International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Series F

Supplement 4

(04/2021)

SERIES F: NON-TELEPHONE TELECOMMUNICATION SERVICES

Overview of convergence of artificial intelligence and blockchain

ITU-T F-series Recommendations – Supplement 4

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Supplement 4 to ITU-T F-series Recommendations

Overview of convergence of artificial intelligence and blockchain

Summary

Artificial intelligence (AI) is one of core essential driving forces of a new round of industrial reform, which can affect promoting the upgrading of the traditional industries. Blockchain presents opportunities for disruptive innovations, which enables global businesses to transact business with less friction and more trust. AI and blockchain promote and influence each other, and their convergence could provide major driving forces for industries and great creativity across a wide range of business applications in many fields.

There are many benefits and challenges to combining AI and blockchain together. This Supplement focuses on the research on the convergence of AI and blockchain, specifically analyses the mutual promotion between AI and blockchain, and provides a technical reference for the application of AI and blockchain. In addition, Supplement 4 to ITU-T F-series Recommendations also provides application analysis of the convergence of AI and blockchain.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T F Suppl. 4	2021-04-30	16	11.1002/1000/14651

Keywords

Artificial intelligence, blockchain, convergence.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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1 Scope

This Supplement provides an overview of the convergence of artificial intelligence and blockchain, and provides a technical reference for the converged application of artificial intelligence and blockchain.

The scope of this Supplement includes:

– Advantages, challenges, characteristics of artificial intelligence and blockchain;

– Mutual promotions of artificial intelligence and blockchain;

– Converged applications of artificial intelligence and blockchain.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 artificial intelligence (AI) [b-ETSI GR ENI 004]: Computerized system that uses cognition to understand information and solve problems.

NOTE 1 – [b-ISO/IEC 2382-28] defines AI as "an interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning".

NOTE 2 – In computer science AI research is defined as the study of "intelligent agents": any device that perceives its environment and takes actions to achieve its goals.

NOTE 3 – This includes pattern recognition and the application of machine learning and related techniques.

NOTE 4 – Artificial intelligence is the whole idea and concepts of machines being able to carry out tasks in a way that mimics the human intelligence and would be considered "smart".

3.1.3 blockchain [b-ITU-T FG-DPM TR D3.5]: A peer to peer distributed ledger based on a group of technologies for a new generation of transactional applications which may maintain a continuously growing list of cryptographically secured data records hardened against tampering and revision.

NOTE 1 – Blockchains can help establish trust, accountability and transparency while streamlining business processes.

NOTE 2 – Blockchains can be classified as three types (i.e., public, consortium and private) based on the relationship of the participants and the way to provide services.

NOTE 3 – Definition compatible with [b-ISO 22739].

3.1.4 blockchain data [b-ITU-T FG-DPM TR D3.5]: The data in a blockchain, such as distributed append-only ledgers, state information, permission policies etc.

NOTE – Blockchain data may be distributed and be stored in blockchain peers. A blockchain peer may store whole or part of the data in a blockchain.

3.1.5 blockchain transaction [b-ITU-T FG-DPM TR D3.5]: An operation (e.g., deploying, invoking and querying results of blockchain contracts) in a blockchain in which an authorized end user performs operations (e.g., reading/writing blockchain data, invoking a blockchain contract).

NOTE – Definition compatible with [b-ISO 22739].

3.1.6 capability [b-ITU-R M.1224-1]: The ability of an item to meet a service demand of given quantitative characteristics under given internal conditions.

3.1.7 machine learning [b-ITU-T Y.3172]: Processes that enable computational systems to understand data and gain knowledge from it without necessarily being explicitly programmed.

NOTE – Definition adapted from [b-ETSI GR ENI 004].

3.1.8 service [b-ITU-T Y.2091]: A set of functions and facilities offered to a user by a provider.

3.1.9 smart contract [b-ITU-T FG-DPM TR D3.5]: Embedded logic that encodes the rules for specific types of blockchain transactions. A smart contract can be stored in the blockchain, and can be invoked by specific blockchain applications.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AI	Artificial Intelligence
AIaaS	AI as a Service
AIoT	Artificial Intelligence Internet of Things
BaaS	Blockchain as a Service
CNN	Convolutional Neural Network
CPU	Central Processing Unit
DPM	Data Processing and Management
GPU	Graphics Processing Unit
IoT	Internet of Things
PoW	Proof of Work
R&D	Research and Development
RNN	Recurrent Neural Network

5 Conventions

None.

6 Convergence of artificial intelligence and blockchain

6.1 Overview of artificial intelligence

From 2006, with the explosive growth of information and the continuous enhancement of computing capabilities, artificial intelligence (AI) has developed rapidly. AI model accuracies are refreshed again and again in the fields of image processing, natural language processing, video analysis and so on. Currently, AI exists in all aspects of our daily life.

The development of AI cannot be separated from the support of three major elements:

– Data,

– Algorithms,

– Computing power.

In terms of AI, data is the foundation, algorithms are the core, and computing power is the driving force. Specifically, collecting data is usually the first step to train AI models, and data is important to ensure the accuracy of AI training results. Appropriate algorithms help to build models based on the actual data. Currently, AI algorithms are commonly used in neural networks, support vector machines, k-nearest neighbours, etc. Computing power is the infrastructure of data and algorithms, which improves the efficiency of data processing, model training, and model testing in AI.

Appendix I provides more detailed information about the relationship of data, algorithms and computing power for AI.

6.2 Overview of blockchain

Blockchain is a peer-to-peer distributed ledger based on a group of decentralized technologies. Blockchain is composed of "block" and "chain". "Block" records the status change of each transaction and stores valid data and messages. "Chain" is formed by connecting each block and their previous block by time order.

NOTE 1 – Blockchain is also to be considered as a decentralized system which supports distributed ledgers. If not specified in this Supplement, the keyword "blockchain" not only refers to a peer-to-peer distributed ledger, but also refers to a system which supports distributed ledgers.

Blockchain has characteristics of decentralization, immutability, openness, and consensus mechanisms:

– Decentralization means processing data in a decentralized way. Blockchain offers a new way to process data without a centralized information technology (IT) infrastructure. Data may be stored by some or all the participants in blockchain.

– Immutability means the information cannot be changed in blockchain. Blockchain guarantees that data will not be easily modified after being uploaded. The data in blockchain can only be extended and previous records cannot be changed. Immutability can ensure the authenticity and reliability of the data in blockchain.

– Openness means transaction processes in blockchain are open and transparent to authorized participants. Blockchain provides sets of privacy protection methods for participants in blockchains.

– Consensus mechanism means that the participants in blockchain negotiate a mechanism through a consensus, so that each participant in the blockchain can exchange data without centralized entities. Consensus mechanisms make participants fully trust transactions and relevant data in blockchains.

NOTE 2 – In blockchains, every participant can see the transaction data stored in the blockchain, but this does not mean that every participant can see the actual content of the transaction. There will be a private key to protect actual content.

6.3 Mutual benefits of the convergence of artificial intelligence and blockchain

In addition to the advantages of AI and blockchain described above, both of them also have their disadvantages. Blockchain has many disadvantages such as high energy consumption, low efficiency, and low scalability. Meanwhile, AI has many disadvantages such as credibility, data privacy and interpretability. Based on the existing disadvantages of AI and blockchain, there are many benefits from the convergence of them:

– AI provides blockchain with automated data processing and intelligent decision-making.

– Blockchain provides a trust relationship for AI and ensures the data in AI systems cannot be tampered with.

The convergence of two technologies seems natural. As shown in Table 1, in the field of data, blockchain can bring data sharing, privacy protection and data security to AI. In return, AI can implement personalized recommendations, provide security and protect privacy to blockchain. In the field of algorithms, blockchain can help to understand the decisions of AI. AI can intelligently monitor and manage blockchain smart contracts. In the field of computing power, blockchain provides AI with more distributed computing power through a decentralized computing power market. AI can plan resources for blockchain reasonably and save energy consumption of blockchain through automatic learning.

Table 1 – Convergence of AI and blockchain

Fields	Blockchain brings to AI	AI brings to the blockchain
Data	Achieve data sharing and ensure data privacy and security	Provide security, protect privacy and personalization
Algorithm	AI decisions understanding	Contract monitoring and management
Computing power	Distributed computing power	Optimize energy consumption

7 Artificial intelligence drives blockchain development

AI and especially machine learning can make decisions through the massive data training. By providing blockchain with automated data processing and intelligent decision making, AI makes blockchain management more efficient.

7.1 Artificial intelligence optimizes blockchain energy consumption

Blockchain is a relatively difficult task and consumes plenty of resources. Currently, resources consumption in blockchain is a major factor limiting development of blockchain technology.

For example, in the Bitcoin network, the problem of proof of work (PoW) must be solved if participants want to upload a new block into the Bitcoin network. If the PoW is not resolved, the transaction history block will not be added.

Energy consumption is a big issue for PoW consensus. In order to cut energy consumption, traditional blockchain systems have adopted a series of measures, such as maximizing throughput and network utility maximizing. These measures also can help to control congestion, routing, and scheduling in blockchain through a distributed solution.

Usually, available resources are limited for blockchain applications. Resources for blockchain applications can be rationally predicted and assigned by machine learning and automatic optimization of AI. When AI technology is integrated into blockchain, the computing efficiency in blockchain can be greatly improved and the energy consumption of blockchain can also be cut.

7.2 Artificial intelligence improves blockchain security and scalability

Although blockchain is well-known for excellent security, this does not mean that blockchain is completely secure. In recent years, several majority attacks have happened on blockchain, causing huge economic losses.

NOTE – 'Majority attack' refers to recalculating confirmed blocks after controlling more than 50% of the computing power in blockchain, which destroys the decentralized characteristic of blockchain.

In recent years, deep learning algorithms in AI achieved satisfactory results in many application fields and they can realize automatic prediction and adjustment in the field of security inspection. Therefore, AI algorithms can be introduced to manage blockchain. When transaction data increases

rapidly, distributed learning systems can improve the scalability of blockchain based on actual conditions. As well as, through the continuous learning of the state of the blockchain, AI easily determines whether the current blockchain is safe or not. So, when a blockchain is attacked or other unusual behaviour occurs, it can be automatically recognized by AI.

7.3 Artificial intelligence achieves the monitoring and forecasting of contracts

In blockchain, participants deploy smart contracts to make transactions automated. The combination of smart contracts and blockchain greatly resolves the trust problem in the blockchain transaction process, and can cut costs of building trust. Usually, smart contracts are designed, tested and deployed by participants. This may cause human errors and affect the security and trust of blockchain.

If AI is integrated in the process of designing, testing, and deploying smart contracts, human errors can be cut and smart contracts can be more intelligent, stable and trustable.

7.4 Artificial intelligence promotes blockchain data management

Blockchain can be regarded as a decentralized database. AI helps manage data in blockchain, making the data in blockchain more manageable, more private and more personalized.

One of the problems limiting blockchain development is the continuous growth of data volumes. Every transaction on blockchain will be recorded and the data in blockchain can only be added but not deleted. AI can help process the data in blockchain automatically to identify and cut data redundancy in blockchain.

In addition, AI can also personalize blockchain data while ensuring privacy protection. For instance, social networks based on blockchain can use AI to personalize contents in end-user devices. The machine learning process can be operated on end-user devices, rather than on blockchain. Any personal data of users will not leave end-user devices, which is good for privacy protection against user data in blockchain.

8 Blockchain drives artificial intelligence development

Blockchain can provide a decentralized coordination platform for AI based on its characteristics of decentralization and immutability, which allows new breakthroughs to be made in the three elements of AI, including data, algorithm and computing power (see Appendix I).

8.1 Blockchain helps data sharing for artificial intelligence

One of the driving forces of the current AI revolution is data, which can be used for research, development, and commercialization.

More data available for learning and analysis leads to more accurate prediction, evaluation, and decision-making for AI. Blockchain can promote data sharing, thereby breaking the "data island". Blockchain establishes a transparent accountability mechanism by providing data processing information, such as data access methods and time, visitor information, etc. This mechanism forms a transparent and open data market, promotes data exchanging and sharing, and allows AI to obtain more comprehensive data in diverse ways.

Blockchain helps users control data by themselves, so that users will be more confident in sharing data. Users know that their data will be used for better personalized services or other beneficial reasons. For example, doctors and researchers can access more anonymous medical records and cases from all over the world via blockchain. They can develop better treatment paradigms and medical procedures according these data. Blockchain guarantees that medical data and patient data cannot be accessed by companies or institutions who are not authorized.

Blockchain helps AI achieve cross-organizational data in a more secure way. Nowadays, an isolated AI system rarely gets the data from other organizations. Blockchain enables organizations to access data securely and reliably by providing standardized data interfaces. In this process, only the data interface is open to other organizations, not the data itself.

Blockchain solves the problem of data sources and data trustiness in AI by providing a traceability path for AI data. Through recording the process of data such as data submission, modification and transaction, blockchain can confirm the source, ownership, user rights, and circulation path of the data, thereby ensuring the authenticity of the data. Blockchain can formulate uniform format requirements for the data recorded on the blockchain, so that the data can be quickly cleaned. Moreover, multiple parties can detect the same data source and even indicate the validity of the data by giving evaluation marks. Therefore, blockchain can be used to improve the data quality for AI training, which indirectly guarantees the correctness of AI decisions.

8.2 Blockchain helps protect artificial intelligence data privacy

After a series of personal data leaking incidents, people are now more concerned about data privacy. In addition to sharing data, blockchain can also sell data through smart contracts, making AI data more secure and private and in which third parties are not needed.

Compared with the central storage centre of a traditional database management system (DBMS), a distributed system gains a variety of benefits. For example, when a blockchain is attacked or a disaster occurs, blockchain can protect the majority of data by not storing data in a single location. Attackers will threaten the security of blockchain only when they occupy most of the blocks.

Additionally, the transaction information is open and transparent on blockchain, but the account information of users is highly encrypted. Account information can only be accessed by the data owner's authorization. Blockchain protects personal privacy from being violated, and it is difficult for illegal enterprises to use a user account to obtain improper benefits.

The combination of blockchain and encrypted algorithms can separate data ownership and data usage rights during the data sharing process, allowing data consumers to use the ciphertext of the original data instead of the original data when training AI model. This can eliminate the risks of raw data leakage, thereby breaking "data islands" among data owners.

8.3 Blockchain helps achieve distributed computing power

AI requires huge computing power. At present, AI enterprises rely on renting cloud services or building their own computing clusters to solve computing power problems. Computational costs include hardware costs, power costs, and maintenance costs. The more complex the model, the higher the computational costs will be. Training and updating AI models often requires significant costs that small and medium sized companies and developers cannot afford.

Blockchain provides AI with more distributed computing power through a decentralized computing power market (i.e., blockchain-based cloud computing). Blockchain allows individual users to contribute and share the computing resources of idle devices, minimizing researchers' demand for powerful central processing unit (CPU) or graphics processing unit (GPU) hardware. The introduction of sharing idle computing resources for training will greatly reduce costs. As compensation, the sharers of computing resources will get paid through blockchain. For example, AI developers use millions of shared GPUs (such as shared by companies) to prepare, train, and run their machine learning model. The shared GPUs are often used only for a period. Therefore, GPU owners can list the computing time for sale in the form of smart contracts and get paid through blockchain. Smart contracts, decentralization and other features of blockchain work together to ensure the security and transparency of users' shared computing resources. Blockchain guarantees that transaction records cannot be tampered with, and ensures that the resource provider can get the proper compensation from the process of renting the resource.

8.4 Blockchain helps optimise algorithms of artificial intelligence

In recent years, AI algorithms have achieved a lot in machine learning and recognition, but the application categories of AI are rare in practical industries. In addition to being affected by limited resources and data, another important reason is that machine learning technology of AI is a "black box" which is not easy to be interpreted to human, which means the decisions cannot be completely confirmed or trusted in practical applications.

Blockchain can serve as an information infrastructure for the development and sharing of AI algorithms. On the one hand, blockchain can aggregate the individual intelligence of each participant in the blockchain into group intelligence, and on the other hand, blockchain can share individual intelligence to avoid repeat training:

a) Transform individual intelligence into group intelligence:

The current AI is more about individual intelligence, which can intelligently complete self-decisions through continuous learning. When individual intelligence makes decisions, they need to obtain as much relevant real-time data as reference. If there is not enough data or the data is not real-time, the individual AI result will become limited intelligence.

Group intelligence involves multiple participants, and the collaboration of multiple individuals greatly affects the accuracy and efficiency of group intelligence decision making. The distributed characteristic of blockchain provides a decentralized and trusted collaborative environment for group intelligence. Blockchain can be an infrastructure for group intelligence. Mechanisms such as smart contracts and consensus will drive the collaboration between decentralized intelligent participants and help AI from individual intelligence to group intelligence.

b) Share individual intelligence

At present, AI companies have developed AI learning frameworks and applications and constructed ecosystems separately. From an industry perspective, it is a waste of industry productivity for companies to train the AI model repeatedly, and there is no interaction between different AI ecosystems. In this part, blockchain can help sharing AI algorithms by providing a consensus-based and distributed virtual AI as a service (AIaaS) cloud infrastructure. Various blockchains can access and provide different AI capabilities through cross-chain technologies.

NOTE – Cross-chain refers to the exchange and circulation of information and value on different blockchains through technical means.

In addition, blockchain can also establish a set of trusted data management systems to track the traceability of data processing and management (DPM) of AI. By this way, users on the blockchain can always observe the changes in the state of AI data, from the source to the destination, so as to effectively understand the algorithmic decisions of AI. When the decision result of AI deviates from the expected result, blockchain can quickly position abnormal point in AI process in order to optimize the AI model timely.

9 Converged application of artificial intelligence and blockchain

Blockchain promotes the development of AI, at the same time, AI also accelerates the progress of blockchain. The convergence of them brings out their respective advantages.

The convergence of the blockchain and AI has created many applications in various industries, such as, retail, logistics, medical, financial, transportation, public safety and Internet of things (IoT).

9.1 Retail

For the retail industry, the convergence of blockchain and AI makes the whole sales process smarter and more reliable.

First of all, blockchain makes the whole sales process more transparent. Consumers can know more details about what they are buying. The traceability of blockchain makes it easier for users to be aware of the sources or production manufacturers of the goods they buy. Additionally, AI can collect real-time data when users query commodity information through blockchain, so as to provide users with more personalized solutions or recommendations through data analysis.

Secondly, the consensus mechanism of blockchain improves the retail industry. Blockchain helps to establish trust mechanisms between manufacturers, users and merchants to ensure that there will be no low-quality products and cheating in transactions. Smart contracts in the blockchain can realize automatic transactions, reducing trust costs and improving transaction efficiency. In this process, AI can analyse the consumer's feedback information stored in blockchain to realize automatic information feedback processing.

In the retail industry, many e-commerce companies have implemented a number of practical applications based on AI and blockchain fusion technologies. For example, some companies can analyse the big data of user's consumption to determine which products are the hottest in which warehouses and in which region, so as to prepare more stock and arrange more labour. Blockchain guarantees the security and reliability of big data.

9.2 Logistics

Blockchain and AI technology also have a huge impact on the logistics industry. Similar to the retail industry, blockchain can realize the transparency of the logistics process and the information sharing of whole industry chains. The traditional logistics process has a lot of transit nodes, and the information of each node is not transparent. The encryption and immutability of blockchain technology make it easier to implement trust mechanisms in the logistics industry. Additionally, with the integration of AI technology, the logistics industry can realize the intelligence of logistics services on the basis of transparency and credibility, for instance, optimal logistics routes recommending, automatic vehicle and cargo matching, warehouse robots, and so on.

In the logistics industry, many logistics companies have applications in AI and blockchain technology, but at the present stage, most of them are separate applications of the two technologies, and the convergence technology of these two has not been fully matured.

9.3 Medical

The convergence of blockchain and AI also has valuable innovations in the medical field. Blockchain technology can guarantee the authenticity of patient information while AI technology can provide the optimal pathological plan according to the patient's historical data.

Compared with the data of retail, logistics and other industries, the medical industry's data quality requirements are particularly high, which must ensure no error, no attack, and no modification. At this point, the blockchain technology can play a key role. As a distributed ledger, blockchain can record patient's medical and health information at any time. The data on the blockchain cannot be tampered with, which can fully protect the privacy of patients. If medical staffs need to collectively analyse the patient's condition, they can directly apply authorization and query the relevant information of the patient through blockchain, rather than through the offline forwarding of information between doctors. Blockchain asymmetric encryption and authorization technology encrypt the key information of patients. Only authorized participants can access the data, which will greatly improve the privacy of medical data.

The integration of AI and blockchain into the medical industry will also be of benefit to doctors and patients. In daily life, AI can analyse the historical data recorded in the blockchain for patients to realize timely health reminders for patients, and get early treatment of minor diseases and early recognition of major diseases. AI technology can also assist medical staffs in the actual treatment process, reducing the labour force and improving accuracy.

In the healthcare sector, some companies have developed a blockchain-based medical data audit system that allows patients to track their health data in real time. The convergence of blockchain and AI can better serve hospitals and patients.

9.4 Finance

Blockchain is a decentralized distributed ledger. In the finance industry, blockchain can realize decentralized storage, lower transaction costs and higher efficiency. Blockchain can realize real-time payment and settlement in the digital currency applications. In terms of securities trading, blockchain can record relevant information of traders' transactions in real time, which can reduce trading risks. The immutability of blockchain can be applied to the credit investigation system of finance to update the transaction records of users at any time.

AI-based applications on blockchain can predict the trend of the entire financial market by analysing the transaction information in blockchain, and provide reasonable investment plans according to the transaction situation of each user. At the same time, based on the credit data of the users in blockchain, automatic decisions on the user's credit degree are realized.

9.5 Transportation

Driven by intelligent sensing technology, vehicle GPS information, vehicle pictures and videos, AI can realize traffic congestion prediction, route planning, intelligent navigation, automatic identification of violations, and autonomous driving, etc., by analysing transportation data and training models. The integration of blockchain helps intelligent transportation systems to no longer rely on a central system which is responsible for deploying and storing all driving information, so as to save on the huge operating costs of the central server.

Blockchain technology, with its characteristics of decentralization, immutability and transparency, has wide applications in the field of intelligent transportation. Sharing transportation has becomes more and more popular in recent years, but there is a difficulty of demand-supply matching. The introduction of blockchain technology enables real-time recording of vehicle information in each area and the situation of using vehicles, and then realizes the scheduling of vehicles with AI technology. Blockchain can play a key role in information security protection in the development of the Internet of vehicles. For the Internet of vehicles, smart cars need to keep communicating with base stations or other vehicles all the time. Blockchain can protect information from being leaked or tampered with during the whole communication process.

In addition, the traffics administrative department needs to obtain all kinds of traffic information. The integration of blockchain can ensure that the traffic information uploaded by the public is credible and accurate, and the released information cannot be modified without authorization, so as to realize the open and transparent prediction of traffic conditions.

9.6 Public safety

The convergence of AI and blockchain can help ensure users' data privacy while realizing public safety. When the public safety system tracks down criminal suspects, it will collect a large number of surveillance videos to look for clues. Massive video data is the basis of AI technology. AI technology can realize feature extraction and machine learning based on surveillance video. In addition, the information of the suspect can be analysed in real time by AI, and the optimal tracking route can be recommended according to the trajectory of the criminal suspect. A relatively mature application like a face recognition system can be applied to various fields of security, including airports, railway stations, business circles, and so on.

Smart camera is one of the most important assistants in the field of public safety, but in recent years, there have been many incidents of privacy leakage by smart cameras. In order to resolve this problem, blockchain technology can be integrated into the field of intelligent public safety. Blockchain technology can establish a trust relationship between various nodes of a smart city, and

can achieve mutual authentication between users and equipment (e.g., cameras). Further development of related application systems is needed in this regard.

9.7 Internet of things

Internet of things (IoT) is developing rapidly, and a large number of IoT devices are being deployed and applied. IoT devices generate large amounts of data that can be analysed by AI. Integrating AI with IoT can create "smart devices" that can make smart decisions without human intervention. At present, artificial intelligence Internet of things (AIoT) has been widely used in scenarios such as smart homes and smart wearables.

Blockchain helps realize trusted access and exchange of sensor data which is the basic requirement to realize the intelligence of the Internet of things. The IoT connects billions of sensors and has a large amount of real-time data. Sensors and devices distributed in different areas can be connected to blockchain to achieve trusted collaborations and data exchange among them.

In addition, the blockchain technology provides an effective solution for the identification of IoT devices. The characteristics of blockchain, such as decentralized storage, asymmetric encryption and immutability can effectively protect the privacy and data security of user identities, and improve the efficiency of identity services. Blockchains store the key information of the IoT identity and its usage records on the distributed ledgers, avoiding the risks of misuse and tampering by the third parties.

10 Prospect of the convergence of artificial intelligence and blockchain

With the continuous implementation of AI applications, AI is rapidly changing human life. At present, plenty of countries around the world have adopted AI as one of the key points of national competition. Blockchain technology, as a technology to enhance trust, is developing with AI. Blockchain can promote the rapid development of AI and help AI applications solve problems such as computing power, privacy, security, and authenticity. The convergence of them brings more changes to current Internet and human life. In summary, if an application scenario requires multi-party collaboration, has extremely high requirements for data security, and needs to achieve high-quality information sharing, then the convergence technology of AI and blockchain can be applied.

It is worth pointing out that the technology and standards of the convergence of AI and blockchain are still in the early stage and need to be further studied. However, the convergence of the two has a great prospect for development and applications, and this prospect is foreseeable.

Appendix I

Essential elements of artificial intelligence

The essential driving elements of AI include data, algorithm, and computing power. As depicted in Figure I.1, data is the foundation of AI, algorithm is the core of AI, and computing power is the driving force of AI:

– For AI data, it mainly comprises the two steps of obtaining data and processing data. The AI process starts with obtaining data, making corresponding data labels according to actual tasks, formulating corresponding training sets, test sets, and verification sets, and processing data according to the actual application if necessary.

– For AI algorithm, it mainly comprises model selection, learning, and tuning. The algorithms need to be selected based on the actual data situation, then train model and test model, and if necessary, tune model. Generally speaking, the more data, the better the data quality, and the better the algorithm performance. AI algorithms such as convolutional neural network (CNN) and recurrent neural network (RNN) have become very popular recently.

– For AI computing power, data processing, model training and model testing need to be driven by strong computing power. Computing power is the infrastructure of algorithms and data. With the vigorous development of artificial intelligence, the demand for computing power is growing rapidly.

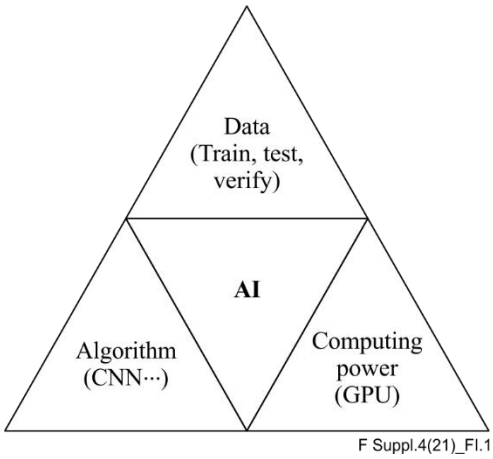

Figure I.1 – Three essential elements of AI

Appendix II

Blockchain ecosystem

With the development of blockchain-related technologies, more and more organizations and individuals have participated in research and applications. Figure II.1 provides a simple depiction of a blockchain ecosystem.

Blockchain is based on communication networks (for example, Wi-Fi, 3G, 4G, and 5G) and supporting platforms (such as the Internet of things, cloud computing, big data, AI, and network security systems). Generally, blockchain ecosystem includes four parts:

– Blockchain open-source platform: Many communities and developers have contributed to the blockchain open-source platforms, such as Bitcoin, Ethereum, and Hyperledger.

– Blockchain as a service (BaaS): BaaS is a platform based on blockchain open-source platform and support platform. BaaS provides high-performance and scalable blockchain services.

– Blockchain platform: Based on the blockchain open-source platform and BaaS, many developers, communities, alliances, companies and investors develop their own blockchain platforms.

– Blockchain application: Based on the blockchain platforms, companies and communities develop their blockchain applications.

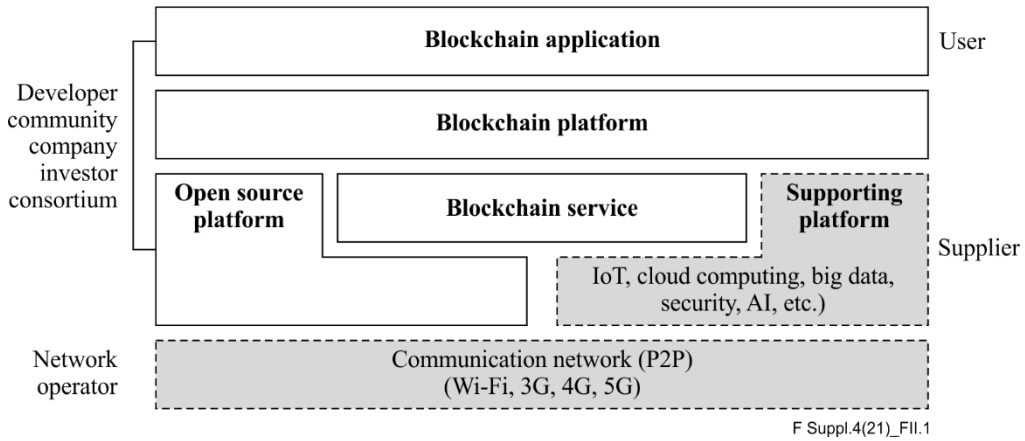

Figure II.1 – Blockchain ecosystem

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Printed in Switzerland
Geneva, 2021