Energy-Efficient Wireless Sensor Networks Using Learn Protocol

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Abstract

A number of energy-aware routing protocols were proposed to seek the energy efficiency of routes in multihop wireless networks. Among them, several geographical localized routing protocols were proposed to help making smarter routing decision using only local information and reduce the routing overhead. However, all proposed localized routing methods cannot guarantee the energy efficiency of their routes.

We first give a simple localized routing algorithm, called Localized Energy-Aware Restricted Neighbourhood routing (LEARN), which can guarantee the energy efficiency of its route if it can find the route successfully. We then theoretically study its critical transmission radius in random networks which can guarantee that LEARN routing finds a route for any source and destination pairs asymptotically almost surely.

We also extend the proposed routing into three-dimensional (3D) networks and simulate these networks using **NS2**(network simulator 2) tool

Introduction

Sensor networks have emerged as a promising tool for monitoring the physical worlds, utilizing self-organizing networks of battery-powered wireless sensors that can sense, process and communicate. Wireless sensor networks [2] consist of small low power nodes with sensing, computational and wireless communications capabilities that can be deployed randomly or deterministically in an area from which the users wish to collect data. Typically, wireless sensor networks contain hundreds or thousands of sensor nodes that are generally identical. These sensor nodes have the ability to communicate either among each other or directly to a base station (BS). The sensor network is highly distributed and the nodes are lightweight. Intuitively, a greater number of sensors will enable sensing over a larger area. As the manufacturing of small, low-cost sensors become increasingly technically and economically feasible, a large number of these sensors can be networked to operate cooperatively unattended for a variety of applications like military applications, disaster management, habitat monitoring, health applications, home applications etc . The features of sensor networks are as depicted below.

- Varying network size – The size of a sensor network can vary from one to thousands of nodes.
- Low cost – For the deployment of sensor nodes in large numbers, a sensor node should be inexpensive.

- Long lifetime network – An important characteristic of a sensor network is to design and implement efficient protocols so that the network can last as long as possible.

- Self-organization – Sensor nodes should be able to organize and form a network automatically without any external configuration.

- Query and re-tasking – The user should be able to query for special events in a specific area, or remove obsolete tasks from specific sensors and assign them with new tasks. This saves a lot of energy when the tasks change frequently.

- Cooperation/Data aggregation – Sensor nodes should be able to work together and aggregate their data in a meaningful way. This could improve the network efficiency.

- Application awareness – A sensor network is not a general purpose network. It only serves specific applications.

- Data centric – Data collected by sensor nodes in an area may overlap, which may consume significant energy. To prevent this, a route should be found in a way that allows in-network consolidation of redundant data.

Recent advances in wireless sensor networks have led to many new protocols specifically designed for sensor networks. Most of the attention, however, has been given to the routing protocols since they might differ depending on the application and network architecture [3, 4]. To prolong the lifetime of the sensor nodes, designing efficient routing protocols is critical. Even though sensor networks are primarily designed for monitoring and reporting events, since they are application dependent, a single routing protocol cannot be efficient for sensor networks across all applications. Multihop routing technique is the first step towards minimizing energy consumption in sensor networks.

Energy conservation and scalability are probably two most critical issues in designing protocols for multihop wireless networks, because wireless devices are usually powered by batteries only and have limited computing capability while the number of such devices could be large. In this paper, we focus on designing routing protocols for multihop wireless networks which can achieve both energy and efficiency by carefully selecting the forwarding neighbours and high scalability by using only local information to make routing decisions.
Numerous energy aware routing protocols have been proposed recently using various techniques (transmission power adjustment, adaptive sleeping, topology control, multipath routing, directional antennas, etc). Most of the proposed energy-aware routing methods take into account the energy-related metrics instead of traditional routing metrics such as delay or hop count. To select the optimal energy route, those methods usually need the global information of the whole network, and each node needs to maintain a routing table as protocol states.

1. We propose a new localized routing protocol, called localized energy-aware restricted neighborhood routing (LEARN). In LEARN, whenever possible, the node selects the neighbor inside a restricted neighborhood that has the largest energy mileage (i.e., the distance traveled per unit energy consumed) as the next hop node.

2. We prove that LEARN is energy efficient i.e., when LEARN routing finds a path from the source node to the target node, the total energy consumption of the found path is within a constant factor of the optimum. LEARN routing is the first localized routing which can theoretically guarantee the energy efficiency of its routes.

3 We also prove the energy efficiency using LEARN by simulating it in the 'NS2 tool'.

Energy Efficient Localized Routing

We describe in detail our energy-efficient localized routing method, called LEARN, which is a variation of classical greedy routing. In greedy routing, current node u selects its next hop neighbor based purely on its distance to the destination, i.e., it sends the packet to its neighbor who is closest to the destination.

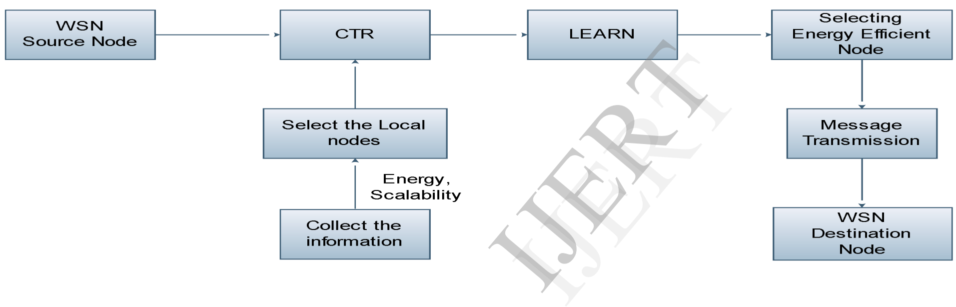
However, such choice might not be the most energy-efficient link locally, and the overall route might not be globally energy efficient too. The definition of energy mileage provides us the insight in designing energy efficient routing. Whenever possible, the forwarding link that has larger energy mileage should be used. In addition, to save the energy consumption, the total distance traveled should be as small as possible. Thus, we introduce a restricted region to restricting the forwarding direction. Intuitively, our routing protocol will work as follows:

1. The current intermediate node u with a message first finds the “best” neighbor v among all neighbors w inside a restricted area (i.e., angle $\angle vut \leq \alpha$ or a parameter $\alpha \leq \pi/3$) as shown in Fig. 1a. Here we define the “best” neighbor as the node v such that its energy mileage $\|uv\|/c\|uv\|$ is maximum among all such neighbors (i.e., $\|uv\|$is the nearest to r_0 and $\eta_1 r_0$ $\|uv\| \leq \eta_2 r_0$ where η_1 and η_2 are two constant parameters). Recall that r_0 is the best link length that achieves the maximum energy mileage.

2. If there is no neighbor inside the restricted area (or $r_0 \geq r$), current node u finds the node v inside the 2α-sector region (as shown in Fig. 1b) with the minimum $\|t - v\|$. The use of the angle α(restricting the forwarding direction) in our algorithm is to bound the total distance of the routing path. This can help us to prove the energy efficiency of the route.

3 . When there is no neighbor in the 2α-sector region, classical greedy routing (as shown in Fig. 1c) or face routing can be applied.

Block diagram of localized routing



Notice that the ideas of using restricted region and energy mileage are not completely new. Restricted region with an angle has been used in some localized routing methods, such as nearest/farthest neighbor routing , while concepts similar to energy mileage have been used in some energy-aware localized routing methods. However, combining both of these techniques to guarantee energy efficiency of paths has never been done before.

Algorithm 1: illustrates our localized energy-aware routing protocol. In our protocol, there are four input parameters:

1) $\alpha \leq \pi/3$ is an adjustable parameter to define the 2α-sector restricted forwarding region;
2) η_1 and η_2 are two constant parameters to control the restricted forwarding region around r_0 if $r_0 < r$, usually $\eta_1 < 1$ and $\eta_2 > 1$;and
3) r_0 is the link length with maximum energy mileage which can be derived from energy model c(x) (e.g., $r_0 = \sqrt{c}$ for energy model $c(x) = x^2 + c$). For example, the following setting of these parameters can be used for energy model $c(x) = x^2 + c$: $\alpha = \pi/4$, $r_0 = \sqrt{c}$, p , $\eta_1 = 1/2$ and $\eta_2 = 2$. To make the later analysis easier, we call the routing algorithm LEARN if no Greedy routing and no Face routing is used when no node v

satisfying that $\angle vut \leq \alpha$. If greedy routing is applied afterward, then the routing protocol is called LEARN-G. Furthermore, if the Face routing is used at the end to get out of the local minimum, the routing protocol is called LEARN-GF.

Algorithm

LEARN: Localized Energy-Aware Restricted Neighborhood Routing
Input: Three parameters $0 < \alpha < \pi/3$ and $\eta 1 < 1 < \eta 2$ defining the restricted region, and the best energy mileage distance r0.

1. while node u receives a packet with destination t do
2. if $\|t \_ u\| \leq r$, i.e., t is a neighbor of u then
3. Node u forwards the data to t directly and return.
4. else if (r0 < r) and (Ev with $\eta 1 r0 \leq \|uv\| \leq \eta 2 r0$ and $\angle vut \leq \alpha$) then
5. Node u forwards the packet to such a neighbor v such that $| \|uv\| - r0 |$is minimized. See Figure 1a.
6. else if Ev with $\|t - vk\| < \|t - u\|$and $\angle vut \leq \alpha$ then
7. Node u forwards the packet to the node v with the minimum $\|t - v\|$. See Figure 1b.
8. else if Ev with $\|t \_ v\| < \|t - u\|$ then
9. Node u forwards the packet to the node v with the minimum $\|t - v\|$. In other words, node u applies the traditional Greedy routing. See Figure 1c.
10. else
11. Node u simply drops the packet, or applies the Face routing method to guarantee the delivery.
12. end if
13. end while

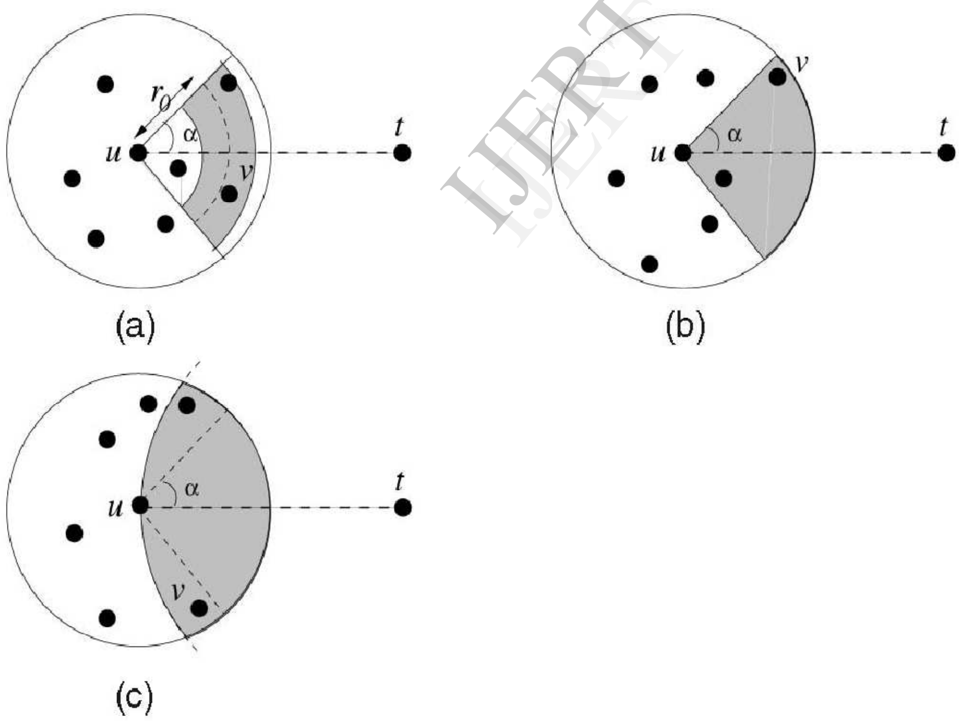


Fig-1: Illustrations of LEARN routing:
(a) energy efficient forwarding in a restricted forwarding region,

(b) greedy forwarding in the 2_-sector region, and
(c) classic greedy forwarding when the sector region is empty.

Implementation and Simulation

Network simulator 2(NS2)

Network Simulator (Version 2), widely known as NS2, is simply an event driven simulation tool that has proved useful in studying the dynamic nature of communication networks. Simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP) can be done using NS2. In general, NS2 provides users with a way of specifying such network protocols and simulating their corresponding behaviours. Due to its flexibility and modular nature, NS2 has gained constant popularity in the networking research community.

Simulation Metric

Latency

This performance metric measure the average end-to-end delay of data packet transmission.

The end-to-end delay defines the average time taken between a packet sent by the source, and the time for successfully receiving the message at the destination. Measure this delay takes into account the propagation delay of the packets and queuing. The time taken to deliver a packet to the base station from the origin node will be looked at when evaluating the protocols. In addition the per hop time delay will also be looked at as performance metric for the network. So that Lower latency is always preferable to higher latency.

Life time of sensor based on delay: The life time of sensor is based on energy consumed on each hop and delay produced by each node while transmitting signals from one node to other node.

Total energy consumed: The power consumption is the sum of used power of all the nodes in the network, where the used power of a node is the sum of the power used for communication, including transmitting (Pt), receiving (Pr), and idling (Pi). The amount of power used during the simulation will be monitored and used for evaluating the protocols. Batteries have a finite amount of power and nodes die once power runs out. For this reason lower power usage is preferable to higher power usage.

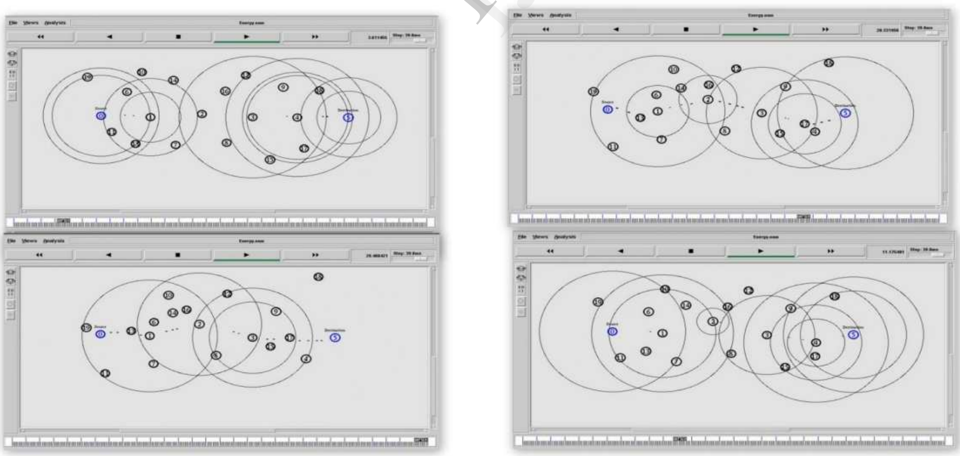
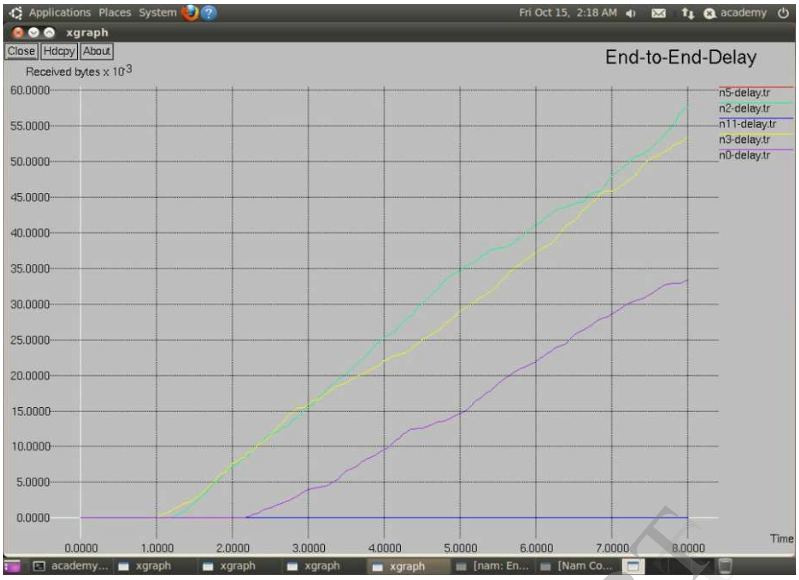


Fig-2: Transmission of data from source to destination in different routes.

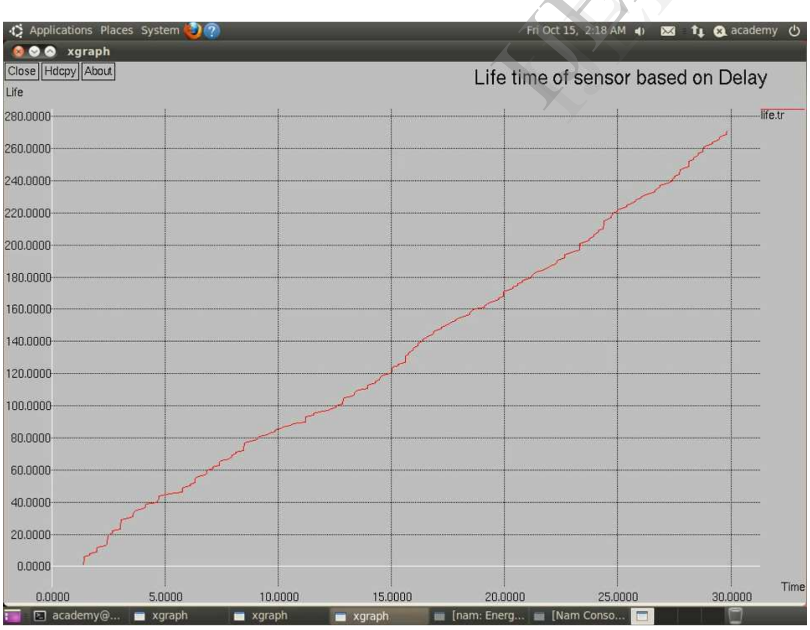
Simulation results

The output from the simulator stored in an output file has been processed in order to evaluate the protocols based on the metrics specified. The processed results are depicted below.

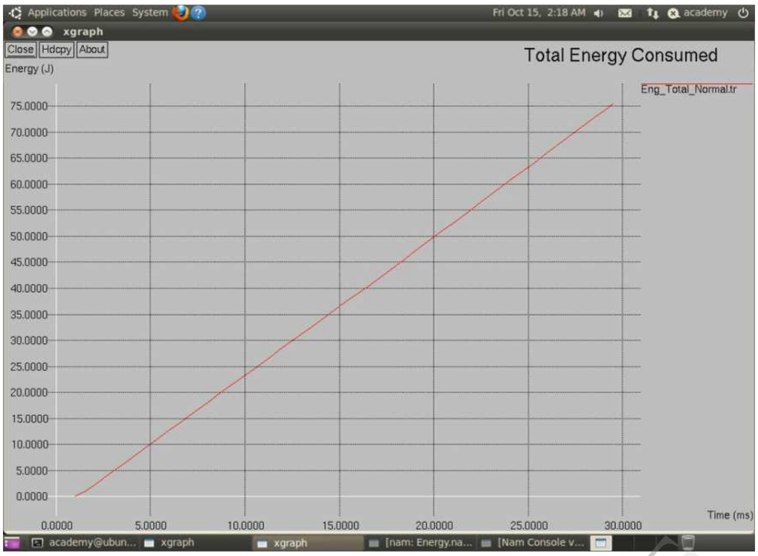
End to End delay in different paths



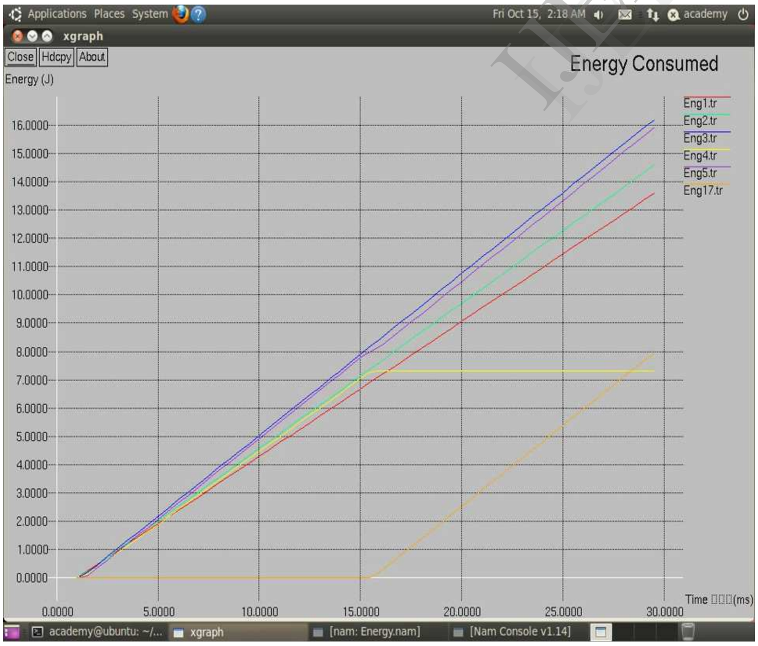
Life time of sensor based on delay



Total energy consumed



Energy consumed in different paths



Conclusion

We proposed the localized energy aware restricted neighborhood routing protocol for wireless networks. We theoretically proved that our LEARN routing protocol is energy efficient if it can find a path. We also studied its critical transmission radius[1] for the successful packet delivery. We also extended the proposed routing method into 3D networks.

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