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STUDY ON THE OPTIMIZATION AND PERFORMANCE OF TDMA ALLOCATION ALGORITHM IN SHIPS' AD HOC NETWORKS

Xiaofeng Han, Ph. D.[1]
Yan Li, Ph. D.[2]
Guodong Liu, Ph. D.[3]
[1] College of Mathematics and Systems Science, Shandong University of Science and Technology, Qingdao 266590, China
[2] College of Electrical Engineering and Automation, Shandong University of Science and Technology, Qingdao 266590, China
[3] Jinan Branch, Shandong University of Science and Technology,Jinan 250031,China

ABSTRACT

This paper analyzes the requirements of the information transmission network of ship integrated condition monitoring system, and proposes a design scheme of ship condition monitoring system based on wireless ad hoc network. The wireless ad hoc network protocol was designed, its networking process was analyzed in detail, and the network transmission performance of the monitoring system was tested. The results proved the feasibility of the system. The above solution can be used for the transmission of ship state information that satisfies the requirements of wireless transmission, and has important theoretical and practical significance. The slot allocation algorithm has been receiving extensive attention as an important part of the TDMA system research. This paper analyzes the summarization and summarization of TDMA time slot assignment algorithms from several aspects such as slot synchronization, existing slot allocation algorithm, and slot assignment model, laying an important foundation for researchers to do further research. In the TDMA system, time is divided into non-overlapping time frames, and the time frames are divided into non-overlapping time slots. Each node in the network performs corresponding operations in each time slot.

Keywords: Timeslot allocation algorithm; Ships; Ad hoc network

INTRODUCTION

The number and types of ships in China have also been continuously developed. Therefore, the application of modern technologies to enhance the ship's own safety management has always been an important research field for shipping safety. The ship navigation safety state real-time monitoring system is a combination of sensing technology, network technology, and computer technology to realize the safety status of the hull structure, the ship loading status, the cabin and the cab environment. Provides the analysis and control basis for the safe operation of the ship, as well as the early danger alarm and damage assessment, thus greatly enhancing the overall monitoring system for the survivability of the ship [1,2,3]. For a long time, all kinds of state signal transmission networks have been based on fieldbus technology. Due to the limited space on the ship, the cables on the ship were laid too much, which caused difficulties in troubleshooting and overhauling. How to reduce the laying of cable networks and improve the transmission capacity of ship status information is a hot topic in recent years. Because it does not require wiring, it can be dynamically networked, so since its debut, it has been favored by all walks of life. If the wireless sensor network can be applied to the collection of state of ships and the transmission of some state signals of ships suitable for wireless transmission, the wiring of the ship's wired network will be effectively reduced, and the dynamic joining or withdrawal capabilities of its monitoring objects will be improved. In this way, a more scientific and reasonable form of shipbuilding networking can be achieved, providing a more convenient way for the condition monitoring and network maintenance of ships [4,5,6]. Based on the above ideas, this paper proposes a ship integrated condition monitoring system based on wireless ad hoc networks. The self-organizing principle of the networking and the networking process are analyzed in detail, and the performance of the networking is tested specifically. This provides a new solution for the development of the ship status monitoring system [7,8,9].

In actual operation, the sensor node is mainly responsible for collecting various status data of the ship monitoring area, and after parsing and encoding the collected data, it is transmitted to the upper routing node through the ad hoc network. The routing node is responsible for forwarding the received data and managing the sensor nodes, and then transmitting the vessel status data to the upper routing node or aggregation node. The aggregation node transmits the status data of the ship to the ship comprehensive condition monitoring and management platform through the serial port. The ship status monitoring and management platform is responsible for analyzing, storing and displaying these data, and is also responsible for managing the nodes in the network. In addition, the platform also provides mobile terminal services to facilitate the management personnel to view the status information of the ship in real time through the Android client anytime anywhere [10,11,12]. The above hierarchical structure can greatly reduce the complexity of the network and can also reduce the power consumption of the terminal nodes. The sink node and the routing node do not have the requirement of low power consumption, and are set to remain in the information receiving state during their idle time. The sensor node works in the dormant state most of the time, and periodically sends wake-up information and heartbeat information.

In addition, the sink node does not directly communicate with the sensor node. The sensor node and the sensor node do not need to communicate with each other, which reduces the complexity of the network and reduces the power consumption. All nodes in the sensor network have unique physical addresses. Common channels and general physical addresses are used for broadcast and private physical addresses are used for unicast. The design of the system's routing protocol relates to the performance and quality of the network. Therefore, the network topology of this system adopts the form of hierarchical clustering. In this paper, the sensor nodes are roughly distributed in the nacelle, compartment and so on [13,14,15]. According to the regional distribution of sensor nodes, sensor nodes located in the same area form a cluster. If the sensor nodes in the same area are distributed more, they are divided into multiple groups. After receiving the networking command from the vessel condition monitoring and management platform, the sink node starts listening to the requesting network access information in the network. After receiving the network access request information of the routing node, if the address space of the child node of the convergence node is not full, it is allowed to access the network, the network address of the corresponding routing node is allocated, and the routing node is returned. After a successful network access, the routing node is listening and receives information from other nodes. Then, after the sensor node is powered on, it starts sending network requests. The routing node checks its address space after receiving the information. When the address space is not full, the child node information is returned and its network address is assigned to allow access. When the address space is full, its access to the network is denied.

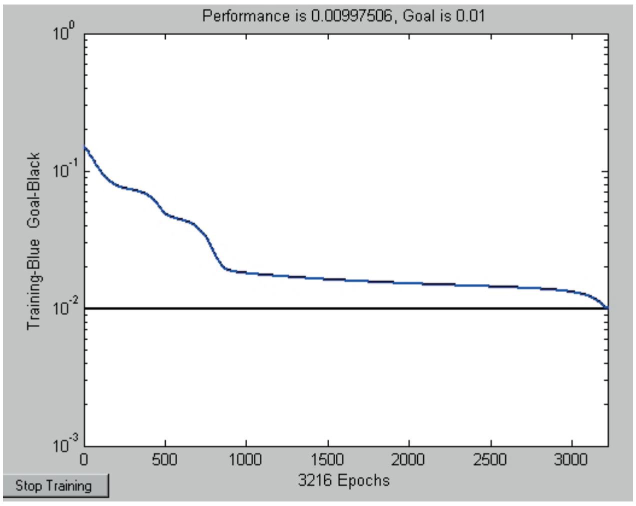

Fig. 1. TDMA-based fixed slot allocation algorithm frame structure

HOC NETWORK PROTOCOL DESIGN

Before the routing node accesses the network, the communication process sends a network request to the routing node in broadcast mode. After receiving the request, the aggregation node processes the message format and determines whether the node address is full. If the address space of the child node is not full, the incoming network information is immediately restored. The information includes the network address assigned to this routing node by the parent node. After receiving the reply message from the sink node, the routing node replies with an ACK and sets the network address of this routing node as the network address allocated by the sink node. If the address space of the sub-node in the sink node is full, the sub-node is denied access to the network. After the routing node successfully enters the network, the aggregation node and the routing node use the network address to communicate, that is, complete the communication process in the form of private signaling. The current family of wireless ad hoc network routing protocols is very large, but none of them are specifically designed for ship ad hoc networks. However, because there is a commonality between the ad hoc network and the wireless ad hoc network, the latter's routing protocols can also be applied directly to the former or can be applied to the former in the light of specific marine scenarios. This chapter begins with the analysis of the requirements of the ship's ad hoc network, studies and compares the advantages and disadvantages of the current routing protocol applied to it, and selects a more suitable routing protocol; Then, based on the requirements, the best route for the current routing metrics cannot be selected, and it is difficult to deal with the insufficiencies of the complex and ever-changing marine transmission environment, and a route improvement scheme is proposed.

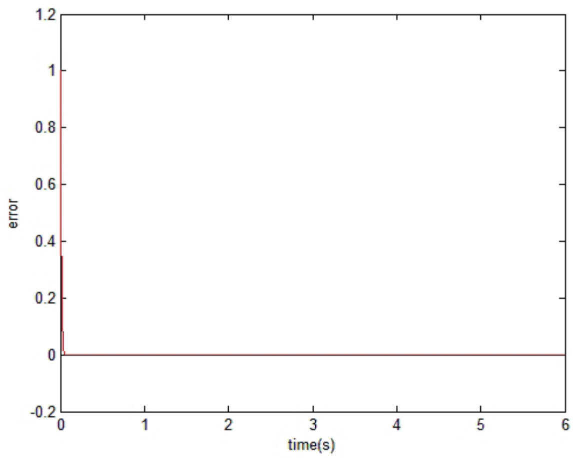

Fig. 2. Allocation based on MAC protocol performance

As an improved version of the OLSR routing protocol, MP-OLSR inherits its advantages of establishing a convenient and rapid route. It also made full use of network resources by adopting multiplexing, and it also added route repair and loop detection mechanisms, which improved the stability of the transmission and effectively reduced the delay. We believe that MP-OLSR can also play its own advantages in marine ad hoc networks with ocean backgrounds, and have better performance than OLSR. Therefore, it is the basis of the agreement. With the increasing demand for maritime Internet access, Ocean Internet has emerged, but it is still in its infancy. In order to meet the needs of marine safety, marine information, and the needs of offshore operators, the development of the Ocean Internet is of strategic importance. However, the traditional idea of land-based Internet construction is not suitable for promotion to the sea because of its vast sea area and the lack or even the inability to lay down infrastructure. At this time, using a ship's device to easily form a ship ad hoc network in a sea area is an idea for the development of the maritime Internet, among which, routing protocols are one of the key technologies.

SHIP INTEGRATED CONDITION MONITORING SYSTEM

In actual operation, the sensor node is mainly responsible for collecting various status data of the ship monitoring area, and after parsing and encoding the collected data, it is transmitted to the upper routing node through the ad hoc network. The routing node is responsible for forwarding the received data and managing the sensor nodes, and then transmitting the vessel status data to the upper routing node or aggregation node. The aggregation node transmits the status data of the ship to the ship comprehensive condition monitoring and management platform through the serial port. The ship status monitoring and management platform is responsible for analyzing, storing and displaying these data, and is also responsible for managing the nodes in the network. In addition, the platform also provides mobile terminal services to facilitate the management personnel to view the status information of the ship in real time through the Android client anytime anywhere. The above hierarchical structure can greatly reduce the complexity of the network and can also reduce the power consumption of the terminal nodes. The sink node and the routing node do not have the requirement of low power consumption, and are set to remain in the information receiving state during their idle time. The sensor node works in the dormant state most of the time, and periodically sends wake-up information and heartbeat information. In addition, the sink node does not directly communicate with the sensor node. The sensor node and the sensor node do not need to communicate with each other, which reduces the complexity of the network and reduces the power consumption.

All nodes in the sensor network have unique physical addresses. Common channels and general physical addresses are used for broadcast and private physical addresses are used for unicast. Before the routing node accesses the network, the communication process sends a network request to the routing node in broadcast mode. After receiving the request, the aggregation node processes the message format and determines whether the node address is full. After receiving the reply message from the sink node, the routing node replies with an ACK and sets the network address of this routing node as the network address allocated by the sink node. If the address space of the sub-node in the sink node is full, the sub-node is denied access to the network. After the routing node is successfully connected to the network, the aggregation node and the routing node communicate using the network address. The design of the system's routing protocol relates to the performance and quality of the network. Therefore, the network topology of this system adopts the form of hierarchical clustering. In this paper, the sensor nodes are roughly distributed in the nacelle, engine compartment and so on. According to the regional distribution of sensor nodes, sensor nodes located in the same area form a cluster. If the sensor nodes in the same area are distributed more, they are divided into multiple groups.

Based on the characteristics of actual tasks, the analysis of the data network requirements of the network clearly identifies the type and number of NPG members, the frequency of messages sent by members, throughput estimation during system operation, message update rate, and relay opening sequence. This results in the requirement of time slots for the members, and then estimates the size of the time slot blocks required by each NPG, and allocates them accordingly. Although the research of the ship's ad hoc network has just started, the research of the wireless ad hoc network has been very in-depth. As one of them, the ship self-organizing network can learn from the latter's research results and combine its own characteristics to develop a theoretical system with its own characteristics. The same is true for ship ad hoc routing protocols. This chapter will introduce the characteristics of the ad hoc network from the aspects of the characteristics of wireless ad hoc networks, the characteristics of marine scenes, the characteristics of ships, and the architecture of ship ad hoc networks. Subsequently, the ship ad-hoc network routing protocol was introduced, including its main categories and routing metrics. Finally, two protocols, OLSR and MP-OLSR, were highlighted.

Vessel ad hoc network is a kind of wireless ad hoc network, which has all the characteristics of the latter. Due to its dependence on the marine background, the ship is a mobile node. Compared with the wireless ad hoc network in the general sense, it has other special properties. The status of each node in the wireless ad hoc network is equal, and each node is a receiving and sending terminal as well as a relay route. Due to their mobility, they enter or leave the network frequently and do not need to inform others in the network in advance. Their entry or departure will not affect the communication between other members. Nodes collaborate through wireless links to exchange and transfer data. Due to the limited transmit power, the source node and the destination node may not be able to directly communicate with each other, and it is necessary to rely on multiple relays of other nodes of the network to transfer data packets. Accordingly, a routing protocol is also required for packet forwarding decision.

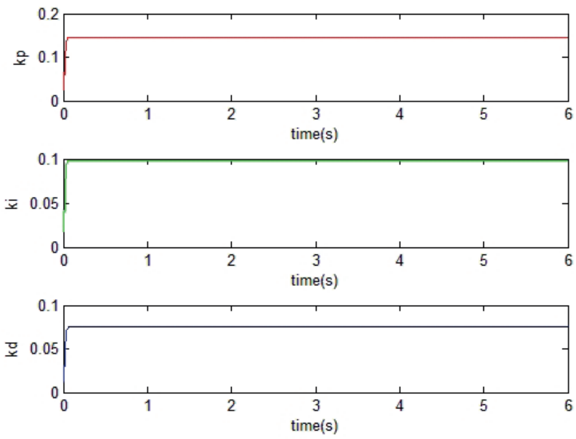

Fig. 3. NS2 mobile node structure diagram

This routing protocol requires each node to maintain the link state of each member of the network at any time. It is a distributed routing protocol, so there is no requirement for a control center to reliably transmit routing control information. The information available in the marine communications environment is not limited to the quality of the link, including the location of the vessel. Subsequent protocols can use the position information of the vessel as a reference condition for routing and optimize the performance of the routing protocol.

Tab. 1. Classroom activity process

Name	good	commonly	Not so good
Design ideas	16	2	0
	41	5	0
progress	18	6	0
	45	15	0
Incentive	13	17	0
	32.5	42.5	0
Applicability	3	11	1
	7.5	27.5	2.5

Analyze and calculate the number of time slots allocated by the members of each NPG and the operational satisfaction requirements of the time slot occupation method. For example, analyze the calculation of the collision probability or the system response time of different priority messages. If the requirements are met, the designed time slot allocation scheme passes, and based on the main evaluation indicators such as data volume, message update rate, and relay requirements, the overall performance of the protocol is given. Otherwise, the time slot allocation scheme will be re-evaluated.

VALIDATION OF SIMULATION MODEL

Comparison of commonly used time slot allocation strategies. At present, many of MANET's theories and technologies are still in the exploratory stage, but their enormous potential will receive more and more attention from people. Based on the fixed time slot allocation algorithm based on TDMA, this paper proposes an improved dynamic TDMA time slot allocation algorithm, which adopts a dynamic hierarchical classification of nodes and a two-tier topology structure. Under the premise of guaranteeing the basic service quality, according to the increase of the number of nodes, the communication demands of a large number of users are met to the maximum extent.

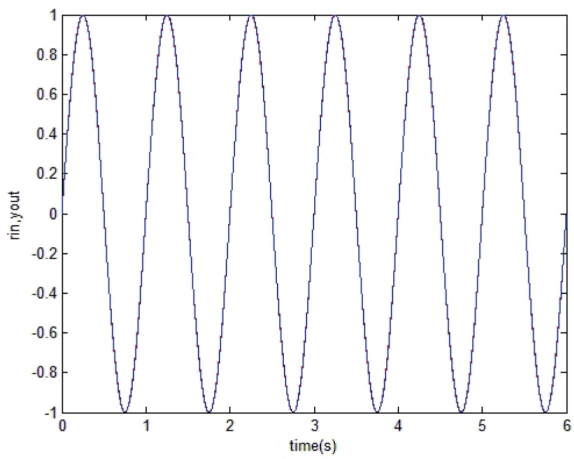

Fig. 4. CBR data flow diagram

To study the TDMA protocol, the most important thing is to study the slot allocation algorithm. This paper analyzes, sums up and summarizes the TDMA time slot allocation algorithms from the connotation, status quo, and theoretical support, so that researchers can review the research situation in the field and lay an important foundation for further in-depth research. In the contention-based MAC protocol, when a node has a transmission task, it usually occupies the channel by means of free competition. When the number of nodes competing for the same channel at the same time is equal to or greater than two, a collision occurs:

$$\triangle w_{jk} = -\alpha \frac{\partial E}{\partial w_{ij}} = -\alpha \frac{\partial E}{\partial net_k} \cdot \frac{\partial net_k}{\partial w_{ij}} \tag{1}$$

In the fixed time slot allocation algorithm based on TDMA, each node will allocate time slots evenly under normal operating conditions, so that the system has the lowest delay guarantee, ensuring the stability and timeliness of data transmission:

$$\triangle v_{ij} = -\beta \frac{\partial E}{\partial v_{ij}} = -\frac{\partial E}{\partial net_j} \cdot \frac{\partial net_j}{\partial v_{ij}} \tag{2}$$

$$\triangle w_{jk} = \alpha \delta_k^o \cdot y_j = \alpha \left(d_k - o_k\right) o_k \left(1 - o_k\right) y_j \tag{3}$$

In the fixed time slot assignment algorithm based on TDMA, each node can averagely obtain the time slot. This has good performance in delay performance and node anti-collision performance when the transmission efficiency is not high:

$$\triangle v_{ij} = \beta \delta_j^y x_i = \beta \left(\sum_{k \; 1} \left(\delta_k^o w_{jk} \right) \right) \cdot y_i \left(1 - y_i\right) x_i \tag{4}$$

However, when the number of nodes gradually increases and the network transmission efficiency is required to be higher, the fixed time slot allocation algorithm based on TDMA does not adapt well to such a dynamic scenario:

$$\hat{L} = \frac{L - L_{\min}}{L_{\max} - L_{\min}} \tag{5}$$

Therefore, it is necessary to propose a new TDMA time slot allocation protocol that can dynamically adjust these parameters according to the number of nodes:

$$\left.\begin{aligned} O_1^{(3)} &= K_p \\ O_2^{(3)} &= K_I \\ O_3^{(3)} &= K_D \end{aligned}\right\} \tag{6}$$

Especially in areas where marine disasters and meteorological environment are unstable, major monitoring is needed:

$$\left.\begin{aligned} \frac{\partial u(k)}{\partial O_1^{(3)}} &= e(k) - e(k-1) \\ \frac{\partial u(k)}{\partial O_2^{(3)}} &= e(k) \\ \frac{\partial u(k)}{\partial O_3^{(3)}} &= e(k) - 2e(k-1) + e(k-2) \end{aligned}\right\} \tag{7}$$

The frequency of periodic detection is dynamically adjusted according to the number of secondary nodes in its neighbors:

$$\frac{\partial E(k)}{\partial net_l^3} = \frac{\partial E(k)}{\partial y(k+1)} * \frac{\partial y(k+1)}{\partial u(k)} * \frac{\partial u(k)}{\partial O_l^{(3)}} * \frac{\partial O_l^{(3)}}{\partial net_l^{(3)}} \tag{8}$$

The hierarchical division of mobile nodes follows a fundamental principle that each secondary node has at least one primary node within one hop. Two kinds of algorithms are compared and simulated. The simulation results show that the improved dynamic TDMA slot allocation algorithm can adapt to the changing number of nodes. MANET is usually composed of a group of mobile terminals with wireless transceivers. It is a dynamic network that does not require infrastructure support. The TDMA protocol based on the dynamic allocation algorithm allocates the required time slot to the node when it needs to send data. After the data is sent, it no longer allocates the time slot to the node.

CONCLUSIONS

The slot allocation algorithm has been receiving extensive attention as an important part of the TDMA system research. This paper analyzes the summarization and summarization of TDMA time slot assignment algorithms from several aspects such as slot synchronization, existing slot allocation algorithm, and slot assignment model, laying an important foundation for researchers to do further research. In the TDMA system, time is divided into non-overlapping time frames, and the time frames are divided into non-overlapping time slots. Each node in the network performs corresponding operations in each time slot. The system uses TDMA access, which requires designing how to allocate time slots. That is, how to allocate time slots to each node in the network so that collisions occur when packets are transferred between adjacent nodes, and the throughput and spatial reusability of the system are as high as possible. The centralized dynamic TDMA protocol generally has a central control node that knows the information of the entire network node, and the central node allocates timeslots for the nodes in the entire network. The distributed dynamic TDMA protocol does not exist in the control node. The nodes in the network reserve the respective transmission time slots through mutual information. The TDMA protocol based on the hybrid allocation algorithm fixedly allocates time slots to the corresponding nodes, while allowing other nodes to compete for the time slots without disturbing the use of the transmission of the nodes. The slot allocation model is an important mathematical theoretical basis for the slot allocation algorithm. Different slot allocation schemes have different slot allocation models. The fixed time slot assignment model and distributed dynamic time slot assignment model are respectively introduced below.

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CONTACT WITH THE AUTHOR

Xiaofeng Han, Ph.D.
e-mail: hanxiaofeng@sdust.edu.cn

College of Mathematics and Systems Science
Shandong University of Science and Technology
Qingdao Shandong, 266590
CHINA