



TSGR: Two Stage Geographic Routing in Wireless Sensor Network with Mobile Sink

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Abstract

We consider a wireless sensor network where nodes contain small buffers and low power. In this paper, we propose a novel routing scheme called TSGR in wireless sensor networks with mobile sink. In TSGR, the sink informs its current location only to a minimal number of nodes compared to the existing schemes. Therefore, the sink needs fewer location broadcasts and decreases energy consumption. Our simulation experiments show that TSGR consumes lower energy than the existing routing schemes with comparable end-to-end delay.

Keywords: Sensor network, Mobile sink, Routing, Energy.

1. INTRODUCTION

Sensor networks usually contain a large number of sensors distributed in a controlled area. Today's wireless sensors are very limited in terms of battery, processing power, and memory capacity. For example, MICA2 contains 4 kilobytes memory [1]. Most of the existing studies on wireless sensor network assume the sink is fixed [2-7]. Sink mobility has a number of applications in wireless sensor networks [10].

A number of routing algorithms are recently proposed for such networks. Routing includes the process of discovering a route between a source sensor and the sink. Generally speaking, sensor nodes do not have a priori knowledge of the location information of the mobile sinks. A naive approach to addressing the problem of communicating with a mobile sink whose location information is unknown is through flooding.

While flooding ensures that the mobile sink receives data packets from sensor nodes, the data rate that can be supported in the network may be very low due to drastically increased collisions in transmitting flooding packets from sensor nodes [12].

Another approach is for the sink to consecutively inform its new location information to the sensors, such as DRP (Dynamic Routing Protocol) [13] and GRAB (GRADient Broadcast) [14]. But both DRP and GRAB require that the mobile sink needs to continuously propagate its location information throughout the entire network, so that all the sensor nodes get updated with the direction of sending future data reports. However, frequent location updates from the sink can lead to both large energy consumption of the sensor nodes and collisions in wireless transmissions [15].

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To address this problem, Adaptive Local Update-based Routing Protocol (ALURP) is proposed in [10]. When the sink node moves, it only needs to update its location information within a local area other than among the entire network, so it consumes less energy in each sensor node and also decreases the probability of collisions in wireless transmissions.

In this paper, we propose a novel routing scheme called TSGR based on ALURP in wireless sensor networks with mobile sink. In TSGR, the sink informs its current location only to a minimal number of nodes compared to ALURP and the existing schemes. Therefore, the sink needs fewer location broadcasts and decreases energy consumption.

The rest of this paper is organized as follows. We review related works in Section 2. We propose TSGR in Section 3. Section 4 contains our simulation results and section 5 concludes the paper.

2. RELATED WORKS

In this section, we review related researches that focus on routing in wireless sensor networks. We classify the existing routing schemes into researches on wireless sensor networks with A) fixed sink, and B) mobile sink.

2.1. Routing with Fixed Sink

Now we review the existing routing algorithms for wireless sensor networks. Directed Diffusion [2] routing protocol aims at diffusing the data through the sensor nodes by using a naming scheme. Rumor Routing [3] is a variation of Directed Diffusion intended for scenarios where geographic routing is not applicable. LEACH [4] is a cluster-based routing algorithm, but uses single-hop routing and can therefore not be applied to networks deployed in large regions. GPSR [5] uses a greedy forwarding strategy to forward only local information, but it has been designed for mobile ad hoc networks and requires a location service to map locations and node identifiers. GAF [6] is an energy-aware location-based routing algorithm. Its basic idea is to set up a virtual grid based on location information. Spectra [7] uses the cluster-based Ripple routing algorithm. When a CH requires a route to BS, it broadcasts a Route-Request message in the network. If a CH receives a Route-Request and contains a route to BS, then it sends a Route-Reply message to the requesting CH.

2.2. Routing with Mobile Sink

The LBDD [8] routing protocol defines a vertical virtual line which divides the sensor field into two parts. When an ordinary sensor node generates some new data, it forwards the data to the nearest node on the line. In order to retrieve a specific data, a sink sends a query toward the line. The inline-

node propagates the query in both directions along the line until it reaches the inline-node storing the data. The data is then sent directly to the sink.

LURP [9] divides the routing process into two stages. At the first stage, data packets are forwarded from the sensors to a destination area. At the second stage, the data packets are forwarded to the sink in the destination area. ALURP [10] improves LURP by shrinking the destination area as much as possible.

FLOW [11] is a learning-based approach to efficiently forward data to a mobile sink in a wireless sensor network. Moles (nodes that sense the sink) learn the sink's movement pattern over time and statistically characterize it as probability distribution functions. This information collected at the moles is used in a distributed fashion to calculate the likelihood of a node being on a good path to the sink which is used to determine whether to forward data through the node.

3. THE TSGR ROUTING SCHEME

In this section, we propose a routing scheme in wireless sensor networks (see figure 1). We call it TSGR (Two Stage Geographic Routing). Since we assume the sink often moves, it is not cost-efficient to use a topology-based routing algorithm for finding the path between the source and the destination area, because topology-based routing uses message flooding in the entire network. Thus, we can not replace the location-based routing with a topology-based routing algorithm. Our idea is to keep track of sink mobility so that fewer location broadcasts are required.

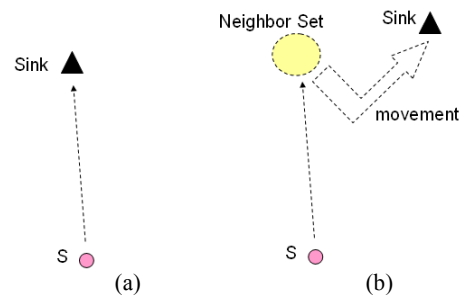


Figure 1. A view of the TSGR scheme

3.1. Basic Design

Figure 2 summarizes node operation in TSGR. When the network is deployed, the sink broadcasts its location information among the entire network, and then the sensor nodes can send their data to the sink. Nodes only know the last broadcasted sink's location. The sensor nodes always forward the data to the sink using geographic routing.

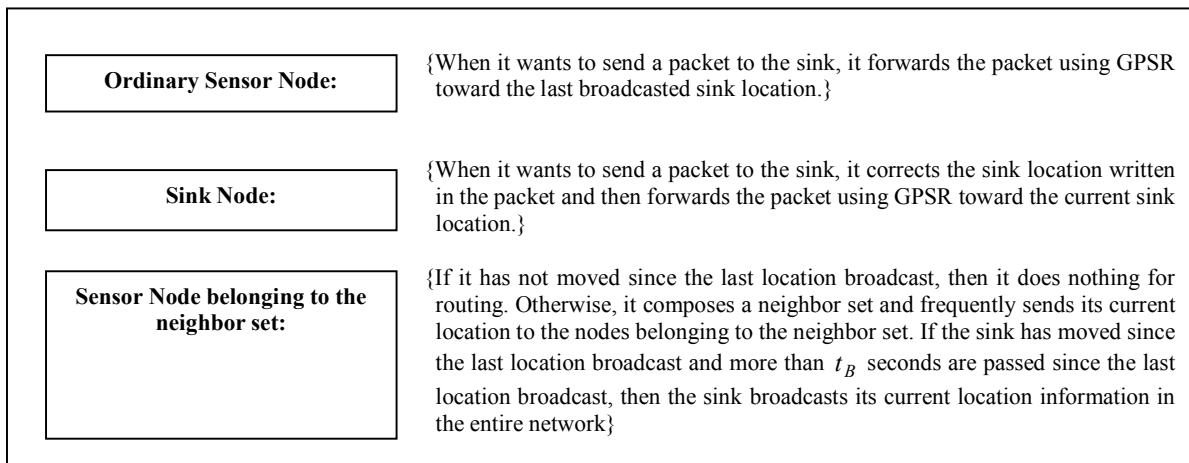


Figure 2. Node operation in TSGR

If the sink moves, it does not immediately broadcast its new location in the entire network. Instead, it let nodes work with the last broadcasted sink's location for a time interval denoted by t_B . When the sink broadcasts its current location, it establishes a neighbor set composed of the 5 closest nodes. This set is valid until the next location broadcast. When the sink moves, it informs its current location only to the nodes in the neighbor set.

The nodes transfer packets to the last broadcasted sink's location. Then, the packets reach either the sink or a node in the neighbor set. If a packet reaches the sink, it means the sink did not move since the last location broadcast and no more forwarding is required. If a packet reaches a node in the neighbor set, the node knows the current sink's location and forwards the packet toward the sink using geographic routing.

3.2. Additional Design Notes

The sink sends location updates to the neighbor set using geographic routing. No matter what physical path the sink travels. The route from the sink and the neighbor set is the shortest path found by geographic routing. Taking 5 nodes in the neighbor set ensures there is probably a node left in the neighbor set when the others fail. The sink sends a location update to the neighbor set whenever both the following conditions are satisfied.

- The sink moves to a new location where the route between the sink and the neighbor set changes.
- The sink is away from the last broadcasted location.

3.3. Location Broadcast Interval

The sink broadcasts its location information among the entire network only when it gets too far from the neighbor set so that two stage routing consumes more energy than a broadcast and one stage routing. In other words, t_B is

variable. The sink determines t_B depending on the following items.

- The traffic volume between nodes and the sink.
- The route length between the sink and the neighbor set
- The traffic sources
- Sink's Location
- Frequency of location updates to the neighbor set
- Sink's mobility speed

It does matter how many updates the sink has to send to the neighbor set during mobility. It is apparent that broadcasting these updates in the entire network consumes much more energy. t_B depends on sink's location because it determines route length.

Let us assume the followings parameters.

N : Number of sensor nodes

N_s : Number of neighbor set nodes

T_c : A constant time interval fixed at 5 seconds

L_1 : The total number of hops packets traveled to reach the neighbor set in the current T_c

L_2 : The total number of hops packets traveled to reach the sink from the neighbor set in the current T_c

L_3 : The total number of hops from the active sources to the sink in the current T_c

L_u : The total number of hops location update packets traveled from the sink to the neighbor set nodes in the current T_c

e : The expected energy consumed for a one-hop packet transfer; We assume e is constant and is calculated using the energy model described in [7].

E_{nb} : Total energy consumption in the current T_c without new location broadcast

E_b : Total energy consumption in the current T_c with a new location broadcast at the beginning of the current T_c

The sink calculates these parameters by examining packet headers. We have

$$E_{nb} = e.(L_1 + L_2 + L_u)$$

$$E_b = e.L_3 + e.N$$

From the last location broadcast, the sink divides the time into T_c intervals when it starts getting away from the neighbor set. The sink computes E_{nb} and E_b at the end of each T_c interval. If $E_b < E_{nb}$, then the sink immediately broadcasts its location information in the entire network. Otherwise, no location broadcast is done.

Table 1. Simulation Scenario I and II

Parameter	Scenario II	Scenario I
Network Area	Proportional to number of nodes	
Node Distribution	Uniform	
Network Traffic	A Pareto-On/Off flow from every node to the sink	
Average Bit Rate per traffic flow	30 bps	
The idle-time period per traffic flow	5 seconds	
Sink Mobility Model	Random Waypoint [17]	
Sink Mobility Speed	Variable from 0.05 to 0.4 m/s	0.1 m/s
Number of Nodes	400	Variable from 100 to 800
Simulation Duration	1 Hour	

4. SIMULATION

We implemented the TSGR protocol in the NS2 [16] network simulator. In this section, we evaluate the performance and the overhead of TSGR and ALURP. To do this, we define the two simulation scenarios presented in Table I.

In scenario I, we change network size and number of nodes in different executions whereas the other parameters are fixed to evaluate the scalability TSGR. In scenario II, we use different values of sink mobility speed in different executions to evaluate the overhead of TSGR under different sink speeds.

Each traffic flow follows a Pareto-On/Off distribution implemented in NS2 that generates variable bit rate during a simulation. Every node sends traffic to the sink. But the idle time of each flow is set to 5 seconds. Thus, the traffic sources

are not all active at the same time. They generate packets at random times.

Both TSGR and ALURP require a geographic routing algorithm which we chose to be GPSR [5] in our experiments. We used the energy model used in [7] for energy consumption in nodes. We only consider the energy consumed for packet transmissions.

4.1. Simulation Results

Figure 3 illustrates how much energy is consumed in sensors in scenario I. The bigger the network, the more traffic is sent to the sink. Thus, more energy is consumed. TSGR consumes about 30 percent less energy than ALURP in this experiment. This energy saving is because of the fact that TSGR considerably reduces flooding.

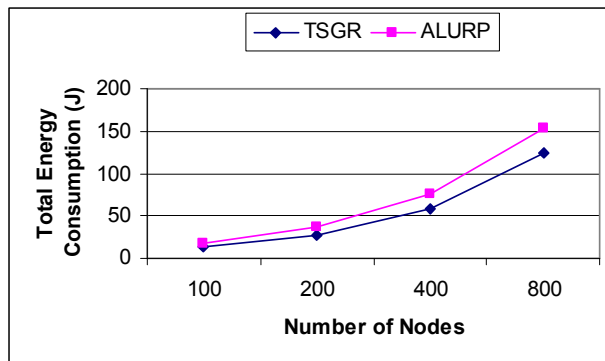


Figure 3. Total energy consumption versus number of nodes (Scenario I)

Figure 4 illustrates how much delay packets experienced in scenario I. Since some packets do not travel the shortest path in TSGR, they face more latency than ALURP. This happens when the sink is located in a point where the two-stage route in TSGR is longer than the shortest path from a source to the sink. Then, the packets from that source face extra delay.

This amount of extra delay is averagely 2 percent in scenario I. The delay slightly increases in both TSGR and ALURP when the network gets bigger. This is because of the fact that the bigger the network, the longer the routes are from sensors to the sink.

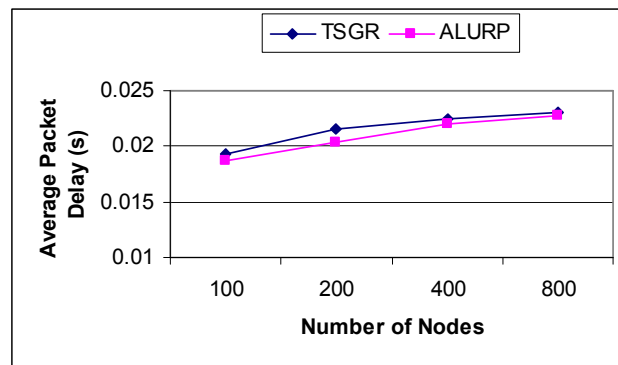


Figure 4. Average end-to-end delay versus number of nodes (Scenario I)

Figure 5 illustrates how much energy is consumed in sensors in scenario II. In TSGR, the faster the sink moves, the earlier it gets away from the neighbor set and then the earlier it reaches the point requiring a new location broadcast. Therefore, energy consumption depends on sink's speed. The

same case happens in ALURP too. As figure 5 shows, TSGR prevents additional broadcasts when the sink is moving compared to ALURP. So it consumes less energy. At high speeds, TSGR copes with sink mobility well. That is why the distance between the two curves gets higher at high speeds.

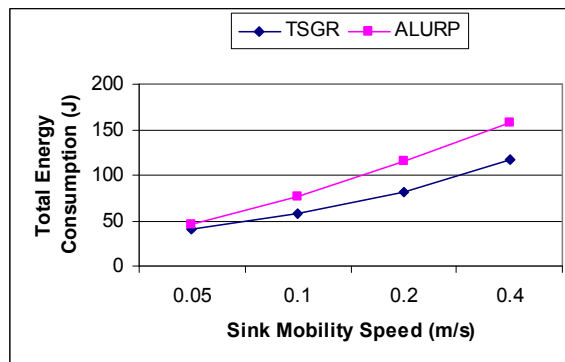


Figure 5. Total energy consumption versus sink mobility speed (Scenario II)

5. CONCLUSIONS

We proposed a novel routing scheme called TSGR in wireless sensor networks. TSGR tries to reduce the times when the network requires broadcasting sink's location in the entire network, thereby decreasing energy consumption. In TSGR, the sink does a new location broadcast only when it is energy-efficient. TSGR may increase end-to-end delay when the sink is located away from the neighbor set. Our simulation experiments show that TSGR consumes lower energy than the existing routing schemes with comparable end-to-end delay.

In TSGR, most of the time, the update of the sink's location information is restricted to the neighbor set and not the entire network, so it reduces the energy consumption in the network.

In ALURP, whenever the sink moves out of the current area, it needs to broadcast its location information among the entire network and a new destination area is built and the routing process repeats. If the sink is always moving, these tasks consume too much energy.

But in TSGR, the sink broadcasts its location information among the entire network only when it gets too far from the

neighbor set when two stage routing consumes more energy than a broadcast and one stage routing.

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