Ship Fuel Usage Monitoring System Based on Big Data Technoloy

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Abstract: In order to meet the compulsory requirements of IMO on fuel consumption data recorded by ships, the monitoring parameter set based on ship oil-engine-environment system was analyzed in this paper and a fuel consumption monitoring system based on big data technology was established. In this paper, the factors affecting the fuel consumption of marine power plant and navigation environment are discussed, it presents the monitoring modes of instantaneous fuel consumption, displacement fuel consumption and average fuel consumption of ships, then uses zigbee technology to build a monitoring network with adaptive function and designs a method of network formation and transformation and an algorithm of network time synchronization.

1 INTRODUCTION

The 69th meeting of the IMO Marine and Environmental Committee (MEPC) raised the mandatory requirement for ships to record and report their fuel consumption figures. According to IMO regulations, the data on fuel consumption collected by the ship is reported to the flag State at the end of each calendar year and the flag State then forwards the data to the IMO Ship Fuel Consumption Database（IMO Ship Fuel Consumption Database). The IMO will then conduct data analysis and provide SEEA with environmental, energy efficiency and other analytical results. The mandatory data collection requirements are passed at the 70th SEA. As a general rule, the mechanism should be implemented after the amendment enters into force. The first reporting period should be 2019, which will have an impact on the fuel consumption of the ship's management monitoring and improving energy efficiency measures put forward higher requirements. Ship management, fuel management is long-standing problem management staff affected by the vagaries of the marine environment, the vessel has a fuel consumption of "uncertainty, difficult to manage," the phenomenon[1]. Traditional monitoring of ship fuel consumption only considers the economy of marine power plant, but due to the fact that it is affected by the performance and natural conditions of diesel engine, the factors such as cargo turnover, transportation cost and emission performance must be considered. Therefore, a big data set, the introduction of big data technology in fuel consumption management is an effective way. Fuel management of big data technologies include ship resource acquisition, storage management, mining analysis, visualization techniques to show, in view of the self-organizing, fault tolerance and flexible networking of wireless sensor networks. It designed ships fuel monitoring system that based on big data technology to effectively solve the problem of the applicability of fuel consumption monitoring.

2 BIG DATA SET BASED ON SHIP OIL-ENGINE-ENVIRONMENT SYSTEM

Ship fuel consumption management big data set refers to all the possible data used in decision-making fuel consumption problem. It is characterized by a huge amount of data, diverse sources, diverse types. It is a complicated comprehensive plan of oil-engine-environment, Ship fuel consumption is a collection IMO proposed the use of large data sets and large data support the consumption decision-making activities[2]. In order to get under what circumstances the ship is fuel-efficient, and how to adjust to a fuel-saving state, it is necessary to conduct investigation, statistics and analysis on fuel consumption of different areas and types of ships so as to determine the factors affecting the fuel consumption of the ship. In order to describe these factors more clearly, these factors can be divided into oil-engine-environment system and the structure shown in Figure 1.

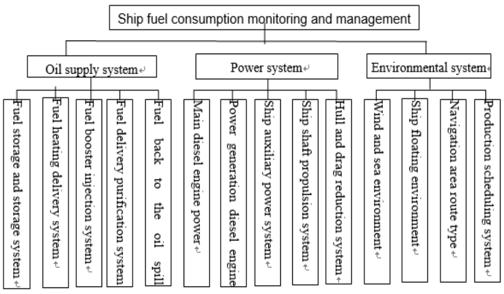

Figure 1． Ship oil - machine - environment system diagram.

There is no doubt, if we take a single monitor fuel flow and calculated manner, the actual situation is that accurate measurement is difficult to achieve. Although precise measurement of the actual ship fuel consumption is difficult, but measurable parameter is very large, therefore, can be collected according to the ship and the parameter value related to fuel consumption, the use of large data processing technology on the ship fuel consumption value is determined and data processing, to obtain a more precise Fuel consumption value.

3.SHIP FUEL CONSUMPTION MONITORING PARAMETERS ANALYSIS

In the ship oil - machine - environment system, the subsystems actually have an impact on fuel consumption in a coordinated manner. To accommodate the diversity required data on fuel consumption, it is necessary to change the sampling frequency parameters flexible fuel consumption monitoring mode, the adjustment of the correlation between the large parameter data, set the number of system subsystems m, use Q_i for a parameter in the system, this subsystem affects the size of the ship's fuel consumption, due to the system's relevance, any Q_i will be affected by Q_1 to Q_m, thus Q_i is a function of all. Also any Q_i is affected by all other Q_i and systems, this effect can be expressed by equation (1). According to different fuel consumption monitoring methods, pick n subsystems to form equation (2), The steady state of the system is again characterized by the disappearance of the variable $\frac{dQ_i}{dt}$, which can be described by equation (3).

$$\begin{cases} \frac{dQ_1}{dt}=f_1(Q_1,Q_2,\dots Q_m) \\ \frac{dQ_2}{dt}=f_2(Q_1,Q_2,\dots Q_m) \\ \vdots \\ \frac{dQ_m}{dt}=f_m(Q_1,Q_2,\dots Q_m) \end{cases} (1) \Rightarrow \begin{cases} \frac{dQ_1}{dt}=f_1(Q_1,Q_2,\dots Q_n) \\ \frac{dQ_2}{dt}=f_2(Q_1,Q_2,\dots Q_n) \\ \vdots \\ \frac{dQ_n}{dt}=f_n(Q_1,Q_2,\dots Q_n) \end{cases} (2) \Rightarrow \begin{cases} f_1(Q_1,Q_2,\dots Q_n)=0 \\ f_2(Q_1,Q_2,\dots Q_n)=0 \\ \vdots \\ f_n(Q_1,Q_2,\dots Q_n)=0 \end{cases} (3)$$

Among them, equation (3) has many sets of solutions, which represent the existence of a number of states of the system, which is the mathematical model for calculating the fuel consumption of ships.

It can be seen from the above that the interaction between the parameters collected and monitored by the fuel consumption monitoring system of the ship is coupled with each other, and the appropriate acquisition precision and frequency must be selected and adjusted in real time according to the correlation between the parameters. Therefore, this system selects the acquisition system based on the ZigBee chip of the internet of things. ZigBee technology is a short-range wireless communication technology with uniform technical standards, and can coordinate and communicate among many tiny sensors. The technology uses the 2.4-GHz IEEE 802.15.4 standard, it is a standard which is a wireless network protocol control network designed for the low-rate, typically has three topologies: Star, Mesh, and Cluster Tree are shown in Figure 2:

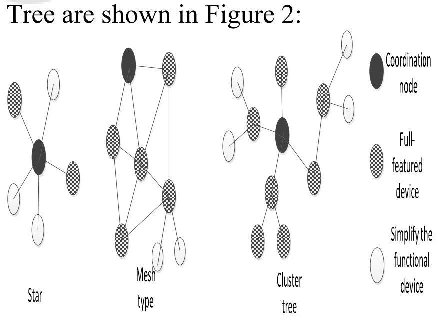

Figure 2． Zigbee network structure.

Star network topology networking technology is simple, but its communication range is very limited; Mesh network topology using peer-to-peer peer-to-peer communications, the router will not only send beacons on a regular basis, but also can improve network fault tolerance, However, the problem of time synchronization and the adaptability of the network must be solved. Because the cluster tree network topology facilitates the synchronization by periodically sending beacons, it can reduce system power consumption and extend the life of the entire network. In the marine fuel consumption monitoring system network structure, due to the great difference between the acquisition accuracy of various monitoring parameters and the frequency, in order to improve the computational efficiency of the network, so, it is necessary to adopt the corresponding network structure according to the fuel consumption calculation demand.

4 BIG DATA BASED FUEL CONSUMPTION MONITORING NETWORK DESIGN

3.1 Monitoring Network Formation Requirements

At present, not only the IMO put forward the fuel data collection requirements, but also the EU MRV regulations regulate the annual fuel consumption, CO_2 emission and shipping management of the ship. China has also formulated the fuel consumption calculation and evaluation for shipping vessels National Standard (GB7187.1-2010), which takes into account factors such as speed of ship, navigation environment, oil, loading and distance[4]. In order to meet the requirements of these codes, the system adopts the following data processing modes of fuel consumption .

1) A power plant operating conditions calculated instantaneous fuel consumption rate. By means of the power failure identification instantaneous fuel consumption of ships, such as oil, or deterioration of combustion state, the instantaneous consumption rate of the main propulsion device by monitoring the main parameters calculated with high accuracy and the sampling frequency acquisition requirements.

2) Ship fuel consumption value is calculated from the displacement conditions of ship sailing. The optimum working point of ship power plant performance can be calculated by displacement oil consumption value. The displacement fuel consumption value is mainly calculated by monitoring the ship sailing performance parameters, which has lower acquisition precision and sampling frequency requirements.

3) Calculate the average ship oil consumption according to the ship's operation management. Based on this value, the operation mode and speed of the ship can be optimized and managed. The average fuel consumption can be obtained by data fusion using instantaneous fuel consumption and displacement fuel consumption.

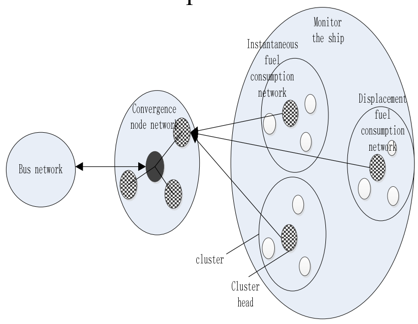

Figure 3． Ship fuel consumption monitoring system structure.

In order to adapt to the different fuel consumption monitoring modes of the above ships, this system designs a multi-hop self-organizing monitoring network with adaptive function so that the network can be transformed in network, tree, star and other models to meet the needs, as shown in Figure 3 .

In Figure 3, the system consists of a control center, a wireless network, a sink node and a cluster node network. A plurality of sensors in the fuel consumption parameter of the ship form a cluster, and each cluster has a cluster head node. The collected data is transmitted to the cluster head node first. Then transmitted to the sink node of the network. The cluster head node represents the specific fuel consumption value calculated by the sensor network. The sink node receives the data transmitted by each cluster and transmits the data to the control center through the wireless network. The control center calculates various fuel consumption values by using various big data fusion algorithms.

3.2 Monitoring Network Formation Method

In the established sensor network, the data sampling accuracy and sampling frequency of different cluster nodes network are different, and the influence weight of network output value on fuel consumption value is also not the same. Therefore, according to the influence weight of network output on fuel consumption value to select monitoring network. Considering the many factors that affect the cluster node weight, including the accuracy, relevance and sensitivity of the monitoring parameters, it is difficult to accurately measure the weight of cluster nodes. Therefore, this paper adopts the weight adjustment process based on the minimum variance of fuel consumption, as shown in Figure 4 .

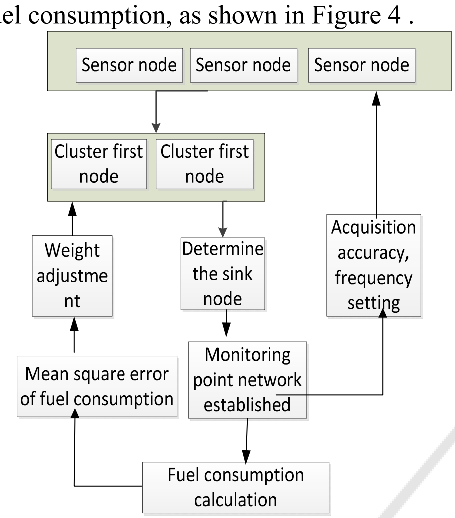

Figure 4 . Sensor network formation process.

1.Each cluster head node based fuel consumption are measured $X_1, X_2, \cdots X_n$, the corresponding weights are $\omega_1, \omega_2, \cdots \omega_n$, the measurement variance are σ_1^2, $\sigma_2^2, \cdots \sigma_n^2$,the weighted fusion algorithm of nodes in a cluster is used to calculate the fuel consumption value as $\hat{x} = \sum_{i=1}^{n} \omega_i X_i$,network output value of the mean square error can be expressed as:

$$\sigma^2 = E((x - \hat{x})^2) = \sum_{i=1}^{n} \omega_i^2 \sigma_i^2 \tag{4}$$

2. In order to minimize the mean square error of the network output value, we should minimize the value of σ^2 when calculating the weight value. The Lagrangeian adjoint equation can be established by solving Lagrange's extremum value:

$$f\left(\omega_1, \cdots \omega_{n,} \lambda\right) = \sum_{i=1}^{n} \omega_i \sigma_i^2 - \lambda \left(\sum_{i=1}^{n} \omega_i - 1 \right) \tag{5}$$

The equation can be obtained on the node optimized weighting coefficients, according to the weight and thus the formation of sensor nodes in the network, so that the fuel consumption of the network output of the right weight accuracy and frequency match network data collection, monitoring to ensure the accuracy of fuel consumption.

3.3 Network Time Synchronization Method

In the ZigBee mesh topology constructed by this system, because the router does not send beacons periodically, the unicast beacons are only required when the equipment in the network requires it. Although the fault tolerance of the network is improved, the nodes in the network. It is difficult to achieve synchronization; on the other hand, due to the different frequency of data collection in different cluster networks, to improve the effectiveness of data fusion of fuel consumption, we must solve the time synchronization problem of node network. Currently ZigBee network clock synchronization algorithm mainly RBS synchronization algorithm, PSN synchronization algorithm, LTS algorithm, etc., the system uses a DMTS algorithm, the algorithm mechanism shown in Figure 5.

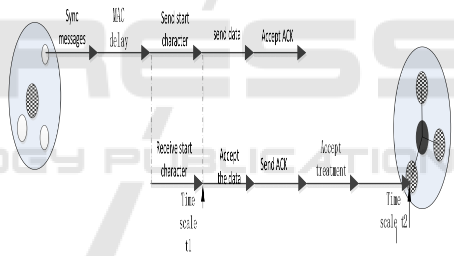

Figure 5 .Time synchronization algorithm

In FIG. 5, when the channel is idle, the sink node adds the current timestamp 1, the start character and the preamble to the broadcast data packet, sets the sent information as 2 bits and sends the required time for each bit as 3, calculate the start character and preamble sending time is 4, the receiving node in the broadcast packet arrival time stamp 5, record the time at this time 6, then the receiving end of the receiving processing delay is 7, and then adjust their own clock is 8 . The receiving node adjusts the clock from 9 to 10. This clock through the receiving node to adjust the entire network to achieve the time synchronization.

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5 CONCLUSIONS

In order to meet the requirements of IMO for ships to collect fuel consumption data, energy efficiency management of ships is strengthened. In this paper, aiming at the present situation of fuel consumption deviation caused by the influence of fuel system, power plant and navigation environment on ships, a fuel consumption monitoring and management system based on big data is designed. Based on the analysis of oil-engine-environment-based monitoring model of ship fuel consumption and corresponding network requirements of nodes, a multi-hop self-organizing monitoring network with adaptive function was constructed by using zigbee technology to ensure fault tolerance and flexibility. In this paper, a weight-based data fusion method is used to set up and transform the network. At the same time, the network time synchronization algorithm is used to ensure the validity of the data. This method can be applied to both oil consumption monitoring under various ship operating conditions. And it also satisfies the needs of current ship fuel consumption monitoring and management.

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APPENDIX

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