Hybrid Routing Algorithm for WSN using Bitmap and Clustering Method

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Abstract. A wireless sensor network (WSN) is only constructed of mobile nodes without the assistance from the fixed infrastructure (i.e. LAN, optical Network, etc.), which can improve the flexibility of the building network. However, it is difficult to maintain a long lifetime for routing in the WSN, since sensor nodes can freely join or drop out of the network. Besides, whole or part of the nodes in a network may have a very low power. In this paper, the senor nodes for vessels in the marine environment are assumed to organize the multi-hop Wireless network, which are fixed on the networks and are operated as full function device (FFD). This paper proposes a hybrid routing algorithm using schemes based on the bitmap and cluster methods. We show the validity of the proposed method by means of computer simulations.

Keywords: WSN, ship area network, routing algorithm, cluster-based routing, bit map.

1 Introduction

Wireless sensor network is an organized mobile sensor node which operates without the assistance of a fixed structure such as wire-line infrastructure. It can enhance the flexibility of constructing the sensor nodes in network. However, it is difficult to maintain long lifetime for routing sensor data of WSN, because routing consumes a high electric power. In addition, nodes in whole or part of the network may often have a very low power. Recently, studies on SAN mostly use wire-line and wireless approaches. The approaches consist of wire-line infrastructure (i.e., power line, Ethernet, cable, optical, etc.) and wireless technologies (i.e., ZigBee, Bluetooth, WLAN (wireless local area network), UWB (ultra wideband), RFID (radio frequency identification), etc.), wired and wireless network. Wire infrastructure for network of inner communications of vessel is constructed when ship is built. However, in the built vessel it is difficult to extend the wired infrastructure network with respect to inner communications of ship. For this reason, wireless technology should be applied in the inner communication of vessel. In this paper, we have considered ZigBee as the wireless technology. ZigBee is suitable for data transfer method with small sensing data. The routing of the WSN in the vessels environment depends on the size of vessel, and its single-hop or multi-hop configuration. In this paper, we assume the following WSN of the vessels. 1) Due to the uniqueness of the vessel which consists

of multi-hop. 2) The sensor nodes are fixed when the deployment is complete. 3) The sensor nodes consist of the FFD (full function device). The wireless sensor network (WSN) only consists of mobile nodes without the assistance from the fixed infrastructure, which increases the flexibility of the network. However, it is difficult to perform routing in the WSN, since sensor nodes freely join in and drop out of the network. In this paper we propose a routing algorithm with cluster head node mobility, rather than the computational power and limited energy of sensor nodes.

The rest of the paper is organized as follows. In section 2, we introduce the related research. The proposed algorithm is described in section 3. In section 4, we show the simulation results using NS-2 for proposed algorithm in section 3. Finally, Section 5 concludes the paper.

2 Related Research of Routing Protocols

Routing in WSN reduces the overall energy consumption and leads to a uniform energy consumption at all sensor nodes. Sensor networking technologies can be classified into three types (flat routing, hierarchical routing, and location-based routing) by network structure. DD (direct diffusion) [1] is an important milestone in the data-centric routing research of sensor networks. SPIN (sensor protocols for information via negotiation) [2] is among the previous work to pursue a data-centric routing scheme. LEACH (low energy adaptive clustering hierarchy) [3] is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. TEEN (threshold-sensitive energy efficient sensor network) [4] is hierarchical routing protocol. GEAR (geographic and energy aware routing) [5] have suggested the use of geographic information while disseminating queries to appropriate regions since data queries often includes geographic attributes.

3 Proposed **Routing Algorithm**

We propose a routing algorithm that improves the survival time and energy efficiency of sensor nodes. In the proposed algorithm, the information for monitoring the vessels WSN environment that can be measured by different types of data assigned with the respective ID. Each node was constructed of clusters with the same ID.

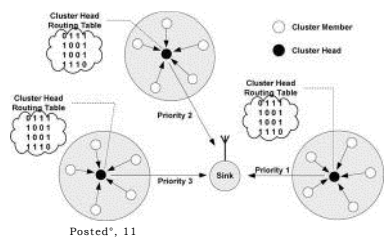

Fig. 1. A basic concept of the proposed routing algorithm.

The cluster head node was selected from the clusters. The cluster head nodes have a bitmap routing table represented as 0 and 1, which connects the information with nodes in the cluster. Compared with residual power of cluster head nodes, cluster head nodes will be changed to other node with enough residual power. Therefore, the energy efficiency and survival time of the network will be improved. Figure 1 shows the basic concept of the proposed routing algorithm. The proposed routing algorithm shown in table 1 can be monitored in vessels environmental information (temperature/humidity, illumination, vibration, etc.) by types of data that can measure the cluster configuration to give priority. The priority is the turn in which data is transmitted from the cluster head node to the sink node or upper cluster head in routing process.

Table 1. Priority of sensor nodes.

Priority	Sensor	ID.
1	Temperature/Humidity	01
2	Illumination	10
3	Vibration	11

All nodes that the state did not determine a cluster are sent Hello message including pre-defined unique ID. If one node received Hello message from the cluster head node, then that node is registered with the cluster members. After completion of registration, when measured data was sent from a source node to a destination node, cluster head node would check the routing table that is composed with a bitmap to determine the location of the destination node. In a sensor network, sensor nodes have identifier to configure the routing table. The bitmap uses the node identifier to display the information between the node and the node connection in bits. The bitmap is composed of bits that connect information with neighbor node, represented by 0 or 1. Equation (1) shows the structure of a node with a bitmap:

$$map[i]D] = \begin{vmatrix} id & id \bullet\bullet\bullet id \\ id & 0 \bullet\bullet\bullet 0 \\ id & 0 \bullet\bullet\bullet 0 \end{vmatrix} \quad (1)$$

In equation (1), map [0] [0] indicates the identifier of the node itself. Cross-point of nodes i and j depend on the presence or absence of the link. If there is a link, cross-point is represented by 1 and if it does not exist than it is represented by 0. Starting with the sink node, each node sends a routing table. Received bitmap is transmitted to neighbor nodes by only once broadcast. All nodes construct a bitmap by the received interest signal and perform the broadcast. After broadcast, when this node has received the same interest signal from neighbor nodes, this node will be performed by OR operator that is its rows and columns of the bitmap will distinguish the neighbor nodes identifier. The process of updating the bitmap is repeated until the nodes perform the response to the application [6]. The communication path is set up after finishing the check of the routing table. The source node sends data to the destination node by sending packets to the node that is the closest to the destination node within the communication radius. The sensor node requires most of the energy when the

node sends messages. The energy required for processing is less than the amount of energy that is needed when a message is received.

Well known LEACH algorithm only depends on the probability to elect a cluster head. This fact of using LEACH algorithm means that each node could not maintain balanced energy consumption [7]. In this paper, we use the improved LEACH algorithm that considers residual energy of nodes for energy balance between nodes:

$$\text{Pi}(t) \begin{cases} \dfrac{k}{N - k(r \bmod \frac{N}{k})} \times E_{node} & : Ci(0 = 1 \\ [0 & : C_i(t) = 0 \end{cases} \qquad (2)$$

In equation (2), i is the identifier of the node, t is the time, N is the number of total nodes, k is the number of clusters, r is the round and E_{node} is the residual energy value of the node. If a new round starts, then the value of threshold ($1^{9}{}_{1}(0)$ is calculated after selecting random number between 0 and 1. If the selected random number is less than the threshold, the cluster head is elected.

Due to the changing characteristic of the wireless sensor network a constant path needs to be set. However, in this paper, routing is done without change of the path because the fixed nodes were considered in the vessel WSN environment. The network lifetime is shortened by frequent routing that increases power consumption of the cluster head node. We could extend the lifetime of the sensor network by changing the cluster head node and using the routing table with a bitmap.

4 Simulation and Results

4.1 Simulation Scenario

A developed simulator NS-2 was used which is based on IEEE 802.15.4 and IEEE 802.15.5 address allocation algorithm was added. We assume that all sensor nodes are fixed without mobility because that all nodes are sensing only relevant data in a vessel environment. The parameters used in the simulation are shown in table 2. A total of 101 sensor nodes were used in the simulation. By default, the wireless communication range of the sensor was set to 9m. Distance between nodes was arranged in the form of uniformly 7m in 80mx 80m square space. All nodes are based on IEEE 802.15.5 address allocation algorithm which maintains a neighbor list as a bitmap. Nodes join the network by starting with sink node (0 node), and consists of cluster tree.

Table 2. The parameters used in the simulation.

Parameters	Value
Network size	80m x 80m
Number of nodes	101 EA
Distance of between nodes	7 m
Simulation time	100 sec
Incidence rate of event	0.5 events/sec
Wireless transmission range	9 m
Value of initial energy	0.5 joules

4.2 Simulation Results

Total number of messages is calculated by sum of the number of sending messages and receiving messages. Figure 2 shows the total number of messages of **DD** algorithm and the proposed algorithm. The total number of messages in the proposed algorithm is reduced 28% and 13% at 2x2 and 4x4 sensor range than **DD** algorithm, respectively.

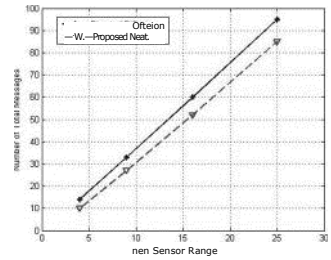

Fig. 2. Compare the number of messages between **DD** algorithm and the proposed algorithm.

Figure 3 shows comparison of routing overhead about the proposed algorithm versus the conventional algorithms. This result shows that routing overhead is increased which depends on the number of nodes. Also, we can find that routing overhead is increased with lower size, because the number of nodes does not increase linearly.

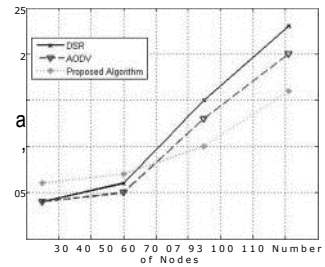

Fig. 3. Comparison of routing overhead about the proposed algorithm versus the conventional algorithms.

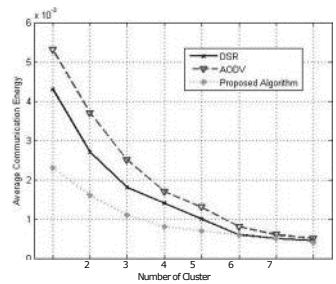

Fig. 4. The average energy per cluster using for communication.

The required average communication energy was measured between the sink node and all sensor nodes in the cluster. Communication energy is proportional to the distance between two nodes. If a cluster is formed by a short distance, then consumption of the average energy becomes minimum. According to the increasing number of cluster, we can see similar average communication energy consumption.

5 Conclusions

In this paper, we have proposed the routing algorithm that improved the survival time and energy efficiency of sensor nodes. The cluster head nodes have a bitmap routing table represented by 0 and 1, which connects information with nodes in the cluster. In addition, the cluster head has been changed by comparing the remaining electric power of a cluster head. As you can see from the simulation results, the proposed routing algorithm is 13% lower than existed algorithms on the consumption of average communication energy. Proceeding from what has been performed in the simulation, it should be concluded that the proposed routing algorithm is better than existed algorithms. These simulation results were found to be in good agreement with the proposed routing algorithm.

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