security and data privacy [1]. With sensitive patient data at the core of healthcare operations, ensuring its integrity and confidentiality is a top priority. Blockchain provides a robust solution by creating an immutable ledger of transactions, making it exceedingly hard for unlicensed parties to tamper with or access sensitive information.

In addition to securing data, blockchain offers an innovative approach to data management and interoperability in healthcare. The introduction highlights the challenges of data silos and incompatibility among different healthcare systems. Blockchain acts as a bridge that allows secure cross-platform data sharing while preserving the integrity and confidentiality of patient records. This not only facilitates more efficient healthcare services but also improves the coordination of care across various providers [2]. The Internet of Things, conversely, embodies an extensive web of linked devices and sensors actively gathering and transmitting real-time data. In healthcare, IoT applications have taken many forms, from wearable devices that monitor vital signs to smart equipment used in hospitals [3]. The introduction to this chapter underscores the significance of IoT devices and their diverse applications in healthcare.

These applications include remote patient monitoring, enabling healthcare professionals to oversee patients' conditions from a distance, and the integration of intelligent hospital equipment. This technology not only enhances patient care but also minimizes human errors and contributes to more effective hospital management. The synergistic relationship between blockchain and IoT is a gamechanger for healthcare. The introduction provides a glimpse into how these technologies work in harmony to revolutionize data management, data sharing, and patient care [4]. By establishing the foundational concepts of blockchain and IoT within the healthcare context, this chapter sets the stage for a complete exploration of the impact, challenges, and upcoming scenarios of this transformative convergence.

As the healthcare industry continues to evolve, the introduction to "Blockchain-Powered IoT Innovations in Healthcare" serves as an essential primer for healthcare experts, researchers, representatives, and technology enthusiasts seeking to direct this exciting intersection and harness the merits of blockchain and IoT in the realm of healthcare.

ENHANCING PATIENT PRIVACY AND DATA SECURITY

Patient privacy and secured data are paramount in healthcare. With the digitization of medical records and the increasing use of electronic health records (EHRs), safeguarding sensitive patient information has become a significant concern. Blockchain technology has appeared as a powerful solution for increasing patient privacy, ensuring that healthcare records remain confidential, tamper-proof, and accessible only to authorized parties. Fig. (**1**) explains how blockchain enhances privacy and data security for patients.

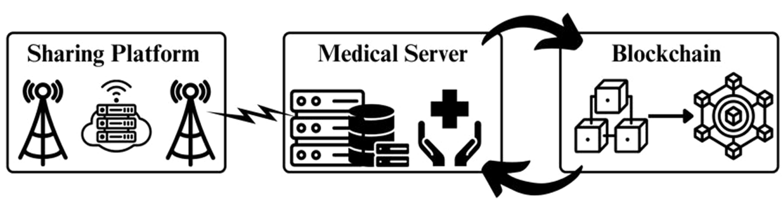

Fig. (1). Enhancing patient privacy and data security.

This figure depicts how blockchain and IoT collaborate to protect healthcare data. Their synergy ensures robust security and privacy.

Blockcain's Role in Securing Patient Data

Blockchain, often described as a distributed ledger technology, offers several key features that make it particularly well-suited for securing patient data:

Decentralization

In contrast to conventional centralized databases, blockchain functions within a decentralized network of computers. Every participant, referred to as a node,

CHAPTER 3

Blockchain-Powered Integrated Health Profile and Record Management System for Seamless Consultation Leveraging Unique Identifiers

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Abstract: Integrated health profile (IHP) utilizes the power of blockchain technology and smart contracts to construct a decentralized and tamper-proof platform for storing and sharing decentralized health records. Ensuring security and removing all vulnerabilities from accessing doctor-patient data remotely aims to reduce patient wait times and chances of incorrect pre-consultation data. In the IHP system, every patient is linked with a unique identifier, and their health records linked to this unique identifier are stored securely. Everyone gets access to a personal IHP card, which plays a pivotal role in the entire IHP framework. It consists of a database of patient health records, including but not limited to reports, prescriptions, medical bills, and insurance receipts. Each card's unique identifier is printed on the physical card with a QR code linked to it. When scanned by the medical practitioner, the request is validated using an OTP-based two-factor authentication. Upon successful verification, the patient controls what subset of their medical database the practitioner would be able to access. This gives the patient control over the privacy of medical records. Implementation of this framework reduces manual doctor-patient questioning time and waiting time at medical center receptions. Overall, it reduces various administrative tasks and eliminates the need to have, keep, and carry physical records, improving operational productivity. This is done by harnessing the strength of application programming interfaces (APIs) that connect customer-centric applications (CCAs) that are used by customers to discover medical facilities to medical service provider applications (MSPs) that fulfill the medical service. Real-time information on medical facilities is fetched *via* APIs, giving all

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CCAs access to real-time information on all MSPs and helping fulfill medical service demands at scale.

Keywords: Blockchain, Blockchain health records, Integrated health profile, Medical service provider, Patient consultation, Record management system, Unique identifiers.

INTRODUCTION

The current healthcare system functions with certain inefficiencies like centralized health record storage, timely access to medical facilities, and various operational inefficiencies that hinder comprehensive and well-informed medical care services, which results in potential diagnostic errors. Moreover, centralized storage of records increases the risk of unauthorized access to sensitive medical information and patients' data. To deal with these challenges, giving patients control over their data has become a necessity [1].

The IHP framework addresses these concerns by assigning a unique identifier to each patient and securely linking their health records to this identifier. At the core of the IHP is an individualized IHP card, serving as an extensive repository for patients' records, including reports, prescriptions, medical bills, and insurance receipts [2]. The proposed IHP system overcomes these challenges by utilizing unique identifiers for each patient, accessed *via* an IHP card linked to a decentralized database of patient health records. The IHP card features a unique QR code connected to the patient's unique identifier (UID). When scanned by a medical practitioner, the patient undergoes a two-factor authentication process, receiving a one-time password (OTP) to ensure additional consent and security. After successful verification, the doctor gains access to a specific subset of the patient's shared records, respecting privacy and confidentiality. This UID is accessed *via* an IHP card through a QR code, which, when scanned, verifies the patient's identity *via* an OTP-based two-factor authentication, providing an additional layer of security measures and more control to the patient as they choose a subset of their medical data that they want the medical practitioner to access [3].

The implementation of the IHP framework brings significant improvements to the customer intake process, eliminating the need for manual data entry at healthcare facility receptions. This reduction in administrative tasks leads to shorter waiting times and enhanced operational efficiency. Additionally, integrating a patient's medical history with the IHP card provides medical service providers with extensive insights into the status of a patient's health, enabling accurate diagnoses and personalized treatment plans. This reduces wait time in queues at receptions, speeds up administrative work, and allows for more patient intake in hospitals. Additionally, it empowers medical practitioners with in-depth, comprehensive insights for each patient, enabling better diagnosis and personalized treatment plans [4].

LITERATURE REVIEW

To facilitate the efficient discovery of medical services, this framework employs standardized application programming interfaces (APIs) to connect customer-centric applications (CCAs) with medical service provider applications (MSPs). Through these APIs, CCAs can access real-time information on available healthcare facilities, ensuring customers receive accurate and up-to-date details about their healthcare options [5].

The objective of this research paper is to explore and develop the IHP framework as an innovative solution for secure and decentralized health record storage and sharing [6]. By leveraging blockchain technology, smart contracts, and standardized APIs, the IHP offers numerous benefits to patients, including enhanced data security, improved privacy [7], streamlined executive processes, and facilitated healthcare service discovery. Through a comprehensive examination of the IHP framework and its potential applications, this study aims to contribute to the advancement of patient-centric and efficient healthcare systems [8]. Table **1** discusses the comparative study of the integrated health profiles for healthcare systems using blockchain, which are already available. Secured remote access to doctor-patient data is the need of the hour as the world moves towards home-based online services [9].

Table 1. Comparative study of the integrated health profiles for healthcare using blockchain.

Article	Blockchain Technology	Type of Data	Merits	Limitations
[10, 11]	•The Multilink system is undependable of proof of stack •Personal blockchain	IHP	Improved and secured audit recording	•Only the Electronic Unit is considered
[12, 13]	•Personal blockchain.	IHP and PHP	Blockchain-based control application used to share healthcare information	•Ignored scalability and availability •Exchange of information is very less.
[14, 15]	•Validity of work •Personal blockchain	Health Image Data	Exchange of health records safely	•Elimination of information sharing

CHAPTER 4

BCT-HC: Application of Healthcare Technology Using Blockchain Technology Hyperledger Fabric

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Abstract: Blockchain innovation offers an information structure with built-in safeguards, including agreement, decentralization, and encryption, which ensure the accuracy of operations. It has broad use in a variety of fields, including smart factories, the Internet of Things (IoT), and healthcare. It is particularly relevant in the areas of healthcare information safety and privacy preservation. Digital healthcare records have been deployed faster because of communication technology, however, this has also increased risks to patient confidentiality, safety, and medical information. Another strategy to deal with the issue of medical data confidentiality and safety is the application of blockchain. Medical and health information includes treatment data gathered during patient care alongside private prevention of illness. Blockchain systems can be used in numerous capacities in healthcare organizations, including confidentiality and safety, to shield information about patients from unwanted access. Nevertheless, healthcare networks confront numerous security concerns, including connectivity, reliability, exchange of clinical information delivery, and patient deliberation, as a result of the inexperienced design of safety measures. Furthermore, deployment and information administration are the main issues for blockchain in healthcare due to the enormous amount of manufactured hardware gadgets. The platform is a communication mechanism that combines the use of computers with health records. It has been suggested that Hyperledger is the most developed collaborative chain technology. In contrast with various blockchain platforms, Hyperledger concentrates on developing enterprise-level standardized implementations. The Hyperledger framework is used for sensitive data in digital welfare, but neither restricted access nor thorough permission was taken into account. It is simple to determine fraudulent data collection by a malevolent person *via* confirmation of data by additional subjects, and the original, unmodified information can be recovered. Data can only be influenced if a bad person has access to over 50% of the blockchain network's nodes through security breaches, which is nearly unattainable. As a result, blockchain technology can stop information from being faked or falsified, improving the data's durability and dependability.

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Keywords: Blockchain, Decentralization, Digital healthcare, Encryption, Healthcare, Hyperledger, Hyperledger fabric, Internet of Things, Smart factory.

INTRODUCTION

Blockchain is essentially a distributed, decentralized electronic record that keeps track of activities safely and irreversibly. Blockchain innovation [1] operates on a network of peers, guaranteeing that no individual has total control over the data. This reduces the chance of information being altered or illicit access while boosting transparency. This feature is especially helpful in the field of healthcare, where patient confidentiality and security of information are crucial. The permanent nature of blockchain files adds a critical degree of safety for health information. Since every item or transaction on the blockchain is cryptographically linked to every other deal, amending previous data would need modifying each transaction that comes afterward. This unchangeable feature safeguards sensitive knowledge and health data, significantly reducing the likelihood of forgery and increasing the trust of patients. A full file of transactions is accessible to all participants in the network, facilitating regulatory adherence, product confirmation, and health information monitoring. The integration of computer science into healthcare [2, 3] gave rise to healthcare technology, which greatly enhanced healthcare. Blockchain computing has several uses in the medical field outside of patient information. These include medication safety, managing supply chains, sickness forecasting, medication accountability, claims processing, and others. The easy-to-use system and reliable environment of blockchain technology yield useful outcomes that increase parties' faith. The Hyperledger Fabric system (individual Blockchain) safeguards patient confidentiality and the integrity of their health information.

AN OVERVIEW OF BLOCKCHAIN TECHNOLOGY AND ITS VERSION

Blockchain is a decentralized technology that allows several parties to conduct operations and keep track of them in a record. It is based on a dispersed network of nodes that securely and irrevocably log and confirm events. Every node in the network confirms every payment as it gets recorded to the blockchain, and its record is copied among all of the nodes [3 - 5]. Blockchain has two types: one is permission, and another is permissionless. The example is listed as follows:

- **Permissioned Blockchain**: Hyperledger Fabric.

- **Permissionless Blockchain**: Ethereum.

Since its establishment, from the initial digital currency to the present blockchain-based deployment for industry, blockchain technology has been utilized by numerous sectors as a component of the infrastructure of various enterprises that demand openness, honesty, and accuracy in Industry 5.0. Blockchain technology has advanced (Table **1**) from version 1.0 to version 5.0, making it more trustworthy and appropriate for use in commercial settings and industrial uses.

Table 1. Blockchain Technology Advancements.

Version	Description
Blockchain 1.0	The innovative digital currency system was driven by the configurable currency known as the digital currency bitcoin. The virtual currency's transfer architecture is decentralized and key-based, which is how the blockchain system got its beginnings.
Blockchain 2.0	Blockchain-based programs have become prevalent in social domains like banking, transactions among peers, data legitimate enrollment, property and trademark approval, and smart leadership. These applications are based on the expandable culture.
Blockchain 3.0	It expands the use of blockchain technology for decentralized apps (DApps), enhancing productivity and trust among people through decentralization, non-tampering, and reliable collaboration.
Blockchain 4.0	An advancement over the prior version that uses the consensus protocol to regulate network behavior and increase the viability of DApps for real-time business situations applicable in the industrial age (IA) 4.0.
Blockchain 5.0	The current version of the blockchain is regarded as an emerging generation due to eliminating conventional blockchain constraints and using simulated links for quicker execution and more protection.

Blockchain versions 1.0, 2.0, 3.0, 4.0, and 5.0 are in distinct deployment phases. They are all concurrent perspectives of growth, ranging from 1.0 to 5.0, and they have proper roles in various industries. Fig. (**1**) shows the extent of blockchain innovation advancement.

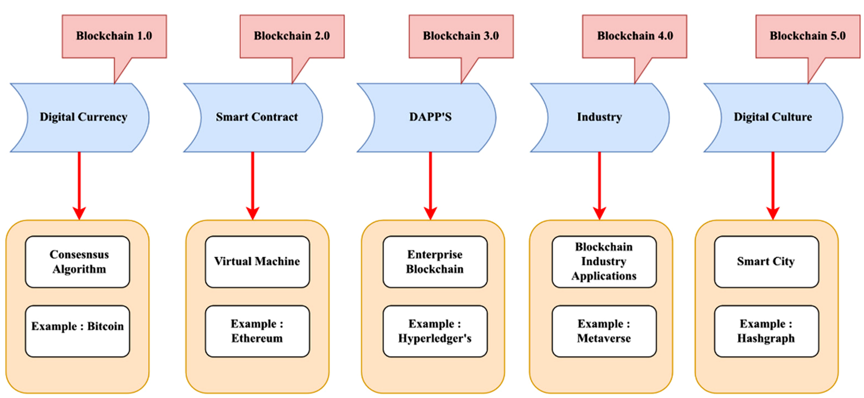

Fig. (1). The range of blockchain technology advancements.

CHAPTER 5

Impact of Blockchain-Enabled IoT Applications for Smart Agriculture and Healthcare to Promote Sustainable Economic Growth and Smart Health Management Ecosystem in Industry 5.0

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Abstract: Within the framework of Industry 5.0, the incorporation of blockchain-enabled IoT applications into smart agriculture and healthcare has significant consequences for long-term economic growth and the creation of ecosystems for smart health management. The environmental, economic, industrial, and stakeholder implications of smart agriculture's transparent supply chains, which are made possible by blockchain technology and precision farming techniques, lessen the environmental impact of conventional farming by cutting down on resource use. Blockchain technology and Internet of Things (IoT) devices safeguard patient records, allowing for more eco-friendly procedures with less paper waste. These innovations maximize the use of agricultural resources, which boosts output while decreasing expenditures from an economic perspective. Better patient outcomes and lower healthcare costs are possible because of blockchain technology's assurance of data integrity and interoperability. This promotes a fairer and more inclusive economic climate, giving smaller players a voice. Innovation and integration are propelled by the industrial sector. By fostering an environment of open communication and cooperation, the tenets of Industry 5.0 aim to bring together many sectors of the economy to improve technological standards, strengthen cybersecurity, and standardize procedures. Awareness, training, and community participation are all made easier by stakeholders, which include NGOs. For these technologies to be adopted in an ethical and responsible manner, their advocacy for legislation that supports them and the protection of data ownership rights are vital. In the future, there will be more international cooperation, new technological solutions to problems with energy efficiency, and the creation of universal benchmarks.

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Keywords: Agricultural resources, Advocacy, Blockchain, Cybersecurity, Community participation, Data integrity, Ecosystem, Eco-friendly, Economic perspective, Environment impact, Healthcare cost, Industry 5.0, International cooperation, Internet of Things, Paper waste, NGOs, Smart health management, Stakeholders, Smart agriculture, Technology.

INTRODUCTION

Blockchain-enabled Internet of Things (IoT) applications have the potential to revolutionise smart agriculture and healthcare. Blockchain and Internet of Things applications can improve supply chain visibility and auditability in the context of smart agriculture. Data from Internet of Things (IoT) sensors, such as those tracking soil moisture, temperature, humidity, and crop health, can be recorded and stored securely on a distributed ledger, giving stakeholders confidence in the reliability of data pertaining to agricultural practises and products. This not only promotes sustainable and ethical agricultural practises but also minimises the possibility of fraud by providing consumers with verified information about the origin and quality of agricultural products. Optimising resource utilisation is one way in which the adoption of blockchain and IoT in agriculture promotes long-term economic prosperity [1]. To guarantee that farmers are fairly compensated for their goods, smart contracts on the blockchain can streamline transactions and legal agreements. Increased agricultural output and profits may result from the greater ease and openness of financial dealings. Moreover, the information gathered by IoT devices may be used for data-driven decision-making, allowing farmers to implement precision agriculture practises that boost productivity while reducing environmental impact. A smart health management ecosystem can be established when blockchain technology is combined with the Internet of Things. Patient data obtained through IoT devices, such as wearable health monitors, can be securely kept on a blockchain. The confidentiality of patient information is protected while open communication between medical professionals is facilitated. Increased patient agency over their own health information supports care delivery centered on the individual. Automating procedures like insurance claims with blockchain-based smart contracts can cut down on paperwork and boost the healthcare system's productivity. Human-centered design and cutting-edge tech go hand in hand in the “Industry 5.0” paradigm shift. In this light, IoT applications enabled by blockchain are congruent with the goal of establishing interdependent ecosystems that put an emphasis on efficiency and sustainability. Blockchain transactions are transparent and safe, so everyone involved in agriculture and healthcare can trust the data being shared between their connected equipment [2]. Industry 5.0 is characterised by the rise of cooperative, networked systems that are capable of enhancing themselves. Blockchain's increased security and privacy is a major selling point when applied to the Internet of Things. Sensitive data is generated and transferred in both smart agriculture and healthcare. The distributed ledger and cryptographic properties of blockchain technology guarantee that information cannot be altered and that only authorised users can access it. This not only promotes good data management practises but also protects the privacy of individuals' health information throughout the agriculture supply chain. It has a significant impact on smart agriculture and healthcare, fostering the growth of sustainable economies and new smart health management ecosystems [3]. As Industry 5.0 develops further, these technologies provide novel answers for the administration of agricultural operations and healthcare systems, with an emphasis on efficiency, transparency, and security.

ENVIRONMENT CONSIDERATION

There are major environmental issues with smart agricultural and healthcare systems that include blockchain and the IoT. In order to solve environmental problems, technical progress in these areas must be in line with sustainability objectives, making these factors critical. The Internet of Things (IoT) allows for the improvement of resource usage in smart agriculture through the use of devices like sensors, drones, and automated machinery. Because of this, farmers are able to use less water, fertiliser, and pesticide, leading to more efficient practices overall. This helps with sustainable farming and resource conservation by reducing the negative impact of conventional farming practices on the environment. The use of blockchain technology in smart agriculture improves eco-friendliness by creating a verifiable and transparent supply chain. By being open and honest about where their food comes from, consumers can rest certain that their food is not part of any unlawful or unsustainable methods that harm the environment [4]. With this information at their fingertips, shoppers can demand more sustainable agricultural techniques that are good for the environment. Blockchain and the Internet of Things (IoT) can also simplify healthcare operations, which in turn reduces the need for resources and the amount of waste produced. There will be less need for paper records thanks to digital health records kept on blockchain systems, which means less paper waste and less pollution. Wearable monitors and remote patient monitoring tools are examples of Internet of Things (IoT) gadgets that are finding use in healthcare. These devices allow for early detection and preventative interventions, which in turn reduce the environmental effect of emergency treatments and hospitalisations. By reducing energy waste and making better use of healthcare resources, this new proactive approach is environmentally friendly [5]. Health data stored on blockchain systems is decentralised and secure, which means less need for physical infrastructure like huge data centres. This means less energy use and a smaller carbon impact. With more and more healthcare systems turning to digital

CHAPTER 6

Stride-Based Threat Modeling for Blockchain-Based Healthcare Supply Chain Management System

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Abstract: The increasing use of blockchain technology in supply chain management has made it imperative to understand the possible security risks associated with its implementation. This research aims to identify important security issues related to supply chain management's use of blockchain technology by doing a thorough analysis of the body of existing literature and looking at actual cases of blockchain deployments. These dangers include the possibility of data privacy breaches, smart contract weaknesses, and 51% attack vulnerability. The report also offers suggestions for reducing these risks, including using multi-factor authentication, regularly carrying out security audits, and enforcing strict access rules. The study's conclusions broaden our knowledge of the security risks associated with blockchain-based supply chain management (BC-SCM) and offer useful guidance to companies thinking about implementing this technology.

Keywords: Blockchain, Data privacy, Information security, Privacy, Supply chain management, Transparency.

INTRODUCTION

A key component of corporate operations is supply chain management, and blockchain technology is becoming more and more popular because of its ability to improve supply chains' efficiency, security, and transparency. Blockchain use

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in supply chain management has several advantages, including the ability to preserve an immutable transaction record and lower fraud risk, but it also presents serious security risks.

Blockchain Technology

Blockchain, a decentralized ledger technology, has attracted a lot of interest because of its potential to revolutionize a number of sectors, including finance, healthcare, and logistics management. It basically works as an open, safe system for registering and confirming transactions. Typically, transactions on a blockchain network are thought of as cryptographically connected blocks that, thanks to sophisticated cryptographic methods, form a safe chain. Because blockchain is decentralized, no one party can have total control over the network, which makes it challenging to alter the data that is stored in the blocks. As a result, blockchain is already being heralded as a revolutionary technology with a wide range of possible uses, such as smart contracts and digital currency. Notwithstanding blockchain's potential benefits, implementation is challenging due to issues with scalability, security, and interoperability. The blockchain network is made up of numerous cooperating computers. There are thousands of exact copies of the blockchain since each computer, or ”blockchain node”, retains a copy of it. Because blockchain replication occurs automatically and a chain is built by hashing codes across blocks, it is difficult for an attacker to change the contents in any block. If one block is changed, the entire chain must also be changed, as well as at least 51% of the nodes' copies of the blockchain, which is not feasible when dealing with a big blockchain or its network.

A block consists of a header, a list of transactions, and a hash, as illustrated in Fig. (**1**). The header of a block contains essential information such as the block number, the date it was appended to the chain, and a distinct hash code generated through cryptographic means. This hash code serves to guarantee the integrity and unalterability of the block's data by acting as a cryptographic fingerprint. Additionally, the header includes a link to the preceding block's hash in the chain, facilitating the connection between blocks and the formation of a blockchain. A block's list of transactions includes details about the sender, recipient, the quantity of crypto currency, or other data being transferred. Once a transaction is confirmed, it is appended to the block's list of transactions. A network of nodes within the blockchain network frequently verifies the transactions. The inclusion of a block nonce typically simplifies the verification process, though it may necessitate the use of intricate algorithms and consensus mechanisms. Through a cryptographic hash function, any alteration, even a minor change of a single bit in the block contents, results in an unexpected and minute modification in the hash code.

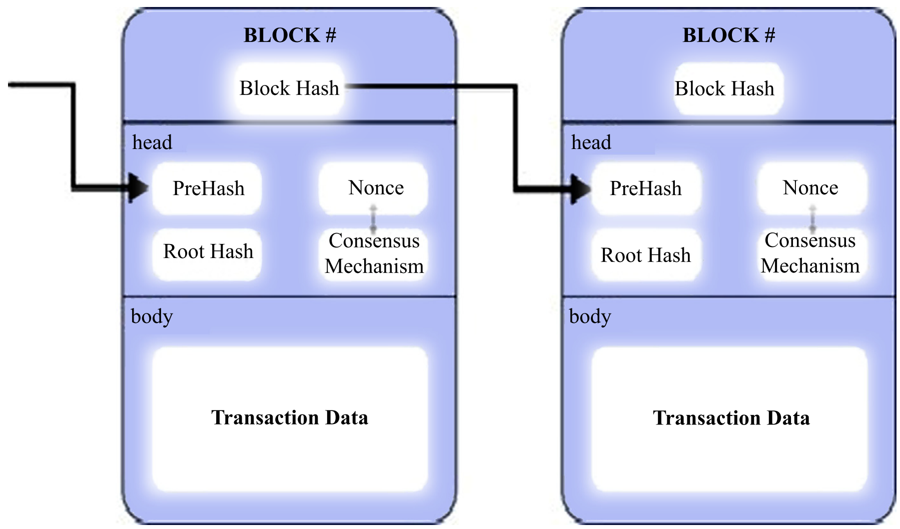

Fig. (1). Basic structure of a block in a blockchain.

In essence, the blockchain's block structure comprises a roster of validated transactions and a block header containing metadata and a link to the preceding block. This arrangement ensures the security, transparency, and immutability of the data stored in the blockchain.

Smart Contracts

Self-executing contracts, known as "smart contracts", are stored on a blockchain, a distributed ledger technology that facilitates safe, open transactions without the need for middlemen. Smart contracts are becoming more and more popular because of their ability to automate various company processes, do away with the need for middlemen, and increase operational performance. In addition, smart contracts provide an irreversible, transparent, and secure degree of integrity and trust that is unmatched by traditional contracts. Smart contracts have garnered substantial interest from scholars and practitioners in a range of industries, such as finance, insurance, healthcare, and logistics, in the past several years. When the conditions agreed upon by both parties are met, a smart contract can be thought of as a piece of self-executing code that only executes a predetermined set of instructions. This guarantees that after the contract is made, neither party may back out.

Supply Chain Management Systems

A supply chain is a well-planned and structured network that links a business to its suppliers in order to produce and market a particular product to consumers in

CHAPTER 7

Applications of Blockchain in Healthcare: State-of-the-Art Survey

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Abstract: This survey provides a state-of-the-art survey of the applications of blockchain technology in the healthcare industry with a few case studies. It aims to explore the significance of blockchain technology in healthcare and its potential to enhance healthcare services in the context of federated blockchain. The paper covers background information on healthcare technology and the benefits, challenges, and limitations of using blockchain technology in healthcare. In this regard, we proposed provenance-based architecture, Hyperledger Fabric-based architecture, and integrated architecture, which contains Aadhar verification and patient history features in the context of India. Overall, the paper demonstrates that blockchain technology has the potential to improve the healthcare industry significantly, but more research and development are required to overcome the challenges and limitations.

Keywords: Blockchain, Cryptography, Cross-enterprise document sharing, Data integrity, Decentralized ledger technology, Digital identity, Distributed databases, EHR, eHealth, FHIR, Healthcare, Hyperledger fabric, IHE, Immutable data records, Interoperability, Medical records management, P4-medicine, Permissioned blockchain, Privacy, Security, Smart contracts.

INTRODUCTION

The blockchain is a decentralized and distributed ledger that stores transactions in a transparent and secure manner. The transactions are stored in a series of blocks linked together using the concept of hashing. The information stored on the blockchain is immutable and transparent. These properties of blockchain make it useful in various applications such as financial transactions, supply chain management, healthcare data management, *etc.* Blockchain technology can help transform the healthcare industry in various ways. It can streamline hospital operations and provide secure, transparent management of patient health records. To safeguard the patients' privacy and security, healthcare data must be protected

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due to its highly sensitive nature. Blockchain technology provides secure and private data storage and sharing. It enables us to store patient data in an encrypted, decentralized way. This reduces the chance of a single point of failure and helps prevent security incidents. Another important benefit is that it facilitates interoperability across various healthcare providers. Healthcare data is often siloed and fragmented, making accessing and sharing important information difficult. By offering a safe and transparent platform for data sharing between various healthcare systems, blockchain technology aids in the resolution of this problem. Additionally, it can help lower administrative expenses and improve operations.

Technological developments such as electronic health records (EHRs), wearable devices, and telemedicine have enabled healthcare providers to deliver more efficient and effective patient care. EHRs, for instance, have streamlined the process for healthcare providers to store, retrieve, and share information about patients, leading to improved care coordination and reduced errors. On the other hand, patients are now able to receive medical care remotely with the advent of telemedicine, which is particularly useful for patients in rural or remote areas. Patients can now more easily monitor their health and wellness thanks to wearable technology, such as fitness trackers, which also give medical professionals useful information for preventive care. These technological advancements have also led to significant cost savings and improved patient care, making them a valuable asset to the healthcare industry.

The healthcare industry involves many stakeholders, including healthcare providers, payers, patients, and regulators. It is responsible for delivering the medical services and products essential for diagnosing, treating, and preventing diseases. It is constantly evolving, pushed by improvements in medical technology, changes in patient needs, and shifts in regulations and policies. However, the industry still faces many challenges, such as rising costs, increasing demand, *etc.* As a result, there is a growing need for innovative solutions to improve healthcare services' quality and affordability. Blockchain technology holds the potential to revolutionize the delivery, management, and financing of healthcare, making it a promising solution to the challenges faced by the industry. By enabling secure and transparent patient data management, blockchain technology can improve stakeholder coordination, reduce errors, and enhance patient care. It can also improve the privacy of patient data, protect against cyber threats, and enable interoperability between various healthcare systems and services. As such, healthcare organizations are increasingly exploring and adopting it to address the challenges and opportunities of the digital age.

This paper attempts to present a comprehensive overview of the innovative applications of blockchain in the healthcare industry. We will also explore its potential benefits and examine the challenges. We also present case studies of successful implementations and identify the prospects for using blockchain in healthcare. By delivering a thorough understanding of the applications of blockchain in healthcare, we aim to inform healthcare providers, policymakers, and researchers about the potential of this technology to transform the healthcare sector and enhance patient care.

LITERATURE REVIEW

Several studies have investigated the possible uses of blockchain technology in healthcare and have identified its benefits and challenges [1]. Bittins *et al.* [2] presented a blockchain-based architecture that aims to improve the trust in existing data transfer solutions built on the IHE technical standards. The authors discuss how blockchain is able to improve trust in medical information-sharing procedures by automating provenance tracking and accountable credential verification, and they situate the latest research findings within the regulatory and technical standard frameworks for healthcare, such as IHE and FHIR. As an inspiring and insightful case study, the data exchange methods associated with international organ transplant operations are used. The authors explain how their blockchain-based architecture incorporates SSI credential verification using the EBSI infrastructure and automatically generated provenance annotations for patient medical data using the W3C PROV standard. The integrity of data interactions among communities is improved by this principled integration. The authors also draw attention to the legal specifications that should be incorporated into the planning and implementation of blockchain-based healthcare services of the future. Incorporating SSI into various healthcare settings can result in services that are more adaptable and convenient for patients. The development of reproducible clinical research can be supported by automatic provenance management, and SSI can open the door to the adoption of the "Once Only Principle" in the healthcare industry. Ciampi *et al.* [3] explored the possibility and difficulties of incorporating the FHIR standard with distributed ledger technologies (DLTs). The authors mention a longitudinal record and a "smart care plan," which are concepts outside the purview of EHR systems, as crucial advances in the direction of predictive, preventive, personalized, and participatory (P4-medicine). The authors claim that the certification and verification of clinical events for the advancement of health processes can be accomplished through the integration of FHIR in DLTs. They also provide examples of how blockchain technologies might be utilized to uphold the integrity of workflows linked to FHIR resources and their authentication. The authors conclude that utilizing FHIR for the specific scenario of dynamic care planning, as described by the IHE DCP

CHAPTER 8

Blockchain-Powered Monitoring of Healthcare Credentials through Blockchain-Based Technology

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Abstract: The healthcare industry is using the Internet of Things (IoT) extensively. The healthcare sector manages sensitive information, including an individual's medical history, blood pressure, and other relevant data. Consequently, the technologies used in this domain are becoming more susceptible to attacks because of their heightened sensitivity. Therefore, it is essential to protect the data. Blockchain technology has been shown to provide substantial benefits in achieving this goal. Incorporating blockchain technology into IoT devices has yielded substantial benefits, thanks to notable technical progress. This chapter thoroughly examines the characteristics of blockchain technology that enhance its efficiency in managing sensitive data and ensuring data security and privacy. Furthermore, this chapter systematically explains the region's many security obstacles and how blockchain technology might successfully overcome them. The study's results indicate that future research should explore how gender, age, and knowledge of blockchains affect the adoption of blockchain technology in innovative healthcare systems. An alternate field of research involves evaluating the many elements that influence the adoption of the technology known as blockchain.

Keywords: AI, Adoption, Blockchain, Clinical, Deep learning, Electronic health record, fraud, IoT, Interoperability, Medical supplies, Monitoring, Research, Smart contracts, Privacy, Pos, Patient, Security, Technology, Tracing, Trail.

INTRODUCTION

The emergence of blockchain technology and its core features of decentralization, transparency, and pseudonymity coincided with the introduction of the Bitcoin cryptocurrency in 2008 [1]. With around 400 million transactions successfully

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executed as of March 19, 2019 [2], Bitcoin is a convincing illustration of how blockchain technology may be used. The substantial discussion and proposal of using blockchain technology in data-intensive areas, such as healthcare, has been well-documented [3]. IBM's study found that 70% of healthcare professionals expect blockchain technology to impact the health sector significantly. This impact would be seen in areas such as enhancing regulatory compliance, managing clinical trials, and creating a decentralized platform for exchanging electronic health records [4]. Moreover, the market worth of blockchain applications in the healthcare industry is estimated to exceed $900 million by 2024. While there is a general belief that blockchain has the potential to enhance healthcare IT, the existing study offers only a restricted comprehension of the designed, evaluated, or implemented applications. Moreover, the current enthusiasm around this technology has fostered notions and tactics that may be more practical and well-founded. When assessing the suitability of blockchain technology in the healthcare industry, which encompasses healthcare, biological medicine, and medical education, it is essential to evaluate if existing research correlates with expected results. Moreover, it has been used in financial services, logistics, energy, commodities trading, healthcare, and more. Using blockchain technology, a safe and immutable system may be established to track the origin and path of medicines, aiding in the battle against the widespread distribution of counterfeit drugs. Blockchain-based distributed shared data systems enable several participants in the supply chain to store and exchange transaction records securely. The use of cryptographic techniques enables the restriction of ledger access to authorized entities while preventing unauthorized entities from gaining entry. It offers a method to prevent the dissemination of counterfeit pharmaceuticals across the pharmaceutical supply chain. This approach oversees and regulates the distribution of fraudulent pharmaceuticals. This chapter analyzes the use of blockchain technology in medication monitoring, examines its advantages and disadvantages, and studies several possibilities for protecting the supply chain of drugs.

HISTORICAL BACKGROUND OF BLOCKCHAIN

Blockchain is a distributed and unchangeable record that keeps track of transactions. It obviates the need for a reliable intermediary to facilitate communication between parties. The blockchain is a type of decentralized digital ledger that maintains an expanding information collection, known as "blocks", sequentially. Once these blocks are included in the blockchain, cryptographic techniques establish connections between them and the preceding and subsequent blocks [5]. When adequately executed, blockchain enables universal access to reading, writing, and verifying the integrity of a data block. Due to these characteristics, blockchain is being contemplated for various applications.

Blockchain technology enables the implementation of smart contracts, eliminating the need for third-party oversight [6]. Bitcoin and other cryptocurrencies pioneered a revolutionary technology known as blockchain in 2008-2009 [7]. It offers various operations in banking, healthcare, transportation, and government, among other areas. This contemporary advancement allows us to meticulously monitor our belongings methodically and securely, beyond any previous methods [8, 9].

INTEGRATE IOT DEVICES WITH BLOCKCHAIN

The secure management of real-time, irrefutable patient health metrics and surrounding environmental factors essential to the effective delivery of healthcare is transformed through the integration of IoT devices with blockchain technology. Wearable health monitors, smart medical devices, and environmental sensors are examples of Internet of Things (IoT) devices that collect a variety and volume of data from patient vital signs and physical activity to medication adherence and air quality and temperature in the surroundings. This information is necessary to be able to offer treatment quickly and effectively. Due to the magic of blockchain technology, this data can be documented and stored on a distributed and immutable ledger, making it untouchable and impossible to tamper with. Now, when IoT data are stored on the blockchain, they are securely authenticated because of the cryptographic hashing, and no unauthorized party is allowed to access these data, owing to the consensus processes *e.g.*, Proof of Authority or Practical Byzantine Fault Tolerance that underpin the blockchain network. Combining IoT and blockchain technologies facilitates real-time data mining with the safekeeping of patient information, making it transparent and tamper-proof, as well as the dependability and precision of patient information, thereby empowering healthcare providers to make evidence-based decisions and deliver more personalized therapies. This will allow patients a higher level of abstraction of data to be more securely shared and maintained, reducing privacy concerns and building trust. Second, by gathering data on the environment, it is possible to better understand and combat environmental health factors, such as pollution or extreme temperatures, and provide full care service. It also directly relates to the betterment of patients, increased data security, and better functioning of healthcare processes.

INCREASING IMPORTANCE OF BLOCKCHAIN FOR HEALTHCARE

The healthcare business increasingly relies on assistance from other areas, such as computer science, which may significantly contribute to this domain [10]. This encompasses a wide range of fields, such as genomics, gene prediction, electronic health records, and the development of disease diagnostic tools [11]. Public health

CHAPTER 9

Revolutionizing Hen Care in Smart Poultry Farming: The Impact of AI-Driven Sensors on Optimizing Avian Health

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Abstract: Automation is taking over the entire globe. To boost efficiency, businesses, governments, and nonprofits are all using automation in their own fields. The demand for and necessity of automation is high in the agricultural industry. The majority of nations have begun to supply and use smart farming solutions. This proposed study focuses on smart poultry farming, an essential aspect of farming, and designs a new prototype. A number of Indian farmers keep chickens as pets, yet their farms' output, longevity, efficiency, and treatment of animals are all lacking.

Therefore, sustainable and lucrative farming is the outcome of integrating cutting-edge technology such as robotics, Internet of Things (IoT) sensors, and artificial intelligence (AI). This prototype incorporates a number of Internet of Things (IoT) sensors for several features, such as lighting (LDR), air quality (MG135), water quality (pH), temperature (DTH11), and lighting (LDR). Minimizing human intervention, keeping tabs on the bird's well-being, making the most of available resources, and increasing output are all outcomes of the automated system's development. With the help of an AI-IoT smart system, poultry producers will be able to manage their farms more efficiently and triumph over a number of obstacles.

Keywords: Agricultural, Automation, Artificial intelligence, Hen health, Internet of Things, Poultry farming, Smart farming, Sensors.

INTRODUCTION

Agriculture is the backbone of the Indian economy. Many Indians rely on agriculture as their primary source of income. Integrating smart technologies into

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traditional farming methods enhances overall productivity and increases the income of the farmers [1 - 5]. Poultry farming is a broader idea behind smart agriculture. It focuses on raising chickens for meat production and egg production. New techniques and technologies are added to every stage of traditional poultry farming practice to overcome traditional farming limitations and optimize productivity, efficiently utilize resources, and focus on the welfare of animals [6 - 9].

Smart poultry farms consist of different sensors, tools, and techniques to build an optimized and automated farming technology for farm management. The main goal behind such smart farms is to enhance efficiency and productivity. There are several factors that need to be considered in designing a prototype [10, 11]. They include an environment that is automatically monitored and controlled using sensors and IoT devices. The environmental attributes taken into consideration are temperature, humidity, ventilation, water quality, and lighting [12 - 14]. The physical attributes recorded are the chicken's health and feed. The chickens that are kept only under an optimal setup will yield enhanced productivity. The observations are monitored and stored at repeated intervals of time. This data can be further used to extract insights into poultry farms and derive trends and patterns for further decision-making processes. The health of the chicken is interrelated to all other parameters [15 - 17]. An automated system to operate and control the poultry farm is designed to concentrate on the food requirement, monitor health and nutritional information, and check on the water quality and continuous supply of water [18 - 21]. The focus is on checking the temperature, humidity, and lighting of the environmental setup of the poultry farm. An automated egg collection system to reduce manpower can be designed to collect the eggs from the poultry farm, segregate the eggs based on their quality, and dispatch them for sale [22]. The poultry farm can be monitored and controlled from a remote location. Real-time updates and alert messages are sent through mobiles to the corresponding person of the poultry farm. The overall farm management can be improved by integrating automation techniques, streamlining farm operations, optimizing the utilization of resources, remote monitoring, and enhancing animal care [23 - 26].

Several factors have contributed to the requirement for this kind of smart poultry farming system, including the rising demand for poultry products like meat and eggs, the efficient use of energy, the constant monitoring of animal health, the difficulties and issues posed by a lack of labor, and the need for early disease detection to prevent financial losses [27]. There are several challenges in designing and successfully setting up a poultry farm for Indian farmers. Very detailed and broader background research on proper planning on the infrastructure size and capacity, area and environment to set up the poultry farm, automation techniques to be implemented, sensors to be used, and health and welfare monitoring techniques are required [28].

Smart poultry farms will provide a promising livelihood for Indian farmers. It will lead to the development and sustainable growth of the agricultural sector and enhance the overall Indian economy. The Indian farmers should learn, adopt, and implement smart techniques in the poultry farms for a successful outcome.

Limitations in Traditional Poultry Farming

Traditional poultry farming has the following problems:

- Traditional poultry farming requires more manpower to maintain the farms.
- Difficult to monitor the climate conditions earlier.
- Earlier bird disease prediction and identification are very difficult in traditional poultry farming.

The integration of smart poultry automated systems can be made possible through APIs to manage different software activities.

Background of the Invention

Agriculture is the backbone of the Indian economy. Many Indians rely on agriculture as their primary source of income. Integrating smart technologies into traditional farming methods enhances overall productivity and increases the income of the farmers. Poultry farming is a broader idea behind smart agriculture. It focuses on raising chickens for meat production and egg production. New techniques and technologies are added to every stage of traditional poultry farming practice to overcome traditional farming limitations and optimize productivity, efficiently utilize resources, and focus on the welfare of animals.

The need for this kind of smart poultry farming system is triggered by several factors like increased demand for poultry products like meat and eggs, proper utilization of energy resources, continuous monitoring of animal health, challenges and issues in facing a labor shortage, and early disease detection to prevent financial losses.

Challenges in Poultry Farming

Environmental factors, dust, and fluctuation can affect the accuracy of the sensors; therefore, we need to maintain the sensors to ensure reliability.

CHAPTER 10

Deep Learning-Powered Visual Augmentation for the Visually Impaired

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Abstract: The interdisciplinary convergence of computer vision and object detection is pivotal for advancing intelligent image analysis. This research surpasses conventional object recognition methodologies by delving into a more nuanced understanding of images, akin to human visual comprehension. It explores deep learning and established object detection systems such as convolutional neural networks (CNN), Region-based CNN (R-CNN), and you only look once (YOLO). The proposed model excels in real-time object recognition, outperforming its predecessors, as previous systems typically detect only a limited number of objects in an image and are most effective at a distance of 5-6 meters. Uniquely, it employs Google Translate for the verbal identification of detected objects, offering a crucial accessibility feature for individuals with visual impairments. This study integrates computer vision, deep learning, and real-time object recognition to enhance visual perception, providing valuable assistance to those facing visual challenges. The proposed method utilizes the Common Objects in Context (COCO) dataset for image comprehension, employing object detection and object tracking with a deep neural network (DNN). The system's output is converted into spoken words through a text-to-speech feature, empowering visually impaired individuals to comprehend their surroundings effectively. The implementation involves key technologies such as NumPy, OpenCV, pyttsx3, PyWin32, OpenCV-contrib-python, and winsound, contributing to a comprehensive system for computer vision and audio processing. Results demonstrate successful execution, with the camera consistently detecting and labeling 5-6 objects in real time.

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Keywords: Accessibility technology, Assistive technology, Artificial Intelligence, Computer Vision, COCO data Set, Deep learning, Deep object analysis, DNN, Google Translator, Human-like object understanding, Image understanding, Inclusive design, IoT, LiDAR, Multimodal object interaction, NumPy, Object detection, Real-time object recognition, Text to speech, Visual impairment assistance.

INTRODUCTION

As artificial intelligence (AI) and the Internet of Things (IoT) advance rapidly, numerous smart devices can link with one another [1]. Various innovative concepts, such as 'Smarter Planet', 'Smart City', 'Smart Community', and 'Smart Campus,' have emerged and integrated into various aspects of human life.

The human eye plays a vital role in the visual system, but it is also susceptible to external factors, including potential exposure to pathogens. The eyes can serve as an entry point for certain viruses to infiltrate the body, leading to possible eye diseases and vision impairment [2]. The World Health Organization (WHO) estimated that by 2019, more than 220 million people worldwide would experience visual impairment, presenting substantial daily challenges [3]. While the traditional white cane remains a widely used tool for the visually impaired [4], it has notable limitations and safety concerns. Therefore, the objective of this work is explicit and compelling: to develop a cost-effective and highly efficient solution that empowers visually impaired individuals to navigate their surroundings with increased ease, speed, and confidence.

Visual impairment is not solely related to issues with the eyes; it can arise from various factors. Common causes include challenges with eyesight, the development of cataracts, problems in the rear part of the eye, or issues with the optic nerve. Individuals experiencing visual impairment often encounter numerous challenges in their daily lives. Limited vision can result in difficulties in safely crossing roads, determining when to proceed at traffic lights, or navigating around obstacles. For educational pursuits, those with visual impairment typically need to learn braille, a tactile system of raised dots. Even routine tasks, such as visiting a doctor, become challenging as they rely on touch and hearing to navigate their surroundings.

In today's context, AI is a prominent and rapidly advancing field. Focused on imbuing systems with intelligence, AI is anticipated to play a substantial role in the future [5]. The progression of AI is driven by the abundance of data and powerful computing resources. Its applications extend across various domains, including retail and delivery services. In the retail sector, AI facilitates inventory management by tracking stock levels and identifying popular items, thereby enhancing the overall shopping experience. Moreover, AI can deliver personalized product recommendations based on individual preferences. In the realm of delivery services, AI excels in planning the most efficient routes for transporting items from one location to another.

AI is significantly reshaping the landscape of education by providing valuable tools for teachers to gauge students' progress and offer tailored support based on individual needs. This personalized approach enhances the learning experience for each student. In the realm of security, AI stands as a powerful ally for law enforcement. Its advanced image processing capabilities enable the identification of suspects in surveillance videos, contributing to more effective and efficient investigations. Moreover, AI plays a crucial role in the surveillance of buildings, promptly alerting authorities to any unusual activities and bolstering overall security measures.

Incorporating AI into ophthalmological practices revolutionizes the landscape of eye care, offering unprecedented opportunities for early intervention and precision medicine. The seamless integration of AI algorithms with contact fundus examination devices streamlines the diagnostic process, empowering clinicians to deliver timely and tailored interventions. Moreover, AI-driven analysis of fundus images enables the detection of subtle abnormalities that may escape human observation, ensuring comprehensive assessment and treatment planning. As the field continues to evolve, the collaborative efforts between AI technology and medical expertise promise to redefine standards of care and elevate the quality of life for patients with ocular conditions.

LITERATURE REVIEW

Cheng and colleagues have put forth a holistic strategy to improve visual localization for individuals with visual impairments [6]. Their established system comprises diverse components, such as a profound descriptor network, validation of 2D–3D geometry, and real-time sequence matching. The process involves the integration of a dual descriptor network with RGB, infrared, and depth images, allowing for the creation of resilient, contextually rich descriptors and local features.

Researchers associated with Springer-Verilog have introduced an innovative LiDAR-based technique designed for the effective prediction of distances and precise measurement of obstacles [7]. Their approach involves employing a lightweight deep learning model, specifically customized for obstacle detection, known as EfficientDet-LiteV4. The anticipated distances are calculated by analyzing depth maps generated by LiDAR. To assess the efficacy of their approach, they implemented it on a Raspberry Pi4 platform integrated with Li-

CHAPTER 11

AI-Assisted Crop Management Using the LSTM Model in Smart Farming

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Abstract: The use of information and communication technologies in agriculture to increase productivity, efficiency, and sustainability is known as smart farming. The implementation of predictive analytics and data-driven insights in smart farming enhances the effectiveness of agricultural systems as a whole, decision-making processes, and resource allocation. This study compares the use of the algorithms long short-term memory (LSTM), support vector machine (SVM), deep belief network, Naive Bayes, artificial neural network (ANN), and gated recurrent unit (GRU) in optimizing agricultural operations. The study highlights how using LSTM in smart farming has the ability to transform traditional agricultural methods, resulting in sustainable, higher-yield output while minimizing resource loss and environmental impact. Smart farming has emerged as a new approach for modernizing and optimizing agricultural practices through the integration of cutting-edge technology, with a focus on machine learning in particular. Various algorithms were applied to this dataset, producing measurable results like accuracy, loss, correct detection rate (CDR), and false discovery rate (FDR). Through an extensive comparative study, it was identified that the long short-term memory (LSTM) algorithm was the most promising choice for the dataset. Following the application of machine learning algorithms on different training to test splits like 80-20, 70-30, 65-35, 60-40, and 55-45, it was found that LSTM has the best accuracy on average, ranging from 95% to 98%. The exploration of LSTM demonstrated its potential to significantly enhance decision-making processes for farmers and researchers, ultimately improving agricultural efficiency and outcomes.

Keywords: Artificial intelligence, Artificial neural network, Correct detection rate, Deep belief network, False discovery rate, Gated recurrent unit, Hyperparameter tuning, Logistic regression, Long short-term memory, Machine learning algorithms, Model architecture enhancements, Naive bayes, Posterior probability, Precision agriculture, Random forest, Rectified linear unit, Smart farming, Support vector machine, Sustainability, Yield optimization.

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INTRODUCTION

When it comes to precision agriculture, where every decision and piece of information are highly relevant, the LSTM (Long Short-Term Memory) algorithm is the cornerstone of innovation. Modern technology has sparked a revolution in agriculture, transforming conventional farming methods into ones that are more effective and sustainable. Intelligent crop management, a multifaceted strategy that seamlessly combines cutting-edge technology [1], most notably machine learning (ML) and the strength of LSTM algorithms [2], is the foundation of smart farming. The key to this agricultural transformation is to carefully optimize procedures and maximize harvests while using as little of the planet's resources as possible. Farmers now have access to the priceless tool of precision agriculture thanks to ML, particularly in the context of that practice.

Farmers now have the power to precisely apply fertilizers, pesticides, and other inputs in strict conformity with regional requirements thanks to LSTM algorithms. These algorithms examine the minute details of soil properties and crop features to produce individualized recommendations that promote the wise use of resources while simultaneously reducing the damaging environmental impact. This well-planned strategy, made possible by LSTM-driven ML, provides a double benefit. On the one hand, prices are successfully lowered, and on the other, sustainability takes center stage with a much lower chance of soil damage. In addition, LSTM algorithms are skilled at keeping track of soil moisture levels, incorporating weather forecasts, and tracking the changing requirements of plants to optimize watering schedules. The conventional distinction between resource conservation and agricultural output is effectively blurred by this finely tuned precision, which not only preserves limited water supplies but also ushers in increased crop yields [3]. LSTM algorithms go even further in the constantly changing world of agriculture, where data-driven insights are the key to success. They are essential for accurate yield estimation and careful crop monitoring. These algorithms examine data from a variety of sources, including satellite imaging and sensor data, and have the ability to analyze crop growth patterns, identify nutrient deficiencies, and compute crop yields [4]. With the abundance of knowledge they now possess, farmers are better able to plan their markets and identify the best time to harvest their crops, thus increasing profitability and ushering in a new era for agriculture.

FACTORS

Phosphorus Level of Soil

A crucial macronutrient for plants, phosphorus is necessary for several physiological activities. Integrating soil phosphorus levels into crop prediction models leads to a more comprehensive understanding of nutrient dynamics [5] and facilitates informed decisions regarding fertilization strategies, soil management practices, and overall nutrient optimization.

Potassium Level of Soil

An essential component for the growth and development of plants is potassium. It is engaged in several crucial plant processes, including the movement of nutrients and water throughout the plant, control over the growth and development of the plant, energy storage, and resistance to disease and pests [6].

Temperature

One of the most significant variables influencing crop growth is temperature. Farmers can calculate how much water and fertilizer they will require by knowing the typical temperature for the growing season. They may schedule the planting and harvesting of crops using temperature data as well [7].

Humidity

Humidity, defined as the amount of moisture present in the air, influences several critical physiological processes in plants, including transpiration, stomatal conductance, and photosynthesis. By considering humidity as a key variable in crop prediction models, deeper insights into the moisture stress experienced by crops can be gained, enabling more accurate predictions about their growth, yield potential, and overall health [8].

PH of Soil

The pH of the soil indicates how acidic or alkaline it is. Various soil pH values are preferred by different crops. Plants may find it difficult to absorb nutrients if the pH of the soil is too high or too low, which could result in stunted growth, low yields, or even death.

Rainfall

Most of the previous irrigation systems did not take weather forecasting information into account when choosing irrigation strategies [9]. When rain is promptly followed by crop irrigation, it wastes freshwater and energy and stunts crop growth. By utilizing weather forecasting data, ML-based solutions can handle these situations and improve irrigation decision support.

CHAPTER 12

Automated Production Management in Horticulture: An Industry 4.0 Perspective

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Abstract: The whole industry has changed as it progresses from 1.0 to 4.0 in accordance with regulations. Horticulture has seen tremendous advances in automated technology production management, which has revolutionized crop cultivation and management techniques. These technological developments have improved product quality, increased crop productivity, decreased labor costs, and reduced negative environmental consequences. The purpose of this book chapter is to investigate the current state of automated production management in horticulture, including its applications, techniques, and potential future directions. This chapter presents an overview of how technology is being used in automated production management, such as robotic harvesting, sensor-based monitoring, and precision irrigation. In addition, the chapter investigates the possible benefits and future possibilities of automated production management in horticulture. It focuses on developing trends, such as the incorporation of artificial intelligence and machine learning algorithms, which can improve decision-making processes and resource allocation. Data analytics, remote sensing, and Internet of Things (IoT) technologies are also covered for real-time monitoring and system optimization. Some aspects of automated horticulture are also investigated, such as crop diversity, development phases, and environmental variables.

Finally, this book chapter presents a complete review of automated production management in horticulture, emphasizing the industry's disruptive significance. It also tackles farmers' and researchers' existing issues with automated horticulture production systems. Horticulture stakeholders may improve productivity, sustainability, and profitability by embracing automated production management in an increasingly competitive and resource-constrained environment.

Keywords: Controlled environment agriculture, Integrated pest harvesting, Precision irrigation, Post harvesting, Remote monitoring, Robotic-crop care.

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THE ORETICAL BACKGROUND

It is anticipated that there will be nine billion people in the world by 2030. The majority of population increase will occur in developing countries in Asia, Africa, and Latin America, where hunger and food scarcity are issues. Horticulture is underdeveloped in the majority of African countries. The region's food priority may be addressed by focusing attention on key horticulture crops and critical challenges. Food shortages, distribution, nutrition, a country's or region's competitive edge, constraints on local and export marketing, and industry strategic planning, including institutional, regulatory, and technological improvements, are some of the primary challenges. This paper discusses the constraints and benefits of combining nutrition education with agricultural research aims, as well as the huge potential of horticulture crops in addressing food scarcity and malnutrition in Africa [1]. The article describes a less costly and labor-intensive method of clonal propagation that uses modified air-lift, bubble column, bioreactors (a balloon-type bubble bioreactor), and temporary immersion systems for the propagation of shoots, bud clusters, and somatic embryos. It explains how to grow Anoectochilus, apple, ginseng, garlic, grape, Lilium, Phalaenopsis, and potatoes. This chapter addresses bioreactor features and the design of bioreactor procedures for automated mass multiplication of diverse plant crops. It also highlights new research aimed at increasing the automation of the bioreactor manufacturing process [2]. Growers are having a difficult time right now because they are under pressure to improve the quality of their products owing to worldwide competition. New safety and procedural regulations must be followed all the way up the food chain. Everyone should prioritize reducing the negative environmental consequences of the industrial cycle in all aspects of life. In general, agriculture has been urged to reduce production costs in order to compete and live on government aid. Almost everywhere in the globe, there are suppliers for the processing industries. New players are eager to emerge and take on crucial responsibilities all across the world. Fresh food distribution has benefited from technology in previously unimaginable ways [3]. The horticulture sector has historically transformed the landscape of the United States through planned cultivar introductions as well as unintended introductions of weeds, insects, and plant diseases. The sales of established invasive plants persist, and the number of new cultivars introduced annually is rising despite the fact that the horticultural sector—especially, the ornamental subsector—has been demonstrated to play a major role in the introduction and spread of invasive species. This study characterizes the distribution channel's complexity and investigates the horticulture trade as a vector for invasive species and associated agents. The recent increase in commercialized cultivars has been linked to a variety of causes, including technological breakthroughs, industrial development, and marketing initiatives. As a result, consumer demand has increased and become more sophisticated, resulting in an intense hunt for novel crops across the world. Many of these crops are introduced into the market without being fully assessed for invasive potential. Traditional techniques for managing invasive horticulture crops (regulation, self-regulation) have had limited effectiveness and buy-in because they overlook the industry's intricacies and financial motivations. These methods concentrate on distributors both before and after crop release [4]. The study examined the productivity of agricultural crops under the conventional agri-horticulture system, as well as the structure, composition, and diversity of fruit tree and shrub species in the mid-hill region of the Garhwal Himalaya, India, between 1000 and 2000 m asl during the summer and winter seasons on the northern and southern aspects. Depending on the aspect, landholding, and farmer requests, the system's tree density, composition, and diversity varied. Twelve fruit tree species were identified in the agri-horticulture system; four of these were found to be common in both the northern and southern aspects, while the other six were found to be common exclusively in the northern aspect and the other two in the southern. It was found that the apple tree (Malus domestica) had the greatest IVI values on both the northern and southern sides [5]. Horticultural crops, with high yields and export value, play an important part in world nutrition. However, the sector is confronted with issues like resource shortages, global warming, and the impact of the COVID-19 pandemic. To solve these concerns, smart farming, sustainable agriculture, and precision farming are becoming more popular. Digitization, robotics, automation, artificial intelligence, and IoT are key to attaining sustainable production and solving obstacles ranging from farming to marketing. The review emphasizes the importance of transitioning to high-tech horticulture to ensure productivity and economic stability in the face of changing climate, growing population, and consumption patterns, advocating for machinery and automation to meet global demand. When compared to typical fluorescent lighting, LED treatments consistently resulted in better plant biomass, fruit output, and energy usage efficiency. Notably, LED illumination increased the antioxidant content of basil leaves while decreasing the nitrate concentration. The study discovered that a red:blue ratio of 0.7 is required for good plant growth and better nutraceutical qualities in both leafy and fruit vegetable crops. Overall, the data show that LED technology has the potential to improve production and nutritional quality in indoor farming [6]. This analysis looks at the historical backdrop and future implications of the industrial and agricultural revolutions, with an emphasis on the difficulties and opportunities of adopting Industry 4.0 in agriculture. While Industry 4.0 has grown quickly in the industry, debates regarding Industry 5.0 have already begun, in contrast to agriculture adoption's sluggish growth. The study emphasizes the disparity in influence between big firms and small- to medium-sized enterprises (SMEs) in both sectors, stressing the challenges that SMEs confront in keeping up with fast technological progress. The report closes

CHAPTER 13

Revolutionizing Agriculture through IoT-Enhanced Data Analytics: A Study from a Blockchain Technology Perspective

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Abstract: The emergence of interconnected systems, blockchain approaches, and the Internet of Things (IoT) is creating novel possibilities for information-driven choices in agricultural production. The knowledge provided in this chapter points out the innovative possibilities of integrated technologies with respect to small-to-large scale, wholesale, vendor, end user, and sustainable farmland. The aim of this study is to incorporate hyperledger formulation in a decentralized blockchain building with the Internet of Things gadgets in automated agriculture. This involves placing actuators and sensing devices on the ground to develop an infrastructure of coupled gadgets that continuously acquire and convey data from the realm of agriculture. This section outlines data collection methods practiced in agriculture using IoT devices as well as blockchain. It emphasizes wired and wireless connectivity and describes the types of sensors used to monitor soil conditions, weather patterns, crop health, and other relevant parameters. An example is that farmers may receive weather- and climate-predicted data promptly. The heart of the research is to understand the study on data analysis in the agricultural sector using blockchain technology. From descriptive analysis for historical data review to predictive analysis for forecasting crop yields and disease attacks, this section provides an overview of the techniques in practice. It examines the increasing trend towards the adoption of edge computing in agriculture, enabling real-time data analysis directly from the ground, which may reduce latency, improve decision-making speed, and reduce the need for centralized cloud processing. The concluding portion addresses pragmatic applications for unified systems in IoT-driven statistical analysis and agribusiness. Supply chain (SC) optimization, surveillance of crops, smart watering systems, and agricultural precision farming are

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several examples. Identifying a handful of the complications that arise with this scientific convergence, the study examines pitfalls that parties in the agricultural sector have to navigate. It involves prerequisites for suitable physical labor, cooperation hardships, and data safety worries. New technologies designed to address the foregoing problems and efforts to fix those conflicts with farm-integrated IoT-driven data visualization are looked at along with their demonstrated intelligent farming approaches. Prospective paths in IoT-driven information mining and a system with embedded components for agriculture-related access without agent marketing are laid out in the investigation's summary. The work discusses the potential effects of artificial intelligence (AI) and machine learning (ML) promotions, strengthened sensory technological advances, and the possible incorporation of blockchain for safeguarding data and the ability to track individuals for sustainable farming and planetary food sustainability. The investigation of embedded equipment and IoT-driven analytical methods in the agricultural industry is addressed in this scientific statement. It offers an explanation of the manner in which agribusiness is adapting to herald in an additional phase of ecological responsibility, preciseness, and operational effectiveness.

Keywords: Blockchain-enabled agriculture, Cloud, Data-driven agriculture, IoT, Farm analytics, Transformative technology.

INTRODUCTION

Conventional methods of farming have experienced a change in perspective as a consequence of the unity of advances in technology, agricultural activities, and Internet of Things solutions that utilize data. The incorporation of distributed ledgers, predictive analytics, and connected devices has developed into an outstanding example of innovation in agricultural environments, with the potential to drastically alter the methods by which people maintain food supplies and cultivate the environment. It looks at the upstart prospects of combining blockchain, data mining, and the Internet of Things in the agriculture domain. Recent advances have been utilized in growing crops, which have traditionally relied on human labor and opportunistic processes, to increase profitability, long-term viability, and traceability along the farming supply chain (SC). IoT gadgets attentively acquire minute information from the field of agriculture as part of the pairing cycle. The sensors that are incorporated into the soil, plant crops, and gearing provide an ongoing source of insights into crop wellness, surroundings, and handling of resources. Such information has an important influence on landowners' awareness, analysis, and behavior toward the demands of their agricultural lands. In parallel, the use of data analytics allows landowners and other parties to make sense of this torrent of evidence by obtaining useful insights that transform how they make decisions. Data science redefines the agricultural environment by promoting trained digital-driven actions from forecasting models and growing timing for planting to distributing assets tactics that promote maximum productivity. This dependence on data advancement has been accelerated by the blockchain system's disruptive ability. An information and communications technology (ICT) portal can be deployed to render data that has been acquired by numerous farmers implementing handheld devices publicly. This platform can give instantaneous information to all individuals, including agriculturalists. Fig. (**1**) indicates the nature of smart farm technology and the functions of ICT [1].

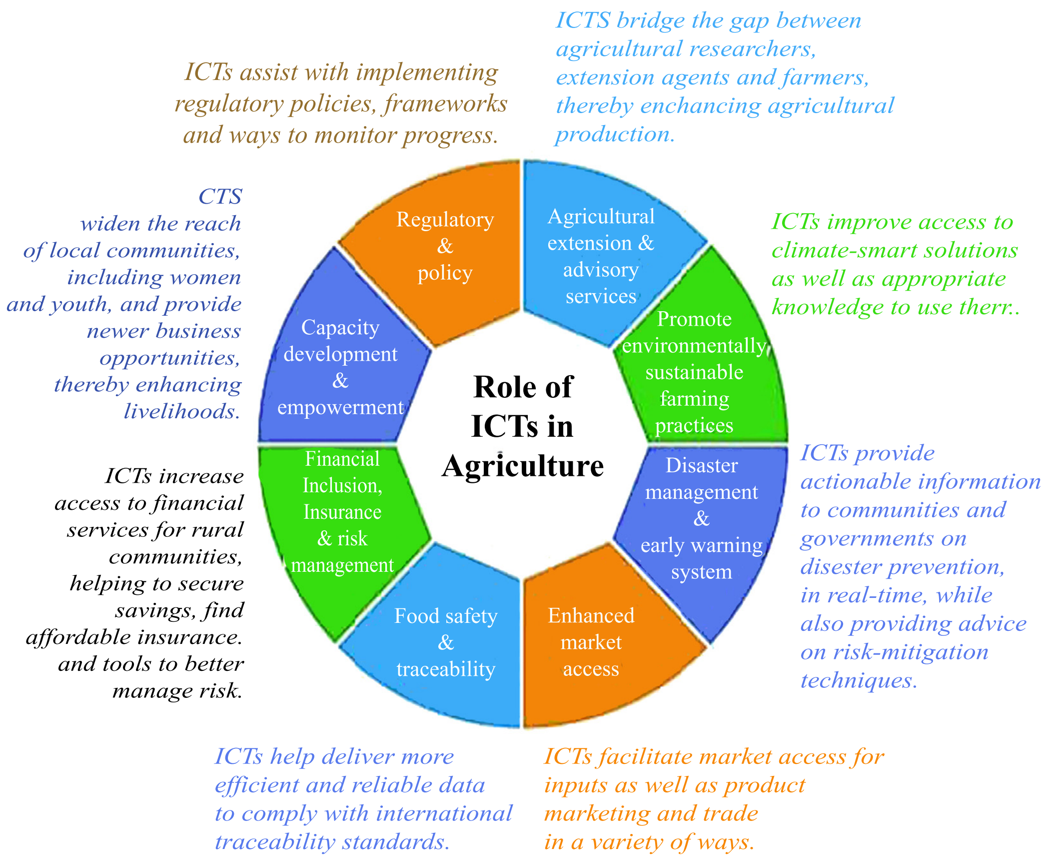

Fig. (1). Scenario-based role of ICTs in agriculture.

The inherent features of decentralized management, inertia, and clarity of blockchain networks find wide application in the verification and safekeeping of data pertaining to agriculture, making sure of its constancy across the SC. Blockchain utilizes the ability to keep tabs on products from cultivation to the surface, raising patron trust and entirely disrupting the circumstances around its source. People want to learn about the hyperlinks between scientific cornerstones and achieve knowledge about their significance and cumulative impact on the rise of agribusiness. It aims to shed light on the radical path of farming practices

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Blockchain-Enabled Internet of Things Applications in Healthcare: Current Practices and Future Directions" is a groundbreaking exploration of how blockchain technology can revolutionize healthcare. It offers insightful analysis on enhancing data security, privacy, and efficiency through IoT integration, making it an essential read for professionals seeking to innovate in the healthcare sector.

Alvaro Rocha
Professor
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