Safe Storage Algorithm of Spreadsheet Data Based on Internet of Things Technology

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Abstract. The traditional data security storage algorithm of spreadsheet is mainly designed for single user scenario. When encountering the problem of multi-user, the traditional method will appear the problem of high delay and high repetition rate. In order to solve this problem, a new secure data storage algorithm is proposed in this paper. The intelligent gateway of Internet of Things is designed, the core board, the expansion board and the flash memory are designed, the multi-copy association model is established, and the association of the same source data is realized by copy cataloging. Finally, lossless coding is used to compress the data of spreadsheet, and the secure data storage algorithm based on Internet of Things is realized. In the simulation experiment, the traditional data security storage algorithm and the designed algorithm are used respectively. Experimental results show that the proposed algorithm can effectively reduce the latency, and the repetition rate of data storage is very low.

Keyword: Internet of Things technology · Electronic forms · Data security storage · Algorithm design

1 Introduction

With the rapid development of computer, human society is moving towards comprehensive digitalization and informationization. Every day, a large amount of spreadsheet data is stored in the network environment. As user data is shared in the network environment, operations such as sharing, downloading or forwarding to other storage service providers by authorized users or storage service providers will inevitably result in multiple data copy files, which will make widely disseminated user data no longer subject to the constraints and controls of the data owner, such as access time periods, which are not under control [1, 2]. When a users data reaches its storage period and needs to be deleted, if there is no effective mechanism for deleting multiple copies of data, the other copies of the user's data will not be effectively deleted, which not only causes great waste of storage space, but also leads to the abuse of user data and privacy leakage and other problems. Data management is out of control and long-term storage has no definite deletion, which seriously affects social stability and endangers national security.

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In the traditional safe storage algorithm of spreadsheet data, the network architecture and mathematical modeling are all aimed at the single user scenario [3]. Although the multi-user problem can be transformed into a single user problem by dividing the storage node capacity, in practice, the data of multiple users may have interference in the transmission process, In the process of allocating storage capacity can not be reasonably allocated, resulting in long delay, so this paper designs a safe storage algorithm of spreadsheet data based on Internet of things technology.

2 Secure Storage Algorithm of Spreadsheet Data Based on Internet of Things Technology

2.1 Design Intelligent Gateway of Internet of Things

The intelligent gateway in this paper is mainly composed of the hardware and communication equipment of the Arduino platform based on the technology of the Internet of Things. In the hardware structure of the Arduino platform, the top is the Arduino EthernetShield expansion board, which is mainly used to maintain the communication between the Ethernet and the Internet of Things in the data storage of the spreadsheet, and the middle is the Arduino GSM Shield expansion board, which is mainly responsible for sending short messages and the bottom is the Arduino UNO core board, and is responsible for the data analysis and processing of the whole intelligent gateway. These two expansion boards and a core board, can be called the system intelligent gateway Arduino hardware devices, plug and play with the characteristics of "electronic building blocks", so the algorithm can easily be combined together. The three hardware boards are stacked together in the form of stacked blocks, as shown in Fig. 1:

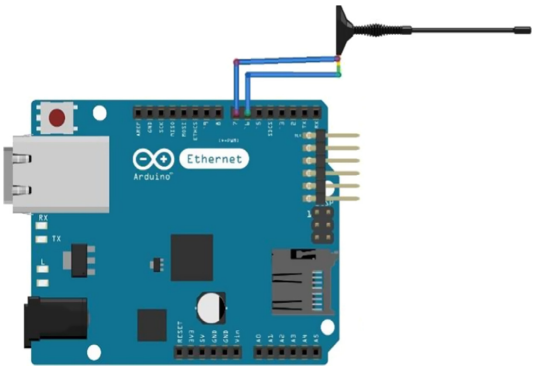

Fig. 1. Gateway hardware device in algorithm

In Fig. 1, the core board is actually a microcontroller board, which provides the most basic information data analysis and processing work for the storage algorithm. The processor model is ATMega328P, and the input voltage range is 6–20 V. It has 14 digital input/output pins, 6 PWM outputs, 3 communication interfaces, and 8 analog inputs.

The crystal oscillator value is 16 MHz, It also has USB interface to connect with other hardware drivers, and has a power jack [4]. In addition, batteries or some power adapters can be used to provide energy.

The function of GSM expansion board is relatively simple, mainly providing the function of sending short messages. It is equipped with a four band modem chip, which has four working bands. It is connected with the upper layer equipment through GPRS. The data transmission rate of uplink and downlink is 85.6 kbps. The communication protocol supports TCP/UDP and HTTP protocols. Compared with the GSM expansion board, the Ethernet shield expansion board is more powerful. It has Ethernet interface and integrated data storage function. The front-end page files of the system are stored in the SD card to avoid occupying ROM resources and improve the network performance of the gateway. In the expansion board, there are 14 digital IO pins, of which 4 are PWM outputs, and 6 Arduino pins are reserved. Pin10–13 is used for SPI, pin4 is used for SD card and pint is used for W5100 interrupt (bridge) by default, and the size of flash ROM is 32 KB, of which 0.5 kb is used for bootloader.

In order to ensure the performance of the gateway, high-end SOC chips are used in the design. In this paper, Arduino platform products are used in the design of intelligent gateway, which can save cost and shorten the delay in the storage process [5, 6].

In the data security storage algorithm, it needs to save the continuous spreadsheet data, and the storage capacity of the algorithm needs to be guaranteed. Therefore, flash memory can be used as storage support. Flash memory is a kind of safe and fast storage element. With the advantages of small size and low cost, it has gradually replaced other semiconductor storage elements and become the mainstream data program carrier [7, 8]. In the storage algorithm of this paper, four Flash memories of H27U4G8F2DTR-BC are used to form a storage array with a total capacity of 4T. The pin diagram of H27U4G8F2DTR-BC is shown in Fig. 2

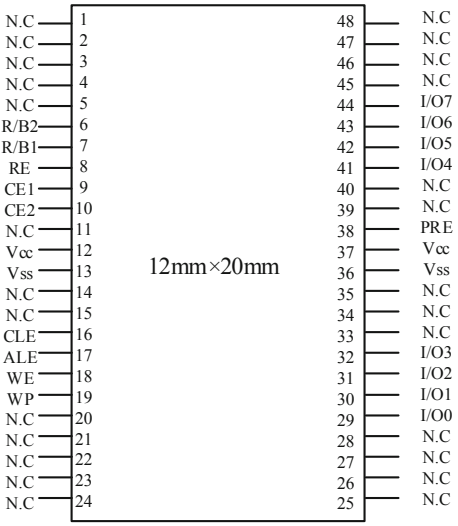

Fig. 2. Pin diagram of H27U4G8F2DTR-BC

The H27U4G8F2DTR-BC in Fig. 2 is 1t × 8-bit NAND Flash is packaged in 48 pin TSOP with a size of 12 mm × 20 mm. The function description of each pin is shown in Table 1.

Table 1. Pin function description

Pin type	Pin name	Function description
Data input/output	I/O0-I/O7	Input command, address and data, and output data during read operation
Command latch	CLE	Enter the active path of the command in the control command register
Address latch	ALE	Input controls the active path of the address in the internal address register
Selected films	CE-CE2	When the device is busy, the device will not return to write operation
Read enable	RE	Re controls serial data output and drives data to I/0 bus when valid
Write/erase	WE	The input control is written to the I/0 port, and the command, address and data are locked on the rising edge of we
Power on read enable	PRE	When connected to VCC, it controls the power on auto read operation function
Power input	Vcc	Device power input
Place of reference	Vss	–
Empty pin	N.C	No internal connection

The design of storage array directly affects the performance of data storage system. Large capacity storage array can store more ship navigation information data, which is an important guarantee for ship navigation safety.

2.2 Establish Data Multi Copy Association Model

Aiming at the problem of data multi copy Association, this paper proposes a data multi copy association model and deletion feedback mechanism, which can meet the needs of data multi copy Association and deletion caused by the operation of authorized users or storage service providers such as sharing, transferring or downloading. A data replica is an exact copy of the source data. Usually, the generation of data replica is to avoid data loss events caused by hardware failure. With the advent of the era of big data and the development of cloud storage technology, the generation of data replica is also due to the consideration of data access speed, data disaster tolerance and reliability. In mrad scheme, the data that are copied and identical with the source data is called data copy. The data copy from the same source data is also called homologous data copy, which is called data copy for short. In order to describe the data multi replica association model proposed in this paper, the concepts of child replica and parent replica are proposed. Similar to the tree structure, the parent copy is the parent node in the tree node, and the

child copy is the child node in the tree node. Each parent copy can produce multiple child copies, and each child copy has only one corresponding parent copy. When a child replica is generated, the information about its parent replica will be recorded accordingly. This information is mainly used for the feedback mechanism when multiple replicas are deleted. As shown in Fig. 3:

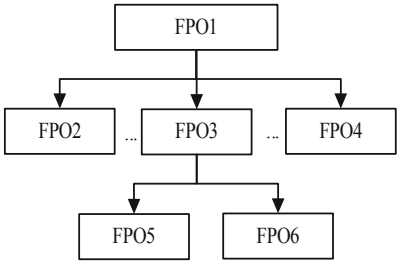

Fig. 3. Tree structure of data replica

In Fig. 3, the parent copy of FPO_3 is FPO_1, and the child copies of FPO_3 are FPO_5 and FPO_6. that is, FPO_3 is copied from FPO, while FPO_5 and FPO_6 are copied from FPO_3. With the continuous derivation of data copies, it is easy to cause copy flooding, which not only wastes storage space, but also has some security risks; And the separation of ownership and management of data copy greatly increases the difficulty of data copy management. In order to improve the multi-user and high concurrency ability of storage algorithm, the read and write operations of information data in the storage process should be separated. The storage is divided into main storage and slave storage. The main storage is responsible for data writing service. On this basis, the slave storage is added to be responsible for data reading. The working process of read-write separation is shown in Fig. 4

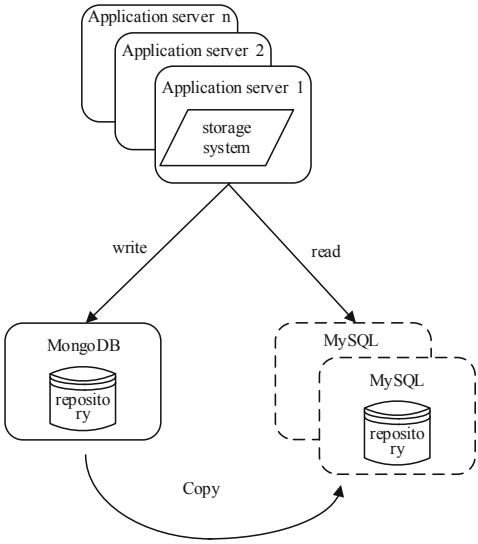

Fig. 4. Read write separation process

The purpose of adding read database is to reduce the pressure of the main database, and the read-write separation technology is applied in the database to reduce the delay phenomenon in the replication process [9, 10]. In the algorithm designed in this paper, the massive spreadsheet data in the storage array is mainly stored in the main database, and the main data stored in the database includes basic information such as users, projects and equipment [11, 12]. After a long time of data synchronization between the main database and the slave database, there will be data redundancy, which will slow down the system performance, so it is necessary to compress the data. In order to achieve data compression, the layer coding algorithm is designed. The compression flow chart is shown in Fig. 5:

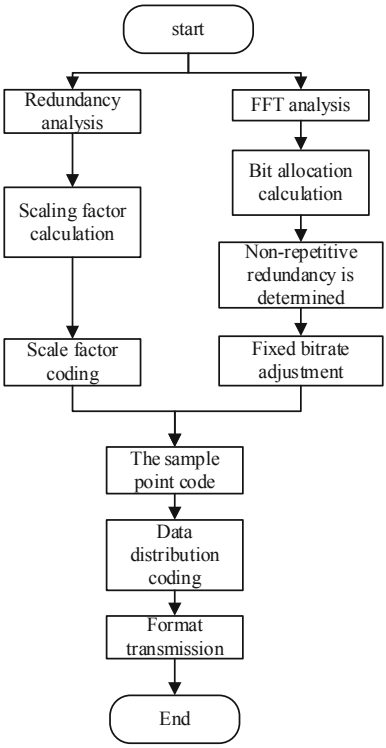

Fig. 5. Layer coding algorithm flow

In this algorithm, input the information data sample i in the database, and calculate the sample point vector $X[i]$ and window vector $C[i]$:

$$Z = X[i]C[i] \tag{1}$$

Window vector $C[i]$ can be calculated by coding standard

$$C[i] = \cos\left[\frac{(2i+1)(k-16)\times\pi}{64}\right] \tag{2}$$

In the above formula, the value range of i is 0–31, the value range of k is 0–63, and the calculation formula of sample vector $X[i]$ is as follows [13]:

$$X[i] = X_1[i] + X_2[i] + ... + X_n[i] \tag{3}$$

Each sub vector in formula (3) is a vector of 64 pieces of information data. After a series of operations of layer coding algorithm, the redundant data in the database is compressed. In the storage algorithm designed in this paper, one of the important performance indicators is whether it has the high concurrency ability of multiple users [14, 15]. It requires the algorithm to respond to a large number of users' storage requests of spreadsheet data in a short time in the storage process. If the high concurrency performance is poor, the user interaction of spreadsheet data will have a large delay, which affects the real-time update of spreadsheet data.

2.3 Lossless Coding and Compression of Spreadsheet Data

At present, the encoding method of spreadsheet data is mainly to explore the spatial correlation of data for compression [16]. The number of frequency bands is large, and the correlation between multiple frequency bands is high. The current encoding method can not eliminate the spectral redundancy, which will reduce the encoding efficiency and affect the frame storage efficiency in the process of storage. In this paper, the lossless coding scheme is improved. The complex prediction operation is transferred from the coding position to the decoding position, and the down sampling and channel coding operations are carried out in the coding position. In the coding scheme, the prediction operation is transferred to reduce the complexity of the coding end. In the decoding end, the information points of each frequency band can be selected by using the information of the frequency band that has been reconstructed before [17, 18]. There are many information points of the frequency band in the information points. In order to achieve the convenience of coding and compression, it is necessary to classify them. In the process of classification, if the pixels are of the same type, it is necessary to detect whether they have the same spectral correlation and choose the adaptive prediction method according to their correlation. Firstly, the sub-copy of the spreadsheet data needs to be down-sampled and bit-by-bit coded [19]. The more such subcopies are decoded, the more current data can be used to obtain edge information. The encoding result for the following sample is shown in Fig. 6:

1	9	3	11
13	5	15	7
4	12	2	10
16	8	14	6

Fig. 6. Schematic diagram of sampling number results

After decoding successfully, the resolution of the sub-copy of the current sample will be improved, which shows that the resolution is progressive and the precision of data storage is also improved. After the coding, we need to compress the data of the spreadsheet, extract the important node in the data of the spreadsheet, and get the sparse measured value after the coefficient transform, then store and transmit the measured value after compressing and processing, and then get the original signal after the sparse reconstruction [20, 21].

In the process of compression, suppose that x is a one-dimensional sparse signal and its size is described by $N \times 1$. When there are K and non-zero values in x, then its sparsity can be described as K. Φ represents a two-dimensional measurement matrix and its size is $M \times N$. Then the one-dimensional measurement signal can be expressed as:

$$y = \Phi x \tag{4}$$

The above equation is a system of underdetermined equations, so it needs to be transformed into an optimization problem [22]:

$$\hat{x} = \arg\min \|x\|_0 \ \ \Phi x = y \tag{5}$$

This process is the perceptual reconstruction in the compression process, and it is also a constraint condition [23]. Its minimum 0 norm is a NP problem, so we need to transform the above optimization problem, that is, to transform the 0 norm problem into the 1 norm problem. In this way, through the given measurement matrix and measurement value y, the signal approximation value of the original spreadsheet data can be further calculated to complete the lossless coding compression of the spreadsheet data.

3 Simulation Experiment

3.1 Experimental Environment

The distributed storage of spreadsheet data using Internet of things technology can effectively reduce the data transmission delay in IIoT on the basis of guaranteeing the data security. The network architecture and mathematical modeling in the traditional data security storage algorithm are all aimed at the scenario of a single user. Although the multi-user problem can be transformed into a single-user problem by dividing the storage node capacity, in the actual situation, there may be interference in the transmission process of multi-user data, and it is impossible to reasonably allocate the storage capacity during the allocation process. The algorithm designed in this paper is optimized for this problem, so it needs to design simulation experiments to verify. Firstly, the network architecture of simulation experiment is built. In IIoT environment, production service puts forward a lot of requirements for delay. Taking industrial monitoring as an example, the camera first captures images of the normal production process and then uploads them to the cloud center for storage. Finally, during the production process, the camera continuously captures images of the production process and compares them with the normal production process of the cloud data center at regular intervals. If there is any deviation, adjustments will be made in a timely manner. In the SD-CFIIoT architecture, fog computing is introduced to reduce latency, distributed storage is introduced to

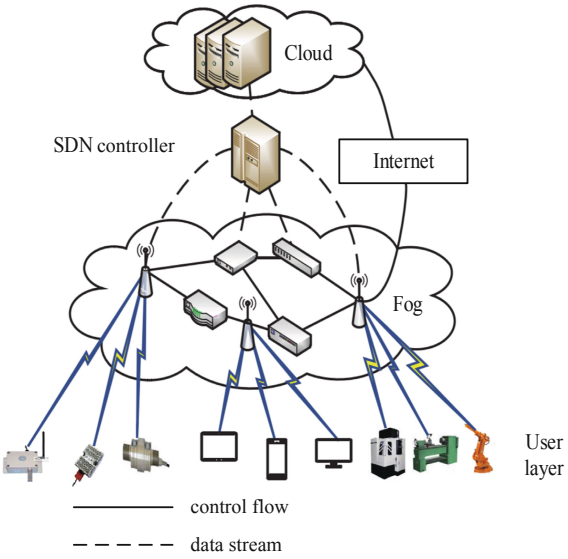

Fig. 7. Network architecture of SD-CFIIoT

enhance data security, and SDN technology is introduced to network management in multi-user environment. The SD-CFIIoT architecture is shown in Fig. 7:

The architecture consists of four layers: cloud computing layer, SDN control layer, fog computing layer and infrastructure layer. The main components of IIoT industrial monitoring application basic equipment layer include camera, electronic eye, monitor and other data acquisition equipment, as well as manipulator, intelligent lathe, alarm and other execution equipment. Data acquisition equipment after the acquisition to the video or image data uploaded to the fog calculating layer distributed storage system and the cloud for storage, after the acquisition device again after the monitoring information collected, compare the intermittent and already stored data, to update or store information according to the feedback information to perform the adjustment of the production process. Fog computing layer is mainly composed of router, base station, switch and other edge network equipment. OpenFlow protocol is running on these fog equipment, which can realize the communication function with SDN controller. In industrial control applications, the mist device receives the infrastructure layer of information collected and stored locally, due to limited storage capacity, fog between devices can form a distributed storage system at the same time, improve storage capacity, at the same time, the distributed storage can improve the safety of production when the information is stored, to prevent equipment being attacked by a single fog caused production secrets. The fog computing layer can not only store the information received, but also actively cache the production information close to the production process of the nearby factories or workshops from the cloud computing layer to provide a more comprehensive service. It can also upload its own stored non-confidential information to the cloud computing layer for global information sharing to provide services for other users. By storing image data in the fog computing layer, the response delay of industrial monitoring applications can

be reduced, and the security of data stored in the fog computing layer can be guaranteed by distributed storage. The SDN controller layer is mainly composed of SDN controllers. The SDN controller centrally controls the SD-CFIIOT network, and obtains the global information of the network, including the storage capacity, communication ability and security of the device, through information interaction with the basic equipment layer, fog computing layer and cloud computing layer.

The cloud computing layer mainly refers to the remote cloud server cluster. Use of its powerful storage capacity for cloud server cluster IIoT environment in various business and equipment to provide services, in the business of industrial monitoring, its main task is according to the infrastructure layer set up production process database, the data collected camera equipment after the collected data, characteristic of information transmission to the cloud layer can be information, The cloud computing layer can rely on powerful computing power to quickly feedback the results of the comparison.

In IIoT monitoring applications, multiple users after the collected data, send data to the center of the fog calculating layer distributed storage system node, at the same time, users also upload data security requirement, how to center node according to the requirement of each user for data security, coupled with the fog calculating layer equipment storage capacity, safety, and communication ability, Reasonable distribution of all users' data to the fog computing layer devices and cloud computing layer for storage is a problem to be solved in SD-CFIIoT architecture. In this section, the total delay of data transmission in the case of multiple users is modeled, and the delay optimization problem under security constraints is proposed, and an algorithm is proposed to solve it. In the SD-CFIIoT architecture, the SD-CFIIoT network composed of M users and m fog computing devices is considered. The corresponding abstract structure of network topology is shown in Fig. 8:

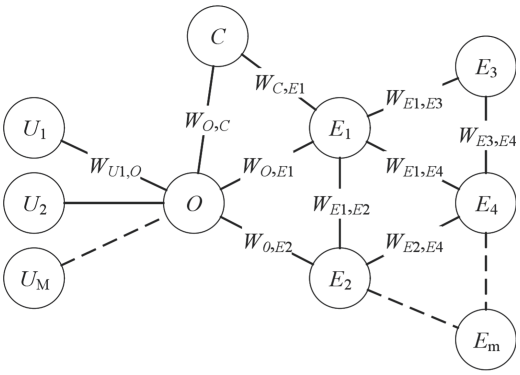

Fig. 8. SD-CFIIoT architecture device undirected diagram

In Fig. 8, the user set can be expressed as $U = \{U_1, U_2, ..., U_M\}$, which means there are a total of M users in the system. In the fog node set $E = \{E_1, E_2, ..., E_m\}$ in the figure above, there are m fog nodes, and the main fog nodes of the 9RZ-type storage system in generation O, where C represents the cloud server. The value w on the edge

represents the data transfer rate between nodes. In the above figure, the data transmission rate between each node is shown in Table 2:

Table 2. Transfer rate table between storage nodes

W	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	O	C
E_1	∞	20	50	35	–	–	–	–	84	–
E_2	20	∞	60	–	40	37	-	–	92	–
E_3	50	60	∞	24	–	43	–	57	–	–
E_4	35	–	24	∞	–	–	–	38	–	–
E_5	–	40	–	–	∞	18	46	–	–	–
E_6	–	37	43	–	18	∞	55	70	–	–
E_7	–	–	–	–	46	55	∞	33	–	–
E_8	–	–	57	38	–	70	33	∞	–	–
O	87	92	–	–	–	–	–	–	∞	7
C	–	–	–	–	–	–	–	–	7	∞

In Table 2, the transmission rate of each node to itself is set to, indicating that there is no transmission delay when the node transmits data to itself, and - means that the two nodes are not directly connected. And take the above equipment architecture as the model, build the simulation experiment environment, and set the parameters in detail.

3.2 Parameter Settings

The above experimental environment was built in the simulation software MATLAB, and the relevant environmental parameters were set as shown in Table 3:

Table 3. Simulation parameters

The parameter name	Numerical	Unit
Total channel bandwidth	5	MHz
Subscriber transmitted power	100	mW
Background noise	− 100	dBm
Path loss factor	2	–
The number of fog nodes	8	a
Maximum number of iterations	1000	Times

Parameters of fog nodes in the simulation software are designed, as shown in Table 4:

Table 4. Fog node parameter table

Node	Attack arrival rate λ_i (times/min)	Storage capacity Z_i/MB
E_1	0.23	160
E_2	0.15	270
E_3	0.37	374
E_4	0.82	682
E_5	0.64	262
E_6	0.51	98
E_7	0.43	753
E_8	0.52	246

In order to verify that the SD-CFIIoT architecture can effectively reduce the time delay of multi-user total data transmission while ensuring the security of IIoT data, In this section, the delay performance of SD-CFIIoT architecture, cloud computing architecture and Single Fog Node (SFN) is compared when the probability of an attack Node being broken is different. In the simulation, the number of users is set to 10, and the relevant parameters of users are set as shown in Table 5:

Table 5. User parameters table

User	The channel gain H_i	Data security requirements ss^i
U_1	0.0027	0.86
U_2	0.0074	0.41
U_3	0.0019	0.73
U_4	0.0035	0.55
U_5	0.0062	0.62
U_6	0.0063	0.46
U_7	0.0054	0.18
U_8	0.0033	0.51
U_9	0.0098	0.38
U_{10}	0.0062	0.74

In the experimental environment of the above formula, the secure storage algorithm of spreadsheet data based on the Internet of Things technology and the traditional algorithm designed in this paper are respectively used for testing, and statistical analysis is conducted on the transmission experiment of total data.

3.3 Experimental Results and Analysis

In the above experimental environment, the influence of the number of users on experimental performance is obtained, as shown in Fig. 9:

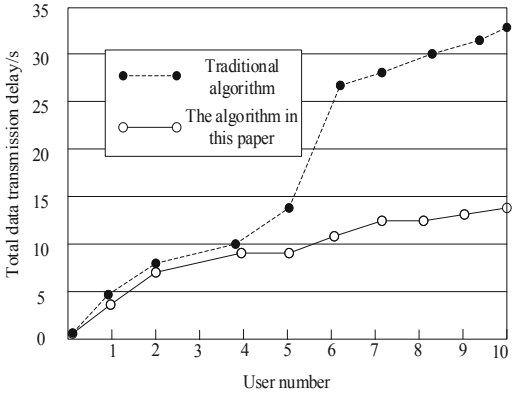

Fig. 9. The influence of the number of users on delay performance

From Fig. 9, it can be seen that with the increase of the number of users, the transmission delay of the two data security storage algorithms is increasing. When the number of users is small, the delay of this algorithm is lower than that of the traditional algorithm, but the reduction amplitude has no obvious advantage. With the increase of the number of users, the advantages of the delay performance are reflected. It can be seen that the total transmission delay of traditional data storage algorithm increases with the increase of the number of users. This is because with the increase of the number of users, the amount of data transmitted will increase, and the mutual interference between users will increase, which leads to the rapid deterioration of the delay of data transmission from the basic equipment layer equipment to the SDN controller, the increase of total transmission delay is accelerated. At the same time, if the single fog node in the traditional algorithm can not meet the needs of any user, it can not adopt this storage architecture, so its application scope is very limited; In the architecture algorithm designed in this paper, although the delay of SDN controller to receive data will increase, all users' data are allocated to a large number of fog computing equipment and Cloud Computing Center for distributed storage, which reduces the transmission delay of data in the allocation stage. Therefore, the increase of transmission delay with the increase of the number of users can basically keep stable. The paper verifies that the electronic table data security storage algorithm based on Internet of things technology can effectively reduce the delay in the case of multi-user.

Two algorithms are used to analyze the deduplication rate of spreadsheet data during secure storage. The result is shown in Fig. 10.

According to Fig. 10, the trend of repetition rates for each method of data storage is non-linear and fluctuates up and down. The repetition rate of spreadsheet data storage is always lower than 10% under the proposed algorithm, which shows that this technique can delete the same data and achieve high quality data storage.

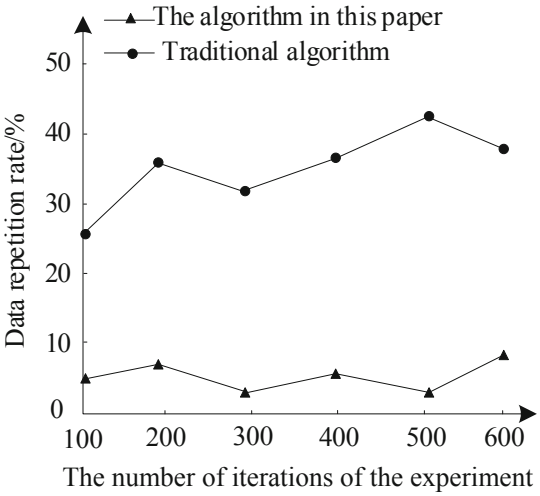

Fig. 10. Comparison of data store repetition rate of different methods

4 Conclusions and Prospects

Thanks to the rapid development of Internet technology and communication technology, the Internet of things industry has entered a stage of rapid development. The Internet of things has been widely and deeply applied in many industries, especially in the industrial field. The network architecture has the problems of high data transmission delay and heavy load of cloud computing center, which is difficult to meet the low delay requirements of massive services in iiot. This paper designs the intelligent gateway of Internet of things based on storage algorithm, designs the core board, expansion board, flash memory and other devices, establishes the data multi copy association model, realizes the association of homologous data copies through the copy directory, and finally carries on the lossless coding compression for the spreadsheet data, Complete the design of electronic form data security storage algorithm based on Internet of things technology.

However, when the intelligent gateway designed in this study realizes the functions of information collection, information input, information output, centralized control, remote control, linkage control and so on, its stability cannot be guaranteed due to the interference of relevant signals, which affects the safe storage of the data in the spreadsheet. In the future research, it is necessary to analyze the stability of the IOT intelligent gateway to avoid data loss and tampering during the remote operation of spreadsheet data.

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