Load Balancing Parameters for Geographic Routing Protocol in Wireless Sensor Networks

BiJun Li, MinJung Baek, SeUng Hyeon, and Ki-Il Kim
Dept. of Informatics, Gyeongsang National University
900 Gajwa-dong, Jinju, 660-701, Korea
kikim93@gmail.com

***Abstract*— Geographical routing protocol has been proposed to reduce the complexity of routing protocols, which are based on topology information in wireless/mobile networks. This kind of protocol is regarded as good working protocol in wireless sensor networks because reduced control overhead in geographic routing protocol is very suitable for each battery-powered sensor node. However, despite of several advantages, original greedy forwarding technique is very likely to cause different type of problems such as congestion. In this paper, we develop new parameters and apply existing possible parameters into original greedy forwarding in order to balance load efficiently. These parameters are derived from key characteristics of wireless sensor networks. Simulation results show that higher packet delivery ratio is achieved by proposed parameters in greedy forwarding.**

Keywords- load balancing, geographical routing, wireless sensor networks

I. INTRODUCTION

As many research works for routing protocols for wireless sensor networks have been conducted, they are mainly divided into two parts according to which information is used to build routing table. One is topology based routing protocol and the other is geographic based one[1]. The topology based routing protocol exchanges topology with others in the networks. By exchange information, they find out the path between source and destination. On the other hand, instead of topology information exchanged with neighboring nodes within networks, the latter makes use of geographic information to forward packets. Thus, this protocol does not need routing table for next hop. Moreover, there is no need to update routing table whenever the topology changes arbitrary. According to this property, geographic routing protocol is considered as good candidate by the researcher in the field of wireless sensor network where node with limited computing capability delivers information to the sink. In this networks, frequent update and exchange information in topology-based routing protocol is not preferred because each sensor node cannot handle amount of traffics related to routing. This implies that geographic routing protocol is expected to play great role in wireless sensor network when it concerns the limitations or constraints of sensor node. Also, due to many query messages including the position information, it is general to use geographic information on each node.

In order to forward packet through geographic information instead of routing table based on topology information, intelligent forwarding algorithm should be employed. The basic principle called greedy forwarding is developed to implement greedy algorithm in routing protocol. For practical example, well-known geographic routing protocol called GPSR[2] employs greedy forwarding as basic principle for packet forwarding. In greedy forwarding procedure, every node should choose one node which is the most near node from its neighbors until the destination is reached. However, this fact means that all packets destined to the same destination will be forwarded to the same next hop. So, if greedy forwarding is decided as basic forwarding scheme, there is another problem, that is, congestion. So, recent some research effort has been proposed to improve the performance of greedy forwarding. Even though their major goal is to develop new algorithm to solve above problems, as far as the authors know, their impact on performance have not been carefully explored and analyzed yet.

In this paper, we propose new parameters to balance load while taking outstanding properties of wireless sensor network into account. And, the simulation results will be given to analyze the impact of parameters for the performance. The parameter introduced in this paper is divided into two major parts. One is parameter for node's stress and the other is for link quality. The former is related to how much overheads are expected to be caused at each node. Thus, these parameters are derived from information form node itself. On the other hand, the latter is related to current wireless link status between adjacent nodes. Since link quality is very critical for communication, we propose some parameters as new indicators for link quality.

The reminder of this paper is organized as follows. In section II, we describe the overview of greedy forwarding and some recent related works for greedy forwarding. We present new parameters to balance load in following section III. Performance evaluation through simulation is explained and analyzed in section IV. Finally, we make a conclusion.

II. OVERVIEW OF GREEDY FORWARDING AND RELATED WORKS

Greedy forwarding means that a forward node can make a greedy choice for choosing the packets' next hop. To implement this function, every node in the network mast maintains their neighbor table which contains the position

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information of their neighbors. And the neighbor table needs to be updated in the period time which is called beacon time in the protocol. By referring these tables, every packet will be forwarded until the packet arrives at the destination. In greedy forwarding procedure, every node should choose one node which is the most near node from its neighbor until the destination is reached. The most near means that the direct distance between the chose nodes to the destination have the smallest value. This packet send procedure is called Greedy forwarding. For example in Figure 1, node A's radio range is denoted by the circle around. In addition, the arc with radius equal to the distance between A and D is shown as the dashed arc about D. Node A forwards the packet to B, that is because the distance between B and D is less than that between D and any of A's other neighbors. The greedy forwarding process repeats until the packet reaches D.

As described before, some literatures have mentioned the solution of greedy forwarding. Currently, recent studies for geographic routing have shown the need to solve the problem of greedy forwarding, which is caused by taking only position information into account while forwarding packets. First, the type of studies has been conducted to avoid hole, which is not covered by any node [3-6]. If a packet is delivered to any hole, there is no way to forward it any more without any special method. Secondly, other approach is to introduce various metrics better than distance. The examples includes metric reflecting lossy link[8], expected progress distance[9], and energy status[7]. Also, the authors in two recent papers[10-11] analyze the impact of several parameters for performance of geographical routing. However, despite of these research efforts, as far as the authors know, there is no previous work to consider load balancing on greedy forwarding. This means that the impact of congestion in geographic routing have not been well explored yet. In this paper, six different parameters are proposed to prevent congestion.

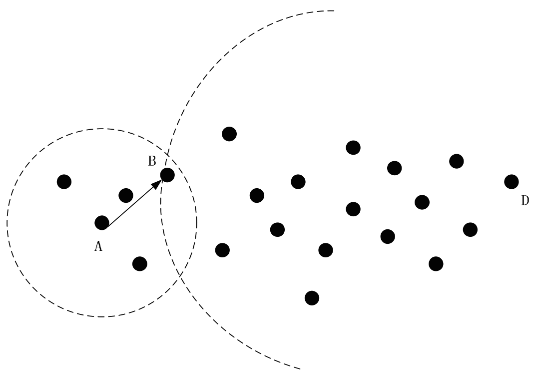

Figure 1. Example of greedy forwarding

III. NEW PARAMETERS FOR LOAD BALANCING

Generally, the procedures to achieve load balancing are as follows. First, a node computes weight value on each link. The basic weight value is decided in equation (1). If packets are arrived, a node sends respective packet according to weight value on the link. And, the total number of packets sent along the link is recorded and counted for computation.

$$W_{i,j} = \frac{LC_{i,j}}{\sum_{k=1}^{n} LC_{i,k}} \tag{1}$$

In equation (1), $W_{i,j}$ represents the weight value for link between node i and j where total number of possible neighboring nodes for next hop is n. $LC_{i,j}$ is the link cost between node i and node j, which is defined by new parameters.

A. Parameter for Node' Stress

A node's stress represents how much works are loaded at each node. If a node suffers from heavy stress, this implies that a node cannot execute several jobs. To measure the node's stress efficiently, we propose four different metrics. The first is the total number of neighbors and the second is the average number of packets received during predetermined time period. The third is number of current routing table entries on each node. Final parameter is related to energy.

First, the number of neighbors can affect the node's stress. In a node locates in densely deployed area, more packets are expected to be delivered to each node than sparse area.

Therefore, a node's stress is likely to vary according to the density by handling their requests and responses. The link cost for density is defined as follows. In equation (2), N_j presents average number of neighboring nodes of node j.

$$LC_{i,j} = N_j \tag{2}$$

If the first parameter is one of the simplest parameters, to be much specified, second parameter is the average received number of packets from neighboring nodes. By choosing this parameter, we will give higher weight on task for communications rather than others. But, different from number of neighbors in equation (2), the number of packets varies according to the time. So, weighed moving average method is applied to smooth the variations. Thus, link cost is defined as equation (3).

$$LC_{i,j} = \varphi \times P_j^{0,t-T} + (1-\varphi) \times P_j^{t-T,T} \tag{3}$$

where $P_j^{t-T,T}$ indicates the number of received packet at node j from time t-T to T when frequency of measurement is set to T.

The third parameter for node's stress is more specialized than two previous parameters. This overhead can be represented by how much overhead to decide next hop is charged on each node. To measure this kind of overhead, we use the number of routing entries as times go. This parameter is easily obtained by replacing $P_j^{t-T,T}$ by $R_j^{t-T,}$, which represents the number of routing entries at node *j* from time *t-T* to *T* when frequency of measurement is set to *T*. Consequently, link cost is computed by equation (4).

$$LC_{i,j} = \varphi \times R_j^{0,t-T} + (1-\varphi) \times R_j^{t-T,T} \quad (4)$$

The last parameter for node's stress is related to energy level. Under assumption that all sensor nodes initially start their operation at the same battery level, current remaining battery level is good indicator for node's stress. If a node's current battery level is lower than others, it implies that this node suffers higher overhead than others. So, link cost can be defined by equation (5).

$$LC_{i,j} = E_j \quad (5)$$

B. Parameter for Link Quality

One of outstanding properties in wireless sensor networks is short-range, low data-rate wireless communications. Because low quality wireless medium causes several problems on the links, therefore, new parameter to consider link quality is required. We introduce two parameters to balance load by using link quality. One is average packet delivery ratio and the other is average retransmission time. Average packet delivery ratio reflects link stability and is computed by counting the number of packets received without error among the total sent packets during predetermined duration. If the delivery ratio is high, it can transmit the more packets correctly to neighboring nodes. Thus, we can set the weight value by containing packet delivery ratio such as equation (6).

$$LC_{i,j} = \varphi \times PDR_j^{0,t-T} + (1-\varphi) \times PDR_j^{t-T,T} \quad (6)$$

where $PDR_j^{t-T,\,T}$ represents the packet delivery ratio at node *j* from time *t-T* to *T*.

Unstable and short range wireless communication hinders reliable communications frequently. To make reliable communications, retransmission scheme is generally used to recover the lost packets. Because packet delivery ratio is supposed to show reliability on the link partly, we introduce the alternative parameter, average transmission time per packet. Average transmission time for each packet is defined as how much time is passed to transmit packets on the link completely. Longer average transmission time means that many packets are waiting for retransmission in a buffer. So, queuing delay and multiple transmission delay make average transmission time longer. Based on this fact, link cost to use average transmission time is defined as equation (7).

$$LC_{i,j} = \varphi \times AT_j^{0,t-T} + (1-\varphi) \times AT_j^{t-T,T} \quad (7)$$

where AT_j^{t-T} represents the average transmission time at node *j* from time *t-T* to *T*. *ART* is computed by starting timer for each packet until it is successfully received by node *j*.

IV. PERFORMANCE EVALUATION

To support a wide range of simulations, our simulation code was implemented around Qualnet simulator [12]. Our simulation models a network of 100 sensor nodes placed randomly within a 1000 * 1000 meter area. Radio propagation range for each node is 50 meters and channel capacity is 256kbit/sec. The multiple runs with different seed numbers were conducted for each scenario and collected data was averaged over those runs. General CSMA is used as MAC protocols and two-ray model is for propagation models. The application for this simulation is SURGE, which reports the sensing information at the predetermined time periodically, 1 second in this simulation. For simulation, the 95% confidence intervals on the mean are computed.

Performance is compared by the impact of load balance in the point of packet delivery ratio and network lifetime. To meet above goal, we compare how many packets are dropped and the network lifetime when we use new parameters to achieve load balancing. Finally, for weighed moving average method in equation (3) – (7), the value is set as 0.8 without special mentioning.

A. Simulation Results on Node's Stress

In this section, we compare the proposed scheme with original greedy forwarding. Simulations are conducted as the traffic loads increases. Traffic load 1 means that the incoming traffic rate is the same as the departing traffic rate. The Figure 2 shows packet delivery ratio on a node in each case.

In Figure 2, parameter to use the total number of packets shows the highest packet delivery ratio. This means that this parameter works very well. On the other hand, the packet delivery ratio of original greedy forwarding drastically decreases as the traffic load increases. This means that many packets are likely to be dropped by congestion on a node. Another factor to be worthwhile mentioning is that the number of routing entries shows similar packet delivery ratio to the number of packets. Among the packets, the data packets have the great impact on congestion in the point of time for forwarding and packet size compared to beacon packet.

Despite the number of neighbors shows the higher packet delivery ratio than original greedy forwarding, its performance is improved little. This implies that the number of neighbor cannot exactly reflect node's stress. Similar explanation is applied to parameter related to energy. Because battery consumption can reflect the node's stress to some amounts, we cannot find out when and where the battery is consumed. Thus, they are not sufficient to current node's stress well.

B. Simulation Results on Link Quality

Similar to previous simulation results, the load balancing parameter based on link quality is compared to original greedy forwarding.

When we compare Figure 2 and Figure 4 together, we can find out the packet delivery ratio based on link quality parameter is better than one based on node's stress. This is mainly because that wireless communications is more critical parameter than node's constraints. Also, many packets are lost due to weak communications environment. Another interesting result in Figure 4 is that retransmission parameter contributes to higher packet delivery ratio. Even though packet delivery ratio can reflect the network environments, this parameter concerns only current packets. On the other hand, retransmission time takes total elapsed time into account. This fact makes the difference between them.

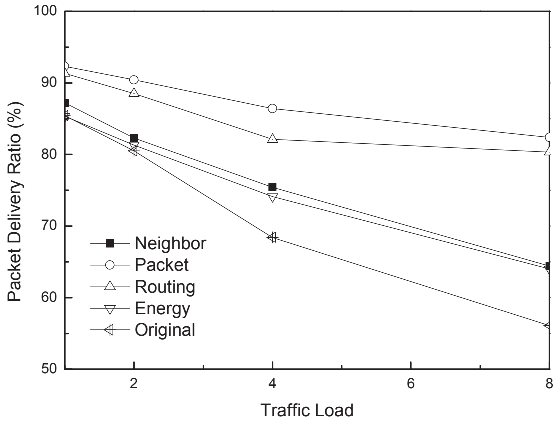

Figure 2. Packet delivery ratio as a function of traffic load

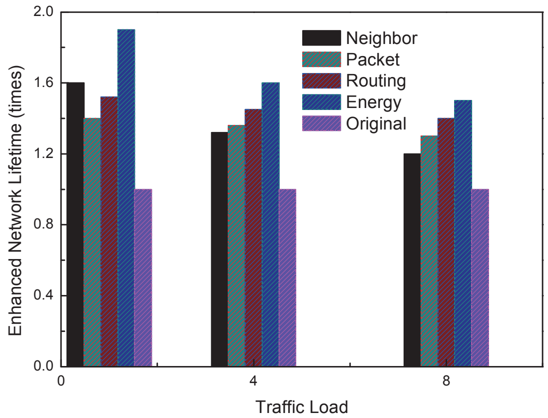

Figure 3. Network lifetime as a function of traffic load

V. CONCLUSIONS

In geographic routing protocol, intelligent forwarding mechanism is essential because there is no information for topology. In this point, greedy forwarding is one of good example to accomplish forwarding scheme. However, it causes several problems because their forwarding decision is made by one parameter, distance. Even though some research efforts have been made to solve problems before, load balancing problem has not been mentioned.

In this paper, we propose several parameters to achieve load balancing on the link in wireless sensor networks. Based on the parameters, we compute the link cost and then assign weight value on them. Finally, we can identify the improve performance in the point of packet loss and network lifetime through simulation.

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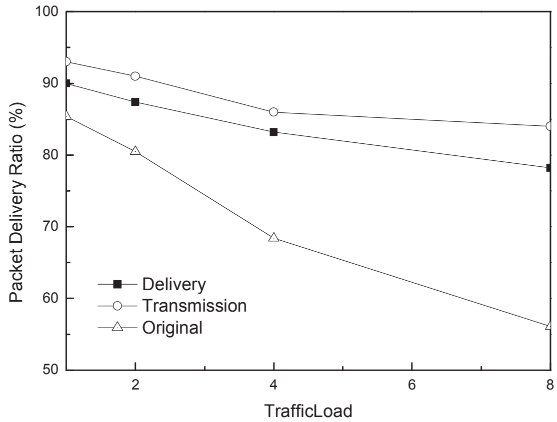

Figure 4. Packet delivery ratio with proposed link quality

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