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Review Article

A Systematic Review of Blockchain Technology Assisted with Artificial Intelligence Technology for Networks and Communication Systems

Kamal Kumar[1], **Vinod Kumar**[2], **Seema**[1], **Mukesh Kumar Sharma**[3], **Akber Ali Khan**[4] and **M. Javed Idrisi**[5]

[1]*Department of Mathematics, Baba Mastnath University, Rohtak 124021, India*
[2]*Department of Mathematics, Shyam Lal College, University of Delhi, New Delhi 110032, India*
[3]*Department Mathematics, Chaudhary Charan Singh University, Meerut, Uttar Pradesh 250004, India*
[4]*Department of Applied Sciences and Humanities, IIMT College of Engineering, Greater Noida, Uttar Pradesh, India*
[5]*Department of Mathematics, College of Natural and Computational Science, Mizan-Tepi University, Tepi, Ethiopia*

Correspondence should be addressed to M. Javed Idrisi; javed@mtu.edu.et

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Blockchain is a very secure, authentic, and distributed technology and is very prominent in areas such as edge computation, cloud computation, and Internet-of-things. Artificial intelligence assists in the completion of activities efficiently and effectively by providing intelligence, analytics, and predicting capabilities. There is an obvious convergence between the two technologies. Artificial intelligence systems can utilize blockchain to establish trust in communication channels, ensuring that messages are securely transmitted and received without the need for a centralized intermediary. By leveraging blockchain, artificial intelligence systems can maintain an immutable record of communications, ensuring transparency and preventing unauthorized modifications. The integration of blockchain and artificial intelligence technologies can enhance the security, transparency, and privacy of communication systems. By leveraging blockchain's decentralized nature and artificial intelligence's analytical capabilities, secure and trustworthy communication channels can be established, benefiting various domains such as finance, healthcare, and supply chain. Overall, the integration of blockchain and artificial intelligence has the potential to offer several benefits, and as these technologies continue to evolve, new and innovative applications will continue to emerge.

1. Introduction

Artificial intelligence, as the name suggests, is the intelligence created artificially. The machine can be taught to respond in a way in which human beings would behave. Alexa and Siri have become popular among the masses and are prominent examples of artificial intelligence in today's world. Blockchain technology has scope for handling huge data records and transactions and can manage data for large size and scale of operations. Blockchain is a complex technology and requires huge costs in terms of hardware capabilities and skilled manpower. Whether the benefits surpass the issues and limitations of blockchain technology depends on the application and availability across different sectors. To achieve this objective, the idea of integrating blockchain with artificial intelligence comes into the picture. Blockchain technology individually has great scope for transforming various operations, but the overall output can be exponentially increased when the benefits of integration are also added.

These two technologies, artificial intelligence and blockchain, when integrated, provide a robust platform for secure communication among the users in the network system. Both technologies complement each other.

Blockchain helps artificial intelligence boost the credibility, integrity, and trust of the users while artificial intelligence provides the necessary intelligence to blockchain primarily eliminating the security risks. There is a lot of research individually on blockchain and artificial intelligence, but there is very little literature available related to the integration of blockchain with artificial intelligence. So, it is imperative to study how the integration of the two technologies can take place. The current study is important as it focuses on the various security concerns related to communication networks and explains which properties of artificial intelligence and blockchain address the security concerns when integrated. The current study is important from another perspective also as it discusses the various unique challenges that create roadblocks in harnessing the true potential of the integration. This paper provides a strong base for further research work related to integration which can address the challenges in integration.

1.1. Motivation and Contribution. Artificial intelligence is being discussed in almost all spheres of life including business, government regulations, and public utilities. Blockchain is a relatively new concept which is gaining huge prominence in the recent past. With the growing need for secure communication, there is a lot of discussion around the integration of artificial intelligence and blockchain to address the security need effectively. Traditional communication is prone to challenges such as unauthorized access, manipulation of the stored data, and issues with confidentiality and integrity. To address these challenges, there is a need to study new and innovative technologies. Blockchain ensures trust and immutability in data exchange while artificial intelligence provides advanced analytics and automated response facilities to security threats. The integration of blockchain and artificial intelligence can revolutionize the secure communication landscape. Hence, there is the need and importance to analyse the synergy of both technologies. This paper will make contributions in the following manner:

(i) The paper contributes towards creating a better understanding of new-age technologies of artificial intelligence and blockchain and analyses the complex capabilities of these latest technologies.

(ii) The study offers an enhanced data privacy approach which is achieved through encryption and authentication and auto-defensive responses achieved through the integration of artificial intelligence with blockchain.

(iii) The synergy achieved through blockchain, and artificial intelligence provides a proactive approach to incident management and response to security threats. The suspicious traffic is automatically blocked, and the issues are flagged automatically before the security threat arises.

(iv) The paper highlights the various challenges that still exist in the integration and paves the way for future research efforts.

1.2. Paper Outlines. As depicted in Figure 1, this paper discusses the concept of artificial intelligence in Section 2 followed by its types in Section 2.1. There have been a significant number of researchers who have researched the concept of artificial intelligence. The detailed history has been discussed in Section 2.2 followed by the benefits and issues in Section 2.3 and Section 2.4, respectively. In the later section, the concept of blockchain has been explained with examples. The benefits, applications, and issues in blockchain technology have been mentioned under various sections in Section 3. Section 4 talks about the security-related concerns in the application of artificial intelligence and blockchain technology. Section 5 gives details on the integration aspects of artificial intelligence and blockchain. In Section 5.1, there is a comparative analysis of the current study with the peer works. The benefits and challenges of the integration have been discussed in Sections 5.2 and Section 5.3, respectively. Section 6 lays down the way ahead in the field of artificial intelligence and blockchain integration.

2. Artificial Intelligence

Artificial intelligence was coined at Dartmouth workshop in 1956 [1]. Over time, artificial intelligence has gained huge momentum and has various applications across different areas such as healthcare, business, education, finance, law, manufacturing, banking, and transportation security. Artificial intelligence has changed the fundamentals of the rules guiding every sector in general. It has shown that the activities can be completed from beginning to end without any human intervention which could not have even been dreamed of a few years ago. Artificial intelligence refers to the comprehensive systems which analyse the surrounding environment, use the intelligence to take the required actions, and use the given freedom to achieve the assigned objectives. It can be both software-based (e.g., voice assistants) or hardware-based (e.g., automatic vehicles). To understand artificial intelligence, it is pertinent to understand what intelligence is. Intelligence is doing the required things at a given point in time through learning, understanding, and adaptation to the environment. Intelligence is the activity of gaining knowledge from the surroundings and applying that knowledge and experience to get the tasks done.

Artificial intelligence is the systems that can think like human beings. Artificial intelligence also has the basic skills that humans have listed above in Figure 2 [2]. Artificial intelligence can interact with humans through chats and voice commands. It can store data over storage devices and uses these data as memory or knowledge like human beings. Artificial intelligence has also the capability to react and monitor its actions in similar ways as living beings. There are various examples of artificial intelligence in our daily lives, e.g., online assistants such as Google Assistant, Amazon Alexa voice artificial intelligence, Apple Siri, connected vehicles, and chatbots. Artificial intelligence can be classified as follows:

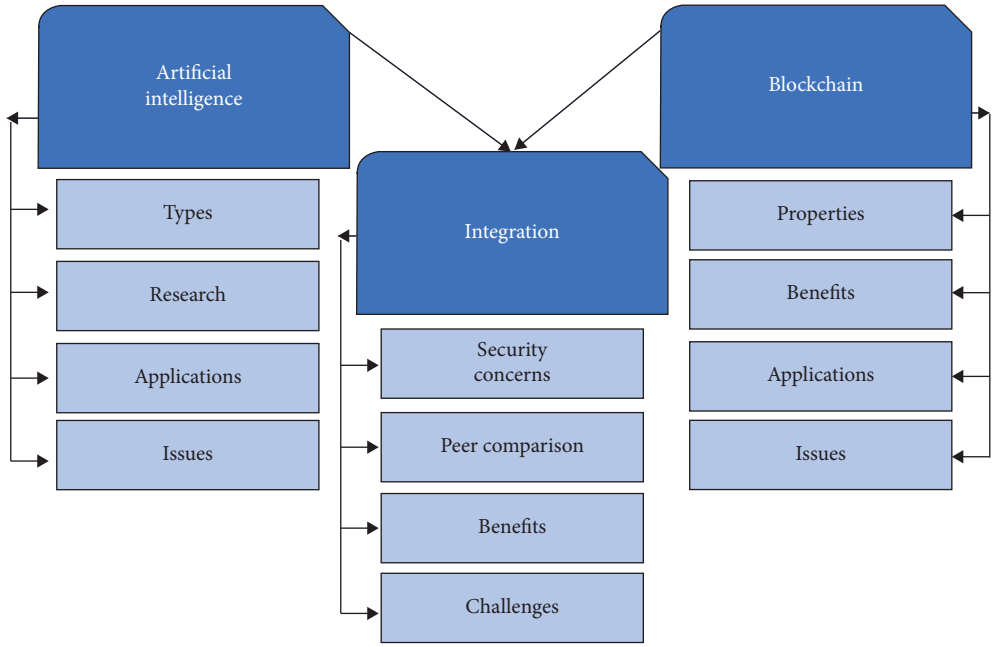

Figure 1: Paper outlines.

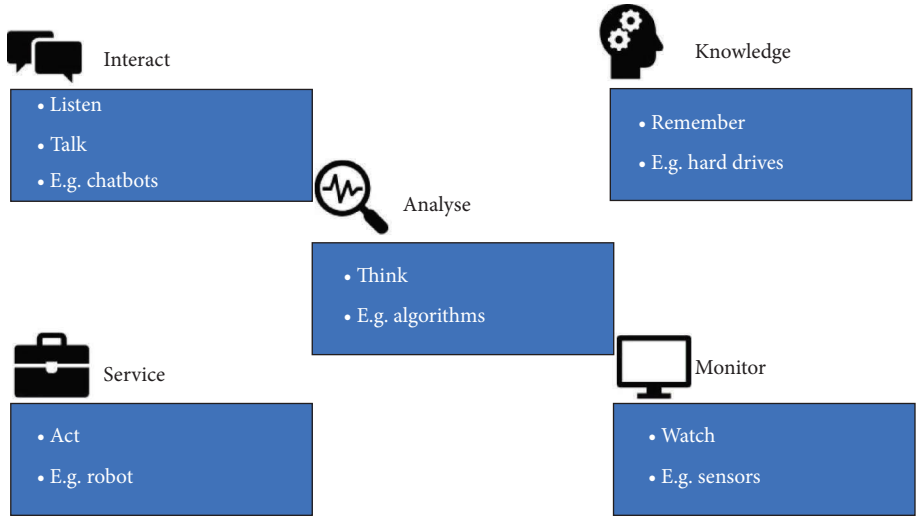

Figure 2: Artificial intelligence.

(i) Narrow artificial intelligence: These types of systems are also called weak artificial intelligence. The main goal of narrow artificial intelligence is to accomplish one goal efficiently and effectively. There are a lot of restrictions and constraints on intelligence and hence is just a simulation of the living human being intelligence level.

(ii) Artificial general intelligence: This is also termed as strong artificial intelligence as it is a full-fledged version of human intelligence and works with much more autonomy compared to narrow artificial intelligence. This type of intelligence is estimated to have cognitive abilities just like human beings. Artificial general intelligence is adaptable and versatile depending on the needs of the users. It has immense learning capacity, and it solves problems using logic and reasoning which resembles the way human beings react to problems.

2.1. Types of Artificial Intelligence. There are four types of artificial intelligence. The same is explained as follows:

(a) Reactive systems: As the name suggests, this type of artificial intelligence reacts based on environmental factors. This type of artificial intelligence cannot store information and use experience or historical knowledge. It just perceives the existing factors and accordingly reacts in the best possible manner [3]. One prime example of a reactive machine is IBM's Deep Blue. This was the name of the computer which

won against the best world champion in a chess game. The computer acted based on the existing situation after every move and could not assess the future moves [4]. Another example of reactive machines is Google's AlphaGo which won against the world-class champion in the Go game [5].

(b) Limited memory systems: As the name suggests, this type of artificial intelligence reacts not only just based on the prevalent factors but also has the limited capability of storing past data and analysing what may happen next. The limited memory process has been summarised in Figure 3. The limited memory process starts with the collection of the base data. After ensuring the base data availability, the data are analysed using the models for the learning system. Using the analytics, it makes the forecasts and predictions which are sent for review and feedback. The overall output of the process is stored for future reference and can be retrieved based on the requirements.

Limited memory follows the three models of artificial intelligence.

(i) Learning through reinforcements: This type of system uses trial and error techniques to arrive at the final decisions. Wherever the results are favourable, that outcome is selected. This type of learning is operated without any supervisor; hence, it requires a very strong set of algorithms.

(ii) Long short-term memory systems: As the name suggests, this type of artificial intelligence uses both long-term and short-term memories and experiences and accordingly builds and develops models for future predictions. These types of systems give more weightage to short-term memory compared to long-term memory while arriving at the final decision-making. The basic assumption behind different weights is that the near past events affect the future outcomes more than the late past events.

(iii) Evolutionary generative adversarial network systems: Generative adversarial network systems keep evolving based on the events and keep going through different evolutionary phases over time. In this type of learning, the systems do not follow the same path, rather the networks search for a better new path every time and evolve to provide better solutions.

(c) Theory of mind: This type of artificial intelligence studies the behaviour in which living beings make decisions. The systems analyse how living beings feel to arrive at decisions till the given level of autonomy. To achieve this, the systems need to understand how the minds of living beings work and conceptualize that knowledge to act accordingly. This type of artificial intelligence is mostly theoretical and not practical as of date.

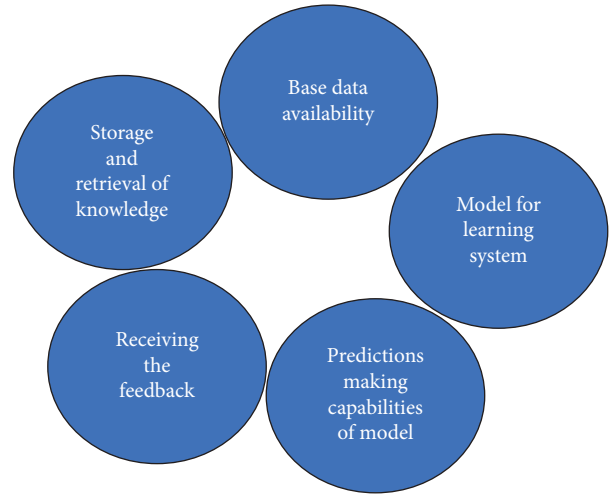

Figure 3: Limited memory process.

(d) Self-awareness: This is the next stage of artificial intelligence which can be achieved only after the theory of mind has been accomplished. This level of artificial intelligence will analyse the living beings' level of consciousness and will not just focus on "what" but will also focus on "how" to achieve a similar level of consciousness [3].

2.2. Research of Artificial Intelligence. The concept of artificial intelligence can be attributed to the past as long as the 1990s. In 1940, John Von Neumann, a prominent mathematician, ideated that the data and processes could be stored as memory in the computer. In 1943, Warren McCullough and Walter Pitts paved the way for neural networks. In 1949, Donald Hebb in his book shared an important model which proposed that experiences create a network of neural ways and these network paths become powerful depending on the frequency of such experiences. In 1950, Alan Turing introduced a test famously known as the Turing Test. This test is conducted to determine whether a given machine or system is intelligent. Marvin Minsky and Dean Edmonds, undergraduate from Harvard University, crafted the Stochastic Neural Analog Reinforcement Calculator [6]. It was a machine with 40 neurons of artificial nature [7]. Claude Shannon in his paper "Programming a Computer for Playing Chess" made a program that enabled a computer to play chess on its own [8]. Isaac Asimov shared three important laws of robotics (Text, Production, and Society) [9]. In 1952, Arthur Samuel wrote a program that enabled machines to play checker games [10]. IBM and Georgetown University together developed a machine that could translate limited Russian lines into English [11].

In 1956, the term artificial intelligence took birth at Dartmouth workshop. It was agreed that intelligence was not limited only to living beings but could also be attributed to artificial machines [1]. Allen Newell and Herbert Simon proposed Logic Theorist which became a pioneer in the field of artificial intelligence. They could think like human beings and act accordingly [12]. In 1958, McCarthy created LISP,

a computer programming language. At Massachusetts Institute of Technology, McCarthy along with Marvin Minsky started a project of artificial intelligence [13]. Later in 1960, McCarthy published the paper "Programs with Common Sense" which talked about machines learning from experiences just the same way humans do [14]. In 1959, Herbert Simon, J.C. Shaw, and Allen Newell proposed a general problem server that could solve general issues [15]. H.R. Gelernter made a program that could solve theorems of geometry [16]. Arthur Samuel introduced the term machine learning while working with IBM [17]. In 1963, McCarthy, known as the father of artificial intelligence, started an artificial intelligence lab at Stanford University [18]. In 1966, the Automatic Language Processing Advisory Committee halted the funding for machine translation projects in the United States [19]. In 1969, an expert system named MYCIN, based on artificial intelligence, was introduced that could identify the type of bacteria from which the patient is infected and what could be the antibiotics for the treatment [20]. Prolog programming language was created in 1972 and gained a lot of popularity worldwide [21]. In 1973, followed by the findings of the Lighthill report, the British government took back substantial financial support from research activities related to artificial intelligence. ALPAC report together with the Lighthill report brought the first winter in artificial intelligence [22].

Later in 1981, Digital Equipment Corporation introduced eXpert CONfigurer making its mark in the field of artificial intelligence and contributing to ending the first winter [23]. In 1982, the Fifth Generation Computer System project was initiated by Japan which could provide a magnanimous platform for future artificial intelligence-related projects. This project was later closed in 1992 for not being able to meet the expectations [24]. In 1983, the Defense Advanced Research Projects Agency started a strategic computing initiative to boost research in machine intelligence. This project was later dropped in 1993 due to not meeting the high expectations [25]. Later during the period between 1987 and 1993, there was a second artificial intelligence winter due to expensive research activities leading to results not up to the mark [3].

Later post-2000, the research activities related to artificial intelligence got huge momentum. DARPA organized a competition whose objective was to boost innovation in vehicles. This competition was won by Stanley in 2005 which was a robotic machine invested by Stanford [26]. The military force in the United States paved the way for investment in robots like Big Dog developed by Boston Dynamics and PackBot by iRobots (renamed later as Endeavor Robotics). Google introduced a speech recognition facility in the iPhone application in 2008 followed by a self-driving vehicle in 2014, AlphaGo in 2016, and BERT language in 2018. There are other breakthroughs such as Apple's Siri in 2011, Amazon's Alexa in 2014, Sophia Robot by Hanson Robotics in 2016, and Waymo One Service by Waymo in 2018. During the COVID-19 pandemic, in 2020, Baidu, a Chinese multinational company provided an algorithm that helped in understanding the virus sequence in just a few seconds using artificial intelligence techniques [3].

2.3. Applications of Artificial Intelligence. Artificial intelligence is a much-talked-about topic in almost all areas. There is no doubt that artificial intelligence has huge potential to revolutionize all spheres of life. The applications of artificial intelligence can be attributed to multiple fields as mentioned in Figure 4 and are explained as follows:

(i) *Healthcare*. There are so many activities involved in healthcare which have been made very easy using artificial intelligence. The simple applications include maintaining patient past and present medical records, appointment scheduling on real real-time basis, billing and payment-related activities, and a lot of other administrative activities. The advanced tools and programming in artificial intelligence are helping in conducting the automatic diagnosis of the patients and sharing the results which make it very easy for the doctors to treat the patients. During the pandemic situation, artificial intelligence proved very helpful in understanding the virus sequence within a few seconds. There is a lot of research in place to take artificial intelligence in the field of medicine to another height where the hospitals could be fully automatic with very little human interference.

(ii) *Business*. Gone are the days when making the product available to the customers was sufficient to make sales. Today is the era of customer delight where the focus is not just on basic satisfaction but also on the delight of the customer so that the customer can be retained for long against the competitive products. A lot of research is carried out to develop new products or introduce new features within the existing products to fulfil the requirements of the consumers. To achieve this objective, it is very important to understand the target market. A lot of analytical tools are used to understand the behaviour of consumers. Artificial intelligence provides complex algorithms which help in enhanced analytics and provide fruitful results.

(iii) *Education*. Artificial intelligence can automate most of the administrative activities which burden the teachers in daily operations. The automation will give much more time to the teachers to focus on the betterment of the students. With more advanced research, there might come a time when artificial intelligence may replace some of the tutors.

(iv) *Finance*. Artificial intelligence is helpful in a lot of areas such as financial data analysis, risk modelling, and trading. Artificial intelligence can be very helpful in giving financial advice to investors. Sophisticated software for trading in shares and derivatives can be enhanced by using artificial intelligence.

(v) *Law*. The law field requires a lot of manual effort in going through a huge number of documents to

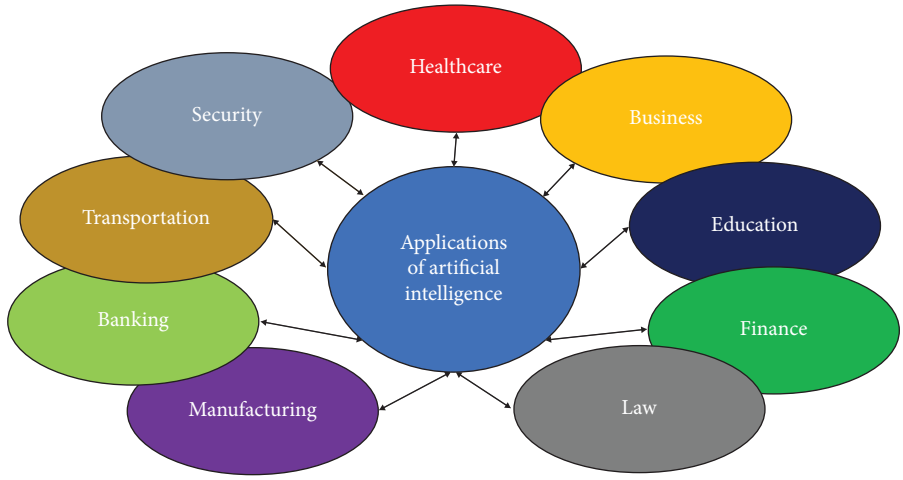

Figure 4: Applications of artificial intelligence.

ensure the veracity of the document and the content and understand the texts. The same can be simplified using artificial intelligence where the machine can quickly verify the source of the documents, share feedback on the truthfulness of the document, and share the understanding of documents in simple words from the text written in complex words.

(vi) *Manufacturing*. In a lot of manufacturing units, most of the work is carried out by machines handled through artificial intelligence with minimum human interaction. In the past, machines were able to function in only one direction, and the machines did not coexist with human workers. Now, artificial intelligence has removed the barrier making the machines handle the full responsibilities from end to end and coexist with human labour.

(vii) *Banking*. Chatbots are the prime example of artificial intelligence when it comes to banking operations. The moment you visit any prominent bank website, you will find a chatbot in the corner offering to help you. The chatbot will ask the user for certain inputs and accordingly resolve the queries. There are a lot of enquiries in the minds of the customers which require huge manpower time and cost. The banking companies spend huge financial resources in managing all the queries. The same has been cut down substantially using artificial intelligence.

(viii) *Transportation*. Artificial intelligence can be very helpful in the transport sector in multiple ways including managing traffic on the road, analysing flight movements, and predicting delays in the flight arrival and connected vehicles.

(ix) *Security*. There are various types of cyberattacks that prevent secure communication in any communication network. Artificial intelligence is very helpful in the early detection of any unauthorized attempt at communication. Security of communication is the need of the hour. Artificial intelligence can prevent the network from various types of attacks when integrated with other technologies like blockchain [27].

2.4. Issues in Artificial Intelligence. Generally, there are a number of challenges associated with the expected benefits. Artificial intelligence is no different. There are enough assurances that artificial intelligence can make things easy and effective for human beings in day-to-day life. However, there are certain issues in the efficient implementation of artificial intelligence as summarised in Figure 5 and are explained as follows:

(i) *Requirement of Complex Technical Knowledge*. Artificial intelligence is a very complex and evolving technology. Researchers have been working on understanding and implementing artificial intelligence for years, but the objectives are far-sighted. It is very difficult for any entity to acquire the required level of technical expertise in one go [28].

(ii) *Huge Costs*. Only very big organizations such as Google and Apple Amazon can manage to allocate huge funds required for research in artificial intelligence. Small organizations, even after having the requisite talent pool, may not be able to afford the required funds for research projects related to artificial intelligence.

(iii) *High Storage Capacity*. The success of artificial intelligence depends a lot on the availability of data. The artificial intelligence algorithms and programming tools analyse a humongous amount of data creating the challenge of storage of such a huge amount of data and information.

(iv) *Niche Workforce*. As already discussed, working on artificial intelligence requires a sophisticated level of technical knowledge. The availability of staff with

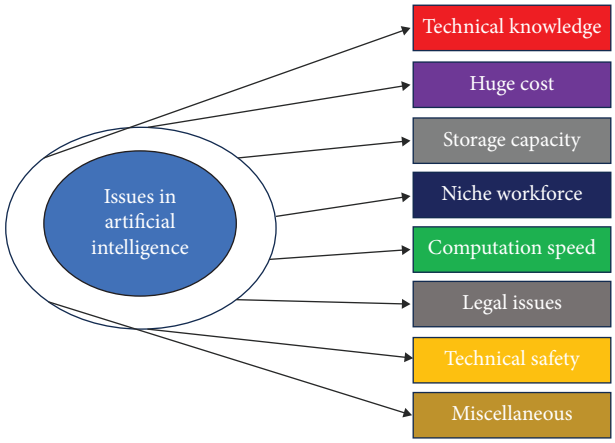

Figure 5: Issues in artificial intelligence.

such technical knowledge is very limited leading to huge costs of hiring such skilled manpower.

(v) *High Speed of Computation*. The algorithms processed in artificial intelligence models are very complex, and there is a need for sophisticated technologies and tools to provide high computation speed.

(vi) *Legal Challenges*. The models made through artificial intelligence can face legal challenges due to a lack of transparency and clear visibility of the functional programming of the machine.

(vii) *Technical Safety*. Under abnormal circumstances, due to some factors that the machine is not able to handle, the machine may pose a severe threat to the safety of other individuals.

(viii) *Other Miscellaneous Issues*. There are a lot of other miscellaneous issues such as massive unemployment, increase in socioeconomic inequality, detrimental impact on the environment, huge dependency, and addiction, which are associated with the artificial intelligence implementation in practical life [29].

3. Blockchain

Blockchain is a type of distributed ledger technology which was introduced to the world by Satoshi Nakamoto in 2008 [30]. Blockchain technology has various applications in multiple areas including banking and finance, business, government sector, and other miscellaneous fields. Blockchain technology has various benefits over other contemporary technologies in terms of security, privacy, trust, and transparency which will be discussed in detail in the later sections. In blockchain technology, the data and information are communicated among the users in a secure network using hash functions [31]. Hash is a type of signature using cryptographic primitives and is immutable.

The properties of blockchain are summarised in Figure 6 and are explained as follows:

(i) *Secure*. All the data and information are encrypted and kept secure from unauthorized access. Using

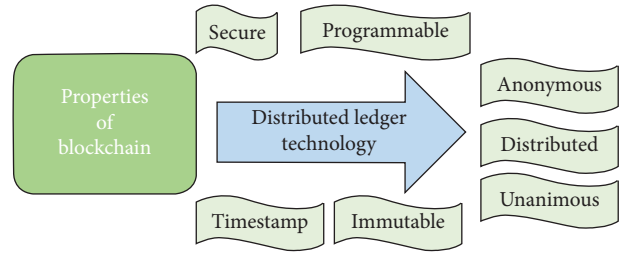

Figure 6: Properties of blockchain.

cryptographic algorithms in blockchain, the public and private keys help ensure the integrity and confidentiality of information shared across the users. The digital signatures help authenticate the exchange of data and information.

(ii) *Programmable*. Blockchain has programmable capabilities that take the scope beyond just recording the data entries. Blockchain technology has a long chain of blocks that are imbibed with self-executing codes, eliminating the need for manual development of codes making it a programmable technology.

(iii) *Anonymous*. The users in the network are anonymous and not easily identified to ensure utmost integrity among the users. To ensure anonymity among the users, blockchain technology uses addresses which have been programmed using cryptographic algorithms and avoids the usage of real identifiers for the users in the communication system. Thus, the true identities of the users are kept hidden.

(iv) *Distributed*. The ledgers maintained in the blockchain are distributed across various nodes. All the users at such nodes can access the records at the same time. In traditional systems, the data and information are stored on a central server controlled by an entity or a group of limited entities. However, in blockchain, the entire chain of data is accessible at each node and hence avoids redundancy in the stored data.

(v) *Unanimous*. The changes can take place only after the unanimous consensus of all the users in the network. This prevents the network from being manipulated by a specific person or group of people. In traditional systems, there was control of a specific person or group of people which has been eliminated by blockchain technology.

(vi) *Immutable*. Except in exceptional situations, the data once input cannot be altered later. If one block is to be changed, it will require changing all the subsequent blocks, making it extremely difficult to make any change at a later stage.

(vii) *Time Stamp*. Every record has a timestamp which is stored on the blocks in chronological order. The time stamp once assigned to any specific data is not available for edition/deletion at a later stage. This prevents any party from denying the transactions in the future.

3.1. Benefits of Blockchain. Blockchain provides a very potent solution for data storage and communication. The distributed technology used in the blockchain complemented with a cryptographic algorithm makes it a very comprehensive technology in the current technological scenario. With the growing needs and rapidly changing environment, blockchain is a very useful technology. The major benefits of blockchain are listed as follows [32]:

(i) *Transparency*. Every user in the network is aware of the activities going on in the network system. All the records are properly maintained with time stamps which are immutable and not allowed for deletion. All these properties ensure the utmost transparency in the system.

(ii) *Continuity of Business*. Since there are multiple nodes in the network, a failure at one end would not affect the network. With growing complexity and uncertainty in the business environment, the entities are concerned that there should be contingency planning and that the system should not fail due to any unforeseen event or activity.

(iii) *Elimination of Intermediation*. Blockchain is based on decentralized ledger technology, and hence, there is no need for intermediaries in blockchain network systems. Elimination of intermediaries provides more efficiency and reduces cost.

(iv) *Trust*. Huge trust can be reposed in blockchain technology as it not only preserves the identity of the users but also provides complete transparency in the records. The records cannot be altered retrospectively in the given scenario and hence provide trustworthiness to the users on the platform [33].

(v) *Privacy*. Blockchain technology works on the encryption function where the data are encrypted using a combination of public and private keys. The secrecy related to the identity of users and the records and information transmitted in blockchain networks are maintained securely.

3.2. Applications of Blockchain. Blockchain has multifold applications in various sectors. From banking and finance to business and government-related activities, blockchain has its importance in all fields. Blockchain is a very flexible technology and can be moulded as per the requirements of different sectors and industries. The major requirement in almost all sectors is large-size data capturing and maintenance. Blockchain technology provides the facility to store such huge size data securely. Blockchain also provides the benefits of nonstop functionality where even if one node fails, the system continues via the other nodes and never fails in totality. The various applications of blockchain are listed in Figure 7 and explained as follows.

3.2.1. Banking and Finance. One of the real-life examples of blockchain technology in the field of banking and finance is RippleNet [34]. RippleNet provides the facility to transfer

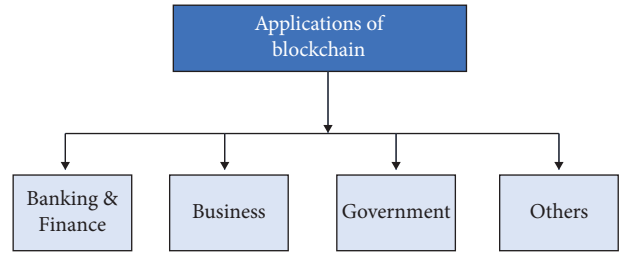

Figure 7: Applications of blockchain.

funds directly without the involvement of subsidiaries at low cost and high speed. There are various applications of blockchain in banking and finance as follows:

(i) *International Payments*. In the current scenario, international payments are settled with the manual intervention of some entities mainly banks across borders. With the help of blockchain technology, payments could be easily carried out from one country to another without any intervention from banks or any other financial entity. Not only will the funds be transferred quickly but also securely.

(ii) *Capital Markets*. There are various challenges in capital markets such as operational issues, settlement delays, and audit challenges, which make these markets less efficient in raising funds. Blockchain technology can remove all these issues and make these markets very effective.

(iii) *Trade Finance*. Trade finance-related activities are very slow due to long documentation and verification procedures. The details related to the buyers and sellers, the product details, the terms, and conditions of the contract are captured between two international trade parties. Blockchain can simplify trade finance-related activities and expedite trade finance.

(iv) *Compliance, Regulation, and Audit*. Blockchain is a very secure technology. It gives a lot of comfort to the regulatory bodies and the auditors in a manner that all the records and the transactions trail are easily available and no one can alter the records and information.

(v) *Protection against Money Laundering*. Money laundering is one of the biggest issues which challenges the objective of lawful financial activities. Blockchain comprises one important function named encryption which caters to this challenge. Encryption functionality helps in making sure that all the transactions take place between legally identified legitimate parties.

(vi) *Insurance*. Blockchain is very useful in the insurance section due to smart contracts property. In smart contracts, it will be made sure that only one claim is made on one item. It will remove the illegitimate multiple claims on the same property.

(vii) *P2P Transactions*. There are a lot of challenges in peer-to-peer transactions. Some P2P applications

might charge fees. These P2P portals are not very secure and may be hacked by attackers. Blockchain is a very optimal tool for peer-to-peer interactions in a secure manner.

3.2.2. Business. One of the examples of blockchain in the field of business is the Food Trust platform. This platform was created by IBM and Walmart in 2016 [35] for tracing food items. It contains the communication established among the farmers, wholesalers, retailers, and distributors where all the stakeholders can trace food items on real real-time basis. There are various applications of blockchain in business explained as follows:

(i) *Management of Supply Chain*. Blockchain has huge potential to completely transform the supply chain mechanisms. All the mobility records of the goods can be tracked on a real-time basis through its immutable ledger property.

(ii) *Healthcare*. A lot of data are required to be stored and optimally managed as patients' information including the age, gender, address, past medical records, current medication, records of the pharma stocks, records of doctors, profiles, and experience. Blockchain can easily capture and maintain this huge data and therefore make the overall operations very robust.

(iii) *Real Estate*. There are lots of changes in the ownership of the plots, houses, and commercial structures. Blockchain can streamline all the processes where the records of buying and selling of any structure will be available from beginning to end and hence will remove the chances of fraud.

(iv) *Media*. Blockchain technology can help in removing frauds, streamlining operations, removing third-party interventions, and making operations efficient and effective in the field of the media sector. Blockchain can be very helpful in managing digital media rights. The artists will get a fair chance to have wider controlling powers on the original work.

(v) *Energy*. There are a lot of activities such as billing, metering, and generation of certificates for emissions, which can be optimized using blockchain technology. Blockchain can also be very helpful in grid management through comprehensive monitoring. The certificates for renewable energy can also be managed through blockchain.

3.2.3. Government. Estonia's government has been using blockchain technology since 2005 [36] for electronic voting in the country. There are various other avenues explained below where blockchain can prove to be a great technology for government purposes.

(i) *Record Management*. There are requirements for huge data record keeping for government-related activities, e.g., population census, government projects and scheme-related information, and citizen records. Blockchain technology has the capability of maintaining such huge data and records.

(ii) *Identity Management*. The identity of people can be created once in the blockchain and encrypted to keep it safe. Once the identity is created, there is no need to share the identity-related information in raw form. Moreover, through blockchain, the know-your-customer requirements can also be fulfilled efficiently.

(iii) *Votes*. Every country faces the challenge of fake IDs during elections. Blockchain technology can remove this flaw. Each vote will be attributed to only one ID, and it will be almost impossible for hackers to tamper with any records due to the immutable property of blockchain.

(iv) *Tax*. Filing taxes are a cumbersome process, especially for large organizations due to the size and scale of the operations. Blockchain technology can simplify the tax filing process and maintain records in case of any legal dispute. Blockchain technology can provide advanced analytical capabilities in forecasting tax burden in advance.

(v) *Not-for-Profit Organizations*. It is very difficult to track the activities of not-for-profit entities due to the very nature of the activities conducted. Blockchain can help in tracking the activities of not-for-profit organizations and provide oversight to these organizations under the government's control.

(vi) *Regulation*. Blockchain technology can show all the records and identify any anomalies to the regulatory bodies on real real-time basis and hence increase the regulation capabilities. Using blockchain, the regulatory reporting process can be streamlined. Not just at the domestic level, but blockchain can be highly effective in managing regulations at cross-border levels.

3.2.4. Others

(i) *Finance and Accounts*. All the financial and accounting activities in any entity, including both public and private, can be conducted using blockchain technology. Blockchain can easily manage large-scale operations and provide output on real real-time basis which will further help organizations in better decision-making and enhance results.

(ii) *Records Making*. Blockchain technology makes sure that no records are duplicated and maintains the records scientifically. Blockchain can handle large amounts of data and transactions. Unlike traditional systems where the entire data are stored on a single central server, blockchain provides decentralized nodes where multiple users can make and access records at the same time.

(iii) *Cybersecurity*. Blockchain helps in the authentication of users. Hence, the probability of unauthorized entities getting access to the communication system

is minimized. Moreover, the encryption facility in blockchain keeps the data safe even if it is accessed by unauthorized entities. The other benefits of blockchain technology such as immutability and privacy make it a very secure technology.

(iv) *Big Bata*. Big data refers to the immense amount of data and information. Big data can be easily stored, maintained, and retrieved using blockchain technology. Blockchain technology maintains the data in the form of blocks, and additional data keep getting added to the additional blocks. Blockchain keeps the data secure from cyber-attacks and hence supports big data applications.

(v) *Data Storing*. A huge amount of data and records regardless of the complexity and type can be easily managed using blockchain technology. There are various nodes where multiple users can store the data at the same time and the entire blockchain copy is maintained at each node. Due to the immutable property, the data once stored cannot be amended later easily.

(vi) *Internet-of-Things*. Internet-of-things refers to the environment where multiple devices are connected through the Internet. These interconnected devices share a lot of data and information. Internet-of-things can be made more effective and efficient using the benefits of blockchain technology in terms of data sharing, data security, and data integrity.

3.3. Issues in Blockchain. The paper has discussed the various benefits of blockchain technology. However, there are a few issues in blockchain technology that create hindrances in the overall expectations from blockchain technology. There is a grave need to address these issues and challenges to optimally utilize the capacity of the technology across different sectors. Some of the issues in blockchain technology are as follows:

(i) *Size of Operations*. For any addition to the chain of blocks, all the previous blocks need to be validated and require the consensus of the network. All such data require huge storage capacities and hence pose a challenge to the scalability of blockchain.

(ii) *Security and Regulation*. Although blockchain is a very secure technology, still it is not completely free from attacks. There are a few attacks like 51 percent attack where if the attacker gains access to 51 percent of the network, the attacker may manipulate the entire network according to his ill will. Also, since the technology is quite new, the rules, regulations, and guidelines related to blockchain technology are still in the nascent stage [32].

(iii) *Cost on Environment*. Blockchain technology requires huge computational powers which ultimately result in huge energy consumption. Such a huge requirement of energy poses a lot of challenges to the environment.

(iv) *Complexity*. Blockchain is essentially based on encryption and cryptographic algorithms, and hence, a very complex technology is not easily understandable by anyone. So, it is difficult to implement in small organizations which do not have enough skills and resources to understand and implement the technology [37].

(v) *Slow Speed*. As already discussed, blockchain is a distributed technology and hence requires the consensus of the users in the network for any changes. It takes time to obtain the confirmation of the users leading to slow processes [38].

4. Security Concerns in Online Communication

One of the biggest challenges that the current technological era is facing is securing communication in the network. There can be various approaches to resolve this issue, but the best method is not the one which just minimizes the risk of attacks from unauthorized access but should also be cost-effective. The objectives of securing communication are as follows:

(i) *Availability*. It implies that all the required data should be available to the users in the network without any restrictions.

(ii) *Confidentiality*. Any entity which is not an authorized user should not have access to the network communication. All the unauthorized access from attackers should be prevented.

(iii) *Integrity*. The communication should be unalterable and not be deleted by any user in the network environment.

There can be various types of security concerns related to both hardware and software. There is no end to the creativity of the attackers, and the hackers may come up with new types of attacks against which the existing security protocols might not support effectively. So, there is always a need to evolve and strengthen the security protocols in the network. Some of the prime security concerns are as follows:

(i) *System Fooling*. In this type of attack, the machine is demonstrated a false picture, and the machine is supposed to decide with the malicious inputs. When the machine works based on such unverified data, it may lead to catastrophic results.

(ii) *Manipulation of the System in Online Environment*. Almost all the systems are connected to the Internet which gives a chance to the attackers to try to manipulate the system online. The same can be managed by using appropriate algorithms which are not easy to crack by hackers.

(iii) *Attacks on Inputs*. The output of any integration depends on the inputs. Most of the time, the attackers try to corrupt the initial input to affect the final output as per the will.

(iv) *Poisoning and Corruption of Data*. One of the prominent security concerns is ensuring that the

data are free from any attack or manipulation. Any changes done in the base data with malicious intent will spoil the overall objective and will lead to unfavourable outputs.

(v) *Attack via Transfer Learning*. In most of the cases, the machines learn from the existing trained models. When this learning transfers from the trained model to the main machine, there is a lot of risk that the already trained model might manipulate or fool the main machine to serve unauthorized purposes.

(vi) *Privacy and Confidentiality of Data*. A lot of attackers try to extract the data from the main systems and use that data to fulfil malicious objectives. So, it is of utmost importance to safeguard the privacy and confidentiality of the data using encryption and various complex algorithmic models.

(vii) *Damage*. A major concern is damage to the machine by the attackers. For example, the attacker may attack the systems and machines in such a manner that the machine is not able to recognize the danger signs and may crash.

(viii) *Hiding*. The attackers might try to create issues in such a manner that the machine is not able to detect that the system is under attack which gives more time to the hackers to manipulate the overall network.

(ix) *Faith Degradation*. The attacker may try to evade the faith of the users in the communication system. For example, the machine may be made to sound an alarm even under normal circumstances and not just in critical cases, which will result in users giving up on the machine itself.

It is imperative to understand why there are huge security concerns despite conscious efforts to prevent unauthorized access from attackers. One of the primary reasons is technological constraints. The hardware and software have inbuilt constraints which make them prone to attacks. Also, there are huge concerns about the configuration. The administrators should try to analyse and understand the risks associated with configuration settings. Security policy is also a very important factor which raises concerns about network security. All the authorized users in the network should abide by all the rules and regulations prescribed in the policy document. Any lapse might lead to attacks by the hackers [39].

5. Integration of Blockchain with Artificial Intelligence for Secure Communication

The combination of blockchain and artificial intelligence is a very useful integration and can completely transform and revolutionize almost every sector or industry. Blockchain will provide double protection against unauthorized access or attacks by hackers. Artificial intelligence can work over huge data and numbers and analyse the same to build patterns in the records. Blockchain can assist in removing the data which is doubtful and may lead to security risks. So basically, artificial intelligence can work on the data stored in blockchain and identify the patterns which might have security concerns. Blockchain will verify the authenticity of such identified records and take necessary remedial actions.

The integration of artificial intelligence and blockchain helps in addressing various security concerns. The decentralized property of blockchain in the integrated framework assures the availability attribute. The confidentiality and integrity of data and information are ensured through anonymous and consensus properties of blockchain complemented by cyber-attacks proactive identification and automated incident resolution through artificial intelligence. Concerns such as system fooling, input attacks, and corruption of data are eliminated through the integration as the authenticity of data is checked through algorithms before generating the output. The manipulation of systems is not possible in integration as there is no central server. The entire communication system is distributed across users in the integration model. The risk of transfer learning is quite limited as the integration model operates on evolving learning mechanisms and does not rely on limited past sources. The risk of hiding is managed in the integration model as the communication system is resistant to manipulation, and the anomalies cannot be kept hidden in the presence of the advanced cryptographic algorithms built into the integration environment. The faith of the users would be restored over time as the integration environment would learn from its mistakes and anticipate any future issues in advance, avoiding any repeat issues. The integration of blockchain and artificial intelligence may offer the following capabilities:

(i) Efficient models for capturing and storing huge data

(ii) Effective systems for ensuring the authenticity of records and verification processes at global levels

(iii) Robust systems to ensure compliance and regulations

(iv) Governance of network systems in a more transparent manner

(v) Various types of advanced analytics which help in predictions

5.1. Peer Comparison. There has been some past research related to artificial intelligence and blockchain. This section provides a comparative analysis of the current study with the previous research works. Wang et al. [40] provide an analysis of the integration of edge intelligence and blockchain technologies. The paper analyses in detail the various fields of industry such as transport, healthcare, manufacturing, energy, and digital communication. However, the study lacks practical real-life examples where the integration of edge intelligence and blockchain has been implemented and provided better results compared to traditional systems. The current study discusses various examples such as RippleNet and Food Trust Platform in Section 3.1 and FINALIZE platform later in Section 5.2 which brings more reliability to

the stakeholders. In Zuo et al. [41], there is a discussion regarding blockchain and artificial intelligence in the field of wireless communication from a 6G perspective. However, there is very little analysis of the various security challenges that are faced by wireless communication systems. The paper does not explain in detail how the integration will help in addressing the security challenges. The current study analyses the various security concerns in Section 4 and discusses how the integration of artificial intelligence with blockchain addresses the security concerns later in Section 5.2. In Lie et al. [42], there is an analysis of blockchain and machine learning in the field of networking systems. The paper discusses how blockchain complements machine learning in terms of data sharing, security, intelligence, and trustworthy decision-making. However, there is a lack of discussion regarding how machine learning helps in bridging the gaps in blockchain technology. The current study discusses the individual strengths and benefits of artificial intelligence and blockchain and explains how both technologies complement each other. The paper proposed by Taherdoost et al. [43] provides the various benefits offered by the integration of blockchain and artificial intelligence in various fields including supply chain, finance, life sciences, healthcare, and social networking. However, the paper does not provide details of the history and developments in blockchain and artificial intelligence. The paper gives references to various peer surveys; however, it does not analyse the contributions and issues in the peer study. The current paper provides the fundamental details of both artificial intelligence and blockchain technology and the related history which gives a comprehensive view to the researchers. The current section analyses the details of the peer work and discusses how the current study addresses the issues identified in peer surveys. In Charles et al. [44], there is a detailed analysis of how the integration of blockchain and artificial intelligence is useful in the field of the supply chain. The paper focuses majorly on the existing research conducted across various territories. However, the paper lacks discussions on the future trends and the challenges in the integration. The current study provides a comprehensive view of the future trends and the various challenges which need to be addressed before implementing the potential of synergy created through artificial intelligence and blockchain. The current study emphasizes addressing these challenges which also works as a direction for researchers and academicians for future research work. Industry experts may develop future models which can address the challenges highlighted in the current study.

5.2. Benefits of Integration between Blockchain and Artificial Intelligence. One of the examples of integration between blockchain and artificial intelligence is the FINALIZE platform. This platform is used in infrastructure-related projects where this software provides benefits of automation in multiple activities including safety regulation, verification, and improved workflows. Achieving the integration of blockchain and integration in all sectors is not very easy and will require huge efforts in successful implementation [45]. Some of the benefits of integration are as follows:

(i) *Security and Protection*. Blockchain technology becomes more secure when integrated with artificial intelligence. Artificial intelligence can build more experience over time identify the patterns of the hackers and accordingly protect the blockchain network from any possible attacks.

(ii) *Efficiency*. Artificial intelligence can do a lot of work done by the miners and hence reduce the cost of mining. Additionally, artificial intelligence can also help in minimizing carbon footprints and bring overall efficiency.

(iii) *Trust*. The trust of the users increases substantially when both blockchain and artificial intelligence technologies work cohesively. The users can track the logs and be aware of how the system is thinking which further increases the reliability.

(iv) *Management*. The integration of these two advanced technologies will eliminate human interference and ensure robust management and error-free processes.

(v) *Privacy*. Privacy is one of the prime requirements while handling confidential data. Artificial intelligence enhances privacy in the blockchain network and keeps the user's privacy as the top priority.

(vi) *Storage*. The storage in blockchain networks becomes more effective when integrated with artificial intelligence. Artificial intelligence tools will streamline the data sets and provide efficiency in large-size data storage.

(vii) *Computation*. The computing power increases multifold due to the integration. The knowledge derived from artificial intelligence speeds up the computation capabilities in the blockchain environment.

(viii) *Diverse Datasets*. Artificial intelligence can work on varied types of datasets which when integrated with blockchain brings more capabilities to handle such heterogeneous data.

(ix) *Monetization of Data*. In the current technological era, data are one of the most important aspects. The data stored in blocks in the blockchain network can be optimally monetized using artificial intelligence. Using artificial intelligence tools, data can be segregated into different buckets and sold to various parties depending on the needs and requirements.

(x) *Authenticity*. It is difficult to challenge the authenticity of the network as tampering with the records becomes almost impossible when artificial intelligence integrates with blockchain technology. Blockchain provides audit trails of all the records which are further verified by artificial intelligence tools resulting in the utmost authenticity of the records.

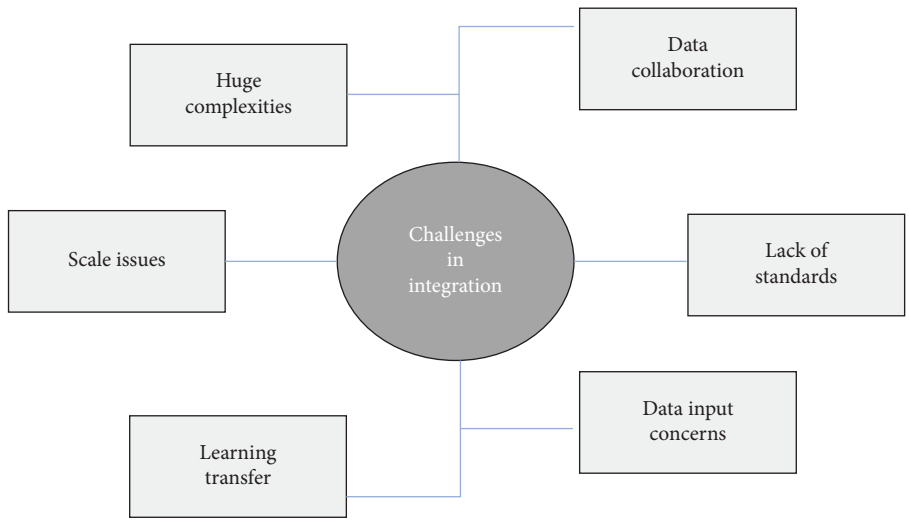

Figure 8: Challenges in integration.

(xi) *Augmentation*. The output of artificial intelligence depends on the level of the data provided. Blockchain technology provides artificial intelligence access to huge data warehouses which is channelled to create meaningful outputs.

(xii) *Automation*. A lot of activities can be highly automated as the data stored in the blockchain network will be worked upon by the artificial intelligence tools on a real-time basis and hence the operations can be automated with zero human interactions. For example, in a pharmacy store, the details of all the stock will be regularly updated in the blockchain network and artificial intelligence will keep on identifying which medicines are short in stock, which medicines are expired, and which medicines are not selling for a long time.

(xiii) *Transparency*. Transparency in the blockchain network strengthens further after integration with artificial intelligence. The users can understand how the machine is operating and all the records are available with time stamps.

(xiv) *Fairness*. Artificial intelligence will ensure that all the parties related to blockchain like miners are rewarded fairly depending on the efforts made by them. No party will get rewarded unfairly.

(xv) *Autonomy*. Autonomy is boosted automatically as artificial intelligence removes manual intervention and brings more autonomy to operations.

(xvi) *Power Management*. Artificial intelligence streamlines all the operations in blockchain and hence helps in optimizing energy consumption.

5.3. Challenges in Integration between Blockchain and Artificial Intelligence. Both blockchain and artificial intelligence have various benefits such as secure network, automation, efficiency, trust, and integrity, but, at the same time, there are a lot of issues and challenges such as huge energy requirements, storage capacity issues, and source systems alignment. Both technologies require data, algorithms, and modelling to achieve the objectives. This paper discusses the benefits arising out of the integration between the two technologies and the various challenges in achieving the optimum implementation. There is no denying the fact that if the optimum balance between artificial intelligence and blockchain could be achieved, then the benefits will far outweigh the costs involved in the integration. Integration of blockchain with artificial intelligence can act as a double-edged sword but it is not easy to realize the true potential that lies in the synchronization benefits. There are various challenges in achieving the optimum integration between the two technologies as summarised in Figure 8 and are explained as follows:

(i) *Data Collaboration*. There are a lot of information systems for different types of activities in any organization. All these traditional systems need to interact with blockchain and artificial intelligence tools to pass on the required data and information. Artificial intelligence will not help much if the data quality from the source systems is poor. It is very difficult to align all the existing systems in line with the requirements of blockchain and artificial intelligence.

(ii) *Huge Complexities*. Both artificial intelligence and blockchain are relatively new technologies in various sectors and come with a very complex inbuilt nature. It takes huge time and resources to understand the nitty-gritty of these technologies and implement and align them according to the business requirements. It will take some time to build the required architecture which may function as fundamental for future architectures.

(iii) *Scale Issues*. The property of consensus in blockchain distributed ledger technology leads to a huge challenge of scalability as every record, data, or transaction will not pass without the consensus

mechanism in the network. The consensus property ensures the trust and integrity of the data but it also results in slow operations and processes. Since the records are maintained for each additional block, the storage requirements are huge and affect the scalability. Artificial intelligence also needs huge data for better analysis and results [46].

(iv) *Lack of Standards*. There are no fixed standards available for blockchain technology and artificial intelligence. Although there has been some work going on in this regard, but still it has not reached at conclusive stage. In the absence of the global standards, the integration might not yield optimum results.

(v) *Data Input Concerns*. Artificial intelligence is dependent on the data available in blockchain to produce meaningful outputs. If there is any issue either in the quality or the quantity, the integration will not work perfectly. To date, most organizations suffer from the challenge of providing enough quality data.

(vi) *Learning Transfer*. Since both artificial intelligence and blockchain technology are quite complex and work on different algorithms and languages, it might be difficult to transfer the output of integration to other machines. New protocols and algorithms must be built to ensure smooth learning transfer from the integrated framework to the other machines.

6. Conclusion and Future Directions

The synergy of artificial intelligence and blockchain addresses the major challenge facing digital communication in the technological era. The integration of the capabilities of artificial intelligence and blockchain offers a multivaried approach which provides security, integrity, and adaptability in communication systems. The decentralization, immutability, and unanimity properties of blockchain bring the trust component among the users while the complex algorithms built in artificial intelligence prevent security threats. These two technologies, combined, provide a secure communication model for the users which takes over the limitations of the past systems. In the digital era, the need for secure communication will keep growing, and the synergy created by blockchain and artificial intelligence is one point solution for the emerging future needs.

Artificial intelligence and blockchain have great benefits and applications individually. Also, after integrating both technologies, the benefits become multifold. From the future directions perspective, the paper discusses various challenges in the path of optimum integration. The best way to address these challenges is through global collaboration. Since both technologies are very complex, segregated efforts will not achieve the results effectively. Another major challenge is the conflict between trust, integrity, and performance due to consensus mechanisms in blockchain technology. Any new addition of block in the existing chain happens only after users' consensus in the network which gives a lot of trust and integrity to the users but at the same time slows down the process and affects performance. There should be an optimum trade-off between these qualities so that the best solution can be obtained. There is also a great need for bringing regulations in the dynamic technological environment. Since both technologies are new, there are very limited regulations. The various organizations involved in the research and development of blockchain, and artificial intelligence and related technologies should come together and enhance the regulatory framework to bring more security and ensure more trust among the users. A strong regulatory framework will bring more entities into this field. The way ahead is to make conscious efforts to increase awareness of the benefits of integration of the two technologies so that more research work can be conducted to achieve optimum integration.

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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