Chapter 19
A QoS Aware Framework to Support Minimum Energy Data Aggregation and Routing in Wireless Sensor Networks

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ABSTRACT
In a wireless sensor network (WSN), the sensor nodes obtain data and communicate its data to a central-
ized node called base station (BS) using intermediate gateway nodes (GN). Because sensors are battery
powered, they are highly energy constrained. Data aggregation can be used to combine data of several
sensors into a single message, thus reducing sensor communication costs and energy consumption. In
this article, the authors propose a QoS aware framework to support minimum energy data aggregation
and routing in WSNs. To minimize the energy consumption, a new metric is defined for the evaluation of
the path constructed from source to destination. The proposed QoS framework supports the dual goal
of load balancing and serving as an admission control mechanism for incoming traffic at a particular
sensor node. The results show that the proposed framework supports data aggregation with less energy
consumption than earlier strategies.

INTRODUCTION
A WSN consists of a number of sensor nodes scattered in a particular region in order to acquire
some physical data. Small size of sensor motes
in WSNs facilitates easy deployment and allows
unobtrusive and inconspicuous detection and
monitoring. Applications such as tactical sentinels,
smart buildings and intelligent monitoring systems
are made possible by deploying large number of
nodes that are small in size and cost-effective.
These sensor nodes have the ability of sensing, processing and communicating (Akyildiz et al., 2002; Arampatzis et al., 2005; Culler et al., 2004). Many recent experiments in the field of sensor networks where low power radio transmission is employed have shown that wireless communication is far from being perfect (Cerpa et al., 2003; Yarvis et al., 2002; Zhao et al., 2003). A routing protocol design must therefore ensure that network can achieve self-configurability, adaptively and resilient to failure with low energy consumption (Akyildiz et al., 2002; Cerpa et al., 2003; Yarvis et al., 2002; Zhao et al., 2003; Bulusu et al., 2001; Estin et al., 2001).

In order to effectively utilize the sensor nodes, we need to minimize the energy consumption in the design of sensor network protocols and algorithms. A large number of sensor nodes have to be networked together. Direct transmission from any specified node to a distant BS is not used since sensor nodes that are farther away from the BS will drain their power sources much faster than those that are closer to the BS. On the other hand, a minimum energy multi-hop routing scheme will rapidly drain the energy resources of the nodes, since these nodes are engaged in the forwarding of a large number of data messages (on behalf of other nodes) to the BS. The application of an aggregation approach helps to reduce the amount of information that needs to be transmitted by performing data fusion at the aggregate points before forwarding the data to the end user (Luo et al., 2006; Li et al., 2006).

Rest of the article is organized as follows: Section 2 discusses the related work, Section 3 describes the earlier proposed ant colony algorithm for data aggregation and routing and our contribution, Section 4 defines the energy model used along with the proposed framework and routing metric, Section 5 provides the simulation and results obtained, and finally Section 6 concludes the article.

2 RELATED WORK

A WSN consists of many small sensors with limited energy resources and thus, requires novel data dissemination paradigms to save the network energy. For many-to-one communication with multiple data-reporting nodes and one BS, protocols like directed diffusion (DD) (Intanagonwiwat et al., 2003) use distance-vector-based routing. In DD approach, BS node first propagates an interest or advertisement throughout the network. By assigning a hop counter to each interested node, reverse paths are established by setting up gradients pointing to the neighbor with the lowest hop counter. The reverse paths then form a routing tree which is rooted at BS and can be used for forwarding data packets. In addition to hop counters, other forwarding metrics, which can be defined by means of gradients, are also possible.

Gradient-based routing (GBR) (Han et al., 2004) improves DD by uniformly balancing traffic throughout the network, using data aggregation and traffic spreading. (Ye et al., 2001), proposes gradient broadcast (GRAB), where packets travel towards BS by descending a cost path. Costs are defined as the minimum energy overhead required to forward packets to BS along a previously established path. Nodes close to BS will have lower costs than far-away ones. All the nodes receiving a packet with a lower cost will participate in packet forwarding. Since multiple paths with decreasing costs exist, GRAB is quite robust and reliable with respect to the delivery of data. However, multi-path forwarding comes at the expense of high energy consumption. Other energy-aware routing schemes are analyzed by (Gan et al., 2004). (Zhao et al., 2003) have studied packet delivery fraction in dense WSN. (Ganesan et al., 2001) proposes partially disjointed multi-path routing schemes, which they call braided multi-path routing. Compared to complete disjointed multi-path routing, they study the tradeoff between energy consumption and robustness. In terms of energy efficiency, braided multi-path routing seems to
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