A stable data transmission method of industrial internet of things communication based on bat algorithm

YiPing Chen

Department of Computer Science and Engineering,
Guangzhou Institute of Technology,
Guangzhou 510540, China
Email: 8964301@qq.com

Abstract: Aiming at the problems of poor transmission stability and long transmission time in the traditional industrial internet of things communication data transmission, a stable transmission method of industrial internet of things communication data based on bat algorithm is designed. Firstly, build the industrial internet of things network model. Then, the sparse basis matrix is used to collect the communication data of industrial internet of things, and the noise in the communication data is removed by Gaussian function to complete the data extraction and preprocessing. Finally, the bat algorithm is used to determine the suitability of the location of the communication data, the updated data is transmitted in the optimised industrial internet of things communication network environment, and the differential genetic algorithm is used to suppress the interference factors to complete the stable data transmission. The results show that the proposed method can effectively improve the stability of communication data transmission.

Keywords: bat algorithm; industrial internet of things; remote communication; data transmission.

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Biographical notes: YiPing Chen received his Master's in Software Engineering from the East China Normal University, in 2014. He is currently an Associate Professor of Computer Science and Engineering at the Guangzhou Institute of Technology. His research interests include machine vision inspection, network system integration and cyberspace security.

1 Introduction

At present, the industrial field tends to be intelligent. Advanced information technology is gradually applied to the industrial field, and the industrial internet of things (Wang et al., 2020; Ma et al., 2021) has also become the main driver in the intelligent manufacturing field. It not only has the advantage of intelligence, but also promotes the transformation and upgrading of industrial enterprises. However, at present, the industrial internet of things mainly uses multiple sensors of different types to realise the real-time monitoring of industrial complex systems by collecting and processing communication data. However, in the industrial internet of things, there are often redundant data transmission methods between various terminals, while the traditional internet of things nodes have simple structure, limited data communication and storage capacity, and single transmission path Lack of secure communication mechanism (Vrana, 2021; Khan and Abuhasel, 2020). Therefore, there is a risk of packet loss, transmission error or easy to be tampered when transmitting data between intelligent devices. How to transmit internet of things data safely and efficiently has become the core problem of current research. The so-called efficient transmission of industrial internet of things communication data is to maintain the integrity, stability and authenticity of data transmission, and have certain confidentiality without disclosing the transmitted data (Faraci et al., 2020). In the communication data transmission of industrial internet of things, it is required that the communication data is not damaged by external equipment, and the received data is exactly the same as the original transmission data (Yang et al., 2019). However, the communication transmission of traditional industrial internet of things cannot meet the needs of complex communication environment. Therefore, some researchers in related fields have also carried out research.

Li (2020) proposed a long-distance transmission method of multiplexed information in the internet of things, which can improve the stability of data transmission. In order to solve the problem of high delay and poor stability of information transmission in the traditional internet of things, this method uses the channel length, energy loss, integrity and time as evaluation indexes to construct a credible evaluation matrix to determine the credibility target in the internet of things, so as to realise the long-distance trusted transmission in the internet of things. This method has good timeliness and stability, but it has poor control effect on its network transmission environment in data transmission, and has some limitations. Dhasarathan et al. (2020) designed an optical system using free space (FSO) a method to provide high-speed information transmission stability. This method combines digital signal processing technology and relevant detection means to carry out long-distance link data transmission and realise effective data communication transmission under 5G and the internet of things. Experiments show that this method can realise high-speed transmission under different weather conditions and has high spectral efficiency. However, this method has problems in frequency resource allocation. In the problem of high energy consumption and poor data integrity. Li and Wu (2020) proposed a secure transmission method of internet of things nodes in an open environment. By analysing the specific attack behaviour of malicious nodes, we can avoid malicious nodes from mixing into data, select reliable data for secure transmission, and obtain the data transmission method. The designed method has high data transmission rate and security, but the data integrity is not discussed. However, this method cannot fully meet the requirements of stable data transmission of industrial internet of things. At the same time, in the process of transmitting communication data in the traditional industrial internet of things, there are problems of single transmission mode and security risks caused by errors in data information transmission.

Therefore, this paper proposes a stable transmission method of industrial internet of things communication data based on bat algorithm. The main framework of this paper is as follows:

Firstly, the industrial internet of things network model is constructed, which is divided into three levels: application layer, network layer and perception layer. The network environment of industrial internet of things communication is determined, and the industrial internet of things network model is optimised by calculating the distance matrix of different devices in the communication network;

Then, in the model, the industrial internet of things communication data are collected with the help of sparse basis matrix, and the noise in the communication data is removed by Gaussian function to complete the extraction and preprocessing of the target transmission object data;

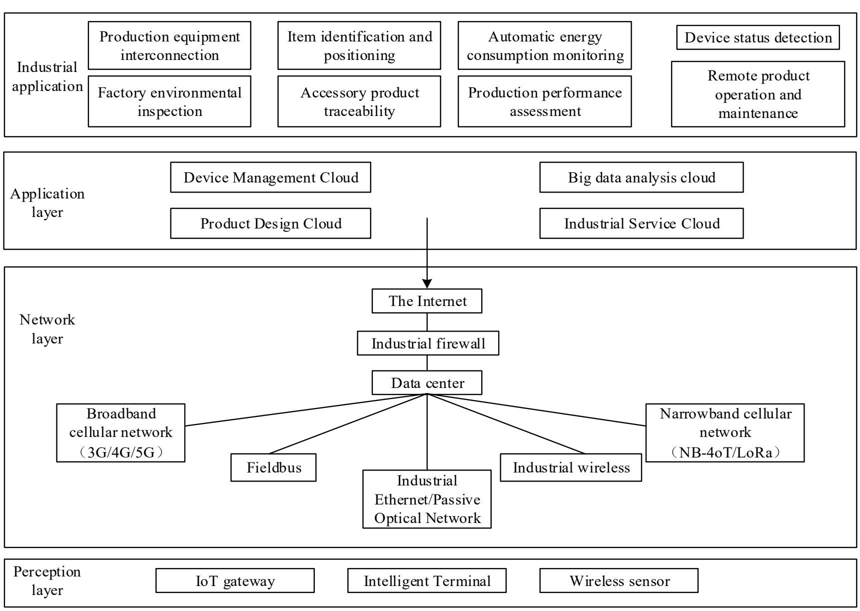
Finally, the bat algorithm is used to determine the suitability of the location of the communication data, the process of bat individual location is simulated into the communication data optimisation process, and the extracted communication data is continuously updated iteratively. The updated data is transmitted in the network environment of the optimised industrial internet of things communication, the interference factors in the transmission are determined and suppressed, Complete the stable transmission of industrial internet of things communication data.

2 Construction of industrial internet of things network model and industrial internet of things communication data acquisition

2.1 Construction of industrial internet of things network model

In order to improve the effectiveness of stable transmission of industrial internet of things communication data, firstly, the industrial internet of things network model is designed. This is because the transmission environment of industrial internet of things communication data is in the industrial network, which affects the stability of industrial internet of things communication data transmission. Therefore, the data transmission environment is determined with the help of the constructed industrial internet of things network model, which lays a stable foundation for subsequent research.

Figure 1 Industrial internet of things network model



The constructed industrial internet of things network model is shown in Figure 1.

Build the industrial internet of things network model as shown in Figure 1. As can be seen from Figure 1, in this study, the IOT is divided into three layers: application layer (Fawaz and Kang, 2021), network layer and perceptual layer, in which three layers combine to support the industrial application. The perceptual layer is mainly used to perceive and generate multi-modal communication data such as location information, accessory product information, factory environment information, etc. The sensing layer can be combined with the acquisition matrix in Section 2.1 to collect communication data using multiple wireless sensors or intelligent terminals. As a bridge between the sensing layer and the application layer, the network layer is mainly responsible for transmitting communication data, and has the function of transmitting multiple cell data simultaneously. At the same time the network layer of the data centre can effectively achieve data management, and responsible for data processing. At the same time, many industrial applications can communicate with the network layer at the same time. The network layer has communication data transmission protocol and transmission quality control to ensure the security and integrity of communication data transmission. The application layer has the functions of equipment access, data analysis and equipment management and maintenance.

2.2 Optimisation of industrial internet of things network model

After constructing the network model of industrial internet of things, it is necessary to optimise and adjust the stability of the network model so as to realise the stable and complete transmission of communication data. In the process of collecting communication data by wireless sensors in industrial internet of things sensing layer, it is necessary to set a threshold α between different devices, calculate the distance matrix of different devices in the communication network, and obtain the distance between two devices in each industrial internet of things environment as follows:

$$D_{m,n} = d_{i,j} \begin{pmatrix} d_{(0,0)} & \cdots & d_{0,n-1} \\ \vdots & \ddots & \vdots \\ d_{m-1,0} & \cdots & d_{m-1,n-1} \end{pmatrix} \tag{1}$$

where $D_{m,n}$ represents the distance value between two devices in the industrial IoT environment, and $d_{i,j}$ is the transmission distance between the i^{th} communication sample and the j^{th} communication sample;

Thus, according to equation (1), the distance between two devices is greater than the value of α, and the industrial devices meeting this condition are eliminated, and all the removed industrial devices are placed in set 1. For any industrial equipment that has been removed from the set, if the distance between the equipment and other equipment is less than α, it is stored in set 2. From this, the distance $D'_{m,n}$ and communication data correlation G for different industrial equipment in the two sets can be calculated. From this, the fitness function can be calculated using the following formula:

$$F(c) = D'_{m,n} \times \sum_{m=1}^{x} G\left(y_c - y_m\right) \tag{2}$$

Among them, F(c) represents the fitness function of the c industrial equipment, and y_c and y_m correspond to the working state and expected working state of the current industrial equipment.

The stability adjustment and optimisation process of the industrial IOT network model is as follows:

1. Discretise and process all the communication and transmission data in the environment of industrial internet of things, and the result is $h'_{i,j}$.
2. Computing the covariance matrix of the data transmitted through industrial internet of things by using the discretisation results:

$$H=\frac{1}{c}|s_{i,j}|\times h'_{i,j} \tag{3}$$

where H represents the covariance matrix, and c represents the degree of discretisation.

   a. Solving the eigenvalues and eigenvectors in equation (3) and constructing the eigenvector matrix H'.
   b. The projection transformation is carried out and the result is $S'=H'\times\varphi^T$.
   c. Comparing the projection results with the α size of the set threshold, if $S'>\alpha$, the communication network of the industrial internet of things is more stable; if $S'>\alpha$, the return Step 1 is re-discretised.

2.3 Industrial internet of things communication data acquisition and preprocessing

Before constructing the network model of industrial internet of things, it is necessary to collect the sample of communication data in industrial internet of things and define the object of data transmission.

Firstly, a collection matrix is designed to make all communication data operate synchronously, so as to improve the transmission efficiency and quality of communication data. Thus, the data signals in the communication environment of the industrial internet of things are sparsely processed and the sparse base matrix is constructed as follows:

$$\varphi=(\varphi_1,\varphi_2,\cdots,\varphi_N) \tag{4}$$

Among them, φ represents the sparse base matrix of communication data in the communication environment of industrial internet of things, $\varphi_1, \varphi_2, \cdots, \varphi_N$ represents the sparse base matrix elements of communication data in the communication environment of industrial internet of things, and N represents the maximum sparsity of the matrix. Based on the sparse base matrix, the data samples of industrial internet of things communication are collected and the following results are obtained:

$$h_{i,j}=d_{i,j}\times|s_{i,j}|\times\varphi \tag{5}$$

Among them, $h_{i,j}$ represents the communication data sample matrix collected in the industrial internet of things environment; $d_{i,j}$ represents the transmission distance between the i communication sample and the j communication sample; and $s_{i,j}$ represents the Gaussian noise attenuation coefficient in communication data transmission, the average of which is 0.

The data vectors in industrial internet of things communication environment are obtained by projection transformation of formula (5) as follows:

$$S = h_{i,j} \times \varphi^T \tag{6}$$

where S represents the vector value of the network data, and T represents the transpose symbol.

Thus, the data sample collection of industrial internet of things communication is realised, and the input conditions and basis for the subsequent construction of industrial internet of things network model are provided.

3 Stable data transmission of industrial internet of things communication based on bat algorithm

The bat algorithm mainly studies is the bat in the detection prey process, may use the sonar to avoid in the detection path the obstruction. The bionic principle of bat algorithm is to map the projection of individual bat with P population to D in multidimensional space, obtain feasible solution, and then use fitness function to evaluate the suitability of bat location, simulate the process of individual bat location as search process or algorithm optimisation process to obtain feasible solution (Maroufi et al., 2020; Huang et al., 2020; Lipare et al., 2021). In order to achieve better results, we need to follow the following principles in the process of building the bat algorithm.

In order to maintain the minimum time and space cost of communication data transmission in the industrial internet of things, the optimal data transmission effect can be achieved. Under the condition that the objective function is minf(x), the variables are mapped to the multidimensional D, and the objective variable is determined to be $X = (x_1, x_2, \cdots, x_D)$, only the optimal solution of the objective function needs to be obtained, the communication data can be transmitted with the least time and space cost.

Assuming that the transmission frequency of the communication data i is f_i, and $f_i \in [f_{min}, f_{max}]$, the corresponding data transmission responsiveness is Y, and the corresponding wavelength range is $[\omega_{min}, \omega_{max}]$, the relationship between the transmission location information W_i^t and the transmission speed V_i^t of the i data sample at the t time is obtained as follows:

$$\begin{cases} f_i = Yf_{min} + \left(f_{max} - f_{min}\right) \\ V_i^t = V_i^{t-1} + f_i\left(x_D - x_i\right)/P \\ W_i^t = W_i^{t-1}\left(\omega_{max} -_{min}\right) + V_i^t f_i \end{cases} \tag{7}$$

In the bat algorithm, if a bat is caught in a local position while searching for prey, it will find a local optimal solution through trial and error (iteration) to get into a new position. For the communication data transmission of the industrial internet of things, in the local search process of the communication data transmission process, it is necessary to find an optimal solution in the local search so as to generate a new data transmission location. The specific process is:

$$W_i^{t+1} = W_i^t + \varepsilon\overline{Y} \tag{8}$$

In equation (8), ε is a set of random parameters, which are generally positive integers; $\overline{Y}$ represents the average responsiveness of all data transmission processes, and this responsiveness is related to the speed of data transmission and the change of location. In general, if the wavelength increases, the responsiveness decreases and an iteration is performed. That is, the set main node value is obtained:

$$Y_i^{t+1} = (x_D - x_i) \times \varepsilon Y_i^t \tag{9}$$

At this point, real-time scheduling results of industrial internet of things communication data can be obtained:

$$J_i^{t+1} = \min f(x) \times J_i^t \times \frac{[\varepsilon\text{-}\exp(f_{max} - f_{min})]}{1 + PY_i^{t+1}} \tag{10}$$

Thus, the real-time scheduling of communication data in industrial internet of things is completed, which provides the basic guarantee for the stable transmission of communication data.

Based on the real-time scheduling of communication data in industrial internet of things, the stable transmission of communication data is realised. In the process of communication data transmission, the differential genetic algorithm in the Bat Algorithm is mainly used. This is because in the Bat Algorithm, there are great differences among different individual bats, and different communication data samples have different characteristics and properties for the communication data transmission of the industrial internet of things (Yang et al., 2021; Sureshkumar and Ponnusamy, 2019). Therefore, the differential genetic algorithm is used to carry out the operation of mutation, crossover and selection on the basis of fully considering the differences among different communication samples, so that the communication data after real-time scheduling is not directly transmitted iteratively, but is iterated after determining whether its position needs to be updated and its transmission position is updated. The initial and real-time positions of the communication data samples are obtained mainly through equation (7). In order to avoid falling into the local optimum, equations (8)–(10) is used to optimise the real-time scheduling and the real-time scheduling results are obtained. Therefore, differential genetic algorithm is used to deal with the mutation, and the data samples to be transmitted are divided into different task groups according to the subtasks, and different task groups are treated differently. The specific methods and steps are as follows:

1. Calculate the fitness of each industrial equipment and transmission sample in the communication environment of the industrial internet of things, and determine the optimal location of the industrial equipment and transmission sample.
2. Obtain the location information, transmission speed and transmission frequency of the data sample by using equation (7).
3. In order to avoid falling into the local optimum, update the location information of the communication data sample.
4. Setting random parameters, updating the fitness iteratively, and completing the real-time scheduling of communication data samples.

5 Compiling the current scheduling results in a differential manner, and updating the latest position of the data samples by compiling, crossing and selecting the initial position information of each data sample.

6 Obtain the fitness again with the new location information, and compare it with the fitness obtained in Step 2, and select the most appropriate fitness value from it.

7 The algorithm shall be terminated after a certain number of iterations. At the same time, the corresponding optimal communication data samples are transmitted, which realises the stable transmission of communication data samples in the industrial internet of things.

4 Experimental analysis

4.1 Experimental scheme

The comparative experiment of this paper is completed in Windows 10 environment, and the transmission range of industrial internet of things communication data is set to 150 × 200. The experimental data selected in this area is 2 GB, and the noise value range of the experimental data is [–2 dB, 2 dB]. In order to ensure the stability of the data in the experiment, the sample communication data is preprocessed at the beginning of the experiment to ensure its effectiveness in the process of the experiment.

This method is compared with the methods presented in Dhasarathan et al. (2020) and Li and Wu (2020), and the experimental results are obtained by comparing the stability, delay and integrity of data transmission.

4.2 Experimental index design

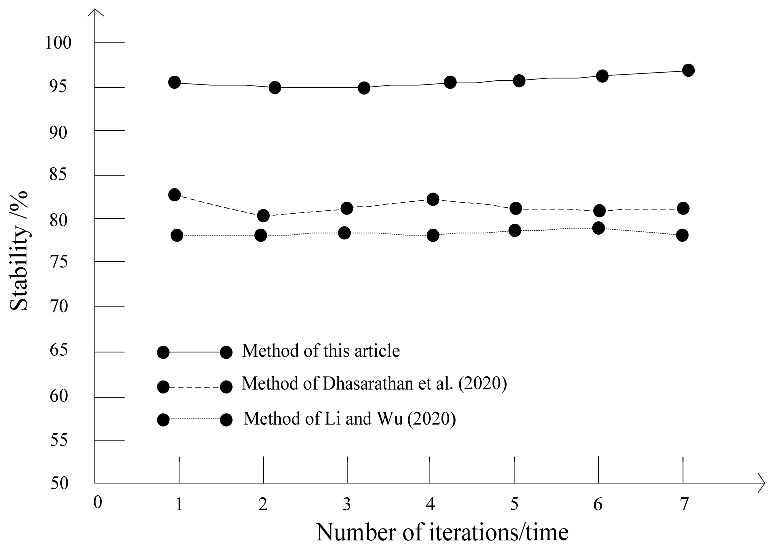
In order to verify the effectiveness of the proposed method, the experimental indicators set in the experiment are industrial internet of things communication data transmission stability, communication delay and communication data transmission integrity. Among them, the integrity of communication data transmission is reflected by the packet loss rate of data.

4.3 Analysis of experimental results

4.3.1 Comparison of communication data transmission stability of industrial internet of things

For the complex structure of the industrial internet of things, the stability is an important indicator of communication data transmission. The stability of communication data transmission is defined as the ratio of the number of communication data samples transmitted steadily in the period range to the total number of communication data samples transmitted in any period range. The comparison between the different methods is shown in Figure 2.

Figure 2 Comparison of data transmission stability



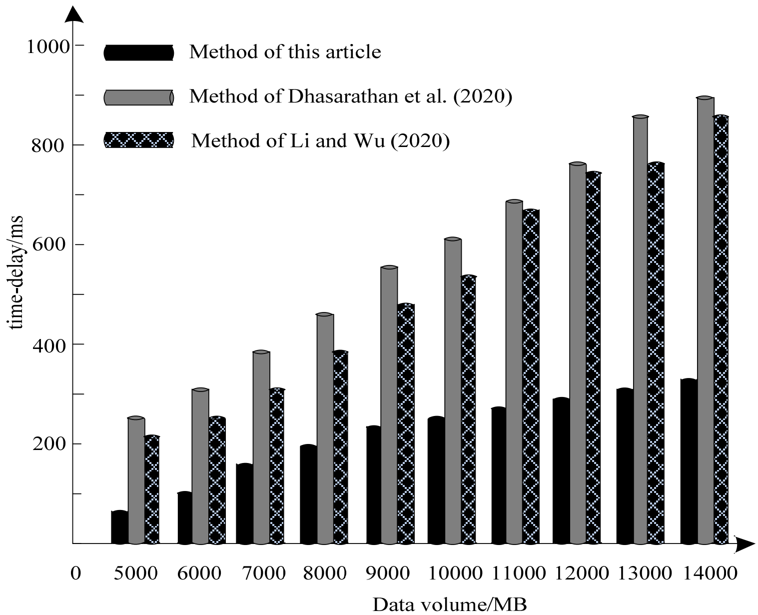
As can be seen from Figure 2, the stability of the proposed method is always above 95%, which shows that the proposed method is more reliable than the two methods in the literature. However, the stability of the methods in Dhasarathan et al. (2020) and Li and Wu (2020) is between 76% and 85%, which indicates that the stability of data transmission is poor in the communication environment of the internet of things, which is not conducive to practical application.

4.3.2 Communication delay verification results

Because there are many equipments connected in industrial internet of things, the data type and amount needed to be transmitted are more, so the faster communication speed is one of the main targets. In order to evaluate the application effect of the methods in this paper, Dhasarathan et al. (2020) and Li and Wu (2020), the communication latency of various methods is calculated in the range of 5,000–14,000 MB. The comparison results of different methods are shown in Figure 3.

As can be seen in Figure 3, the communication latency of the different methods increases with the increase of data volume. The communication data transmission method designed in this paper always has low communication delay, and the overall delay is within 300 ms. However, the two methods in the literature have high communication delay, which does not meet the communication requirements and requirements of the industrial internet of things. This may be due to the different complexity of the algorithm for the complex network structure of the industrial internet of things. Because this method uses the bat algorithm to avoid the communication data falling into the local optimal situation in the transmission process, it has good communication speed. The proposed threshold reduces the computational complexity to a certain extent, which reduces the communication delay relatively.

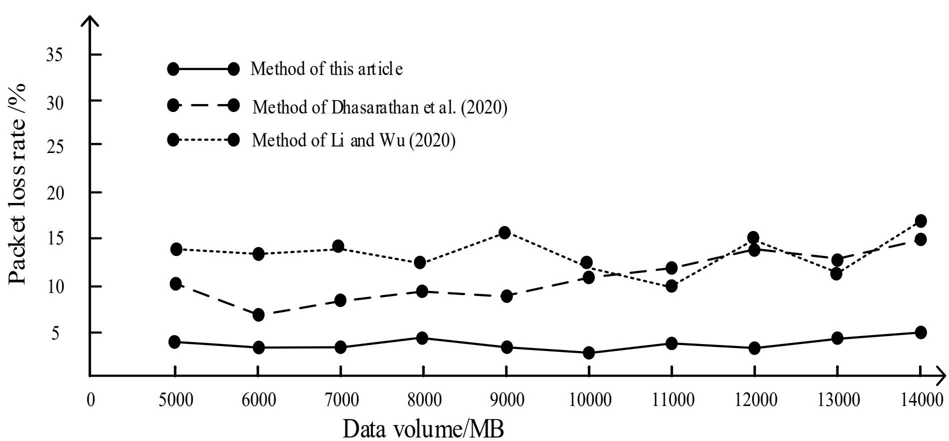
Figure 3 Comparison of communication delay between different methods under different data quantities



4.3.3 Analysis results of communication data transmission integrity

Due to the large amount of data transmitted in the industrial internet of things, the integrity of data information transmission is particularly important. Packet loss is easy to occur in the traditional industrial internet of things data transmission, so the integrity of communication data transmission is detected by packet loss rate. The comparison results of different methods are shown in Figure 4.

Figure 4 Comparison of communication data transmission integrity between different methods



According to Figure 4, it is obvious that the packet loss rate of the proposed method is less than 10% and less than 5% under the condition of increasing communication data in industrial internet of things. The rate of packet loss in Dhasarathan et al. (2020) is between 8% and 15%, and the rate of packet loss in Dhasarathan et al. (2020) is between 10% and 17%. By comparison, this method has obvious advantages in data integrity transmission, which shows that this method can transmit industrial internet of things communication data completely, and has a strong practical application.

5 Conclusions

Aiming at the problems of high delay and poor stability in the communication data transmission process of industrial internet of things, a stable transmission method of industrial internet of things communication data based on bat algorithm is proposed. Based on the collection of communication target data, the industrial internet of things network architecture is constructed, and its stability is optimised and adjusted. Bat algorithm is used to schedule the communication data of industrial internet of things in real-time and avoid falling into local optimisation. Then, the stable transmission of communication data samples is optimised. Experiments show that the designed method has the following advantages:

1 The stability of industrial IOT communication data transmitted by the proposed method is always maintained at more than 95%, which has a certain stability.

2 When using the proposed method to transmit the industrial internet of things communication data, the communication delay is low, and the overall delay is within 300 ms.

3 The packet loss rate of industrial internet of things communication data transmitted by the proposed method is controlled within 5%, which ensures the integrity of the transmitted data.

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