Energy-Efficient Node Selection in Multihop Wirelessntworks

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Abstract
In a single-hop network with multiple relays, selecting a single node to aid in the transmission between a source and a destination outperforms both traditional orthogonal transmissions and distributed space-time codes. The usage of multiple hops will further improve the wireless communication. This paper presents an energy efficient selection of cooperative nodes with respect to their geographical location and the number of nodes participating in cooperative communications in wireless networks. Here, we first give a simple localized routing algorithm, called Localized Energy-Aware Restricted Neighborhood 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 derive its critical transmission radius in 3D random networks. The simulation result shows that the proposed node selection scheme will results in better selection of nodes for large scale random networks. Index Terms—Localized routing, energy efficient, critical transmission radius.

1 Introduction
With the advent of new technologies and the demand for flexibility and ease in working environment, the use of mobile Wireless computing is growing fast. The wireless network contains some tens of nodes up to several hundreds of nodes. Wireless devices are usually powered by batteries only and have limited computing capability while the number of such devices could be large. As the network size increases, it becomes common for the nodes to be dispersed in a larger area than the radio range of individual nodes. A straightforward solution to reduce energy is relying on multihop communication instead of communicating directly with a possibly distant sink node, data is relayed hop-by-hop by the intermediate sensor nodes. Such an approach, coupled with dedicated energyaware routing techniques might result in a more balanced energy-consumption among the network nodes. In this paper, we focus on designing routing protocols for multihop wireless networks which can achieve both energy efficiency by carefully selecting the forwarding neighbors and high scalability by using only local information to make routing decisions. 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. In those localized routing protocols, with the assumption of known position information, the routing decision is made at each node by using only local neighborhood information. They do not need dissemination of route discovery information, and no routing tables are maintained at each node. Previous localized routing protocols are not energy efficient, i.e., the total energy consumed by their route could be very large compared with the optimal.

2. Related Works
In several practical situations, every node in the network is not simultaneously concerned in all transmission; therefore, protocols are required to form groups or subsets of nodes for the purposes of cooperation. These papers consider this difficulty in the circumstance of regenerative nodes and no altruistic cooperation. Greedy routing is simple and efficient but cannot guarantee the packet delivery, while face routing can guarantee the delivery but may take a lengthy exploration. One natural improvement is to combine greedy routing and face routing by using face routing to recover the route after greedy method fails in local minimum. Classical routing algorithm maybe adapted to take into account energy-related criteria rather than classical metrics such as delay or hop distance. Experimental results indicate that the proposed technique can diminish the impact of the possible malicious nodes on transmission performance and the simulation result also indicates the efficiency of the proposed technique.

3 Network Model
Consider the network consisting of a source S, destination D, and NM stationary nodes aligned in a uniformly placed grid.The distance between a node and its four nearest neighbors is d. This simple structure approximately models mesh and other networks where nodes are static with known locations.

●r (1, 1) ● r(1, 2) … ● r(1, M)
●r (2, 1) ● r(2, 2) … ● r(2, M)
. . .
. . .
●S . . . ● D
. . .
●r (n, 1) ● r(n, 2) … ● r(n, M)
●r (N, 1)● r(N, 2) … ● r(N, M)

Figure 1: N X M Network Layout.

r(x, y) denotes a node in position (x, y). Thehorizontal and vertical distance between each node is d. A source node S broadcast data to destination node D with the help of the NM nodes in the grid. The data can be routed from the source to destination over multiple hops, and the nodes may use Selection Cooperative within each hop. The communication between the source and destination is considered as a flow.

Figure 2: Multihop transmission

4 Energy Model

For a sensor node to transmit 1 bit stream over a distance D, the transmitter power $E_{Tx} = E_{elec} + €_{amp} D^k$ The Power E_{Rx} needed to receive 1 bit stream is $E_{Rx} = E_{elec}$ Where E_{elec} is the energy per bit consumed in the transmitter or receiver circuit, E_{elec} = 2 nJ/bit and $€_{amp}$ is the energy dissipated in the transmit amplifier, $€_{amp}$ =10 pJ/bit/m2. k is the path loss, ranges between 2 and 6.

5 Energy Efficient Node Selection

In this section, 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:

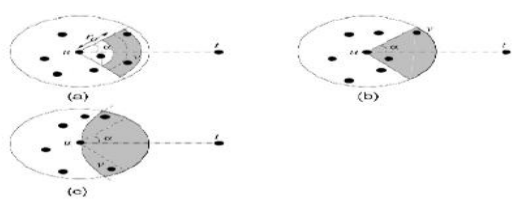


Figure 3: Illustrations of LEARN routing: (a) energy

Efficient forwarding in a restricted forwarding region, (b) greedy forwarding in the 2 α -sector region, and (c) classic greedy forwarding when the sector region is empty. 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 < wut ≤ α for a parameter α < π / 3) as shown in Fig. 3a. Here we define the “best” neighbor as the node v such that its energy mileage ||uv|| / C(||uv||) (i.e., ||uv|| is the nearest to r_0 and $\eta_1 r_0 \le ||uv|| \le \eta_2 r_0$ 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. if there is no neighbor inside the restricted area (or r_0 ≥ ɤ), current node u finds the node v inside the 2α sector region (as shown in Fig. 3b) 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.
 When there is no neighbor in the 2α- sector region, classical greedy routing (as shown in Fig. 3c) can be applied.

6 Critical Transmission Radius

Assume that V is the set of all wireless nodes and each node has a transmission radius r. Then the physical communication network is modeled by a unit disk graph G(V, ɤ) where two nodes u and v are connected in G(V, ɤ) if and only if their Euclidean distance is at most ɤ. A routing method A is successful over a network G if the routing Method A can find a path for any pair of source and destination nodes. It is easy to show that, given a set of nodes V already distributed in a region Ώ, the critical transmission radius ρ(V) for successful routing by our restricted greedy routing LEARN is max min ||w-u|| u,v w:<wuv ≤ α where α is the parameter used by LEARN. By setting the r = ρ(V), LEARN can always find a forwarding node inside the restricted sector region, thus can guarantee its packet delivery. When the destination node is fixed, say node t, the critical transmission radius will be max u min w :<wut ≤ α ||w-t||. We assume that the network nodes are given by a Poisson point process Pn of density n over a convex compact region Ώ with unit area and bounded curvatures. Then, we can prove similar results for our restricted greedy routing method LEARN.

7 Critical Transmission Range For Learn

We first study the study the critical transmission range for restricted greedy routing LEARN in random networks. In our experiments, we randomly distribute n wireless nodes in a disk with radius 5 unit. Node density n is 50, 100, 200,300, 400 and 500. The parameter α is π/4 or π/6. For each choice of α and n, 1000 sample of networks is generated, and the critical transmission range is generated for each sample.

Figure 4 illustrates the average and 95 percentile critical transmission range for our restricted greedy routing LEARN in random networks when α are π/4 and π/6. It is clear the critical transmission range decreases when the number of nodes increases. And with smaller α, LEARN need a larger critical transmission range to guarantee the delivery. Figure 5 shows the detailed distributions of the critical transmission range in random networks with different size when α = π/4.

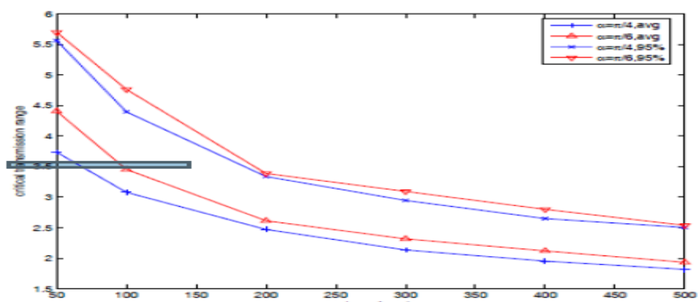


Figure 4: The average and 95 percentile critical transmission range for LEARN routing in random networks when α = π/4, π/6.

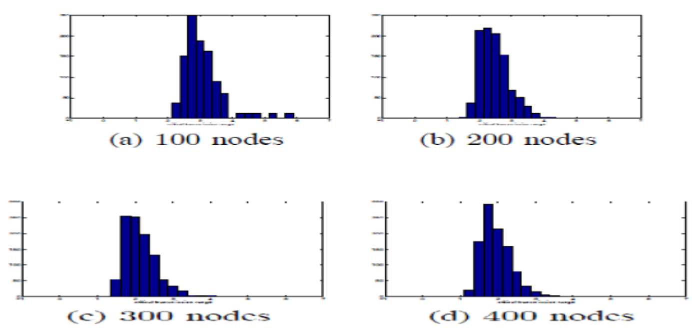
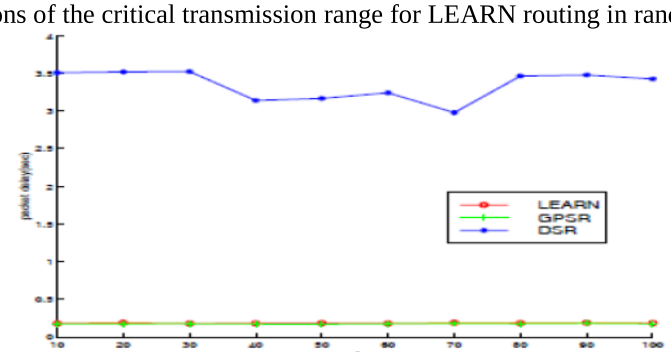
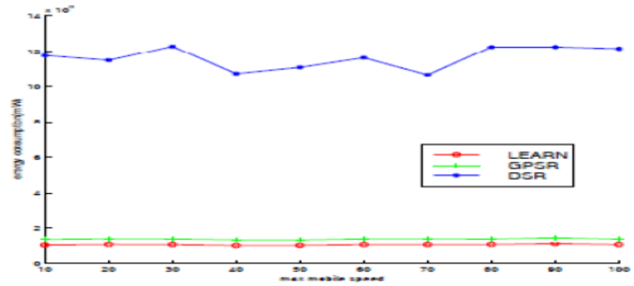


Figure 5: The distributions of the critical transmission range for LEARN routing in random networks when α = π/4.



(a) Packet delay



(b) Energy consumption

Figure 6 (a)&(b): Performance of mobile networks with various maximum speeds (10−100).

8 Conclusions

We proposed localized energy aware restricted neighborhood routing protocol LEARN for wireless or ad hoc networks.We theoretically proved that our LEARN routing protocol is energy efficient. Our mathematical formulation also extends to any routing protocol in which the region to find the next hop node by an intermediate node is compact and convex. We conducted extensive simulations to study the performance of our LEARN routing compared with GPSR and DSR. To the best of our knowledge, our new localized routing method is the first localized routing protocol that has theoretical guarantee of power efficiency of the generated routes in random networks with high probability.

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