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EBVCR: A Energy Balanced Virtual Coordinate Routing in Wireless Sensor Networks

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Abstract

Geographic routing can provide efficient routing at a fixed overhead. However, the performance of geographic routing is impacted by physical voids, and localization errors. Accordingly, virtual coordinate systems (VCS) were proposed as an alternative approach that is resilient to localization errors and that naturally routes around physical voids. However, since VCS faces virtual anomalies,existing geographic routing can't work to banlance energy efficiently. Moreover, there are no effective complementary routing algorithm that can be used to address energy balance.In this paper we present An Energy Balanced virtual coordinate Routing in Wireless Sensor Networks(EBVCR),which combines both distance- and direction-based strategies in a flexible manner, is Proposed to resolve energy balance of Geographic routing in VCS .Our simulation results show that the proposed algorithm outperforms the best existing solution, over a variety of network densities and scenarios.

Keywords: virtual coordinate systems; Geographic routing; energy banlance; delay.

1. Introduction

Wireless Sensor networks consist of a large number of sensor nodes that collaborate together using wireless communications with an asymmetric many-to-one data transfer model — sensors will typically send their data to a specific node called the sink node or monitoring station, which collects the requested information. Sensor nodes have very limited resources, in terms of computing power, memory and battery

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life. In particular, the limited energy can be really problematic. Radio communications are the main cause of energy consumption of a sensor node. Thus, it is of vital importance to reduce the energy consumption due to communications in order to extend sensors lifetime as long as possible. For this reason designing energy efficient routing algorithms for WSN is of paramount importance.

Geographic routing algorithms are well-suited to the special characteristics of WSNs. There are two basic greedy forwarding strategies in geographic routing: 1) the distance-based strategy and 2) the direction-based strategy. In the distance-based strategy, a routing protocol selects the neighbor node that is closest to the sink as the next hop [2], whereas in the direction-based strategy, a routing protocol selects a neighbor node whose deviation angle from the line that connects the current node and the sink is the minimum among all neighbors [3].

However, the performance of geographic routing is impacted by physical voids, and localization errors. Accordingly, virtual coordinate systems (VCS) were proposed as an alternative approach that is resilient to localization errors and that naturally routes around physical voids [4]. However, since VCS faces virtual anomalies,existing geographic routing can't work to banlance energy efficiently. Moreover, there are no effective complementary routing algorithm that can be used to address energy balance. In this paper, we propose a novel routing scheme called EBVCR based on VCS , which uses nodes remnant energy cost Function and these two selection criteria to select a node with a large distance progress as key factors to decide next hop. Our simulation results show that the proposed algorithm outperforms the best existing solution, over a variety of network densities and scenarios.

2. Problem Description

This section describes how the use of an appropriate metric mapping function can turn the optimal forwarding distance in GR into the optimal forwarding metric value in VCS. In our description, The power needed to send a packet from A to C is proportional to r^a+c, where a is power attenuation factor($2 \leqslant a \leqslant 6$), r= |AC| , while c is a constant (c>0). Constant c accounts for the energy needed to run electronic circuits at transmitter and receiver and minimal signal strength for correct signal reception [5].

2.1. Problem Description

We started our work by examining how well the existing GR algorithms work in VCS. The goal is to understand which factors in VCS lead to favor energy banlance and which metric characteristic is the root cause.

We takes an example in which node A currently holding the packet has to select the next forwarding node to route the message to sink node D. According to the above formular, energy of sending a message through each link can be calculated.Therefore, the neighbor that minimizes (r^a+c)/(c-a) will be selected in geographic routing based on location information [1]. This means that the selected neighbor minimizes the power spent per unit of progress made in terms of getting closer to the destination.However,nodes coordinates in VCS is based on hops, instead of node location information.The furthest nodes in one hop,is very probably chosed as next hop.after one period time, network performance will decrease greatly. If the number of dead nodes increase to some extent,it will shorten the network lifetime. So we must try to another method to save energy balancing,which is simliar to the above method in function.

From the above,The distance-based scheme intends to maximize progress; thus, it may introduce a larger hop distance than the direction-based scheme. Even though [1] introduce a shorter hop distance, it produces many overhead at the same time.From the viewpoint of statistics, the distance-based gf intends to consume higher energy along the path toward the sink node, whereas the direction-based gf yields smaller path energy consumption but results in larger hop counts with higher end-to-end delay [3].

Therefore,we introduce the direction-based scheme to reduce path energy consumption based on received signal strengh in VCS.

2.2. Distance- and Direction-Based Criteria

One of the earliest papers [6] proposed an extension of the distance-vector algorithm to find the shortest path to a destination.Lin et. al. [7] proposed three variants of c-GEDIR, c-DIR and c-MFR methods, i.e. original c-path method, alternate c-path method and c-path method, of which the last provides high success rate, and small hop counts for small values of c. In the last method,the message m is forwarded to all neighbors whose direction belongs to the selected range. The range is determined by the tangents from A to the circle centered at D and with radius equal to a maximal possible movement of D since the last location update. The area containing the circle and two tangents is referred as the forwarding set(FS). Our method is similar to their last method where intermediate nodes will forward the message to its best neighbor among those who never received the message. However, there are some significant differences. In the first, we choose to next hop node according to the distance derived from received hello message signal strengh in FS. In the Second, we use the distance and node remnant energy as the performance metrics [8].

To meet our goal of spreading the energy expenditure among the whole FS set, we require an exponential function that starts by slowly increasing the value of $F(E_{battery})$ with decreasing battery, initially giving preference to shorter distances. However, as batteries start to deplete, it should more quickly increase $F(E_{battery})$ in order to use other available neighbors, even if they are much longer, thus maximizing the lifetime of individual nodes. Of course, such a function gives preference to longer energy-rich ditances, and will increase the per packet costs in the network,but it extend the network lifetime.

2.3. Received Signal Strength

For our implementation with the network simulator ns-2, we used the received signal strength Pr to calculate the distance to the transmitter of the packet. ns-2 uses the two-ray ground propagation model described in [19]. Using this propagation model, the distance d to the transmitter of a packet can be calculated as follows:

$$d = \sqrt[4]{\frac{P_t \cdot G_t \cdot G_r \cdot h_t^2 \cdot h_r^2}{P_r \cdot L}} \qquad (1)$$

where Pt is the default transmission power and Pr the received signal power; G_t and G_r are the antenna gains of the transmitter and the receiver, respectively; h_t and h_r are the heights of the antennas, and L is the system loss, which is set to 1 by default. We assumed that the network is homogeneous, i.e., all nodes use the same parameters P_t, G_t, G_r, h_t, h_r and L. If a node transmits with a different signal power P_t, it must include the value of P_t in the options field of the MAC protocol header [9].

2.4. Energy Balance Routing Decision

We now seek to conduct a more thorough study on energy balance in VCS characteristics. Moveover,since VCS inner characteristics make the best dis_{comb} exist inside FS, we design EBVCR to better achive energy balance,which uses hydrate the direction-based gf and the distance-based gf with node's remnant energy factor to banlance the energy-consumption of nodes when the forwarding set (FS)energy is smaller than threshhold.It can balance the energy consumption not only in the forwarding set (FS),but also in all neighbor nodes,thus it will greatly extend the network lifetime.

Moveover,Nodes with more energy are more eager to assist, while nodes with less remaining energy show more reluctance to do so. As a particular choice for the reluctance measure f(A) of node A. Here we concentrate on one combined cost metric to demonstrate how to use such complex cost metrics with VCS. We use a combination of remaining battery on the nodes and minimum distance based on VCS to destination. In this case we calculate a combination of two metrics as follows:

$$discomb=f(DisVCS, Delay, Ebattery) \quad (2)$$

$$f(DisVCS, Delay, Ebattery)=F(Ebattery)\cdot Delay\cdot DisVCS \quad (3)$$

In equation(3), $F(E_{battery})$ is the distance-multiplier, a function that weights the distance estimate based on the remaining battery. For simplicity we drop the "estimation" and denote dis_{comb} as minimum distance and battery. Dis_{VCS} is the distance of node A to the neighbor in FS.

From equation(2) and equation(3),if $F(E_{battery})$ is to linearly increase,there is a problem to extend the network lifetime. For example, a greedy protocol which always uses the best (lowest) dis_{comb} available, when faced with two neighbors with f(1,1, 10%) = 1.9 and f(2,1,100%) = 2, will select the shorter route even though the battery is nearly exhausted, therefore it can't achive better energy balance in FS[10].

3. Algorithm Design

We use algorithm 1 to clearly summarize Energy Balanced virtual coordinate Routing. Algorithm 1 process can be described as follows.

On receive(DATA d):
Use c-path method to decide forwarding set(FS) in nb_list;
Estimate neighbor nodes cost in FS according to equation(3);
Return result = selcet a neighbor node with minimum cost;

4. Performance Analysis

In this section, we test our Energy Balanced virtual coordinate Routing algorithm based on RSS flow and validated successfully with the NS-2 simulator. Our experiment is made based on random 100 nodes. The radio range is equal for all the nodes and fixed to 40m and the size of the scenarios is fixed at $100*100\ m^2$. The source is placed at bottom left corner and the sink at the top right corner. The survival time of the network is compared between our algorithm EBVCR and OLSR based on VCS [1], at the same time we also compare EBVCR with improvedGPSR based on VCS [12] on node average remnant energy.

In Fig 1, there are three different distribution about the number of nodes alive. From the experimental results,it can be seen that the time to live of networks using EBVCR is longer than that using OLSR and improvedGPSR based on VCS based on VCS. Therefore, it can be concluded that EBVCR has better performance than OLSR and improvedGPSR on energy balancing.

Although our algorithm have the near optimal performance when compared to its ideal counterpart in the network lifetime and energy balancing,it does not consider node mobility.In future work, we will investigate possible modifications so that it could support mobility, streaming multimedia and multi-path support, and therefore have a wider applicability. We will address the possible aggregation schemes in a future paper in which we discuss in detail both realistic and unrealistic aggregation schemes in order to make the proposed algorithm suitable for most applications.

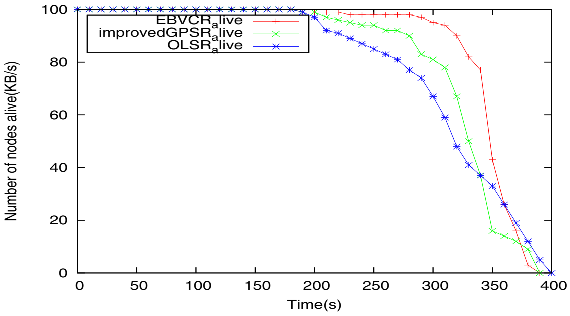

Fig 1. number of nodes alive over time of EBVCR,improvedGPSR,OLSR.

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