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A Short Overview of Blockchain Used for Spatio-temporal Data

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ABSTRACT

Spatio-temporal data is two-dimensional data with time and space. In the past, centralized databases were used to store spatio-temporal data, but this way is weak to resist malicious attacks. As a distributed storage technology developed in recent years, which has the characteristics of decentralization, non-tampering, openness and transparency, security and credibility. The security of the blockchain is jointly maintained by participants, which makes the data stored in it more secure. This article aims to summarize the currently developing blockchain technologies, like blockchain 1.0, 2.0, and DAG blockchain known as blockchain 3.0, and analyze the advantages and limitations of using them to store spatio-temporal data.

Keywords: blockchain technology, spatio-temporal data, DAG, energy

1. INTRODUCTION

Spatio-temporal data is actually an extension of spatial data[1], it is the location data that contains time information, which means that it has two dimensions: time and space. It is mainly used to express the change of position information in time. Many applications now collect spatio-temporal data to provide users with location-based services, such as logistics tracking, autonomous driving, food supervision, etc. In the fields of using spatio-temporal data, the safety and reliability of spatio-temporal data is particularly important. Nowadays, spatio-temporal data is mainly stored in centralized databases. The centralized storage method will cause information to be opaque and easy to be tampered with. Over the years, incidents caused by expired and unqualified products have occurred from time to time, such as the waste oil incident in 2011, the Shandong vaccine case in 2016, and the longevity biological vaccine incident in 2018. In the investigation of these incidents, almost all of the relevant key datasets are missing or tampered with[2].

As a transformative technology, blockchain was first applied in the financial field[3]. Later on, blockchain has been applied in more and more fields, such as in the energy field. For LO3 energy in cooperation with Siemens, 'Brooklyn Microgrid' was established, which allows customers to buy and sell energy to their neighbors through the blockchain[4]. The latest development of blockchain shows that the technology has the potential to store and manage spatio-temporal data. Its decentralized, non-tamperable, traceable, open and transparent features can well solve the problem of opacity and insecurity of centralized databases. Many scholars have now combined blockchain technology with spatio-temporal data. Literature[5] proposed a traceability system for soybean production based on blockchain technology. Literature [6] proposed a supply chain system in the medical field based on blockchain technology. This paper will overview the blockchain technologies. Then it will discuss the usage of blockchain in spatio-temporal data.

2. BLOCKCHAIN TECHNOLOGY

2.1 Basic content of blockchain

Blockchain is a chain composed of blocks. The data or information stored in the blockchain has "non-tamperable", "traceable", "safe and reliable" and other characteristics, these characteristics ensure that the data stored in it is safe and reliable. After nearly a decade of development, blockchain technology has made great progress. From the current point of view, the more mature and complete ones are blockchain 1.0

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and blockchain 2.0 collectively referred to as traditional blockchains. Blockchain 1.0 is a digital currency application represented by Bitcoin. It is the basic version of blockchain technology. Blockchain 2.0 is a blockchain application in the economic, market and financial fields represented by Ethereum[7]. So far, there is no specific architecture for blockchain 3.0, but the blockchain field widely believes that the BlockDAG architecture proposed by the Hebrew University of Jerusalem in Israel should be the blockchain 3.0 architecture[8].

2.2 BlockChain 1.0

The blockchain 1.0 system architecture originated from the design model of the underlying technology of Bitcoin. Its basic unit is the block. And the blocks are connected by hash pointers. The hash pointers ensure the integrity, continuity and legitimacy of the data. The block in the blockchain is composed of a block header and a block body. The block header stores the hash value of the previous block, the hash value of this block, the block timestamp, Number once(Nonce), etc[9]. The block body stores the specific data of this block, which contains several rows of records. Each record corresponds to a hash, in a tree structure, and the final value generated represents the final block. See Figure 1 for details. Bitcoin is a single-chain architecture in which all blocks are stored on one chain. In order to ensure the security of Bitcoin, in the process of generating new blocks, Bitcoin uses a Proof of Work (PoW) consensus algorithm[10] to generate new blocks, and at the same time adjusts the difficulty of the "workload" to ensure that each block needs one Relatively fixed generation time, this time is about 10 minutes. The security of the blockchain is ensured through the connection between the blocks and the proof of work.

2.3 BlockChain 2.0

The birth of Bitcoin opened the door to the blockchain era, but the development of blockchain has been limited to cryptocurrencies for a long time, and it has not been applied to other fields. It wasn't until 2013 that Vitalik Buterin proposed the concept of Ethereum, which was roughly referred to as "the next generation of cryptocurrency and decentralized application platform", which opened the blockchain 2.0 era[8]. Blockchain 2.0 enlarges the extent of application and adds new extensible features for on-chain utility and scalability. Ethereum is based on a state machine model, and it will only be in one state at any time. Due to the unique state, users can quickly query current account information, and Ethereum uses MPT (Merkle Patricia Tree)[11] to improve the efficiency of users' querying account balance[12]. MPT is a tree structure index, which is composed of Merkle Tree and Patricia Tree.

2.4 Traditional Blockchain and DAG BlockChain

DAG (Directed Acyclic Graph) refers to a graph structure with a direction on any side and no loop. The DAG blockchain model structure is shown in Figure 2. The difference between them is actually the difference between chain and graph. For the chain structure, it is impossible to process only one part, but the graph can do it. This is because the graph can have multiple out-degrees and can process multiple out-degree connected nodes at the same time. Simultaneously, the DAG blockchain has made great improvements in data organization and write permissions. In terms of data organization, DAG blockchain allows each block to be connected with one or more forward blocks. In terms of write permissions, DAG blockchain allows multiple users to write to the blockchain. The DAG blockchain has

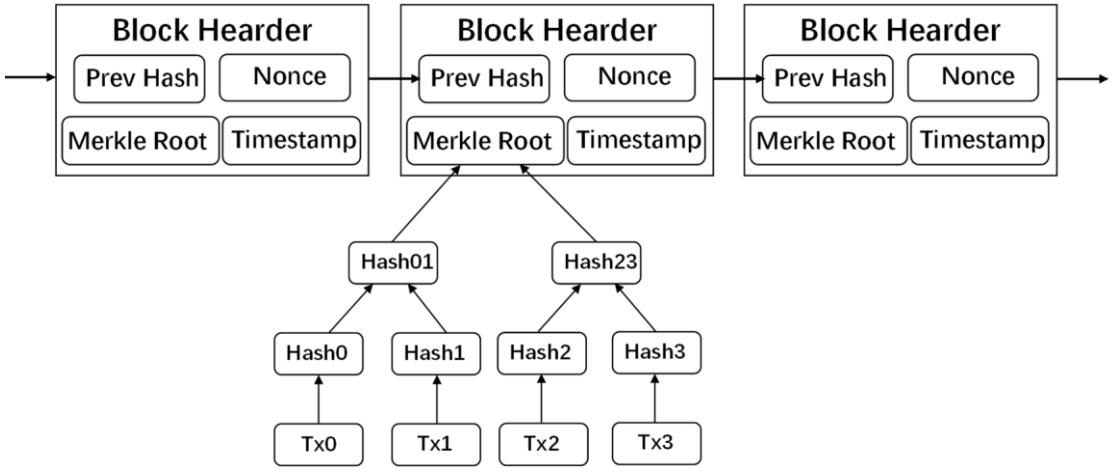

Fig 1 Blockchain structure (adopted from[3]).

faster processing speed, stronger scalability and higher security[13]. Doctoral candidates of the Hebrew University of Jerusalem Yonatan Sompolinsky and Dr. Aviv Zohar jointly published a paper in which they proposed an extensible BlockDAG protocol named "PHANTOM", which is a DAG blockchain structure[9]. The transaction speed of Bitcoin is 7 transactions per second, while BlockDAG can reach 200 transactions per second. The emergence of BlockDAG has actually confirmed the feasibility of DAG blockchain.

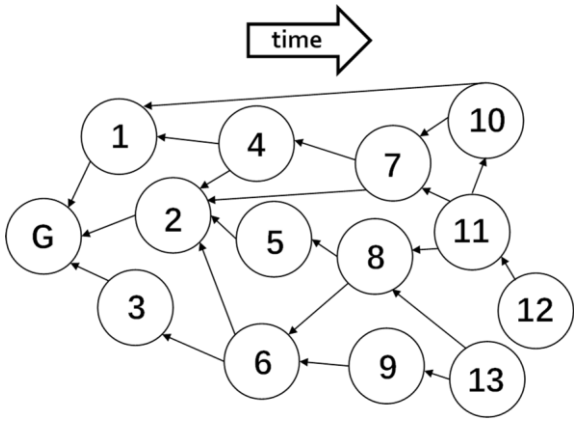

Fig 2 DAG BlockChain structure (adopted from[8]).

2.5 Energy consumption issues and improvements

Since early blockchains used the incentive mechanism of proof-of-work to create blocks, people who participated in the construction of blocks frantically "mined" to obtain rewards, and used a large number of processors to perform countless meaningless calculations, which consumed a lot of electricity. Take Bitcoin as an example. By 2020, the power consumption of Bitcoin will be the same as the current global power consumption. Ethereum also has the problem of high energy consumption. In order to solve this problem, Ethereum plans to replace the proof-of-work mechanism (PoW) with proof-of-stake (PoS)[14]. PoS will randomly select a miner to process the transaction instead of all miners processing the same transaction, which greatly reduces unnecessary calculations. This method is expected to reduce energy consumption by 99%. The DAG blockchain directly cancels the PoW mechanism. In the DAG blockchain, the transaction is followed by one transaction, which means that one transaction can provide proof for the next transaction and does not require mining to create it. This will basically solve the problem of energy waste. I believe that in the future development, energy consumption must no longer be a problem.

3. *BLOCKCHAIN AND SPATIO-TEMPORAL DATA*

3.1 BlockChain 1.0 and spatio-temporal data

Nowadays, although the blockchain 1.0 represented by Bitcoin has matured and its security and reliability can be guaranteed, it still has the problem of low processing efficiency. In the process of block generation, the transaction speed of Bitcoin is only 7 transactions per second, and in order to ensure stability, the average generation time of each block is 10 minutes. At the same time, due to the single-chain structure, When querying historical information, if you need to traverse all blocks, the query efficiency is very low. From this point of view, blockchain 1.0 obviously has the problems of insufficient processing efficiency, longer transaction confirmation time, and poor query efficiency. For spatio-temporal data that is constantly changing and has a large amount of information, if blockchain 1.0 is used to store it, there must be efficiency problems. In order to solve the inefficiency of the Bitcoin framework, some solutions have been proposed. For example, Anthony Skjellum and Carl Worley proposed the use of side chain technology[15] to improve the efficiency of blockchain 1.0 in a document published in 2018. Sidechain technology is actually a sharding mechanism. The main idea of the technology is to shard data and store it on different blockchains. For spatio-temporal data, the time data and spatial data are stored on two chains respectively, and the transaction efficiency is improved through the parallel voting of the two chains.

In addition to the problem of processing efficiency with the combination of the Bitcoin framework and spatio-temporal data, there are also shortcomings in block capacity. When Bitcoin was originally created, the size of each block was specified as 1M. It is obviously not enough to store continuously changing spatio-temporal data. For this reason, block expansion technology[16] was proposed. Block expansion can improve the overall data of the blockchain. Processing capacity, so that the blockchain can better support big data.

With the step-by-step development of blockchain, many problems of blockchain 1.0 have been solved, but due to its own framework, its system limitations always exist, even if it can store space-time data well, At that time, the application area was very limited.

3.2 BlockChain 2.0 and spatio-temporal data

Blockchain 2.0 is developed on the basis of Blockchain 1.0. As the representative of the blockchain

2.0 architecture, Ethereum has made a qualitative leap in its applicable fields. At the same time, its efficiency is much higher than that of Bitcoin. As of now, Ethereum generates a new block every 12.96 seconds. Bitcoin still generates a block in 10 minutes. At the same time, it can quickly query the account balance through MPT, which has a higher degree of support for spatio-temporal data than the previous generation of Ethereum architecture. However, because Ethereum is based on a state machine, it can only maintain the most recent state, which makes it relatively difficult to query historical data. Spatio-temporal data is different from account balances. It is coherent. There is a strong correlation between data and data. Usually, it is necessary to query data from a long time ago, which is very unfavorable for spatio-temporal data.

Blocks in Ethereum are sorted according to the time the block was created, and the blocks are sorted according to transaction time. For two-dimensional data such as spatio-temporal data, if you only consider the time dimension, it will appear when querying geographic information. The problem of inefficiency, for this reason, in addition to considering time, the spatial dimension must be considered to meet all operational requirements. Although blockchain 2.0 has a significant improvement compared to blockchain 1.0, its state machine mode and sequential storage method make it insufficient for spatio-temporal data, and there is still a problem of low efficiency. At present, scholars have proposed solutions to this problem. For example, Yuqin Xu et al. proposed a spatio-temporal data blockchain architecture ECBC (Educational Certificate Blockchain) [10] for storing student status information.

3.3 DAG BlockChain and spatio-temporal data

Compared with the traditional chain blockchain, the DAG blockchain has a higher degree of support for spatio-temporal data. From the perspective of the structure of the system, Bitcoin and Ethereum are single-chain structures, which are equivalent to a single-threaded CPU in processing transaction information. Blocks can only be written synchronously and sequentially according to the block generation time. The processing speed is slow and the efficiency is low. The DGA blockchain is a graph structure with multiple lines, which is equivalent to a parallel processing multi-threaded CPU in processing transactions, which can write transactions asynchronously and in parallel, with fast processing speed and higher efficiency.

From the perspective of transaction determination and block creation, traditional blockchains represented by Bitcoin and Ethereum require complex proof of work, resulting in a relatively long time for block determination. The DGA blockchain uses a fast voting protocol. In BlockDAG, each transaction constitutes a separate block, and each block records the transaction information of the corresponding user. Compared with the traditional chain blockchain, the block's The creation time is greatly reduced. For spatio-temporal data, which is rapidly and continuously changing information, a large amount of information needs to be confirmed. The faster the processing speed, the higher the support. Table 1 summarizes the support of the three existing blockchain architectures for spatio-temporal data.

Currently, researchers have used the BlockDAG architecture to process spatio-temporal data. For example, in a paper published in 2019, Qiang Qu et al. proposed the concept of block-by-block sequential BlockDAG for spatio-temporal data storage, which has more advantages than sequential blockchain access. At the same time, an improved block header organization is proposed to support effective spatio-temporal query[17]. In addition, many BlockDAG architectures for spatio-temporal data are also emerging. For example, Nano and Hash-Graph are all based on BlockDAG, which is a blockchain 3.0 architecture for spatio-temporal data[18].

Blockchain architecture	Internal structure	Transaction speed	Block creation speed	Transaction query speed	Spatio-temporal data support
Blockchain 1.0	UTXO	7 transactions per second	Slow	Slow transaction query	Difference
Blockchain 2.0	MPT	7-15 transactions per second	Faster	Slow historical information query	Better
DAG blockchain	DAG	200 transactions per second	Fast	Fast information inquiry	Good

Table I Comparison of the support of the existing blockchain architecture for spatio-temporal data.

CONCLUSIONS

Spatio-temporal data is extremely important to many fields. For many years, centralized storage of spatio-temporal data has caused many problems. The development of blockchain provides a solution to these problems. However, the combination of traditional blockchain and spatio-temporal data does not have a very good effect. There are more or less problems in both blockchain 1.0 and blockchain 2.0. The most essential reason is the blockchain system. The framework itself is not perfect. The DAG blockchain is not stuck to the traditional chain blockchain structure, and greatly enhances the performance of the block. It can be seen from Table 1 that DAG blockchain is the most suitable technology to combine with spatio-temporal data. I believe that in the future development, blockchain and spatio-temporal data can be highly compatible and promote the development of various fields of society.

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