Evaluation of the Power Consumption of Routing Protocols for Wireless Sensor Networks

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Abstract

Sensor networks are one of the fastest growing areas in broad wireless ad hoc networking field. A sensor node, typically, contains signal-processing circuits, micro-controllers and a wireless transmitter/receiver antenna. Energy saving is one of the critical issue for sensor networks since most sensors are equipped with non-rechargeable batteries that have limited lifetime. Routing schemes are used to transfer data collected by sensor nodes to base stations. In the literature many routing protocols for wireless sensor networks are suggested. In this work, four routing protocols for wireless sensor networks viz. Flooding, Gossiping, GBR and LEACH have been simulated using TinyOS and their power consumption is studied using PowerTOSSIM. A realization of these protocols has been carried out using Mica2 Motes.

1. Introduction

A wireless sensor network (WSN) [1] can, in practice, be composed of tens to thousands of sensor nodes which are distributed in a wide area. These nodes form a network by communicating with each other either directly or through other nodes. One or more nodes among them will serve as sink(s), known as the base node, that are capable of communicating with the user either directly or through the existing wired networks. Large amount of battery power is used up during internal processing and communication. So other than the hardware, even the software loaded with the sensor nodes is desired to be power efficient. This paper attempts to analyze the power requirements of some of the popular routing protocols used in sensor networks.

2. Routing Protocols for WSN

According to nodes' participating style, routing protocols can be classified into three categories, namely, direct communication, flat (Minimum Energy Transmission), and clustering protocols. The basic routing protocols for WSN are Flooding, Gossiping, Gradient Based Routing (GBR) and LEACH [2], [3].

In the Flooding protocol packets were broadcasted to all possible routes to its destination. Gossiping, an improved version of Flooding protocol, instead of broadcasting each packet to all neighbors, the packet is sent to a single neighbor chosen at random from a neighbor table. Gossiping avoids the implosion problem experienced by Flooding as only one copy of a packet is in transit at any one time.

In GBR, each node in the network can look at its neighbors hop count (depth) and use this to decide which node to forward the packet on to. If the nodes' power level drops below a certain level it will increase the depth to discourage traffic through it.

LEACH reduces the number of nodes that communicate directly with the base station by forming dynamic clusters. The leaf nodes were connected to the cluster head which in turn to the base station. Cluster head nodes allocate each leaf node that connects to it a time slot to communicate. This allows the leaf nodes to sleep between its allocated communication slots and there by saving energy. The dynamic cluster head mechanism reduces the energy drain on particular nodes caused by static clusters and spreads energy usage more evenly across the network.

All the above described protocols were chosen for implementation and evaluation.

3. Implementation and Simulation

TinyOS [4] provides a multihop architecture [5] to specify multihop routing applications. The architecture contain two major components viz. a packet movement logic MultiHopEngineM for multi-hop routing and MultiHopLEPSM module for path selection. The components MHFloodingPSM (Flooding), MHGossipingPSM (Gossiping), MHGbrPSM (GBR) and MHLeachPSM (LEACH) were implemented by modifying the base components using nesC [6]. These components maintain routing state and are responsible for selecting a route for a packet.

TOSSIM [7] is used to evaluate the implemented protocols. A loss topology is defined which allows a node to communicate with all nodes within a 5×5 square around itself. All the protocols were simulated for a period of 500 second. The power consumption of the routing protocols is calculated using the PowerTOSSIM [8]. The simulation also tracks the number of messages sent, received and forwarded through each node.

4. Results

Using PowerTOSSIM, power usage per node (median and standard deviation) and power usage per message for each protocol were tabulated. These data were used to compute median and standard deviation and plotted graphically as shown in Fig. 1 The median of the power usage will give the

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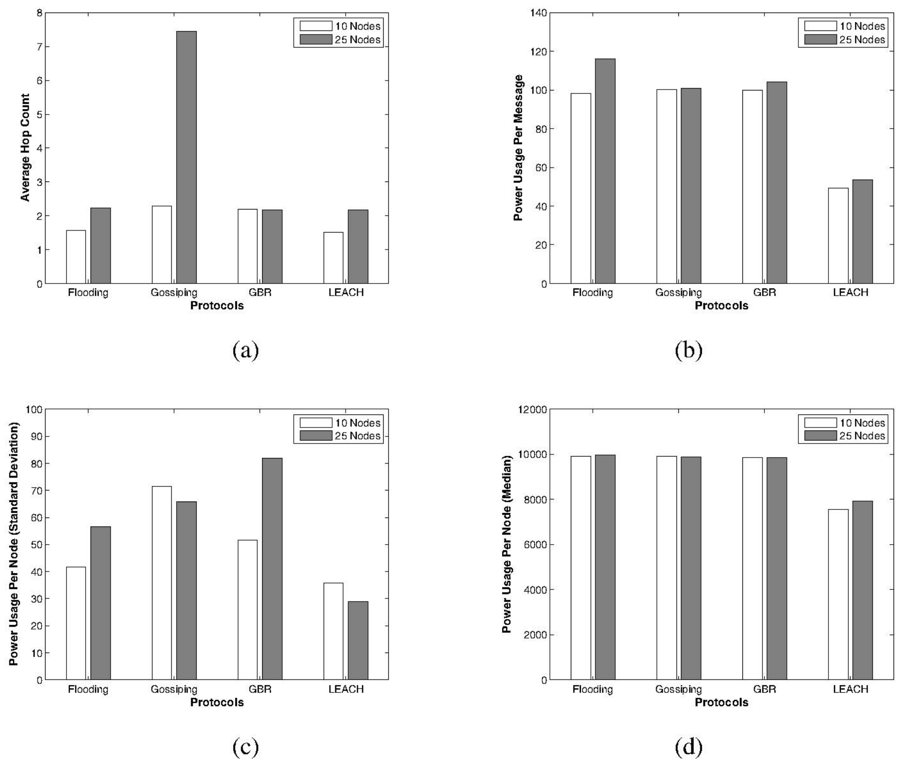

Fig. 1: Results of simulation (a) Average hop count of the messages forwarded by the base station. (b) Power usage per message sent. (c) Power usage per node (Standard Deviation). (d) Power usage per node (Median).

average power consumption of the protocol across the network nodes. The standard deviation of the power usage per node will give an estimate of evenness of power consumption across the network nodes. Also the power usage per message is calculated to get the average power usage for each message sent across the network.

Evaluating the simulation results of the four routing protocols namely - Flooding, Gossiping, GBR and LEACH we analysed that Flooding is the worst in case of power efficiency. Gossiping provided some improvement over Flooding in terms of power usage per message but the power usage per node was still higher. Gradient Based Routing protocol was giving lower power usage figures than the previous two; as the number of node increases the power usage becomes uneven across the network nodes since many nodes were getting over utilized in routing packets. The median and standard deviation for power usage per node is less for LEACH when compared to all the other protocols analysed.

5. Conclusions

In this work, four routing protocols for wireless sensor networks namely - Flooding, Gossiping, GBR and LEACH were simulated and their results were evaluated. The dynamic cluster based protocol LEACH stands out among the other three for the best power utilization figures. For LEACH, the power consumption per node was less and the power usage among the network nodes was even as well, making it the ideal routing protocol for power constrained wireless sensor networks. The developed protocols were realized on a wireless sensor network based on Mica2 Motes.

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