Feedback Based Dynamic Energy Aware Routing Protocol

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1 Abstract

With the advancement of wireless sensor network many routing strategies have been developed which deal with distinguishable features of wireless sensor networks like energy,bandwidth,high rate of interaction with environment etc. Tiny wireless sensors could be deployed in wilderness areas, where they would remain for many years without the need to recharge or replace their power supplies. Thus power management is a very important issue in this kind of networks because of the battery driven nodes. The sensor nodes should be routed in such a way that the energy consumed along the routing path is as less as possible. The energy aware routing protocols for WSNs developed so far are static in nature in terms of node energy. Energy efficient routes are being developed on the basis of energy initially available in nodes. Some node energy is used up in transmission of messages. The energy of the node continually gets depleted with transmission. But this dynamic behaviour of node energy is not taken into consideration in the following rounds. This paper proposes a Feedback based Dynamic Energy aware Routing Protocol(FDERP)which deals with this dynamic behaviour of node energy. In contrast with LEACH it decreases the average energy consumed per node increasing the network lifetime. The paper concludes with open research issues.

2 Introduction

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. The applications for WSNs are many and varied. However the use of sensor nodes are restricted by many factors including energy and bandwidth. Deployment of large number of nodes maintaining these constraints is a major issue of concern in the design and management of sensor networks. The main goals for delivering messages following an energy efficient route are to increase the lifetime of the network as well as decreasing end to end delay between nodes. The paper is organized as follows. In section 2 we cover few of the existing energy aware routing schemes. Section 3 summarizes the algorithm for this feedback based dynamic energy aware routing scheme, the assumptions made and definition of the term cost, the steps followed and the proof that the cost of a node increases with the utilization of it. In section 4 experimental results are included comparing this protocol with LEACH in terms of average energy consumption per node. Finally section 5 provides a summary including open research issues.

3 Earlier Works

A great deal of research have been dedicated for developing energy efficient routing protocols for wireless sensor networks. Few of them are summarized below.

LEACH(LOW ENERGY ADAPTIVE CLUSTER HIERARCHY)– This routing protocol[1]is an example of cluster based hierarichal routing. The operation of this routing protocol is divided into rounds. Each round consists of two phases.
i) Setup Phase-Clusters are organized. Each node selects a number between 0 and 1. Now if it is less than the threshold value for the node it will become a cluster head. Then it sends an advertisement message for discovering its neighbours.The nodes will send an acknowledgement of being the part of the cluster as that node to be a cluster head
ii) Steady State Phase-Cluster head collects messages from its neighbours and combine them into a single packet and sends them to the base station.
However it is based on single hop routing, so it is not suitable for distributed networks.

PEGASIS(POWER EFFICIENT GATHERING SENSOR INFORMATION SYSTEM–In [2] an improved protocol is discussed over LEACH. Here nodes are placed randomly in the field. They will be organised to form a chain and advertise it to the nodes. Each node transmits and receives a single packet in each round and only one node will communicate with base station. i mod N will become the leader on round i where N the total number of nodes. So each node will get the chance to be a leader in every N rounds. The leader gathers data from the adjacent nodes and put the data into a single packet and send that single packet to the base station. However PEGASIS introduces excessive delay for distant nod on the chain. In addition the single leader can become a bottleneck.

ENERGY AWARE ROUTING– This approach[3] rightly points out the fact that using the minimum energy path all the time will deplete the energies of all the nodes in the path. Choosing a path from a set of multiple path probabilistically is the main idea of this approach. the choice is done by a probability function which depends on the energy consumption of each path.How ever, such single path usage hinders the ability of recovering from a node or path failure.

MINIMUM COST FORWARDING–This routing protocol[4] mainly wants to find a minimum cost path from any given source to any interested client. For that purpose a concept of cost field is developed. At each node, the cost field is defined as the minimum cost from that node to the sink on the optimal path. Once the cost field is established, messages may flow to the sink along the minimum cost path. Here, it achieves minimum cost path forwarding without maintaining explicit path information at any intermediate node.

4 Algorithm

The algorithm is designed in such a way that the participating nodes can always select the least cost path thereby increasing the energy efficiency of the system.
Assumptions : Each sensor node is identified with an index which is nothing but an integer. These indices are globally unique and acts as an indentifying factor of the node.
Each node must have knowledge about the cost and index of its every neighbouring node.
In a particular node the updation of cost of a neighbouring node does not lead to any loss of energy.

Cost of a node : We have assumed that all the sensor nodes are alike and have similar kind of energies. Typically a sensor node has three types of energy–Transmission Energy,Reception Energy,Available Energy. We know the transmission energy,reception energy and available energy of every node.We make the cost of sink 0. Now cost of the other nodes in the network is defined as follows-
Initially the cost of every node is defined as the energy required to transmit a message to the sink. So, the cost function of the immediate neighbour of the sink will be transmission energy of those nodes. The cost function of the neighbouring nodes of these neighbours will be equal to the sum of the transmission energy of the node(i.e the energy to transmit a packet to its immediate neighbour) and the minimum of the cost of their neighbours i.e

$$c = \text{Minimum c of its immediate neighbour} + \text{Transmission energy of the node}$$

During the rounds of message passing if a node is used in the process then its cost will be modified by a factor and this will become its new cost. After receiving an acknowledgement or message the cost of a node changes by the reciprocal of the reception factor as defined below.
$\text{Reception Factor} = 1 - \frac{\text{Reception energy}}{\text{Present available energy of the node}}$
$\text{Present cost of the node} = \frac{\text{Present cost of the node}}{\text{Reception factor}}$
Present Available energy of the node = Present Available energy of the node − Reception energy of the node
After transmitting an acknowledgement or message the cost of a node also changes by the reciprocal of the transmission factor as defined below.
$\text{Transmission Factor} = 1 - \frac{\text{Transmission energy}}{\text{Present available energy of the node}}$
$\text{Present cost of the node} = \frac{\text{Present cost of the node}}{\text{Transmission factor}}$
Present Available energy of the node = Present Available energy of the node − Transmission energy of the node
The logical explanation of the modifying factors is as follows—
When a node is used up its energy is reduced by the factor of transmission and reception energy. So in the following round using the node again will be costly to the system. In order to reflect its increased cost the value of its cost must be increased as if it will be more costly to send message using this node than the previous round. Thats why the modifying factor is used as the denominator.

Steps : The initial cost is calculated for every node in the network in a depth first manner described above. We start with the source node. Here we are generalising by indicating the transmitting node by i and receiving node by j.
Let us assume that node i has got k neighbours having indices i1,i2,,ik with the costs c1,c2,cj..,ck.
Minimum of the neighbours' cost is found out and the corresponding index(j) of the node is noted; i.e min(c1,c2,..cj,.ck) is found out.
This index will be matched with the indices of all the neighbouring nodes of node i. Message will be transmitted to the node with whom the index has matched.
Upon reception the cost and available energy of node ij will change and the necessary updation will take place.
This message will be retransmitted to the neighbouring node of ij having the least cost following the same steps described above. Simultaneous updation of cost and available energy of the transmitting node will also take place due to this transmission.
This process continues until the message reaches the sink.
When the message finally reaches sink the sink sends an acknowledgement to the node from which it has received the message.
On receiving the acknowledgement the previous node changes its cost and available energy due to the reception as well as for the transmission of acknowledgement to its previous node along with its changed cost.
On the previous node updation of cost of the acknowledgement sending node which is present in its neighbours' list takes place.
The same procedure repeats with this node until the source is reached.
So for any intermediate node the number of transmission=2
The number of reception=2
Foe source and sink the number of transmission =1
The number of reception=1
So after every round of operation each node posses a list of neighbours' id and updated cost. The following round of operation will take place with these updated cost.

Proof : Let,
Transmission energy=t, Reception energy=r, Available energy=a
For the starting node 1 transmission and 1 reception of message will take place.
So, the available energy=a-r-t and

$$\text{cost of a node} = \frac{\text{Initial Cost.Original Available Energy}}{\text{Present Available energy of that node}}$$

For the intermediate nodes 2 transmission and 2 receptions will take place. So, the available energy=a-2*r-2*t and

$$\text{cost of a node} = \frac{\text{Initial Cost.Original Available Energy}}{\text{Present Available energy of that node}}$$

Now we have to prove that the modified costs of the participating nodes after a round of transmission and reception of messages and acknowledgements are greater than the previous costs.
Present available energy of a node $<$ Original available energy

$$\text{so, } \frac{\text{Present available energy of a node}}{\text{Original available energy}} < 1$$

$$\frac{1}{\frac{\text{Present available energy of a node}}{\text{Original available energy of that node}}} > 1$$

$$\frac{\text{Intial Cost}}{\frac{\text{Present available energy of a node}}{\text{Original available energy of that node}}} > \text{Initial Cost}$$

Modified cost of that node > Initial cost of that node

5 Simulation

The simulation was carried out with 48 sensors each of which is given the same initial energy of 200nJ. Transmission uses 10 nJ of energy and reception uses 5 nJ of energy. The performance of this protocol is compared against that of LEACH. The simulation shows that the average energy consumed per node is reduced to 15 nJ from 27.32 nJ showing an improvement of 45%,resulting in a cooler network. This is basically due to the dynamic behaviour of the protocol which allows it to determine the least cost path. The reduction in the average consumed energy of the nodes increases the lifetime of the network.

6 Conclusions and Future Work

This routing protocol enables the sensor network to select the least cost or the most energy efficient path for message transmission and reception. The concept of changing sensor node energy as well as changing cost of a path is also taken care of, thereby giving the protocol a dynamic chracteristics. However the performance run are done considering that there is no loss of packet during the transmission and reception of messages and acknowledgements. Future work will be focussed on making this protocol more fault tolerant.

7 References

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