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BLOCKCHAIN IN ARTIFICIAL INTELLIGENCE

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Abstract

Blockchain and artificial intelligence (AI) are important disruptive, emerging technologies. When both of them are combined, they can help you build an immutable, safe, and decentralized system. This will lead to major data and information security advances in different industries. We have witnessed that AI and blockchain are the two leading technologies worldwide, and they have attracted wide attention in both academia and industry. Their collaboration has the potential to push data exploitation to newer heights and has brought many new opportunities. For example, their joint application has helped the healthcare industry to navigate the COVID-19 crisis. This paper considers the combination of AI and blockchain and its applications.

Keywords: blockchain, distributed ledger technology, Bitcoin, artificial intelligence, machine learning.

INTRODUCTION

A blockchain is a distributed, decentralized, immutable ledger used to store encrypted data. On the other hand, Artificial intelligence (AI) is the engine or the "brain" that will enable analytics and decision making from the data collected. It is a technology that can perform complex tasks that require human intelligence, and it holds the potential of exceeding human capabilities. The amalgamation of AI and blockchain holds great potential to create new business models enabled through digitalization. The combination of AI and blockchain can take place in multiple dimensions. There are examples where AI and blockchain can be integrated for process improvement and value creation (e.g., asset management, customer service, dispute resolution, fraud prevention, production evaluation, supply chain monitoring) [1].

OVERVIEW OF BLOCKCHAIN

Blockchain (BC) technology is a permanent record of online transactions. It is a distributed tamper-proof database, shared, and maintained by multiple parties. It is a new enabling technology that is expected to revolutionize many industries, including business. It has the potential for addressing significant business issues. The BC technology allows participants to move data in real-time, without exposing the channels to theft, forgery, and malice.

The term "blockchain" refers to the way BC stores transaction data – in "blocks" that are linked together to form a "chain." The chain grows as the number of transactions increases. Since every entry is stored as a block on a chain, the care you receive is added to your personal ledger. The first Blockchain was conceived in 2008 by an anonymous person or group known as Satoshi Nakamoto, who published a white paper introducing the concept of a peer-to-peer electronic cash system he called Bitcoin [2]. Typical blockchain architecture is shown in Figure 1 [3]

At its core, blockchain is a distributed system recording and storing transaction records. In a blockchain system, there is no central authority. Instead, transaction records are stored and distributed across all network participants. Rather than having a centrally located database that manages records, the database is distributed to the networks and transactions are kept secure via cryptography. BC eliminates the need for a middleman that traditionally may facilitate such transactions. Figure 2 shows how blockchain works [4].

Fundamentally, blockchains are distributed digital database that record and maintain a list of transactions taking place in real time. They may also be regarded as decentralized ledgers that sequentially record transactions or interactions among users within a distributed network. They have the following properties [5]:

- Firstly, they are autonomous. They run on their own, without any person or company in charge.
- Secondly, they are permanent. They are like global computers with 100 percent uptime. Because the contents of the database are copied across thousands of computers, if 99 per cent of the computers running it were taken offline, the records would remain accessible and the network could rebuild itself.
- Thirdly, they are secure and tamper-proof. Each record in blockchain is time stamped and stored cryptographically. The encryption used on blockchains like Bitcoin and Ethereum is industry standard, open source, and has never been broken.
- Fourthly, they are open, allowing anyone to develop products and services on them.
- Fifthly, as blockchain is a shared system, costs are also shared between all of its users.

The blockchain was designed so transactions are immutable, i.e. they cannot be deleted. Thus, blockchains are secure and meddle-free by design. Data can be distributed, but not copied. When it comes to digital assets and transactions, you can put almost anything on a blockchain. Different scenarios call for different blockchains. Blockchain is used in different areas such as depicted in Figure 3 [6].

The BC technology currently has the following features [7,8]:

1. Peer-to-Peer (P2P) Network: The first requirement of BC is a network, an infrastructure shared by multiple parties. This can be a LAN at a small scale or the Internet at a large scale. All nodes participating in a BC are connected in a decentralized P2P network. Transactions are broadcast to the P2P network. Due to some limitations of P2P networks, some vendors have provided cloud-based BCs.
2. Cascaded Encryption: A BC uses encryption to protect transaction data. Blocks are encrypted in a cascaded manner, i.e. the encryption result of the previous block is used in encrypting the current block. The BC is secured by public key cryptography, with each peer generating its own public-private key pairs.
3. Distributed Database: A BC is digitally distributed across a number of computers. Each party on a BC has access to the entire database and no single party controls the data or the information. Since BC is decentralized, there is no need for central authorizes such as banks.
4. Transparency with Pseudonymity: Each node or participant on a blockchain has a unique 30-plus-character alphanumeric address that identifies it. Users can choose to remain anonymous or provide proof of their identity to others.
5. Irreversibility of Records: Once a transaction is entered in the database and the accounts are updated, the records cannot be altered. Records on the database is permanent, chronologically ordered, and available to all others on the network.

There are two types of Blockchains: public and private. Public Blockchains are cryptocurrencies such as Bitcoin, enabling peer-to-peer transactions. Private Blockchains use Blockchain-based platforms such

as Ethereum or Blockchain-as-a-service (BaaS) platforms running on private cloud infrastructure. A private BC is an intranet, while a public BC is the Internet. Companies will be disrupted the most by public Blockchains.

ARTIFICIAL INTELLIGENCE BASICS

Artificial intelligence (AI) is one of the most important global issues of the 21st century.

The term "artificial intelligence" (AI) was coined in 1956 by John McCarthy during a conference held on this subject. AI is the branch of computer science that deals with designing intelligent computer systems that mimic human intelligence. The ability of machines to process natural language, to learn, to plan makes it possible for new tasks to be performed by intelligent systems. The main purpose of AI is to mimic the cognitive function of human beings and perform activities that would typically be performed by a human being. AI is stand-alone independent electronic entity that functions much like human healthcare expert. Today, AI is integrated into our daily lives in several forms, such as personal assistants, automated mass transportation, aviation, computer gaming, facial recognition at passport control, voice recognition on virtual assistants, driverless cars, companion robots, etc. AI technologies are performing better and better at analyzing data [9,10].

An important feature of AI technology is that is can be added to existing technologies. AI has benefited many areas such chemistry and medicine, where routine diagnoses can initiated by AI-aided computers. It embraces a wide range of disciplines such as computer science, engineering, chemistry, biology, physics, astronomy, neuroscience, and social sciences.

AI is not a single technology but a range of computational models and algorithms. The major disciplines in AI include expert systems, fuzzy logic, and artificial neural networks (ANNs), machine learning, deep learning, natural language processing, computer vision, and robotics. The various computer-based tools or technologies that have been used to achieve AI's goals are the following [11,12]:

- Expert Systems: An expert system (ES) (or knowledge-based system) enables computers to make decisions by interpreting data and selecting between alternatives just as a human expert would do. It uses a technique known as rule-based inference in which rules are used to process data.
- Neural Networks: These computer programs identify objects or recognize patterns after having been trained. Artificial neural networks (ANNs) are parallel distributed systems consisting of processing units (neurons) that calculate some mathematical functions. The ANN model represents nonlinear relationships which are directly learned from the data being modeled. Neural networks are being explored for healthcare applications in imaging and diagnoses, risk analysis, lifestyle management and monitoring, health information management, and virtual health assistance.
- Natural Language Processors: Computer programs that translate or interpret language as it is spoken by normal people. NLP techniques extract information from unstructured data such as clinical notes to supplement and enrich structured medical data. NLP includes applications such as speech recognition, text analysis, translation and other goals related to language. There are two basic approaches to NLP: statistical and semantic. Healthcare is the biggest user of the NLP tools [13].
- Robots: Computer-based programmable machines that have physical manipulators and sensors. The introduction of intelligent robots in the healthcare domain enhances patients' satisfaction, accuracy of diagnosis, and operational efficiency of hospitals. Medical robots can help with surgical operations, rehabilitation, social interaction, assisted living, etc. Robotic-guidance is becoming common in spine surgery [14].
- Fuzzy Logic: Reasoning based on imprecise or incomplete information in terms of a range of values rather than point estimates. Fuzzy logic deals with uncertainty in knowledge that simulates human reasoning in incomplete or fuzzy data. The fuzzy model is robust to parameter changes and tolerant to impression.

- Machine Learning: Algorithms to make predictions and interpret data and "learn", without static program instructions. ML is a statistical technique for fitting models to data and training models with data. ML extracts features from input data by constructing analytical data algorithms and examines the features to create predictive models. The most common ML algorithms are supervised learning, unsupervised learning, reinforcement learning, and deep learning. The most common application of ML is precision medicine. ML algorithms are a good fit for anti-malware solutions because machine learning is well suited to solve 'fuzzy' problems.
- Deep Learning: A subset of machine learning built on a deep hierarchy of layers, with each layer solving different pieces of a complex problem. It aims at increasing the capacity of supervised and unsupervised learning algorithms for solving complex real-world problems by adding multiple processing layers.
- Data Mining: This deals with the discovery of hidden patterns and new knowledge from large databases. Data mining exhibits a variety of algorithmic tools such as statistics, regression models, neural networks, fuzzy sets, and evolutionary models.

Some of these tools are illustrated in Figure 4 [4]. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. AI technologies are drastically influencing the retail industry and customer experience. Applications of AI technologies for cybersecurity tasks are attracting greater attention from the private and the public sectors due to the rate at which threats are developing.

BLOCKCHAIN AI

Blockchain is an expensive medium of storing vast data in a traditional method. It is popular for its decentralization and transparency. Therefore, it gives the perfect instrument for peeling the layers of complex AI algorithms to understand their decision-making processes. Blockchain is a shared and permanent ledger that is being used for the encryption of data, while AI enables an individual to analyze and make decisions from the collected data. Combining the two technologies will have multiple complexions but will provide many benefits. AI approaches the use of blockchain for providing decentralized learning by facilitating the secure sharing of knowledge and trust in the decision-making process.

Blockchain technology is interlinked with AI in many ways. Below are the major integrations [15]:

- Authenticity: Blockchain technology can help validate the authenticity of images, video files, text documents, or other types of media by being able to cryptographically verify where a piece of content originates from and whether it has been tampered with or altered in any way. The integration of AI and blockchain can help to ensure the authenticity of information about credit evaluation and the verification of ensuing financial transactions by traders.
- Augmentation: AI understands and processes the data at a great speed by bringing higher intelligence to the blockchain-based business networks. By providing access to large volumes of data from within and outside of the organization, blockchain helps AI scale to provide more actionable insights, manage data usage and model sharing, and create a trustworthy and transparent data economy.
- Automation: Blockchain technology ensures that the automation process is quicker than centralized databases. It will also ensure that only admins will be able to modify the data that is sent to the machine learning model. Automation, AI, and blockchain will bring newer values to business processes that span different parties like adding, removing friction, and increasing speed and efficiency. The integration of AI and blockchain facilitates the automation business.

APPLICATIONS OF BLOCKCHAIN AND AI

AI and blockchain are the key technologies propelling the wave of digital transformation. By combining the powerful analytical capabilities of AI with the secure, decentralized nature of blockchains, the technologies could be applied to wide range areas such as education, healthcare, energy, social impact,

agriculture, urban planning, data-driven decision-making, autonomous vehicles, finance, smart cities, and 6G networks. We will consider some of these applications [16,17]:

- **Smart Computing Power:** Operating a blockchain requires large processing power. AI affords us the opportunity to tackle tasks in a more intelligent and efficient way.
- **Creating Diverse Data Sets:** Unlike artificial intelligence based-projects, blockchain technology creates decentralized, transparent networks that can be accessed by anyone, around the world. While blockchain technology is the ledger that powers cryptocurrencies, blockchain networks are now being applied to a number of industries to create decentralization. Diverse algorithms can be built on diverse data sets.
- **Data Protection:** The progress of AI is completely dependent on the input of data. Basically, data feeds AI, and through it, AI will be able to continuously improve itself. On the other hand, blockchain is essentially a technology that allows for the encrypted storage of data on a distributed ledger. When combining blockchains with AI, we have a backup system for the sensitive and highly valuable personal data of individuals.
- **Data Monetization:** Another disruptive innovation that could be possible by combining the two technologies is the monetization of data. Monetizing collected data is a huge revenue source for large companies, such as Facebook and Google.
- **Trusting AI Decision Making:** As AI algorithms become smarter through learning, it will become increasingly difficult for data scientists to understand how these programs came to specific conclusions and decisions. Through the use of blockchain technology, there are immutable records of all the data, variables, and processes used by AIs for their decision-making processes.

Other applications include the following [17]:

- **Healthcare:** The healthcare industry is another sector where the convergence of AI and blockchain has enormous potential. Blockchain protects privacy and increases security of health data and enables the secure storage of patient data. When access is granted, health professionals gain insights from this data through the use of AI. Integration of AI and blockchain create predictive system contributing to clinical workflow. Combining advanced data analysis with a decentralized framework for clinical trials enables data integrity, transparency, patient tracking, consent management and automation of trial participation and data collection.
- **Financial Services:** Blockchain and AI are set to transform financial markets. The convergence of the two technologies is also re-inventing the financial services industry by increasing the speed of transactions and enabling trust among transacting parties. The amalgamation of the two technologies has also introduced decentralized autonomous business models that brings greater flexibility, agility, and cost-effectiveness to business. Blockchain and AI are transforming the financial services industry by enabling trust, removing friction from multiparty transactions, and accelerating the speed of transactions.
- **Supply Chain:** AI can help enhance the efficiency and transparency of supply chains in the transportation sector and other industries. By digitizing a largely paper-based process, making the data shareable and trustworthy, and adding intelligence and automation to execute transactions, AI and blockchain are transforming supply chains across industries and creating new opportunities.
- **Security:** Decentralized, blockchain-based systems have been designed from the ground up to combat manipulation by various adversaries, and these security measures could extend to the use of adversarial AI agents. With the implementation of AI, blockchain technology becomes safer by making secure future application deployments. The utility of AI models and the security of blockchains can help reduce attack vectors and bolster the security of AI applications.
- **Education:** The future of education relies on advances in and use of smart technologies, particularly those involving blockchain and artificial intelligence.

- **Smart City:** A smart city is a technologically advanced urban area where intelligent subsystems connect people and organizations. It uses large data sets to offer stakeholders real-time access to high-quality public services and thus improve the quality of life in the city. AI and Blockchain have great potential to support the development of smart city. AI and Blockchain can provide significant benefits to many areas of the city's functioning: it is a huge database for collecting and analyzing data. Blockchain consensus methods allow greater transparency and less susceptibility to manipulation. AI and blockchain support smart city as depicted in Figure 5 [18].

Some of these applications of blockchain and AI combined are illustrated in Figure 6 [19].

BENEFITS

Across industries, combining AI with blockchain delivers new opportunities and brings new value to business. The integration of blockchain and AI could unlock entirely new business models, create operational efficiencies for organizations, help automate repetitive tasks for individuals, enable more secure and efficient data exchange, enhance decision-making processes through AI-driven smart contracts, and improve overall trust and transparency in key infrastructure and economic processes. AI and blockchain are proving to be quite a powerful combination, improving virtually every industry in which they are implemented. The confluence of AI in blockchain creates perhaps what is the world's most reliable technology-enabled decision-making system that is virtually tamper-proof and provides solid insights and decisions. Other benefits of the confluence of AI in blockchain include the following [20,21]:

- **Security:** With the implementation of AI, blockchain technology becomes safer by making secure future application deployments.
- **Efficiency:** AI can introduce even new decentralized learning systems such as federated learning or new data-sharing techniques that make the system much more efficient.
- **Trust:** When blockchain is applied in conjunction with AI, users have clear records to follow the system's thinking process. This, in turn, helps the bots trust each other, increasing machine-to-machine interaction and allowing them to share data and coordinate decisions at large.
- **Better Management:** The benefit of better management is an obvious reason for which it is important to consider AI and blockchain combinations. When it comes to cracking codes, human experts get better over time with practice. So, AI additionally helps in managing blockchain systems better.
- **Privacy:** Privacy protection techniques arising from the integration of AI and blockchain are of notable significance. Making private data secure invariably leads to it being sold, resulting in data markets/model markets. Blockchain facilitates AI applications in secure data sharing, preserving data privacy, and supporting trusted AI decision.
- **Efficient Storage:** Blockchains are ideal for storing the highly sensitive, personal data which, when smartly processed with AI, can add value and convenience.
- **Automation:** AI can help enhance the performance of blockchain networks by automating processes and improving accuracy. By automating processes and analyzing data on the blockchain, financial institutions can improve their risk management and compliance processes.
- **Financial Services:** As mentioned earlier, one of the most significant use cases of AI and blockchain is in the financial industry. Blockchain and AI are transforming the financial services industry before our eyes. Financial institutions deal with vast amounts of data. AI and blockchain together can help manage this data more efficiently. The combination is poised to transform the accounting profession.
- **Trust:** Accountability is one of the challenges AI is facing, affecting the trust people have in its outputs. To trust AI, how its algorithms work must be explainable. This understanding would lead to more confidence in the accuracy of AI outputs.

Some of these benefits are illustrated in Figure 7 [22].

CHALLENGES

While blockchain struggles with scalability and efficiency, AI struggles with transparency and privacy, which makes the two technologies the perfect match because each can address the other's weaknesses. Blockchain provides the trust, privacy, and accountability to AI, while AI provides the scalability, efficiency, and security. Blockchain's immutable digital records may be a way to offer insights into AI's framework and model to address the challenge of transparency and data integrity. While blockchain and AI definitely make a good pair, there are many obstacles in their way.

CONCLUSION

Blockchain is a distributed immutable ledger system that can be used for implementing cryptocurrency with security, while AI is used to make an intelligent system. The combination of the two technologies is still a largely undiscovered area. The combination can improve current business practices and introduce new business models that can act as independent economic agents making decisions autonomously. The blend of AI and blockchain could introduce radical innovations in the future. The challenges for combining both also play a major role in defining their future together. AI and blockchain are promising technologies for all nations. More information about blockchain in AI can be found in the books in [23-32].

REFERENCES

1. "Artificial intelligence and blockchain integration in business: trends from a bibliometric-content analysis," April 2022, https://link.springer.com/article/10.1007/s10796-022-10279-0
2. M. N. O. Sadiku, Y. Wang, S. Cui, and S. M. Musa, "A primer on blockchain," *International Journal of Advances in Scientific Research and Engineering,* vol. 4, no. 2, February 2018, pp. 40-44.
3. M. J. Tuyisenge, "Blockchain technology security concerns: Literature review," https://www.diva-portal.org/smash/get/diva2:1571072/FULLTEXT01.pdf
4. "The future of AI and blockchain technology & how it complements each other? https://www.turing.com/kb/how-blockchain-and-ai-complement-each-other
5. S. Depolo, **"**Why you should care about blockchains: The non-financial uses of blockchain technology," March 2016, https://www.nesta.org.uk/blog/why-you-should-care-about-blockchains-non-financial-uses-blockchain-technology
6. O. Bheda, "What is blockchain?" https://builtin.com/blockchain
7. M. Iansiti and K. R. Lakhani, "The truth about blockchain," *Harvard Business Review*, Jan./Feb. 2017. https://hbr.org/2017/01/the-truth-about-blockchain
8. W. T. Tsai et al., "A system view of financial blockchains," *Proceedings of IEEE Symposium on Service-Oriented System Engineering,* 2016, pp. 450-457.
9. M. N. O. Sadiku, T. J. Ashaolu, and S. M. Musa, " Artificial Intelligence in medicine: A primer," *International Journal of Trend in Research and Development,* vol. 6, no. 1, Jan.-Feb. 2019, pp. 270-272.
10. Y. Mintz and R. Brodie, "Introduction to artificial intelligence in medicine," *Minimally Invasive Therapy & Allied Technologies*, vol. 28, no. 2, 2019, pp. 73-81.
11. R. O. Mason, "Ethical issues in artificial intelligence," *Encyclopedia of Information Systems*, vol 2, 2003, pp. 239-258.
12. A. N. Rames et al., "Artificial intelligence in medicine," *Annals of the Royal College of Surgeons of*

England, vol. 86, 2004, pp. 334–338.

13. M. N. O. Sadiku, Y. Zhou, and S. M. Musa, "Natural language processing in healthcare," *International Journal of Advanced Research in Computer Science and Software Engineering*, vol. 8, no. 5, May 2018, pp. 39-42.
14. "No longer science fiction, AI and robotics are transforming healthcare," https://www.pwc.com/gx/en/industries/healthcare/publications/ai-robotics-new-health/transforming-healthcare.html
15. "The future of AI and blockchain technology & how it complements each other?" https://www.turing.com/kb/how-blockchain-and-ai-complement-each-other
16. A. Banafa, "Blockchain and AI: A perfect match?"

    https://www.bbvaopenmind.com/en/technology/artificial-intelligence/blockchain-and-ai-a-perfect-match/
17. "Blockchain and artificial intelligence (AI)," https://www.ibm.com/topics/blockchain-ai
18. S. Kauf, "Artificial intelligence and blockchain for smart city," https://bibliotekanauki.pl/articles/2204746
19. "Use cases of AI in blockchain," May 2023, https://blog.chain.link/blockchain-ai-use-cases/
20. "Integration of blockchain and AI,"

    https://www.geeksforgeeks.org/integration-of-blockchain-and-ai/
21. J. Murphy, "Use cases show the combined potential of AI and blockchain,"

    https://www.techtarget.com/searchenterpriseai/tip/Use-cases-show-the-combined-potential-of-AI-andblockchain#:~:text=AI%20can%20help%20enhance%20the%20efficiency%20and%20transparency%20of%20supply,companies%20to%20optimize%20their%20operations.
22. "Does artificial intelligence impact blockchain technology?"

    https://www.turing.com/kb/does-artificial-intelligence-impact-blockchain-technology
23. S. S. Smith, Blockchain, *Artificial Intelligence and Financial Services: Implications and Applications for Finance and Accounting Professionals.* Springer, 2020.
24. T. James, *Blockchain and Artificial Intelligence: The World Rewired*. De Gruyter, 2021.
25. P. M. S. Choi and S.H. Huang, *Fintech with Artificial Intelligence, Big Data, and Blockchain*. Springer, 2021.
26. A. Kumar et al. (eds.), *Blockchain, Artificial Intelligence, and the Internet of Things Possibilities and Opportunities.* Springer 2021.
27. G Suseendran, R Anandan, Sam Goundar (eds.), *Convergence of Artificial Intelligence and Blockchain Technologies, the: Challenges and Opportunities.* World Scientific Publishing Company, 2022.
28. P. M. Tehrani (ed.), *Regulatory Aspects of Artificial Intelligence on Blockchain.* IGI Global, 2021
29. P. Fraga-Lamas and T. M. Fernández-Caramés (eds.), *Advances in the Convergence of Blockchain and Artificial Intelligence.* IntechOpen, 2022.
30. B. K. Rai, G. Kumar, and V. Balyan (eds.*), AI and Blockchain in Healthcare*. Springer 2023.
31. P. Karthikeyan, H. M. Pande, and V. Sarveshwaran (eds.), *Artificial Intelligence and Blockchain in*

Digital Forensics. River Publishers, 2023.

32. G. P. Kumble, *Practical Artificial Intelligence and Blockchain: A guide to converging blockchain and AI to build smart applications for new economies.* Packt Publishing, 2020.

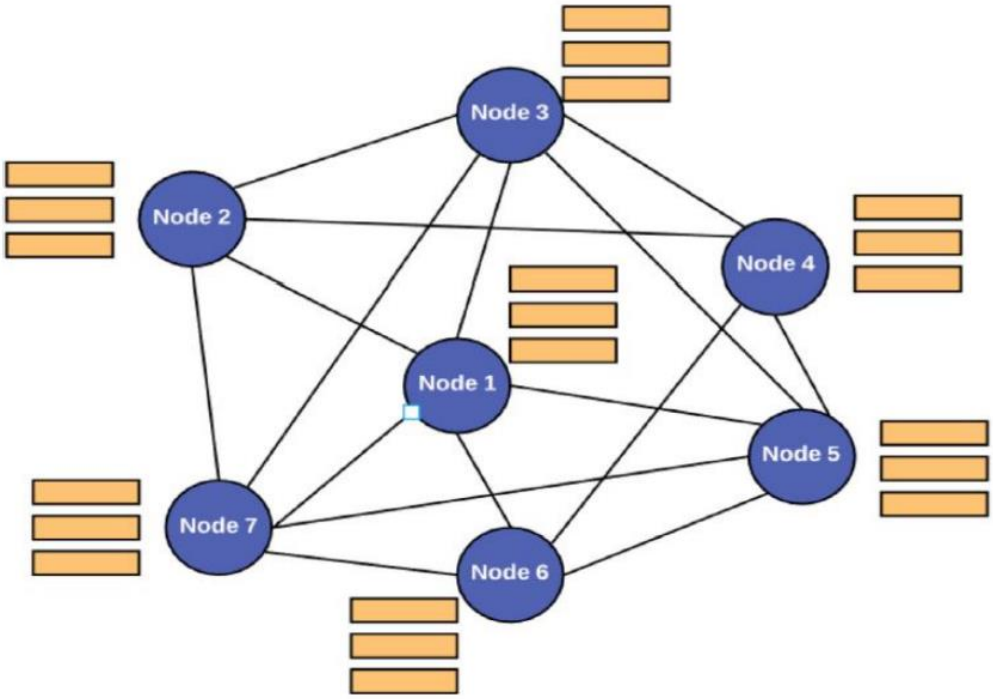

Figure 1 The blockchain architecture [3].

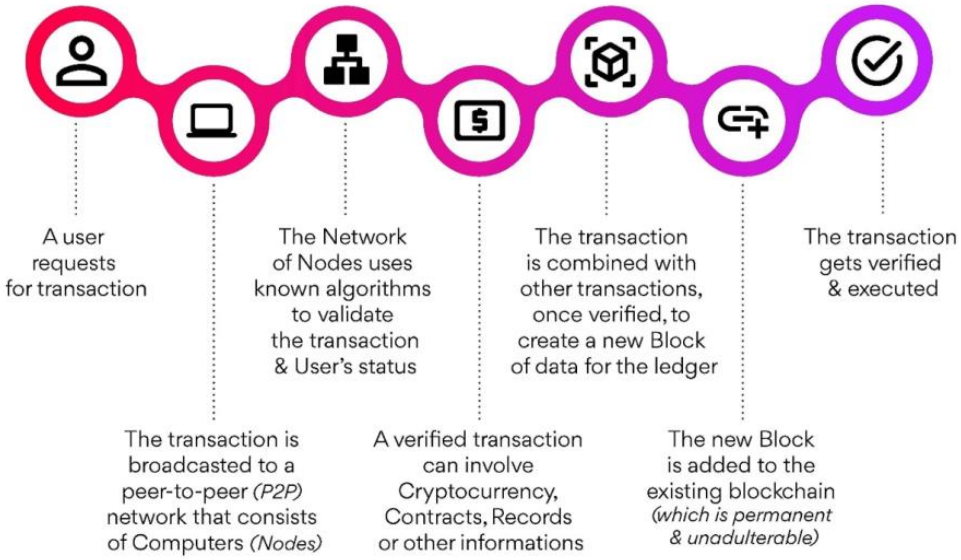

Figure 2 How the blockchain technology works [4].

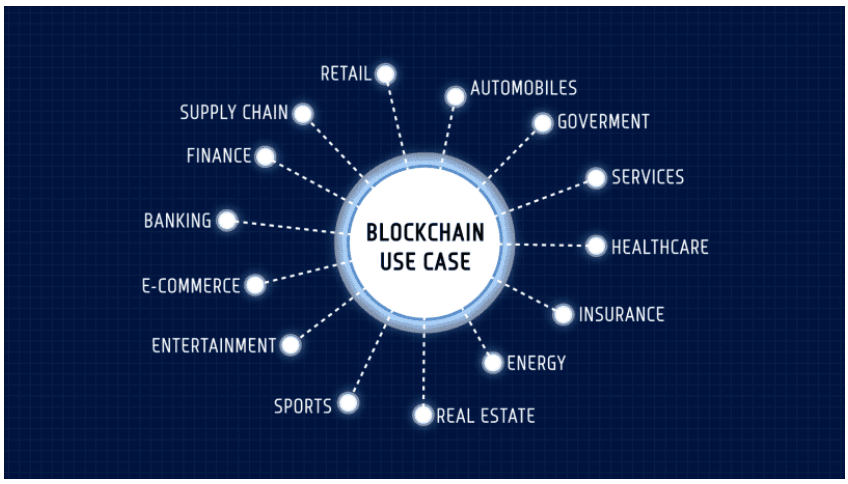

Figure 3 Different uses of blockchain [6].

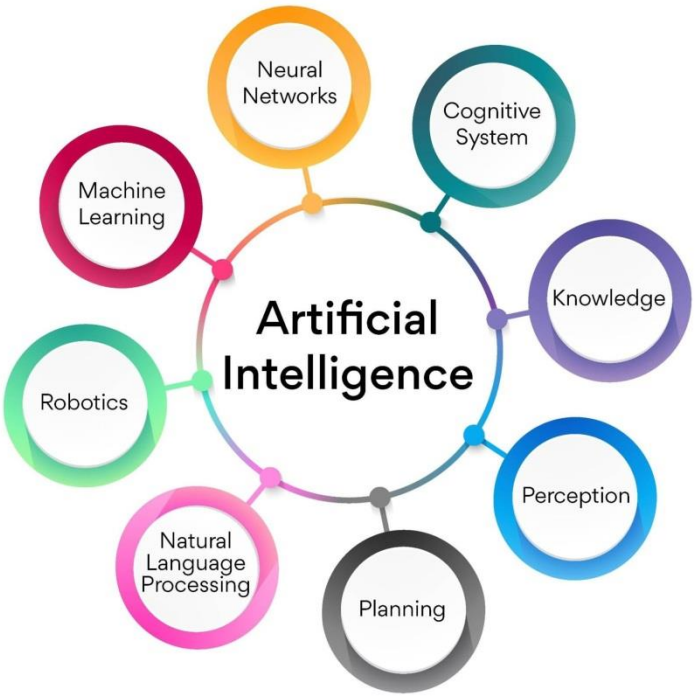

Figure 4 AI tools or branches [4].

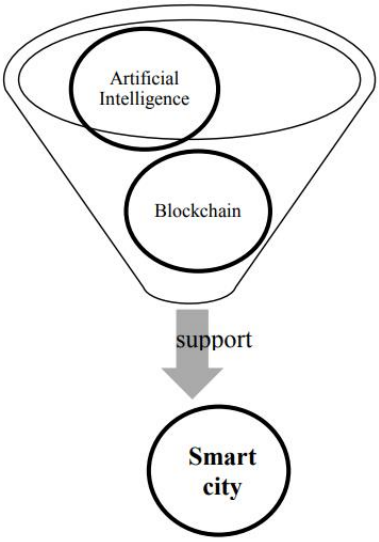

Figure 5 AI and blockchain support smart city [18].

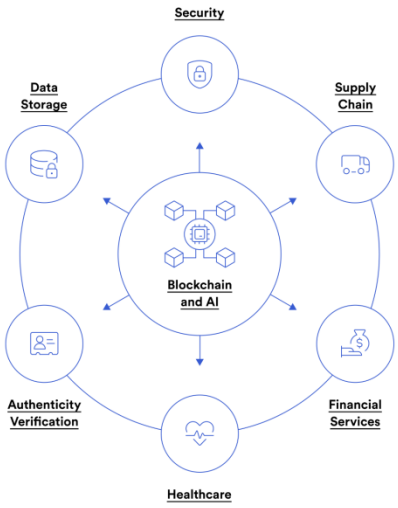

Figure 6 Applications of blockchain and AI combined [19].

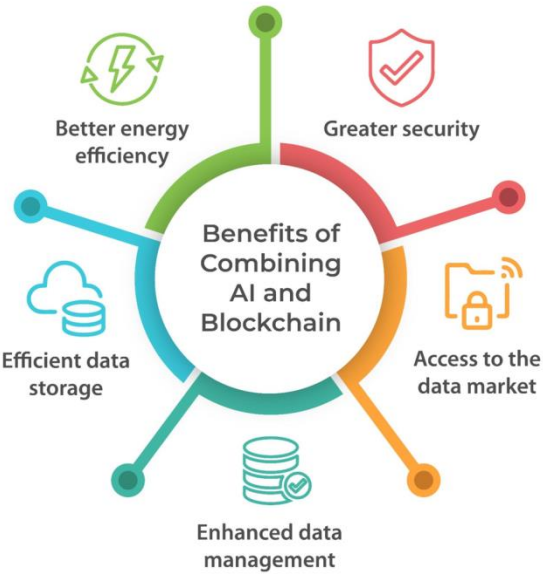

Figure 7 Some of these benefits of combining AI and blockchain [22].