The Improved WCMRP Protocol for Mobile Wireless Sensor Networks

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Abstract—For the purposes of monitoring or controlling, numerous of wireless sensors might be widely deployed to obtain and send information in the wireless sensor network (WSN). The applications of the WSN can be found in environment monitoring, industrial process monitoring and controlling, health caring, smart homes building and traffic controlling. To sending message efficiently in WSN, routing problem is an essential issue and must be taken into consideration. Instead of considering the problem routing among immovable sensors (nodes) in WSN, this paper discusses the problem of routing among moveable nodes. Although many routing protocols have been proposed for message delivering, some of them work well for sending message to single destination but not for multiple destinations. Due to the necessity in some applications, multicast service has been an indispensable function in the mobile WSN. Since Weight-based Clustering Multicast Routing Protocol (WCMRP) is one of the proposed protocols for multicast outperforming in the mobile network, with little modification on weight function, an improved WCMRP protocol (IWCMRP) is proposed for a mobile wireless sensor network. To illustrate the performance of IWCMRP, the results of simulation running with NS-2 are given, which shows IWCMRP performs better than WCMRP.

Index Terms—wireless sensor networks, multicast, clustering architecture, routing protocol, mobile network.

I. INTRODUCTION

With the advances in mobile devices and wireless techniques, to create a mobile wireless sensor network has been realized and is becoming a promising network supporting many applications. Among these networks, the ad hoc network is one of the wireless network architectures, which is a self-configured network and nodes in the network are connected by wireless links. Message delivering between nodes can be done without any infrastructure, and nodes in the network are allowed to move freely. Since the characteristics of ad hoc network with easily construction and dynamic network topologies, it can be formed as a wireless sensor network (WSN). In a WSN, there may be a number of sensors widely deployed to collect data. The sensors forward the collected data to the control center for making proper reactions. The applications of WSN can be found in

environment monitoring, industrial process monitoring and controlling, health caring, smart home building and traffic controlling.

Although many studies have been discussed about the routing issues in WSN, most of them assumed that the sensors in the WSN are immovable. Hence, many proposed routing protocols will no more be workable if the sensors are deployed to the equipment with mobility, such as vehicles or animals. Instead of considering the problem routing among immovable nodes in WSN, to discuss the problem of routing among moveable nodes will be more meaningful.

In the mobile WSN, the sensors are not stationary and the network topology is dynamic. In such a dynamic environment, the messages delivering will be difficult to maintain. Moreover, if the multicast services are required in the network, it will be a challenge in data transmission. Even though there are many protocols proposed to provide multicast in the mobile networks, such as Multicast operation of Ad hoc On-demand Distance Vector Routing Protocol (MAODV)[1], On-Demand Multicast Routing Protocol (ODMRP) [2], and Weight-based Clustering Multicast Routing Protocol (WCMRP) [3]. In the mobile network, WCMRP protocol is one of the outstanding protocols in multicast. In this paper, an improved WCMRP protocol is proposed for a mobile wireless sensor network, in which the nodes are allowed moving with high speed.

The rest of this paper is organized as follows. Section 2 introduces some related works. The improved WCMRP protocol is proposed in Section 3. Section 4 illustrates the results of simulation running with NS-2. Finally, the conclusions are drawn in Section 5.

II. THE RELATED WORKS

Since the sensors in a mobile WSN can be equipped to the mobile nodes, the nodes might join or leave the networks anytime. In order to deliver the messages among sensors correctly and efficiently, peer-to-peer data transmission mechanisms with multi-hop routing through wireless links are required. However, in such a rapidly changing network topology, routing problem will be essential and difficult. Needless to say, multicast routing problem will become more and more difficult to deal

with, which is also due to the characteristic of nodes' mobility. Therefore, it is important to develop a proper multicast routing protocol with correctness and efficiency in the mobile WSN.

According to the working features, the multicast routing protocols for mobile ad hoc networks can be classified into tree-based and mesh-based mechanisms. In the tree-based mechanism, data between the source and destination is delivered over a single shortest path, such as Ad hoc Multicast Routing (AMRoute) [4] and Multicast Operation of the Ad Hoc On Demand Distance Vector Routing Protocol (MAODV) [1]. Instead of routing via a single path, the mesh-based mechanism transmits data over multiple paths, such as On-demand Multicast Routing Protocol (ODMRP) [2] and Multicast Core-Extraction Distributed Ad hoc Routing (MCEDAR) [5]. Although tree-based protocols are usually more efficient than the others in data transmission, they suffer from no alternative path between the source and destination, and they are vulnerable if network topology is changing.

Clustering is a technique to group network nodes into some logically separated entities, and these entities are called clusters. Due to the features of clustering, there are some advantages for multicast with clustering technique. The advantages are:

- (1) The number of routing paths and the size of routing table are reduced because the routing paths are built from clusters to clusters;
- (2) The communication overhead for distributed routing is reduced because the routing paths are limited within cluster;
- (3) The spatial reuse is possible in the clustering if there are some shared channels in the network.

For the advantages of clustering mechanism, it is usually adopted to maintain the multicast in mobile ad hoc networks [6][7][8][9][10][11][12][13][14][15]. In the clustering mechanism, nodes are classified into two roles: the cluster head and cluster members. Each cluster contains only one cluster head and several cluster members. Cluster head is the one who maintains the information of members, and cluster members are those who join the nearby cluster head. It is clear that the network maintenance and data transmissions will be easy and efficient if a cluster head could be selected properly. There are many algorithms focus on selecting cluster head [3][16][17][18][19][20] for an efficient routing and network maintaining, the WCMRP protocol[3] is one of them.

In the WCMRP protocol, the selecting of cluster head is according to the weight function $W_i = \alpha \times BN_i + \beta \times NN_i + \gamma \times Deg_i$, where W_i is the weight of node i , BN_i is the number of border nodes managed by node i within 2 hops, NN_i is the number of neighbor nodes of node i within 2 hops, Deg_i is the degree of node i , and $\alpha + \beta + \gamma = 1$. The border nodes are defined as the nodes at the boundary of a cluster if node i is the cluster head. The neighbor node is defined as a node that can be reached from node i within 2 hops, including node i itself. The degree of node i is defined as the number of

communication links to it. The coefficients in the weight function should be set as $\alpha > \beta > \gamma$. Since the more border nodes a cluster head manages, the more multicast requests with only local cluster routing it can satisfy. Thus, the multicast traffic between clusters is reduced and multicast traffic in the entire network is also alleviated. Therefore, α should be the largest one of the three coefficients. The more neighbor nodes a cluster head maintains, the easier message delivering and the more possibility of local routing will be. It is clear that 2-hop neighbor nodes can provide more information in routing than 1-hop neighbor nodes can do. Consequently, β is set to be the second largest of the three coefficients. Since the degree of a node is the number of communication links to the node, it can be seen as 1-hop neighbor nodes. Hence, γ is the smallest of the three coefficients. According to the above concepts, a node with the largest number of 2-hop border nodes is the cluster head. Simulation results show that the weight function work well in selecting cluster heads, and the WCMRP protocol outperforms the existing mesh-based multicast routing protocols.

III. THE IMPROVED WCMRP PROTOCOL

Since a mobile WSN is a network with dynamic topology, the cluster head selection is an important issue, which will greatly affect the whole network performance. Hence, selecting a cluster head with proper information to make multicast routing more flexible is the core of multicast routing in the mobile WSN.

With little modification on WCMRP's weight function, the improved WCMRP protocol is proposed. The weight function of the improved WCMRP protocol is $W_i = \alpha \times BN_i + \beta \times GW_i + \gamma \times NN_i + \delta \times Deg_i$, where W_i is the weight of node i , BN_i is the number of border nodes managed by node i within 2 hops, GW_i is the number of gateway nodes managed by node i within 2 hops, NN_i is the number of neighbor nodes of node i within 2 hops, Deg_i is the degree of node i , and $\alpha + \beta + \gamma + \delta = 1$.

In the above function, the border nodes are the nodes at the boundary of a cluster. Figure 1 illustrates a simple example of a clustered network, in which node **A** is the cluster head, and the border nodes managed by the cluster head within 2-hop range are nodes **H**, **G**, **F**, **D**, and **C**. The number of gateway nodes is the additional parameter in the proposed weight function, which could lead to a more precise calculation of a node's weight. The gateway node is a node connecting the other clusters. For that the nodes in the mobile WSN are moveable, the data transmission might fail due to the receiving nodes have left to the other clusters. The function of gateway node is to connect the other clusters and forward the messages to other clusters during data transmission. Obviously, the more gateway nodes a cluster head manages, the easier message exchanging will be. In Figure 1, there is only gateway node **G** in the cluster dominated by the cluster head **A**. The neighbor nodes managed by the cluster head **A** within 2 hops are nodes **B**, **C**, **D**, **E**, **F**, **H**, **G**, and the cluster head **A**. The degree of the node **A** is 5.

Figure 1. An example of a clustered network

Although the clustered architecture improves the mobile WSN in managing nodes and data transmission, it is still an important issue to select a proper node as the cluster head for achieving high network performance. For selecting an appropriate node as a cluster head, the paper modified the weight function of the WCMRP protocol by adding the number of gateway nodes to be $W_i = \alpha \times BN_i + \beta \times GW_i + \gamma \times NN_i + \delta \times Deg_i$. From the original weight function of the WCMRP protocol, the relationship among the coefficients is $\alpha > \beta > \gamma$. Since there is a new coefficient δ added in the improved weight function, the relationships among α , β , γ and δ need to be decided for the requirement of performance simulation. In the following, some simulations are given to examine the relationships of the coefficients, α , β , γ and δ . Then, the performance simulations will be studied and compared to the original WCMRP protocol.

IV. THE SIMULATION RESULTS

A. The Examinations of Coefficients in the Improved Weight Function

In the original WCMRP protocol, the weight function to select the cluster head is $W_i = \alpha \times BN_i + \beta \times NN_i + \gamma \times Deg_i$, where $\alpha + \beta + \gamma = 1$ and $\alpha > \beta > \gamma$. To improve the performance of the original WCMRP protocol, the information of gateway nodes is added in the WCMRP protocol's weight function. Hence, there are four coefficients α , β , γ , and δ in the improved weight function,

$W_i = \alpha \times BN_i + \beta \times GW_i + \gamma \times NN_i + \delta \times Deg_i$. In order to decide the relationships among the four coefficients, there should be four factorial cases need to be examined. Since the improved WCMRP weight function inherit the original WCMRP weight function, $\alpha > \beta > \gamma$. Hence, there are only four cases need to be discussed about. The four cases are:

- Case 1: $\alpha > \beta > \gamma > \delta$.
- Case 2: $\beta > \alpha > \gamma > \delta$.
- Case 3: $\gamma > \alpha > \beta > \delta$.
- Case 4: $\delta > \alpha > \beta > \gamma$.

Figures 2 and 3 are the simulation results of the improved WCMRP weight function with 2-hop mechanism for the above four cases. Under the constraints of different speeds, the average packet delivery rates and the average transmission times are shown in Figures 2 and 3 respectively.

According to the simulation results in Figures 2 and 3, the improved WCMRP weight function is well performed under the constraint of case 1. Hence, the relationships among the four coefficients in the improved weight function should be $\alpha > \beta > \gamma > \delta$, where $\alpha + \beta + \gamma + \delta = 1$.

B. The Comparisons in Performance to the WCMRP Protocol

In this section, the comparisons in performance between the improved WCMRP protocol with different number of hops information and the original WCMRP protocol are given. In Figures 4 and 5, the number of nodes is set to be 50. In Figure 6 and Figure 7, the speed is set to be 100 km/hour. According to the result $\alpha > \beta > \gamma > \delta$ and $\alpha + \beta + \gamma + \delta = 1$, α , β , γ and δ are respectively set to be 0.4, 0.3, 0.2, and $\delta = 0.1$ in the following simulations.

Most routing protocols adopt 2-hop information for an efficient routing in the mobile WSN, the original WCMRP protocol is one of them. However, the routing information with different number of hops might affect the network performance. In order to realize the performance of the improved WCMRP protocol with different number of hop information, the number of hops information will be set from 1 to 4 in the following simulations.

Figure 2. An example of a clustered network

Figure 3. The average transmission times for the four cases under different speeds.

Figure 4. The average transmission times under different speeds.

Figure 6. The average transmission times with different number of nodes

Figure 5. The average packet delivery rates under different speeds.

Figure 7. The average packet delivery rates with different number of nodes

The simulations show that the improved WCMRP protocol with 2-hop information always performs better than with other number of hop information and the original WCMRP protocol in average transmission time

and average packet delivery rate. The simulation results imply that 2-hop information is a valid mechanism for cluster management and routing path protocols. Moreover, the simulation results illustrate that the

information of gateway nodes will greatly improve the data transmission in the mobile WSN, which provides more information in routing and leads to improved WCMRP protocol performs better than the original WCMRP protocol in the mobile WSN.

V. CONCLUSIONS

Because of the mobility of nodes in the mobile WSN, routing problem become an essential issue in such an environment. In this paper, with adding a gate note information in the weight function of WCMRP protocol, an improved WCMRP protocol is proposed. The simulation results showed that the information of gateway nodes do improve the performance in the mobile WSN, which leads to improved WCMRP protocol performs better than the original WCMRP protocol in average transmission time and average packet delivery rate. The simulations also validated that a routing protocol with 2-hop information is an effective mechanism for cluster management and routing path protocols.

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