Comparing different topology construction algorithms for Wireless Sensor Networks

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1 Introduction

Wireless Sensor Networks are autonomous devices forwarding locally collected data to a so-called sink node along multi-hop wireless paths. The main constraint is the limited (battery) power. We assume here that sending packets costs much more than receiving or computing.

2 Goals and methodology

We want to extend the network lifetime by minimizing the number of sent packets, focusing on routing and topology control algorithms. Our first step is to evaluate the cost-field based routing algorithm included in GRAB (Ye et al. [1]) or in the technique proposed by Li Xia et al. [3], and measure the influence of the cost measure.

3 Experiments and results

We simulated the cost-field construction included in GRAB with the cost measure based on:

- the hop-count (always available in practice) or,
- the distance between nodes, squared (more related to the minimum energy needed to transmit a packet but not always available; note that if the nodes only use one transmission power, this cost does not represent what the nodes actually use).

The other parameters are set identical for both cost types: i.e. 2000 nodes, an area of $150m^2$ and a range of $10m$. Such a range implies that a node has many neighbors (high density).

We ran five experiments of both types and averaged the number of messages needed to establish the cost field.

The following graphs show the routing trees used during the forwarding phase: with the distance, squared (figure 1) and hop-count (figure 2), as costs. If a node decides to forward a packet, it will send it to only one next-hop node so there is only one route from one source to the sink (otherwise the routing structure would be more complex than shown here). To do that, a node keeps the ID of the node that sent the best ADV message.

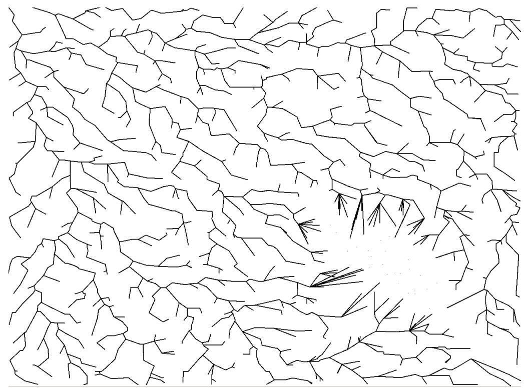

Figure 1: An almost stable forwarding tree with cost based on minimal transmission energy.

Let us examine that more deeply.

3.1 The quality of the forwarding tree

During the forwarding phase, messages will flow from all the nodes, to the sink. It is clear that the nodes, that are closer to the sink, have more chance to be

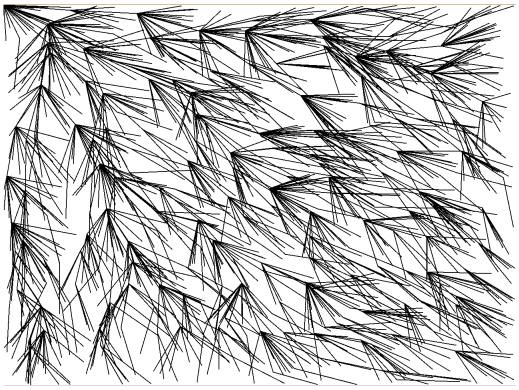

Figure 2: Same settings as above but using hop count as cost. The load on the nodes will not be well balanced during data forwarding.

part of many node-sink paths but we aim at balancing the load as much as possible.

The routing tree on (figure 2) is a *bad* one, in that respect, because only a few nodes will have to forward the full traffic of the network. Why? What happens at the beginning of the establishment of the field? The sink sends an ADV message. All the nodes in range (many since the range is big), are one hop away from the sink and will therefore keep that cost (best cost). Let us call this group of first nodes G1. Now suppose A is the first of those nodes to rebroadcast the ADV message. A is likely to reach a lot of nodes that are also one hop away from many other nodes in G1. A will then be the "forwarder" for all those nodes, while many nodes in G1 will avoid that burden (the ones that share at least one one-hop neighbor with A).

Now again, if the nodes do not use power control, with the range and nodes density used here, the structure built with the cost based on minimal transmission energy (distance, squared), will lead to multi-hop paths that will be much less efficient than the ones obtained with the hop-count cost, since much more energy than needed will be used on each edge of the path!

This shows how careful we must be while evaluating performance, in this context. For example, if we assume the nodes can not tune their transmission power, it is impossible, without further experiments, to tell which solution is the best: will the overloaded nodes (hop-count cost) failure rate be worse than the expensive paths (energy cost)? Moreover, the solutions, depending on the case, will differ: cost-field refresh (hop-count) or power control (energy).

3.2 Conclusion

If the range is not adapted to the nodes density, another mechanism is needed.

The first results suggest that the cost-field algorithm used in GRAB could be enhanced, for example with power-control (both during the cost-field construction and the forwarding phase), to adapt the range to what is strictly necessary, hopefully leading to a more optimal forwarding scheme, even with a hop-count based cost.

4 Future work

The next step is to compare the performance of existing cost-field based algorithms that use power-control (like BIPAR (Morcos et al. [2]), based itself on GRAB), with our own approach, that we are currently developing.

References

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[2] Hany Morcos, Ibrahim Matta, and Azer Bestavros. *BiPAR: A Bimodal Power-Aware Routing Protocol for Wireless Sensor Networks.* In Proceedings of the First International Computer Engineering Conference (ICENCO 2004), Cairo, Egypt, December 2004.

[3] Li Xia, Xi Chen, and Xiaohong Guan. *A new gradient-based routing protocol in wireless sensor networks.* Lecture Notes in Computer Science 3605: 318-325 2005.