LoCoDuo - Low Cost Dual Hop Clustering based Routing Protocol for Wireless Sensor Network

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Abstract— As with the cases of other works in routing protocols of wireless sensor networks, the focus of this research is power efficiency and thus achieving increased network lifetime so that the sensor network can be used for a longer period of time. Here we proposed all new concept of two hop low power transmission of data between the cluster head and sink in case of clustering based routing protocols and then compared the results with LEACH protocol and some of its other recent variants and obtained better performance in network lifetime. It is also seen that apart from being the most power efficient, this proposed algorithm works best as compared to others when the number of nodes deployed is less i.e. it is best suitable for low cost sensing.

Keywords: LoCoDuo, LEACH, clustering, multihop, power alteration, thresholding, low-cost, dualhop

I. INTRODUCTION

In recent past fast development of low cost sensors nodes gave way in building wireless sensor network for utility in various fields of earthquake detection, military surveillance, structural health monitoring and other disaster mitigations. Although the concept of such wireless sensor networks is still in scientific laboratories there is no doubt that it is the next generation of emerging technologies. A sensor node is equipped with a transceiver antenna, a control unit and a power unit with which it performs a continuous surveillance of a geographical area in which it is deployed. But its battery power is limited and a node dies off when its battery power is depleted. The network remains active until maximum of the nodes die off and wireless sensor researchers around the globe try to maximize this network lifetime. There is a base station or sink to which the nodes transmit the sensed data and is not constrained in power. Traditionally, the sensor nodes send radio signals to the neighbour nodes and the neighbour in turn passes the signal on until the signal has reached the base station but this data routing technique, called flooding, un-necessarily consumes power of the intermediate nodes and the network dies off very early. The base station, sometimes called sink also has the ability to query data from a single node or a collection of nodes. However in this context all the nodes do not have a direct communication link to the base station and the message has to travel multiple hops through other nodes to reach the destination and reverse. Here basically we propose a routing protocol to improve on the network life time, which besides using a new idea, combines power saving schemes from some other already proposed clustering based protocols into core LEACH protocol.

The rest of the paper is arranged as follows, the literature survey part briefs the details of the existing routing protocols and points out their pros and cons. Next we put forward our proposed algorithm and in the following section we give our experimental results and compare the results with that of other protocols. We conclude this paper with a section called conclusion and future works.
II. RELATED WORKS

In this section we study LEACH protocol and some of its recent variants.

A. LEACH

LEACH [1] is the most preferred of all wireless sensor network routing protocols and most of the researchers compare their protocols with the parameters in LEACH. Here the sensor nodes self-organize themselves into clusters at the start of each round [2], which is called dynamic clustering and this avoids a single cluster head to lose energy every time. When clusters are created each node autonomously decide whether it can be a cluster head for the next round using a stochastic formula:

$$P(n) = \frac{P}{1 - P \times (r \mod 1/P)}$$

Where P is suggested percentage of cluster head in a round and is determined a priori and r is the current round number. The purpose of using this formula is to ensure that each node becomes the cluster head only once in 1/P rounds. The outcome of this round calculation in LEACH is nothing but a threshold, T(n), and if a random number generated by all node (except previous round cluster head) is less then T(n), the node is selected as the cluster head. The cluster heads communicate the aggregated data from the cluster to the base station directly. The other member nodes of a cluster periodically send their sensed data to the cluster head and rest all other time. Each node decides its cluster by comparing received signal strength of advertisement message sent by elected cluster nodes in each round.

B. Multi-hop LEACH

Multi-hop LEACH [5-7] is another variant where all cluster heads do not transmit aggregated data directly to the base station but through other cluster heads and they choose the path with lowest hop count. Only the neighbor cluster heads communicate with the base station.

C. LEACH-SC

LEACH-SC [9] slightly modifies the cluster formation in LEACH. Here a non-cluster node associates itself with the cluster head which is nearest to the midpoint between itself and the base station. In this way this protocol prohibits data flow in a direction away from the base station during the data transfer from a node to the cluster head and as the data always flows towards the base station the protocol saves considerable energy as compared to its other counterparts.

D. MODLEACH

MODLEACH, proposed recently in [10], uses dual transmission mode for data transfer depending on the distance between cluster member and cluster head or cluster head and base station. In each transmission energy of the transmitting node reduces by a factor f, which is evaluated using formula:

$$f = \frac{ETX \times EDA + EM \times 4000 \times (dist \times dist)^a}{ETX + EDA + 2 \times EM \times 4000}$$

where ETX is Transceiver idle state energy, EDA is data aggregation energy (which is zero for a intra cluster transmission), EM is energy mode constant it is ten times high in long distance communication as compared to a short distance one, dist is the distance between the sender and the receiver and a is a constant with a value of 1 in case of low power mode and 2 for high power mode. Apart from dual power transmission mode, MODLEACH also
restricts repeated cluster formation by using energy level thresholds.

E. TEEN

Threshold sensitive Energy Efficient sensor Network protocol [11] is an event driven protocol. It uses a new concept to save power by transmitting sensed data only when some event happens like sudden increase in temperature etc. It has two type of thresholds like hard and soft threshold. Hard threshold is a globally set value whereas soft threshold is chosen adaptively by a cluster by co-operating with other clusters. Although TEEN is one of the most energy efficient protocol, but it cannot be applied to applications where periodic report of sensed data is needed to be passed to the sink because sensors nodes only switch on their communication module (radio transmitter) when some event occurs. TEEN has shown simulation results to outperform LEACH [11].

F. PEGASIS

Power Efficient Gathering in Sensor Information System [12] is a massive improvement with a small change in LEACH protocol. Here the aggregated data from cluster heads gets transferred to the single cluster head which is nearest to the base station.

![Figure 3: Chain Clustering in PEGASIS](image)

As an obvious disadvantage, cluster c2 in figure 3 has to wait to receive the aggregated data from both sides and it aggregates the data received from all the clusters and sends it to the base station. PEGASIS achieves 100% to 300% more power efficiency then LEACH [4]. But the single cluster connecting to the base station (sink) becomes a bottleneck moreover a delay is introduced as the single cluster, in our case cluster c2 in figure 2, has to wait for data from other clusters. To combat this delay Hierarchical PEGASIS [12] was developed by combining the idea of LEACH and PEGASIS.

III. PROPOSED ALGORITHM

Our work is aimed to better the network lifetime and for this we need to have nodes alive till maximum number of rounds. We assume that the nodes are power constrained and are supplied a fixed amount of initial energy and when the energy goes to zero the node becomes dead permanently. On the other hand the base station is supplied with continuous power. Furthermore, the nodes are not mobile and are deployed randomly in the area of 100x100. The base station is placed in the centre of the target region i.e. in the co-ordinate (50,50) because we get maximum network lifetime in average case for a random organization of nodes. For comparison the number of nodes is kept 50 and the value of percentage of clusters (p), from the LEACH is 0.1. This means that in every round 0.1% of the total number of nodes will be cluster heads.

We combine power saving concepts from of the existing clustering protocols along with our proposed dual hop data transfer scheme. Mahmoud et. al in [10] pointed out that the nodes need less power to transfer their data within the cluster to the cluster head and need high power while communicating with base station or other cluster heads if cluster head selection criteria is minimum distance, assuming that the low power transmission amplification energy is ten times less than that of high power. Accordingly the communication type is characterised as intra cluster, inter cluster or cluster head to base station. We designed our algorithm such that the member nodes in a cluster which only needs to do intra cluster communication requires transmission energy ten times less than that needed for other two types of communication. This we say as the dual mode transmission power. If the distance between the sender and the receiver is less than d0, we can use the low power transmission otherwise we use high power transmission. This threshold d0 is equal to square root of the ratio between high and low transmission mode energy.

Next as we used that thresholds can be applied to perform power saving, but applying thresholds restricts producing periodic data. LEACH has the problem of losing energy as in every round the nodes need to re-cluster themselves as a new cluster head comes to existence. Therefore we applied the hard thresholding scheme in a way that if the cluster head did not exhaust away half of its initial energy then we avoid the re-clustering to save energy. This type of a thresholding scheme was also used in MODLEACH.
So in order to improve the network lifetime, we incorporated a whole new idea of transmitting aggregated data from the cluster head to the base station in two low power hops to save energy, rather than using one single high power hop to the base station. The data is send from a cluster head to another cluster head within a distance of less than d0 from itself and also the receiver cluster head should have a distance less than d0 from the base station. This idea is based on the phenomenon that if we use alternating power transmissions, routing of data using two low power hops is more energy saving than using a single hop high power transmission. The figure 3 suggests the various power saving schemes used in this proposed scheme.

ASSUMPTIONS OF PARAMETER VALUES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Size</td>
<td>100x100</td>
</tr>
<tr>
<td>Initial Energy of the sensor nodes (E0)</td>
<td>0.5J</td>
</tr>
<tr>
<td>Packet Size</td>
<td>40000 bits</td>
</tr>
<tr>
<td>Transceiver Idle State Energy (ETX)</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Data Aggregation Energy (EDATA)</td>
<td>5nJ/bit/record</td>
</tr>
<tr>
<td>Long range transmission amplification energy (EFS)</td>
<td>10pJ/bit/</td>
</tr>
<tr>
<td>Short range transmission amplification energy (EMP)</td>
<td>0.0013pJ/bit/</td>
</tr>
<tr>
<td>Long range intra-cluster transmission amplification energy (EFS1)</td>
<td>EFS/10</td>
</tr>
<tr>
<td>Short range intra-cluster transmission amplification energy (EMP1)</td>
<td>EMP/10</td>
</tr>
</tbody>
</table>

IV. EXPERIMENTAL RESULTS AND COMPARISON

The proposed routing protocol is simulated using matlab (R2011a) and the resulting network lifetime is compared with LEACH and its two recent variants LEACH-SC, MODLEACH. It is seen that the proposed algorithm has a better network lifetime in all the tested scenarios. As the nodes are deployed randomly using matlab random function and that is why the resulting network lifetime varies between two extremes as shown in table 1 below. The table shows the number of rounds for which the network remains active in a fixed area of 100x100 for variable number of nodes and we find our algorithm to be more stable and scalable. By more stable we mean that the network lifetime remains fixed on any random distribution of nodes unlike traditional LEACH and LEACH-SC. A much scalable scheme means that the algorithm performs well irrespective of increase or decrease of nodes. Moreover, the algorithm gives more lifetime using even minimum number of nodes. That is why we call this proposal a low cost sensing one. We plot network’s remaining energy versus rounds for all the protocols in figure 4 where the number of nodes is kept at 50. The network dimension is 100x100 in every case. The graphs show us that the network remains alive for 700 rounds and 1600 rounds for LEACH and MODLEACH respectively (Fig. 4 (a), (b)) while the lifetime extends a little over 1900 for our proposed algorithm (Fig. 4(c)).

<table>
<thead>
<tr>
<th>No. of Nodes</th>
<th>LEACH</th>
<th>LEACH-SC</th>
<th>MODLEACH</th>
<th>PROPOSED Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10-350</td>
<td>10-500</td>
<td>1650-1850</td>
<td>1900-1950</td>
</tr>
<tr>
<td>30</td>
<td>100-1200</td>
<td>300-700</td>
<td>1550-1700</td>
<td>1700-2000</td>
</tr>
<tr>
<td>50</td>
<td>100-1200</td>
<td>300-700</td>
<td>1500-1700</td>
<td>1700-1850</td>
</tr>
<tr>
<td>70</td>
<td>100-1300</td>
<td>100-850</td>
<td>1500-1700</td>
<td>1600-1800</td>
</tr>
<tr>
<td>90</td>
<td>100-1300</td>
<td>400-1300</td>
<td>1500-1700</td>
<td>1650-1850</td>
</tr>
</tbody>
</table>

Fig. 4 (a,b,c): Graphs for network life vs rounds for (a) LEACH, (b) LEACH-SC (c) MODLEACH and (d) proposed algorithm
V. CONCLUSION AND FUTURE WORKS

As in the previous section we see that as compared to the other existing protocols, our proposed algorithm performs best in respect to the network lifetime in variable the number of nodes in the given area. Also as compared to others both MODLEACH and the proposed algorithm are more stable i.e. having limited range of outputs as compared to two LEACH and LEACH-sc. Our algorithm is the most scalable of all as already shown in table 5 and moreover it is distinctively the best when the number of nodes is less. So this method is most suitable when the number of nodes are less, i.e. for low cost sensing. We have also observed in experimentation that if we use three hops in place of two hops the network lifetime is less varying against random deployment of nodes but gives little lesser lifetime. So we can use triple hop variant of the proposed algorithm for more guarantee of lifetime against arbitrary node deployment.

However, if we arrange the clusters in such a way that there are maximum low power dual hops, the power efficiency can be pushed up further which we look forward to do in the near future.

VI. REFERENCES


