

Approaches of Blockchain with AI: Challenges & Future Direction

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Abstract: Artificial Intelligence and Blockchain have recently become the two hottest technology trends. Blockchain can be defined as the chain of blocks in which every block holds the record of every transaction happening among the mining nodes in a network that is not controlled by any authority. A Blockchain is a distributed ledger that ensures the security, immutability, and transparency of the stored data. Once the data gets stored in the ledger, it becomes an extremely difficult task to temper with. This technology is being widely used in many sectors like cryptocurrency, smart contracts, government, and many others. On the other hand, Artificial Intelligence (AI) is a branch of computer science that is mainly focused on creating such machines that are capable of performing various typical tasks that require human intelligence, sometimes also known as machine intelligence. Researchers have been exploring the combination of these two technologies, as the integration of these two technologies can highly develop the block chain's underlying architecture and enhance AI's dormant.

Keyword: Artificial Intelligence, Machine Learning, Blockchain, Human Intelligence.

1. Introduction

Blockchain is a wide-ranging technology that ascertains many new features for the industrial and business world [1]. These features help to improve the existing industrial and business processes. Blockchain consolidates many different techniques to maintain a distributed ledger among all the participants in a network such that all the transactions remain secured and unaltered once being added, and every participant agrees on its content. It also allows the detailed tracing and tracking of transactions. Blockchain works upon a decentralized system where it enables a bunch of realities that can list an agreement without any need for a third party [2]. These agreements can be built upon any activity like a voting activity, payment transaction activity, medical activity and these activities can be secured and registered using Blockchain. Now, to assure the legality of the conducted agreements, this technology combines both the benefits of cryptographic algorithms and peer-to-peer networks. Also, without any interference of any regulatory authority or a third party, the chances of the data getting leaked decrease. The transactions or information recorded on a ledger is publicly available and transparent to every member to validate [3]. The elimination of intermediaries makes the process of exchanging information and transactions a lot faster. Blockchain does ensure a promising future for the world, it has built trust in many sectors.

Artificial Intelligence can be described as the intelligence of machines. AI helps the machine think more like a human so that they can perform various task [4]. A task which requires sudden thinking or immediate response is difficult to be performed by the machines, that's where AI comes in handy. To make the machine work like humans' various algorithms are required to. First the goal is to decide what we want from the product to achieve finally. Then algorithms are written accordingly, which decides on how the device will work under certain circumstances and how it should respond [5]. With the increase in demand for newer and

better technology that reduces human efforts, AI has a very huge scope in the future and in the present time also. It can be used with various other technology for the betterment of the product. AI when used with IoT is known as AIoT, which stands for the Artificial Intelligence of Things. With a huge network and various IoT devices, AI has so much room for doing the work [6]. With the features of data recording and analyzing of IoT and features of decision making of AI, a machine can do a lot of amazing things.

Artificial Intelligence when combined with Blockchain is known as Decentralized AI [7]. The main purpose of Blockchain is to store data and transfer data, so when it is combined with AI, we can say that the stored data can make decisions of their own or we can say that they will have the intelligence of their own. Also, the data on which the AI works can be transferred to various other networks with a reliable and secured Blockchain system [8]. With the combination of Blockchain with the AI the data will easily available for the users and they will able to see the data but will not be able to edit it. Third-party involvement will not be required because of the Blockchain technique. AI will add intelligence to that data which will then analyze the data by its own and respond to events which require a quick response. Planning and plotting of each technology come out with excellent results. The purpose of Blockchain technology is to maintain the privacy and security. In Spite of this, we have faced numerous limitations in Blockchain technology such as, high transaction cost, complexity, network size, and so on. To remove these limitations, unification of Blockchain and artificial intelligence contributes significantly in current years [9].

This paper investigates the integration of blockchain with AI, gives a complete review of the role of AI with the blockchain. This includes their benefits, their applications in different sectors like business, industrial and many others, and also the challenges faced by the decentralized AI and how both the technologies together can overcome those issues. Together, the blockchain and AI can make a better combination as the blockchain is a highly secured and trusted platform whereas AI works on a huge amount

of data and is very capable of making good decisions. The key aspects of this paper are as follows:

- The paper discusses about the Blockchain and its features.
- The paper discusses about AI with their uses.
- The paper discusses the merger of the two techniques and its benefits.
- The paper discusses various applications of Blockchain with AI.
- The paper discusses the challenges faced while using the Blockchain with AI.

So, the rest of the paper is categorized as follows. Part 2 explains Blockchain and AI individually and how they can transform each other with their integration. Part 3 explains the applications of decentralized AI. Part 4 discusses the various research challenges and issues and Part 5 concludes the paper.

2. Related Work

This part explains about the Blockchain and AI individually and then will explain the integration of the both of the technologies.

2.1 Blockchain

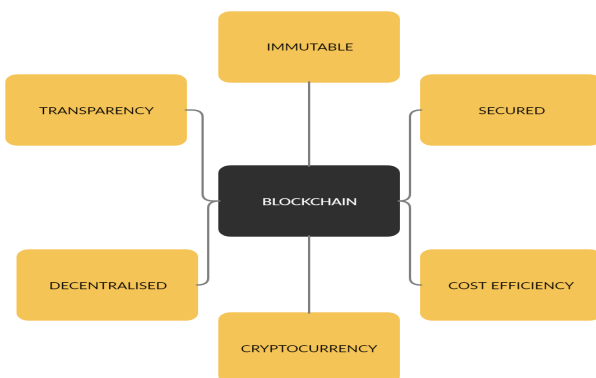


Figure 1- Overview of Blockchain

Blockchain in simple words can be described as a data structure that records all the transactions happening among the participants of the network in the form of blocks while ensuring decentralization, transparency, and security [10]. Every member of the network can validate or check the data without any need for the authorization of the third party which makes the process more effective, faster, and cost-efficient. Each block in the network stores the information of the transactions, but once the data is stored in the ledger no member can tamper with it [11], [12]. All the data in the blockchain is stored digitally using the digital signatures and encryption algorithm that proves its authenticity and decreases the chances of leakage of data. Blockchain also makes the payment system more secure and easier for example, if you are looking to transfer some money to your relative who lives far from you [13]. A general option that will come to your mind will be any online

payment application or bank that will include the third party in order to transfer the money or make the transaction, due to which you will also have to pay the extra fee. Besides, there is no full security for your money any hacker can hack the system and seize the money. Here the blockchain enters [14]. Using blockchain instead of the traditional banking system for the process of transferring money, can be more secure and easier. This technology excludes the need for a third-party and the transaction can directly be processed by you so there is no extra fee to pay [15]. Blockchain works upon a decentralized system means all the data stored in a blockchain is not confined to a single place, the data stored in the network is public and decentralized. Every transaction in the network is directly visible to every participant, everyone contains a copy of the distributed ledger but no one can edit the data appended in the ledger [16]. This maintains the immutable history of every member's activities and offers the full traceability and transparency of all the transactions to everyone that ever happened in the network [17].

Now let's understand how the blockchain technology works. In a blockchain network, every block contains the hash of the preceding block along with some information [18]. Now a hash can be defined as a mathematical code that every block carries its own. If a block stores the modified information, the hash will also subject to the modification. These unique hash keys in the chain of blocks ensure the security in the blockchain network [19]. There are nodes in the blockchain network that access or validate all the transactions that are taking place. In Bitcoin blockchain, there are miners that validate the transactions but in order to validate the transaction they use the proof-of-work concept. And for a valid transaction, every block needs to commit the hash of the previous block [20]. This makes the blockchain unalterable as every modification in the chain of blocks is visible to the complete network and gets caught easily. Blockchain also provides a feature in which two or more peers can securely make an agreement or arrangement over a private network on certain activities like healthcare activity, business activity without the requirement of any third party or authority [21]. The involved peers can be total strangers and still can make the agreement. Once the agreement is recorded in the network, it is impossible for any of the involved peers to deny, cancel or alter the agreement [22]. To assure the validity of the agreement recorded in the network, the "mining" process is used. The data stored in the blocks are highly secured with the powerful cryptocurrency that makes sure that the transactions recorded in the network cannot be tampered or forged [23]. This makes the blockchain a trusted platform and allows the cryptocurrency to sustain a trusted transaction network without any need for authority. Also, for the past few years, the blockchain has been playing a vital role in the enhancement of cryptocurrencies. Therefore, because of the enhancing properties of the blockchain, this technology is evolving very frequently and investing the various enhancements in different fields [24].

2.2. Artificial Intelligence

Artificial intelligence is the technique to give the machines some kind of intelligence. The ability of a machine to do work without the interference

of any human and also giving the machine intelligence which helps it to take decisions by itself. Various new devices are coming with this technique and this technique helps them to be more useful to humans and is increasing the demand for such new devices. Some of the few popular AI-based software and application that humans use on a daily basis are Siri, Alexa and Google voice [25], [26]. All of these software's work immediately according to the response they get from the user. One more example of this technique is self-driving cars, Tesla Motors is one of the major manufactures of such cars and with the help of this technique the cars can literally drive themselves without human involvement, the working of such cars take place because of the information gathering and decision making of the software. All of these AI applications are able to work because of the algorithms which are written to make such software [27]. Various different algorithms are required for an AI device to work perfectly. Each scenario is kept in mind and algorithms are written accordingly.

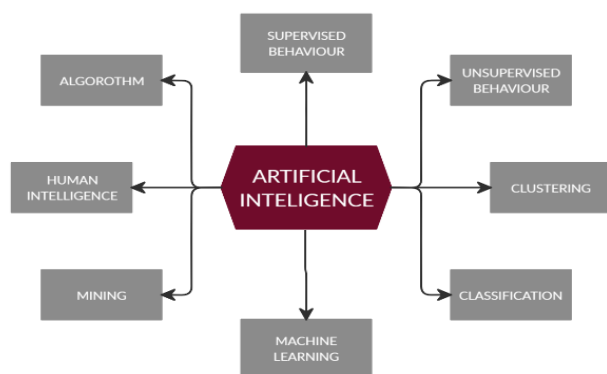


Figure 2- Overview of Artificial Intelligence

Artificial intelligence is of two types centralized AI and decentralized AI. Centralized AI can be explained as the AI technology which requires third party interference to do a task. Which means that AI technology will be under the guidance of human intelligence, humans will be required to tell what the software can do at a specific thing or a situation. Data can be tempered easily in the centralized AI and also there will be no authenticity of the software which will increase the risk of using that software to a huge extent. That is where decentralized AI is required. In decentralized AI no governed party is required to make or take decisions for the AI. The combination of AI and Blockchain together is known as decentralized AI [28]. With the help of the Blockchain the AI can perform all the tasks without the interference of any party. So, all the analysis and decision making can be performed on a secured and private platform. Also, data tampering is not possible in a decentralized AI platform. AI and machine learning are two different techniques but they are connected to each other in a way. Machine learning is a technique that the AI software uses to take action on the tasks which are present in front of them. Now during the making and training of the AI, the learning methods that can be used are supervised learning and unsupervised learning. Supervised learning is the technique of providing the AI machine the solution for every problem that it can face. This will prepare the machine in such a way that it will already

know all the problems that it can face and will have all the solutions to it. It is a very long and detailed learning process. The second way of learning is known as an unsupervised way of learning, in this method no solution or answers are provided to the AI software. The machine is provided with a lot of data which it has to analysis itself and find the answers to the questions itself. For example, if the machine has to predict who will win the elections this year, then the machine will be provided with a lot of data related to that election and the machine will analyze it and will find a solution by itself. This is where IoT and AI are merged together because the data can be taken from an IoT device which gathers information related to it and store it in a cloud, further that cloud can be provided to the AI software for finding the results of the problem provided to them [29]. Classification of the data according to the problem is very necessary and is done with the help of classification training given to the AI. The second important thing for data analysis after data classification is data clustering. Data clustering is basically a process of keeping similar data together so that it can be used to find solutions related to a problem. Nowadays more and more people are opting for this technology because of the features it provides and how it is affecting human life.

2.3. Integration of Blockchain with AI

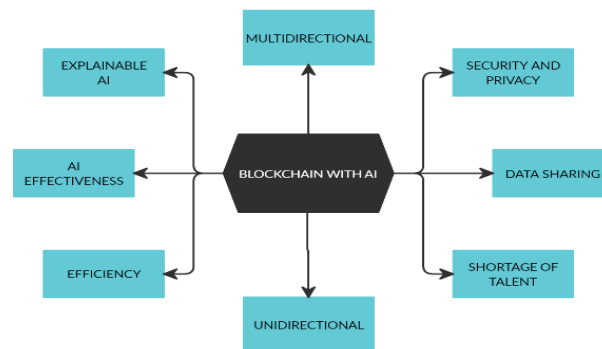


Figure 3- Integration of Blockchain with AI

Blockchain, and artificial intelligence imitate extraordinary chances for the public sector and business sector. Unification of these two technologies equip predictive methods, share data from one device to another with privacy and security, and solve neurons regarding problems and share data resources between machines. Each and every field is proficient to deed these technologies through which they create new models, enhance the ongoing processes and grant services for the customers.

2.3.1. Explainable AI

Explainable AI is a program of artificial intelligence which performs as a framework and set of tools that help us to thrive and comprise its IoT applications such as smart healthcare, enterprises and autonomous vehicles. Explainable AI performs indubitably with machine learning models that construe its rationale purpose and decision-making process. This process is so glaze that each and every device can easily perceive it. The preeminent leverage is getting by integration of Blockchain with artificial intelligence that is a confidential platform of decision for data as

all the data and information can be seen by everyone on the Blockchain.

2.3.2. AI Effectiveness

Artificial intelligence is the technology which cohere the humans to machine and create the virtual world where both humans and machines work together. It is way more effective in the era of digital marketing acting as predictive technology [30]. Artificial intelligence procures lots of operations such as analysis of prescriptive, analysis of adaptive, analysis of continuous and analysis of predictive. It is propitious for both post event processing and real time. AI effectiveness conceivable for machines to perform like humans. This is a glance of AI effectiveness. Mainly it uses machine learning tech for interaction with the human's brain. Currently, it is maintaining its focus on one-to-one optimization.

2.3.3. Efficiency

Efficiency is a drawback of artificial intelligence. AI is the massive network which has a huge number of data that increases the volume of fetching and sharing the data enormously with high speed. It is accompanied within a network. As we all know, AI improvised almost every field, but sometimes it is inadequate. However, this application is used to amend resources to improvise efficiency but it failed. To resolve this problem, Blockchain technology is the best option to use by annihilate the third party therefore costs of transaction are well-nigh insignificant. To make this more proficient, AI technology is used after integrating with Blockchain. Efficiency is always checked on the basis of technical, allocate, productive, social and dynamic.

2.3.4. Data Sharing

In any network or technology, sharing of data is one of the dominant strides in devices. It is the competence in which we Dutch the data of the same resource among numerous applications. It aids us in discrete features such protection of data, storing data and looking out for security and privacy of data. The framework of network availed in sharing of data where all the technologies or network works axiomatically when it gets strengthened by AI technologies. Sometimes, the barriers of data come in between device operators and operands spawn the bottleneck in network of AI, all because of separation in their respective network.

2.3.5 Security and Privacy

Recently, amelioration in the field of AI regarding its technologies in smart agriculture, smart cities, smart homes and smart everything has been substantial drift from computing to AI, cloud computing and edge to procure more conducive and brilliant services to the users. Because of this massive shift in archetype, numerous challenges and issues have come up in sustaining the security and privacy of the information and data of particular devices. If we did not unified artificial intelligence with Blockchain technology, there would be lots of risk like anyone can hack the data with an ease. This unification has resolved the maximum number of problems [31]. It perpetuates data management and makes it robust. It enhances the privacy and trust of end users.

2.3.6. Shortage of Talent

It is one of the curbs of unification of Blockchain with AI. Linked devices are spawning much more susceptible to security of details, that's why applications of AI require lack of talent. The application is using trainers to accord training to the existing employee and is also corking the voids of

security. As AI technology is not noteworthy, so the concept of Blockchain has come into play. It basically aids us to ameliorate the qualities which accord the knowledge regarding diner in the field such as Ethereum, multichain, bitcoin, hyper ledger and open-chain for enhancing the skills. AI technology has driven this to bestow the data regarding virtual agents that aids us to interact with the non- humane things or machines and also bestow new ledger in communication.

2.3.7. Unidirectional

In unidirectional, data can only be transferred in only one specific direction i.e. unidirectional manner. Data can flow through upstream from the device that is the sensor. The applications are secured, but we face some kind of flaws that limit us in this era. To look out this problem, technology of Blockchain shore up and is used to ameliorate the transactions which set foot in networks and the operations get verified by all miners in the network of Blockchain. However, this technique is not working out wholly so some of the researchers came up with AI technology which provides us decentralized knowledge.

2.3.8. Multidirectional

In multidirectional, data can be transferred in multiple directions. For the multi directional communication, we used a centralized database in devices. In this, each and every device is linked up with a centralized database. As data is growing expeditiously which might not be tackled by a centralized database. So Blockchain technology was introduced which is used to stockpile the transactions or data in a disbursed or scattered way for fathoming the issue.

3. Application of Blockchain with AI

In this section, we give a complete review of the Blockchain and artificial intelligence applications. This decentralized Blockchain system can be used in many sectors and can transform them for better living.

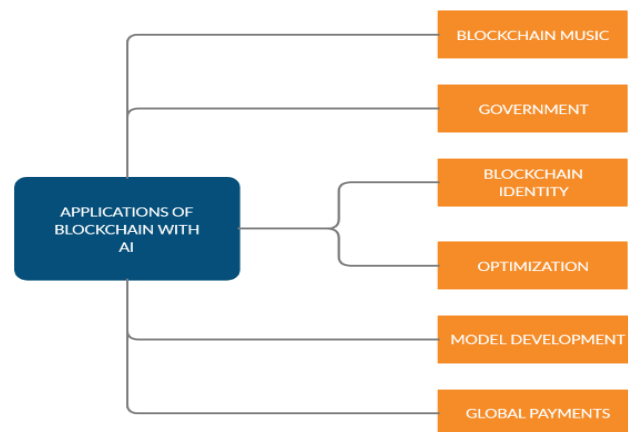


Figure 4- Application of Blockchain with AI

3.1. Global Payments

The process of financial transactions on a global scale through established banking channels is a complex and multistep process that includes several intermediaries. Each step requires time and money to process, which makes it frustrating. Blockchain can solve these problems by providing a

secure distributed ledger that stores every transaction that is taking place, it does not require any third party, no unnecessary fees or any delay. As soon as the transaction is recorded on the ledger, the payment is directly accessible. Blockchain-based payments are advantageous to businesses and consumers as these are time-efficient, cost-efficient, transparent and secure. Santander bank was the first bank who enabled customers to make global payments in 2004, merging the Blockchain with payment apps. AI can be used to help the financial industry to interact with money more smartly by making decisions that are smarter and safer [32].

3.2. Blockchain Music

The music industry experiences some key problems because of the centralized system such as ownership rights, lack of transparency over the content creator and many more. The digitized music industry may fail to notice the ownership rights as it mainly concentrates on monetizing productions. The Blockchain and smart contracts create a decentralized music platform that can have an accurate database of worthy creators or recipients, it enables the transparent tagging system which certifies the ownership of the song. As a result, the players or the creators of the track get digitally paid the right amount of fees as specified in the contracts. The publishing of original tracks created by the artists, distribution management, control of licensing options, all this can be done on the Blockchain-based platform. An average of \$23.40 paltry a musician gets for every music sold of \$1000. Because of Blockchain distributed ledger technology, smart contracts are gaining accountability and transparency. Blockchain streamlines workflows for stakeholders among the smart contracts. Whereas AI can also be very emerging for the industry but not yet has been applied to smart contracts, AI can be used to design contracts or negotiate terms on behalf of people.

3.3. Government

The voting system was questioned by Republicans and Democrats in the 2016 elections, even the parties called for a recount. According to computer scientists, electronic systems can be hacked to manipulate votes. But with the ledger system, votes become encrypted and can be prevented from getting manipulated, can be confirmed by the private individuals that their votes were counted. This system also saves money even for the government. The Blockchain ledger-based platform provides an open data that is freely available to the citizens over the internet and can make the world \$2.6 trillion richer. This technology can be used by many entries such as startups, farmers, parents, and many others according to their goods. Currently, only once a year the data is released but the Blockchain public ledger makes the data open to citizens anytime. Through Blockchain technology, the government can strengthen up the trust and accountability by providing cybersecurity, integrated hyper connected services [33].

3.4. Blockchain Identity

The Blockchain ensures your identity by encoding it and making sure about it from spammers and advertising plans. Regardless, online associations thoroughly get us. Some associations whom we purchase from sell our identity nuances to marketing specialists who send you their advancements. The Blockchain prevents this by making an ensured point of information where you scramble only the data that you need applicable individuals to know at specific occasions. When matched with a decentralized identity, clients can introduce the confirmed identifier as a QR code to demonstrate their personality and access certain administrations. For instance, in case you're heading off to a bar, the

barkeep just needs the data that discloses to him you're more than 21. Governments and digital identity associations influence Blockchain innovation to move away from soloed and make it decentralized systems. AI has a scope of uses in government as it tends to be utilized to promote public policy destinations, just as it helps people, in general, to communicate with the government.

3.5. Optimization

One of the main features of an artificial intelligence system is to find the best solution available for a given problem. Now AI system works on various environments. An AI system works on a mobile phone, a local area network and other environments also. So, the system of the AI is made in such a way that for different devices it shows different results by analysing the data. This is done in a centralized form till now but newer technologies are developing which will do the optimization in a decentralized manner.

3.6. Model Development

Continuous learning is one the major task for an AI system. A lot of testing and training is done before releasing the AI applications in the market. This is done in two ways, centralized and decentralized way. Centralized way is costly as a lot of data and instruction are required for the training purpose. In decentralized way the machine analyses by itself and takes decision. This can be used in various application to find and solve the bug by itself.

4. Research Challenges

In this section we will discuss about the challenges faced by the unification of the Blockchain with Artificial Intelligence.

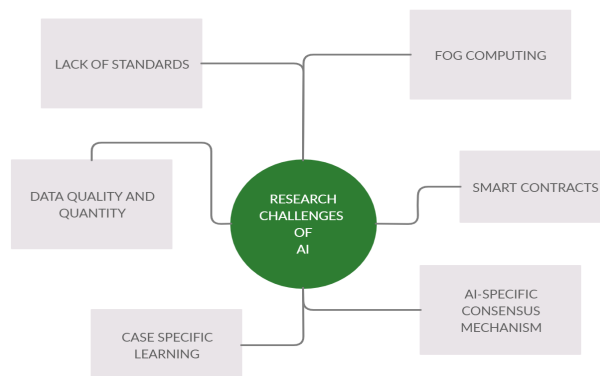


Figure 5- Challenges of Blockchain with AI

4.1. Fog Computing Paradigm

This property is newly expatiating which allows localized computing of the data that is created by the IoT devices or the customers. These fog nodes are usually used for the enlargement of the incited delay in the cloud environment [34]. With regards to Blockchain and AI, these nodes will have to be enabled with Blockchain interface as well as outfitted with ML and AI capabilities, also the fog nodes perform the control and access of the data.

4.2. Smart Contract

It is quite difficult to make sure that the implementation of a smart contract

is firm against attacks and bugs free. The information and the code on the network are needed to be safeguard as they are vulnerable to attacks. This issue of vulnerability occurs because of the poor programming studies in the language in which the smart contracts are written. It has now become a critical significance for vulnerabilities for testing smart contracts, also for the smart contract code's security state new tools have been formed [35]. Besides, the outcomes of smart contract execution cannot be probabilistic. For decentralized AI, this can profess a key challenge in which the decision- making algorithms based on ML and AI get executed, in which the outcome of smart contract execution is usually in deterministic.

4.3. AI Specific Consensus Mechanism

The consensus protocols that already exist considers the Blockchain network by facilitating the different proof of work or stake or X protocols. For future researchers, there are so many research opportunities are available, to investigate if the consensus protocol could be structured deliberating various verifications like the quality of optimization, efficient search strategies, efficient learning models.

4.4. Lack of Standards

Until now, the standards of Blockchain technology are still needed to be advanced. Many institutions like IEEE, ITU, NIST are working on this, and many, they put forth the standards for Blockchain integration, architecture, and interoperability. Although, worldwide, institutional and governmental guidelines should amend rules and regulations for the dispute handling, upliftment, and deployment of Blockchain, in the contrast of public Blockchain transactions using cryptocurrencies and AI applications. This involves research aimed at devising models [36].

4.5. Data Quality and Quantity

AI applications are very much reliable on the data which is being provided to them. So, the quality of the data plays a very important role in building the AI application accordingly. If the data is biased the application will also work in that way only. Secondly quantity of the data is also important. Huge amount of data is required by one single AI application to work perfectly. If data is not enough for the proper working of the application then AI will not be able to analysis all the problems. Providing the best quality and quantity of data is difficult for the companies.

4.6. Case Specific Learning

Artificial Intelligence lacks behind human intelligence in communicating things. The data which is stored and collected by AI while performing a task or solving a problem may be useful in some other technology. But extraction of that data from the AI machine and to use it in different technology is very difficult because AI is case specific language. Transfer of data will require a lot of time.

5. Conclusion

As we have studied and talked about the present situation, integration of blockchain and artificial intelligence is at an acme in the tech world. However, we are facing lots of drawbacks in upgrading of technology so we cannot rely on other one base of technology to get rid of the complications. In this paper we have confabulated about two rampant technologies that come together, work in sync and build the completely new era for the researchers. Blockchain is an independent dais which can

perform by itself but according to our needs, blockchain is not competent. That is the reason that it becomes decisive to unified artificial intelligence with blockchain. Firstly, we talked about blockchain and its application. Blockchain is the wide-ranging technology that aids in to transfer the information and transactions all over the place. Blockchain works on a decentralized system. Combining blockchain with any of the radiating technologies, accord the output that is variably way far more interesting than any of its independent tech. Blockchain and AI pageant successful amalgamations which helps us to mitigate various problems. As we have discussed before, blockchain itself is secured technology but when it drives artificial intelligence, it works way better. Artificial Intelligence (AI) is the technique in which we interwoven human intelligence with the machines. It has the competence to rationalize and step forward to accomplish targets. AI is continuously giving perks to the tech industries. When we unified AI with blockchain, it is called decentralization that we have explained in this paper.

In the last three sections we conferred its applications, how this integration helps us to resolve the limitations and how this gives us challenges. Blockchain with artificial intelligence is the amalgamation that is used in different platforms but with the enhancement and better working quality such as blockchain music, government, blockchain identity, optimization, model development, global payment and many more. However, it is not obligatory that it always give us perfectly whatever we want so at that point of time we face limitations and challenges. Moreover, limitations and challenges are conferred very well. Shortage of talent, security and privacy, explainable AI, AI effectiveness and efficiency are major limitations that we faced and integration of blockchain and AI is the best way to mitigate. In the last section, we talked about research challenges such as smart contracts, case specific learning, data quality and quantity, AI-specific consensus mechanism and lack of standard.

REFERENCES

1. W. Zheng, Z. Zheng, X. Chen, K. Dai, P. Li and R. Chen, "NutBaaS: A Blockchain-as-a-Service Platform", *IEEE Access*, vol. 7, pp. 134422-134433, 2019.
2. W. Lai, C. Hsueh and J. Wu, "A Fully Decentralized Time-Lock Encryption System on Blockchain", *2019 IEEE International Conference on Blockchain (Blockchain)*, 2019.
3. Varshney, T., Sharma, N., Kaushik, I., & Bhushan, B. (2019). Authentication & Encryption Based Security Services in Blockchain Technology. 2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS). doi: 10.1109/icccis48478.2019.8974500
4. V. Bracamonte and H. Okada, "The issue of user trust in decentralized applications running on blockchain platforms", *2017 IEEE International Symposium on Technology and Society (ISTAS)*, 2017.
5. Aditya Khamparia, Babita Pandey, Comprehensive analysis of Semantic web reasoners and tool: A survey, Education and Informatic technologies, Springer, pp 1–25 2017, DOI: 10.1007/s10639-017-9574-5.
6. A Maxmen, "AI researchers embrace Bitcoin technology to share medical data", *Nature*, vol. 555, no. 7696, pp. 293-294, 2018.

7. V. Petrovic, "Artificial Intelligence and Virtual Worlds – Toward Human-Level AI Agents", *IEEE Access*, vol. 6, pp. 39976-39988, 2018.
8. Jadon, S., Choudhary, A., Saini, H., Dua, U., Sharma, N., & Kaushik, I. (2020). Comfy Smart Home using IoT. SSRN Electronic Journal. doi: 10.2139/ssrn.3565908
9. Varshney, T., Sharma, N., Kaushik, I., & Bhushan, B. (2019). Architectural Model of Security Threats & their Countermeasures in IoT. 2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS). doi: 10.1109/icccis48478.2019.8974544
10. Aditya Khamparia, Babita Pandey.: Association of Learning styles with different E-learning Problems: A Systematic Review and Classification, In: Education and Information Technologies, 2019, (Springer), <https://doi.org/10.1007/s10639-019-10028-y>.
11. Soni, S., & Bhushan, B. (2019). A Comprehensive survey on Blockchain: Working, security analysis, privacy threats and potential applications. 2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICT). doi: 10.1109/iciict46008.2019.8993210
12. G. Gottlob and S. Szeider, "Fixed-Parameter Algorithms for Artificial Intelligence, Constraint Satisfaction and Database Problems", *the Computer Journal*, vol. 51, no. 3, pp. 303-325, 2007.
13. W. Chang, L. Chen and K. Su, "DeepCrash: A Deep Learning-Based Internet of Vehicles System for Head-On and Single-Vehicle Accident Detection with Emergency Notification", *IEEE Access*, vol. 7, pp. 148163-148175, 2019.
14. G. Zhang, T. Li, Y. Li, P. Hui and D. Jin, "Blockchain-Based Data Sharing System for AI-Powered Network Operations", *Journal of Communications and Information Networks*, vol. 3, no. 3, pp. 1-8, 2018.
15. Arora, D., Gautham, S., Gupta, H., & Bhushan, B. (2019). Blockchain-based Security Solutions to Preserve Data Privacy and Integrity. 2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS). doi: 10.1109/icccis48478.2019.8974503
16. B. Marr, "Artificial Intelligence And Blockchain: 3 Major Benefits Of Combining These Two Mega-Trends", *Forbes*, 2020.
17. "Ledger — hyperledger-fabricdocs master documentation", *Hyperledger-fabric.readthedocs.io*.
18. Sharma, T., Satija, S., & Bhushan, B. (2019). Unifying Blockchain and IoT: Security Requirements, Challenges, Applications and Future Trends. 2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS). doi: 10.1109/icccis48478.2019.8974552
19. G. Wood, "Ethereum: A secure decentralised generalised transaction ledger," Ethereum project yellow paper, vol. 151, pp. 1-32, 2014.
20. "Blockchain Basics: Introduction to Distributed Ledgers", *IBM Developer*, 2020.
21. Gupta, S., Sinha, S., & Bhushan, B. (2020). Emergence of Blockchain Technology: Fundamentals, Working and its Various Implementations. SSRN Electronic Journal. doi:10.2139/ssrn.3569577
22. L. Ismail, H. Materwala and S. Zeadally, "Lightweight Blockchain for Healthcare", *IEEE Access*, vol. 7, pp. 149935-149951, 2019.
23. Ali Syed, T., Alzahrani, A., Jan, S., Siddiqui, M., Nadeem, A. and Alghamdi, T., 2019. A Comparative Analysis of Blockchain Architecture and its Applications: Problems and Recommendations. *IEEE Access*, 7, pp.176838-176869.
24. Tiwari, R., Sharma, N., Kaushik, I., Tiwari, A., & Bhushan, B. (2019). Evolution of IoT & Data Analytics using Deep Learning. 2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS). doi: 10.1109/icccis48478.2019.8974481
25. Sai, A., Buckley, J. and Le Gear, A., 2019. Privacy and Security Analysis of Cryptocurrency Mobile Applications. *2019 Fifth Conference on Mobile and Secure Services (MobiSecServ)*.
26. Arora, A., Kaur, A., Bhushan, B., & Saini, H. (2019). Security Concerns and Future Trends of Internet of Things. 2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICT). doi: 10.1109/iciict46008.2019.8993222
27. Sodhro, A., Pirbhulal, S. and de Albuquerque, V., 2019. Artificial Intelligence-Driven Mechanism for Edge Computing-Based Industrial Applications. *IEEE Transactions on Industrial Informatics*, 15(7), pp.4235-4243.
28. Salah, K., Rehman, M., Nizamuddin, N. and Al-Fuqaha, A., 2019. Blockchain for AI: Review and Open Research Challenges. *IEEE Access*, 7, pp.10127-10149.
29. Hamburger, H., Lodgher, A., Maney, T., Jardine, C. and Siff, F., n.d. A decentralized AI system for transcript applications. [1990] *Proceedings. The Fifth Annual AI Systems in Government Conference*.
30. Xue, M. and Zhu, C., 2009. A Study and Application on Machine Learning of Artificial Intelligence. *2009 International Joint Conference on Artificial Intelligence*.
31. Chakarverti, M., Sharma, N., & Divivedi, R. R. (2019). Prediction Analysis Techniques of Data Mining: A Review. SSRN Electronic Journal. doi: 10.2139/ssrn.3350303
32. Goel, A. K., Rose, A., Gaur, J., & Bhushan, B. (2019). Attacks, Countermeasures and Security Paradigms in IoT. 2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICT). doi: 10.1109/iciict46008.2019.8993338
33. Lin, Y., Lin, Y. and Liu, C., 2019. Altalk: a tutorial to implement AI as IoT devices. *IET Networks*, 8(3), pp.195-202.
34. Singh, S., Rathore, S. and Park, J., 2019. BlockIoTelligence: A Blockchain-enabled Intelligent IoT Architecture with Artificial Intelligence. *Future Generation Computer Systems*.
35. Dinh, T. and Thai, M., 2018. AI and Blockchain: A Disruptive Integration. *Computer*, 51(9), pp.48-53.
36. Nawaz, A., Gia, T., Queralta, J. and Westerlund, T., 2019. Edge AI and Blockchain for Privacy-Critical and Data-Sensitive Applications. *2019 Twelfth International Conference on Mobile Computing and Ubiquitous Network (ICMU)*.
37. Malik, A., Gautam, S., Abidin, S., & Bhushan, B. (2019). Blockchain Technology-Future Of IoT: Including Structure, Limitations And Various Possible Attacks. 2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICT). doi: 10.1109/iciict46008.2019.8993144
38. Henry, R., Herzberg, A. and Kate, A., 2018. Blockchain Access Privacy: Challenges and Directions. *IEEE Security & Privacy*, 16(4), pp.38-45