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Energy based path planning for wireless sensor networks

Amit Patwardhan

School of Interdisciplinary Sci. and Tech. I2IT, P-14, Pune Infotech Park Phase-1, Hinjawadi, Pune (MS) INDIA

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ABSTRACT : Wireless Sensor Networks (WSN) having large number of sensor nodes which will cover the earth in time to come. Sensor Networks covering vast areas are already in the wild and are instrumental in ways not possible using preexisting technology. The most important resource on these nodes is the energy supply and in almost all the cases a battery in the node is responsible for supplying energy for the entire lifetime of the node. The deployment of nodes could be at inaccessible locations and hence once the battery has drained the node is unusable for the network. Increasing the lifetime of the node becomes a very important factor to bring the technology mainstream. This paper analyses the energy consumption pattern in a WSN with a mobile base node. The path of the base node is generated for each traversal using heuristics so as to maintain energy equilibrium in the WSN. Paper also discusses the limitations, assumptions and methodology followed for the simulations.

Keywords : Wireless Sensor Networks, Energy, ns2

I. INTRODUCTION

Since its inception wireless has revolutionized the methods of communication. It has had a greater effect on day-to-day life since the advent of powerful embedded devices capable of wireless communication (commonly known as the Cell Phone). Although such networks provide mobility but the network is basically static in the sense that communication between different nodes is through centralized system that takes care of routing, channel allocation and such. Each and every node in the network should communicate to the central location directly and hence has to be within its range. A network without a controlling central entity provides interesting scenarios to explore. Recent advances in microcontroller technology and wireless communication have paved the way to the design and manufacture of tiny embedded devices capable of interacting with their surroundings and communicating the data generated to their neighbors wirelessly. These devices often called as motes are the base of a wireless sensor network [1].

The wireless sensor nodes or motes as they are generally called have on board sensors, microcontroller, a wireless communication system and a power supply. The software on the sensors is capable of transmitting and receiving data and also acts as a routing agent to forward the data towards the destination. The network thus formed does not require any existing setup and hence are termed as Ad Hoc networks. Ideally the motes are spread in an area randomly the final destination for the data is a base station which is capable of storing, forwarding or processing the data.

II. MOTIVATION

The biggest advantage in case of WSN is also their biggest limitation, the unconnected nature of the network also limits the life time of the network. Energy hole problem limits the total life time by disconnecting the network from the base node. It is important to note that in a given network the total energy left even in this situation is more than 70% [2, 3]. For many WSN implementations it is practical to have a mobile base node, where a mobile base node traverses through the nodes on land or in air to collect data. Instead of communicating to each and every node the energy consumption can be decreased by useing dynamic routing protocols developed for Ad hoc networking [4, 5]. Maintaing a constant path for all the traversals of the base node is equally bad since even this will result in the formation of energy holes in the network. Generating a different path for each traversal with node energy as constraint will provide an equalibrium in energy consumption hence giving longitivity to the WSN.

For the purpose of simulation the network is maintained within the following constrains.

1. Sensor nodes are distributed over a large area and may or may not have a layout in distribution.
2. The distance between two nodes is not greater than the communication range of the nodes and does not interfere with the formation of the network.
3. Individual nodes do not communicate to the base unit instead in a neighborhood a single node acts as an agent between the nodes and the base unit.
4. A mobile base unit is responsible for retrieval of data.

5. The base unit has recharging option as it is to return to a docking station.
6. The data from the base unit is retrieved by a Data Storage and Computation Facility (DSCF).
7. The DSCF is capable of executing software and performs analysis on the data.
8. DSCF computes sufficiently efficient path to be followed by the base unit in the next data collection session.
9. Number of sensor nodes is limited and known, for larger number of nodes the heuristics will have to be updated.
10. Old data has to be stored and retrieved for later use.
11. Nodes have to communicate their energy state along with the data.

III. SIMULATION SETUP

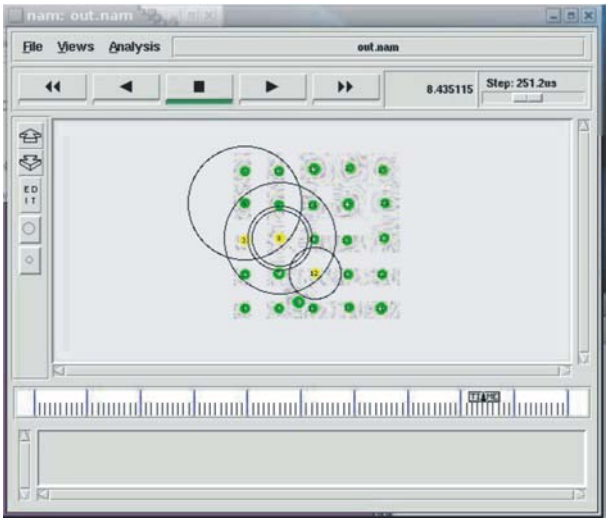

Fig.1. Nodes communicating to base node.

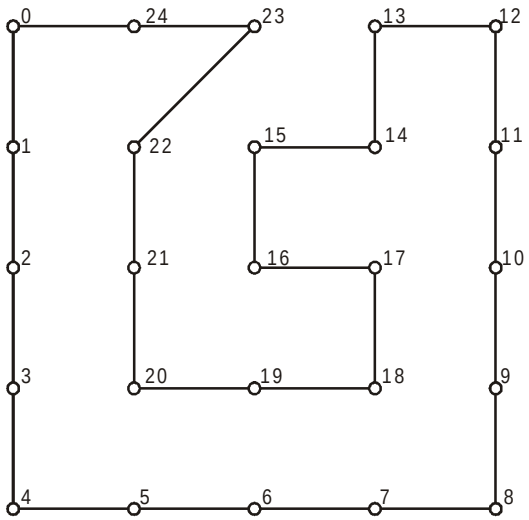

Fig.2. Fully connected path for nodes.

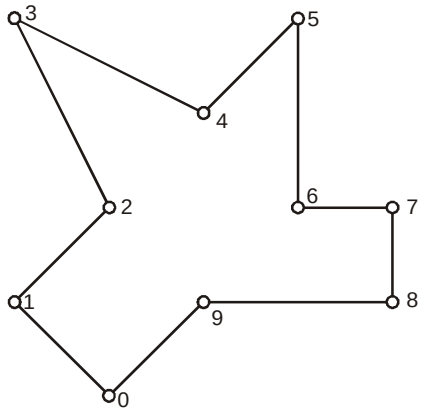

Fig.3. Sufficiently efficient path with energy constraint.

A. Software

In order to test the system and measure the performance simulator is the best choice since it allows manipulation of various values without having to design the complete system. In this setup ns2 has been used [6]. Ns2 is an open source project with contributions from researchers all over the world; although it was designed for wired communication it has been upgraded to be useful in wireless simulation as well. Ns2 is a discrete event simulator. It is basically an OTcl interpreter with network simulation capabilities.

B. Simulation setup

The simulation script sets-up the topology of the network. The motes are placed in a grid of 5 × 5 hence a total of 25 nodes in addition to these static nodes there is one mobile base unit which is the receiver of all the data. The base unit is to travel around the network and is the only node which can retrieve data and all the other nodes only act as sources or as routers to carry the data to this final destination the base node. Energy of the nodes is consumed in mainly four states sleep, idle, listening and transmitting, with amount of energy consumption being in ascending order.

The simulation is run in two different scenarios. In case one the mobile base node traverses the network in a standard route following the same route in every traversal. In case two a new route is generated before each traversal. The algorithm for route generation is basically hill climbing with energy level as the heuristic. To generate a path some of the highest energy nodes from the network are selected (10% to 20% nodes) and a sufficiently efficient route is created. The output file generated from the simulation is parsed using an AWK script while the route generation is done using a Python script.

An animation of the simulation can be viewed using a software called nam(network animator) small colored circles with numbers within are the nodes and the color of the node reflects the energy state of the node, communication

is shown as big circles emerging out of the node. Fig.1 is a typical run of the simulation where nodes are represented in different colors to indicate remaining energy and large circles indicate the wireless signal during communication. The energy state of the nodes is extracted from the trace file generated through simulation using an AWK script. The path to be traversed is generated through a python script Fig. 2,3.

IV. RESULTS AND DISCUSSION

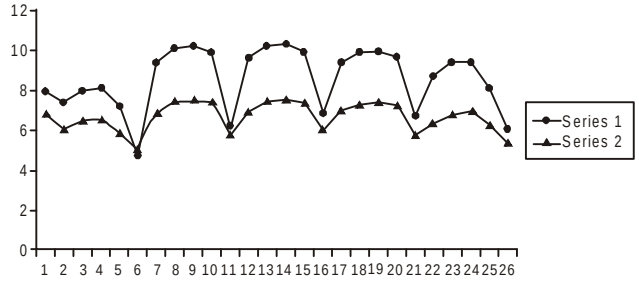

Fig.4. Node wise energy use with and without path planning.

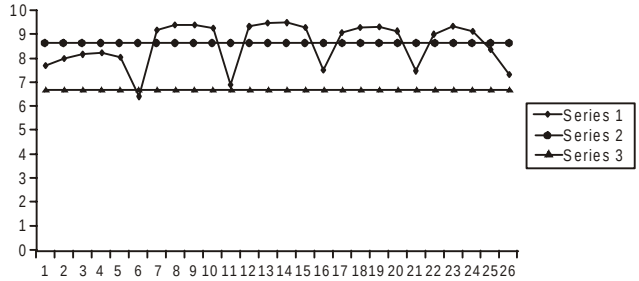

Fig.5. Node wise energy difference plotted on average used energy.

Fig.4 series 1 is the node wise plot of energy used in the network without path planning. Series 2 shows the node wise plot of energy used during the run of the simulation with path planning.

In Fig.5 series 1 is the difference of energy used values in the two cases. Series 2 is the average energy used in the network without path planning whereas series 3 is the average energy used in the network with path planning.

Comparison of the energy levels in the two cases indicates average energy use is more if no path planning is used. By planning the path traversed by the mobile base node the number of sensor nodes communicating the base node directly is constrained. Most of the communication to the base node is from a select few nodes in each traversal. This limits the total energy spent on communication and since this is the most energy hungry operation the total energy consumption goes low.

The network maintains energy equilibrium where all the nodes are within certain energy levels. This avoids formation of energy holes. This is crucial for extended life time of the wireless sensor network. This also indicates that finally when the network comes down the reserve energy will be very low i.e. the total energy left in the network will be very low. Hence giving a high energy efficiency to the WSN.

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