Design of Monitoring System for Electric Vehicle Charging Facilities Based on Cloud Platform

Jian lv

State Grid Zhejiang Electric Vehicle Service Co., Ltd.

Deputy General Manager

E-mail: 1850508590@qq.com

Jingyun Chen

State Grid Zhejiang Electric Vehicle Service Co., Ltd.

Operation Management Department

Bo Li

State Grid Zhejiang Electric Vehicle Service Co., Ltd.

Operation Management Department

Luyu Han

State Grid Zhejiang Electric Vehicle Service Co., Ltd.

Operation Management Department

Abstract—**The cloud platform in the paper was introduced into the monitoring system of electric vehicle charging facilities, and a model of electric vehicle charging facility monitoring system based on cloud platform was proposed. Aiming at the difficulty of charging facility monitoring system in large concurrent data processing, a M/M/C queuing theory model was presented. Data concurrency control algorithm. The transmission process of the data frame in the monitoring system was analyzed, and the concurrent processing algorithm was applied to the large charging station for analysis experiments. The experimental results showed that the proposed algorithm not only satisfied the real-time and concurrency requirements of data frame transmission, but also proved that the gateway optimization method could accurately derive the optimal number of gateways.**

Keywords-Cloud Platform; Charging Facility; Monitoring System

I. INTRODUCTION

With the gradual promotion and use of electric vehicles, which supporting charging and replacing power stations have become essential basic service facilities. At present, charging facilities are mainly divided into three types: power station, charging station and charging pile. The charging and replacing equipment is all high-power electrical equipment. The disorderly usage will increase the peak-to-valley difference of the grid load and bring about harmonic pollution. At the same time, due to the electric vehicle battery has high charging requirements; it is necessary to real-time collect and monitors the data such as voltage, current, power and temperature during the charging process.

The monitoring data of the charging facility is mainly divided into two categories: charger data and battery pack data. The charger data includes voltage, current, and charger fault alarm data; the battery pack data includes module voltage, temperature, battery parameters, battery pack status, and alarm data. According to the national standard of the charger and battery management system communication protocol, the communication server needs to parse about 1 500 CAN protocol frames per second during the charging process of the vehicle battery pack. For a large and medium-sized charging station with 100 chargers, if the charger is working at the same time, the communication server will need to process 150,000 CAN frames per second; which is just the amount of data in the battery pack and does not include monitoring data for the charger[1-2]. If we consider a power station with multiple battery boxes and robots, the amount of real-time data will be even larger. In summary, the difficulty and key point of real-time monitoring of large-scale charging and replacing power

stations is to improve the concurrent processing capability of the monitoring system data, and it is urgent to carry out large-scale data concurrent transmission control research in the monitoring system.

On the basis of the cloud platform, in the paper, we proceeded from the probability analysis of the data frame generation source and demonstrated that the CAN frame generation obeyed the Poisson distribution. On the basis of the establishment of the typical queuing theory M/M/C model, a data concurrency control algorithm based on multi-thread and multi-queue was proposed. The theoretical data processing and experimental analysis were used to demonstrate the data processing and transmission efficiency of the concurrency control algorithm[3].

II. ELECTRIC VEHICLE MONITORING SYSTEM BASED ON CLOUD PLATFORM

The power industry should use the information network as a platform to deeply integrate the physical industry and leverage the advantages of Internet information dissemination to innovate the development ecology of the industry. The cloud platform in the paper was introduced into the monitoring system, and an electric vehicle monitoring system based on the cloud platform was presented, which was mainly composed of two modules: the monitoring system and the cloud service platform, as shown in Figure 1.
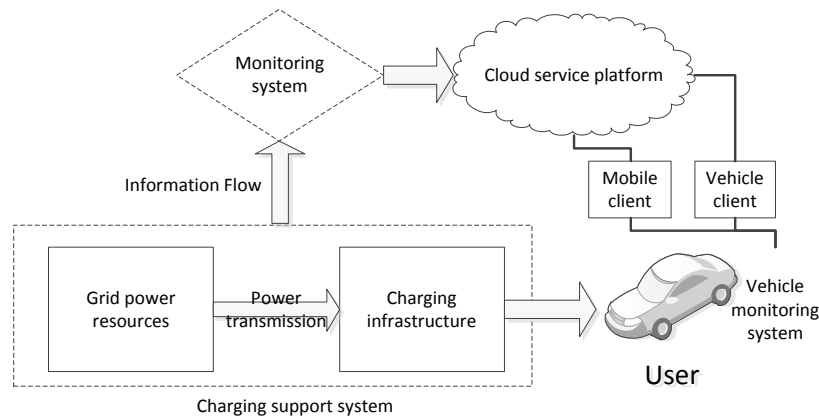

Figure 1.   Intelligent service system structure

A. *Cloud service platform*

The cloud service platform played the role of central control, and linked various macro information exchanges through the network to provide users with real-time information inquiry, charging fee collection, charging facility power grid monitoring and other services. The cloud service platform was the brain and data service center of the whole system, and played a decisive role in the whole system. In the initial stage of advancement, government agencies should formulate development policies, unify technical standards, provide appropriate financial support, and guide various stakeholders to participate to promote orderly integration and coordinated advancement of various subsystems. After the development to maturity, the government should withdraw from the market, only macro-regulation of the industrial chain, and the operation and maintenance of the charging service industry were coordinated by all relevant entities. The complete enterprise cloud platform infrastructure consisted of physical servers, storage systems, networks, and platform software. VMware software with a high market share in the paper was employed[4].

B. *Monitoring system*

The monitoring system could integrate the station charging equipment, battery box replacement equipment, power distribution equipment, video and environmental monitoring equipment, and other intelligent equipment status information, parameter configuration information, charging,

and real-time information of the power exchange process in the station to realize monitor, control and management the equipment, and had the communication function with the superior monitoring management system.

III. MONITORING SYSTEM STRUCTURE

A. Data collection process

The data acquisition process of the monitoring system was shown in Figure 2. The field charger and battery pack data were transmitted to the gateway through the CAN bus. The gateway then packed the CAN data frame into an Ethernet frame format to ensure the reliability and efficiency of data transmission[5].
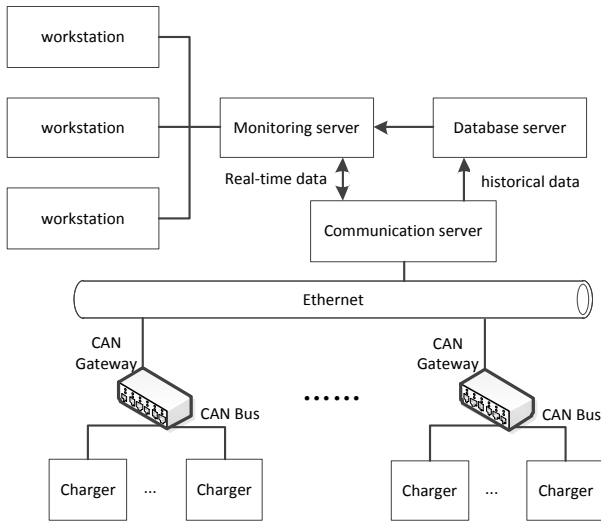

Figure 2.   Charging monitoring system structure

In the monitoring system, the communication server was mainly responsible for three aspects: establishing and maintaining socket connection, CAN frame analysis, and data processing.

B. Probability analysis of data frame generation

Definition1. Data frame arrival probability. Let $N(t)$ be the number of data frames arriving at a CAN gateway within the time interval $[0,t)$, and define $P_n(t_1,t_2)$ as the probability of n data frames arriving within the time interval $[t_1,t_2)$, which was as shown in Equation 1.

$$P_n(t_1,t_2) = P\{N(t_2) - N(t_1) = n\} \quad (t_2 > t_1 \ge 0, n \ge 0) \quad (1)$$

For stand-alone chargers, $N(t)$ satisfied the following conditions.

1)   The arrival of data frames was independent. In the non-overlapping time interval, the generation of the charger data frames was independent of each other, that is, in the process of the data frame reaching the CAN gateway, the arrival situation before t_n had no effect on the arrival situation after t_n, which was called Markov characteristic.

2)   The arrival of the data frame was smooth. For a sufficiently small time $\triangle t$ that was within the time interval $[t, t + \triangle t]$, the number of data frames received by the CAN gateway was independent of t and was proportional to $\triangle t$, which was as shown in Equation 2.

$$P_n(t_1,t_2) = \lambda \triangle t + o(\triangle t) \qquad (2)$$

Where λ was a constant, it indicated the probability that a data frame arrived at the CAN gateway per unit time, which was called the probability strength; $o(\triangle t)$ was the high-order infinitesimal of $\triangle t$.

3)   The arrival of data frames in c was universal. For a sufficiently small time $\triangle t$, the probability of having 2 or more data frames arriving was so small that it could be considered equal to 0, which was as shown in Equation 3.

$$\sum_{n=2}^{\infty} P(t, t + \triangle t) = o(\triangle t) \qquad (3)$$

Theorem 1. For the number $\{N(t), t \ge 0\}$ of data frames arriving at the CAN gateway, which its arrival probability $P_n(t)$ obeyed the Poisson distribution, as shown in Equation 4.

$$P_n(t) = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \quad t \ge 0, n = 0,1,... \qquad (4)$$

Where $P_n(t)$ was the probability that n data frames arrived at the CAN gateway within time interval t, and its mathematical expectation and variance were $E(N(t)) = \lambda t$ and $D(N(t)) = \lambda t$, respectively.

The proof process was as follows:

From condition (1), it was acquired that $P_n(t, t + \vartriangle t) = P_n(0, t + \vartriangle t)$ in a certain time interval $[0, t + \vartriangle t]$ from time 0.

C. Data frame concurrent processing model based on M / M / C

The data concurrency processing algorithm based on M/M/C queuing theory adopted multi-thread and single-queue processing mechanism, that is, data frame listening, receiving and transmitting were multi-thread processing, and data frame receiving and request queues were two-level buffer single-queue structure. The algorithm structure was shown in Figure 3.
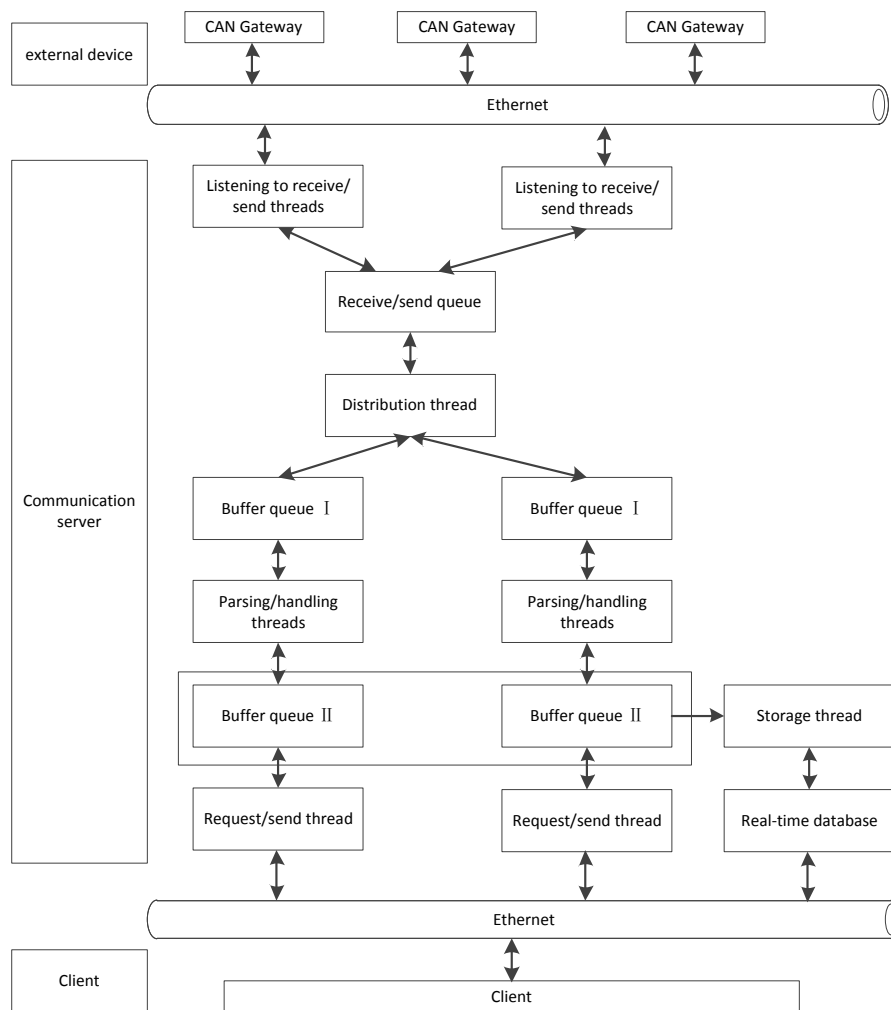

Figure 3.   Concurrency Control Algorithm Structure Based on Standard M/M/C Service Model

The idea of the algorithm was to treat the processing of CAN data frames as a queuing system. The input of each queue is a CAN data frame, and the service organization was a CAN gateway. The queuing rules of a single-queue, parallel multi-service desk model were adopted.

IV. EXPERIMENT ANALYSIS

The concurrent processing algorithm was applied to a large and medium-sized charging station with 60 chargers. The monitoring server CAN data frame arrival rate was $\lambda = 105 \, f/s$, and 12 CAN gateways were used for data frame transmission and reception, and the data processing rate of the average service of each gateway was $\mu = 1.2 \times 104 \, f/s$, Then the service strength was $P = 10/14.4 = 0.69 < 1$, which meted the requirements. The idle probability of the CAN gateway data sending and receiving threads was

$$P_o = \frac{1}{\sum\limits_{k=0}^{11}\frac{8.33^k}{k!} + \frac{1}{12!} \times \frac{1}{1-0.69} \times 8.33^{12}} = 0.023\%$$

The number of CAN data frames waiting to be sent in the send queue was

$$L_q = \frac{8.33^{12} \times 0.69}{12!(1-0.69)^2} \times 0.023 = 0.3985$$

$$L_s = L_q + \frac{\lambda}{\mu} = 8.7285$$

The waiting time and stay time expectation values of the data frame in the systemare, respectively, were

$$W_q = \frac{0.3985}{100000} = 0.004 \, ms \text{,} \quad W_s = \frac{8.7285}{100000} = 0.087 \, ms$$

Probability of waiting after a data frame was reached,which was

$$P(n \geq 12) = \frac{\rho^c}{c!(1-\rho_s)}P_0 = \frac{8.33^{12}}{12! \times (1-0.69)} \times 0.023 = 17.56\%$$

It could be seen from the calculation results that, first, The CAN gateway transceiver thread idle rate was very low, and the device utilization rate was very high; second, the stay time of the CAN data frame in the system was only $0.087 \, ms$, that is, the waiting time of a short message from generation to transmission is almost 0. Which showed that its real-time performance was very high; finally, the waiting probability of CAN data frames was only 17%, which most data frames were forwarded and processed immediately after arrival.

The three types of loss costs c_1 , c_2 with the corresponding optimal number of gateways c^* were analyzed, which was as shown in Table 1.

TABLE I. RELATIONSHIP BETWEEN LOSS WEIGHT AND OPTIMAL NUMBER OF GATEWAYS

Group	c_1	c_2	c^*
First group	0.5	0.5	11
Second Group	0.6	0.4	13
Third group	0.9	0.2	15

The relationship between the cost of loss and the number of gateways, as well as the number of gateways and the length of the queue were tested in the paper. The experimental results were shown in Figure 4 and Figure 5.
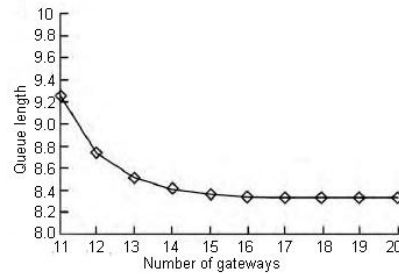

Figure 4. The relationship between the queue length and the number of gateways
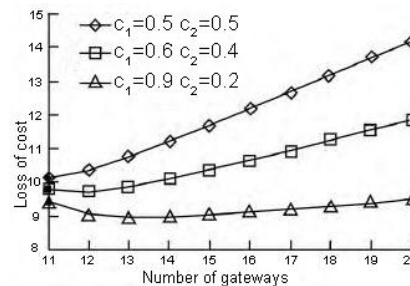

Figure 5. The relationship between the cost of loss and the number of gateways

As could be seen from the figure, the queue length decreased as the number of gateways increased, and there were fewer data frames waiting to be queued in the system, which increasing the number of gateways could improve system performance. However, when the number of gateways increased to a certain value, the queue length would not change any more; which increasing the number of gateways would not increase the system performance

without limit, and wasted resources and increased the cost of the system.

It could be seen from both the theoretical results and the experimental results that when the loss cost value of the discarded data frame was high (namely, $c_1 \geq c_2$), the communication server was in a busy period, and more data frames were entered into the server. In order to reduce the fact that data frames could not be transmitted in time, and were then discarded; more gateways were needed to receive, so as to avoid the impact on the real-time communication.

When c_1 was small, it indicated that the communication server was in an idle period, and there were fewer data frames entering the system, which did not require more gateways. Although there was no packet loss in this case, the system resource utilization rate was not high. In addition, it could be seen from the results of the three groups that the optimal number of gateways obtained by theoretical analysis was in complete agreement with the experimental results.

V. CONCLUSION

In the paper, the data acquisition process in the charging station monitoring system was deeply analyzed, and it was found that solving the real-time and concurrency problems of the system was the key to improving system performance. Through the probabilistic analysis of the source of data frames, it was demonstrated that the generation and arrival of data frames obeyed the Poisson distribution, thus a concurrency control algorithm model based on M/M/c queuing theory was established. On the basis of the model, the real-time concurrent processing of CAN data frames was realized based on multi-thread and buffer queue technology.

ACKNOWLEDGEMENT

REFERENCES:

[1] Bohm P. Incremental Modelling and Verification of the PCI Express Transaction Layer[C]/ / Proceedings of the 7 the International Conference on Formal Methods and Models for Co-design. Washington D. C.,USA:IEEEPress, 2009.

[2] Bohm P. Incremental and Verified Modeling of the PCI Express Protocol[J]. IEEE Transactions on Computer-aided Design of Integrated Circuits and Systems, 2010,29(10):1495-1508.

[3] Zhou Yanhong, Wang Tiancheng, Lv Tao, et al. Path Constraint Solving Based Test Generation for Hard-to-Reach States[C]/ / Proceedings of the22nd Asian Test Symposium. Washington D. C.,USA:IEEE Press, 2013:239-244.

[4] Zhou Jun, Wang Tiancheng, Li Huawei, et al. Survey of Verification Techniques for Network-on-Chip of Multi-core Processors[C]/ / Proceedings of the15th Chinese Fault Tolerant Computing Conference. Washington D. C.,USA:IEEE Press, 2013:33-39.

[5] Schubert K D, Roesner W, Ludden J M, et al. Functional Verification of the IBM POWER7Microprocessor andPOWER7Multiprocessor Systems[J]. IBM Journal of Research and Development, 2011,55(3):1-17.