ABSTRACT

The primary challenge of wireless sensor networks are to improve Network life time to overcome this challenge, In this paper we introduced two approaches for improving network lifetime, 1. Relay nodes to alleviate network geometric deficiencies and Particle Swarm Optimization (PSO) based algorithm has been used to locate the optimal sink position with respect to those relay nodes to make the network more energy efficient. The relay nodes are responsible to communicate with the sink instead of the sensor nodes. 2. ENERGY-BALANCED TRANSMISSION ALGORITHM FOR WIRELESS SENSOR NETWORKS -routing protocols that take into account the battery residual energy in sensor nodes and the energy required for transmission along the path 1. For each transmission round, only the nodes which have their remaining energies greater than a threshold can participate as relays for other nodes data in addition to sensing the environment. This choice allows the distribution of energy load among any sensor nodes, thus extends network lifetime.

Keywords- Wireless sensor network, lifetime, sensor node, relay node, particle swarm optimization, sink.

1. INTRODUCTION

A sensor network is a network of sensor nodes which are capable of sensing, computing and communicating elements and it gives an administrator the ability to measure, observe and react to events and phenomenon in a specific environment. Sensor networks are typically applied to the area of data collection, monitoring surveillance, military applications, and medical telemetry. Recent advancement in wireless communications and electronics has enabled the development of low-cost, low-power, multi-functional miniature devices for use in remote sensing applications. The combination of these factors has improved the viability of utilizing a sensor network consisting of a large number of intelligent sensors, enabling the collection, processing analysis and dissemination of valuable information gathered in a variety of environments.

A WSN is usually deployed on a global scale for information sharing; over a battle field for military surveillance and reconnaissance, in emergent environments for search and rescue, in factories for condition based maintenance, in building for infrastructure health monitoring, in homes to realize smart homes, or even in bodies for patient monitoring. One can retrieve required information from the network by injecting queries and gathering results from the sink. A sink acts like an interface between users and the network. A wireless sensor node is equipped with sensing and computing devices, radio transceiver and power components.

In a wireless sensor network, all the information collected by the sensor nodes are routed towards a sink and it is assumed that these sensor nodes are aware of the sink location [1][2]. In multi-hop communication, all these information are routed from one node to another until they reach the sink. In this process of data transmission and reception, the sensor nodes spend a significant amount of their stored energy [3][4]. Reducing this energy consumption is necessary to maintain a sustainable network, as the network loses its connectivity and hence its ability to function when the stored energy of the sensor nodes are expended. One of the solutions is to find the optimal sink location, which is a critical factor in designing a wireless sensor network.
locate the optimal location of the sink; for homogeneous nodes and as well as for heterogeneous nodes where single-hop routing was used. The limitation of this approach is- the energy consumptions of the nodes located far from the sink rises significantly as the distance increases while wide area network is considered. This limitation due to single-hop communication remains in [6][7] also, where an algorithm based on Particle Swarm Optimization (PSO) is described for finding the optimal position of the sink. Wei Wang et al. [8] proposed the use of mobile relays along with the sensor nodes for extending the network lifetime. But the locations of mobile relays are limited to only two-hop distance from the sink. Y. Thomas Hou et al. [9] worked on optimal sink selection for any cast routing. Here the authors considered multiple sinks in a wireless sensor network, which may not be feasible for many applications. In the previous work [10], our approach was based on PSO algorithm for locating the best position of the sink where multi-hop communication was considered. But in multi-hop communication the sensory data collected by all the nodes of the network reach the sink through the nodes close to the sink and thus these nodes tend to die soon as they have to pass a huge amount of data. In this paper, we have introduced relay nodes in conjunction with the PSO based algorithm. These relay nodes reduce the burden of the data traffic on the sensor nodes, especially of those, which are close to the sink, by carrying the data traffic to the sink. Hence the energy consumptions of the sensor nodes decrease and the lifespan increase. The optimal location of the sink with respect to those relay nodes is found by using the PSO based algorithm.

2. RELATED WORKS

Several communication protocols have been proposed to realize power-efficient communication in the WSN. The Directed Diffusion protocol proposed in [8], [9] is data centric in that all communication is for named data. All nodes in a directed diffusion-based network are application aware. This enables diffusion to achieve energy savings by selecting empirically good paths and by caching and processing data in-network. This protocol is not usable for the applications that require continuous data delivery to the sink such as environmental monitoring. In addition, it generate more traffic control in the network. M. Ettus [10] and T. Shepard [11] proposed the so-called MTE (Minimum Transmission Energy) routing scheme, which selects the route that uses the least amount of energy to transport a packet from the source to the destination. Assuming that the energy consumption is proportional to square distance between nodes, the intermediate nodes, that operate as routers, are chosen for minimizing the sum of squared distances over the path. For example, assume that a network is formed by nodes A, B, and C. The node A would transmit to node C. In the MTE, the node B participate to the route only if:

\[ d_{AC}^2 > d_{AB}^2 + d_{BC}^2 \]

Shah et al. [12] proposed a routing protocol that is suitable for low energy and low bit rate networks. The idea behind the protocol is very simple using the lowest energy path always is not necessarily best for the long-term health of the network. Thus using a simple mechanism to send traffic though different routes helps in using the node resources more equitably. Using probabilistic forwarding to send traffic on different routes provides an easy way to use multiple paths without adding much complexity or state at a node.

3. MODELS AND ASSUMPTIONS

A. Network model

Our network model has the following properties:

- Each node performs sensing task periodically and always has some data to send to the sink.
- All nodes are stationary and energy constrained.
- All the nodes are located in a two-dimensional space.
- Location of each node is known, according to GPS or LPS[11].
- There is no energy hole in the network.
- Sink is externally powered.
- All the nodes use multi-hop routing method to forward the data to the closest relay node.
- Relay nodes carry the sensory data to the sink.
- Sink has the ability to communicate directly with all the sensors in the network.
- Interference range is twice of the transmission range.
- All the nodes use FDMA and data aggregation at each hop to avoid collision and interference.
- There is only one transmission range field for all the nodes.
- Each node has a data rate to carry all the data traffic.
- Each node is assigned a number according to its location.

B. Radio energy mode

We have used the same radio energy model as used in [10] with few changes. Path loss co-efficient is considered as two. According to the model, we have:

\[ E_{Tx}(l,d) = \begin{cases} 
    l \times L \times E_{elec} + l \times L \times E_{Rx} \times d^2, & \text{if } d < d_o \\
    l \times L \times E_{elec} + l \times L \times E_{Tx} \times d^4, & \text{if } d > d_o 
\end{cases} \]  \tag{1}

\[ E_{Rx} = l \times E_{elec} \]  \tag{2}

Here ETx represents the transmission energy, ERx represents the energy used in reception, d is the distance between two nodes or between a node and the sink, Eelec is the energy dissipated per bit to run the transmitter or the receiver circuit, E_{trans} and E_{recev} depends on the transmitter amplifier model, do is the threshold transmission distance and I is the length of the data.
transmitted. We have used the same values as we used in [10] and so $E_{eiee} = 50 \text{nJ/bit}$, $E_{Fs} = 10 \text{pJ/bit/m}^2$, $E_{Tr} = 0.0013 \text{pJ/bit/m}^4$, $d = \text{transmission radius, dlr. e}$

Lifetime model

The network lifetime is defined as the time elapsing from initial deployment to the instant of the probability of connectivity reaching the prescribed threshold [12]. In our work, we defined the lifetime of the network as the length of time from the network deployment until the first relay node drains out of its energy. Lifetime is expressed in terms of seconds in this paper and for a single node it can be evaluated by the following equation:

$$L = \frac{e_{initial}}{e_{total}}$$  \hspace{1cm} (3)

where $e_{initial}$ is the initial energy of a sensor node and $e_{total}$ is expressed as:

$$e_{total} = E_{Tx} (I, d) + E_{Rx} (I) \hspace{1cm} (4)$$

The upper limit of the number of relay nodes, $N_{r_{max}}$ which can be used in a wireless sensor network, is given in [13]. It can be calculated by the following equation:

$$N_{r_{max}} = \sum_{i=1}^{N} \left\lfloor \frac{D_i}{d_{los}} \right\rfloor - 1 \hspace{1cm} (5)$$

Here $D_i$ is the distance of the $i^{th}$ sensor from the sink, $d_{los}$ is the near field distance and $N$ is the number of sensor nodes. In practical condition, as one relay node relays more than one sensor node, the value of $N_{r_{max}}$ Eq. (5) reduces greatly. In our work, as the optimal position of the sink is yet to be located, $D_i$ will be the distance of the $i^{th}$ sensor from a reference point. The reference point is taken in such a way that we can minimize the value of $N_{r_{max}}$.

4. PSO ALGORITHM AND OPTIMAL SINK LOCATION

The PSO algorithm is a population based optimization technique, introduced by R. C. Eberhart and J. Kennedy in 1995[14]. The model of this algorithm is based on the social behaviour of bird flocking. It works by initializing population of random solutions and searching for the optima by updating generations. The PSO technique uses several particles, each represents a solution, and finds the best particle position with respect to a given fitness function [15]. The PSO algorithm we have used for finding the optimal location of the sink is given below:

PSO Algorithm for Optimal Location of the Sink in Wireless Sensor Network Using Multi-hop Routing

1. Initialization:
2. Generate a group of n particles, each particle 3 representing

4. a possible solution for the sink b and each group
5. contains p elements
6. Set $p_{Best}$ and $g_{Best}$ equal to zero
7. Set the order of system to p
8. Set the maximum value of generation m
9. Set the upper and lower bound for the sink location
10. Set the inertia weight w
11. Generate an initial velocity
12. At each generation, m:
13. For each particle n
14. loop
15. For sink b
16. Calculate dh! And ph
17. For each node i
18. calculate $d_{iJ}$, $h_{ct}$, $L_{iJ}$, $E_{Li}$, $E_{total i}$
19. calculate $L_{i(k)}$ or particle $k$
20. calculate the lifetime of the whole network as its fitness value, fitness $(k)$
21. if (fitness $(k) > p_{Best k}$)
22. update $p_{Best k} = \text{fitness} (k)$
23. set $g_{Best} = \max_{k} \{p_{Best k}\}$
24. set $g_{Best} = \max_{k} \{p_{Best k}\}$
25. update the velocity of the $k^{th}$ particle, $V_{id}$
26. update the position of the $k^{th}$ particle, $X_{id}$
27. end
28. Repeat 14 to 28 until generation reached maximum

The definition of the parameters used in the algorithm is summarized in TABLE I. As the velocity of each particle dynamically changes according to $p_{Best}$ and $g_{Best}$, the velocity, $V_{id}$, is updated according to the following equation:

$$V_{id}^{\text{new}} = w \times V_{id}^{\text{old}} + c_1 \times R_1(\bullet) \times (p_{Best id} - x_{id}) + c_2 \times R_2(\bullet) \times (g_{Best id} - x_{id}) \hspace{1cm} (6)$$

After the velocity is updated, the position for a particle is also updated:

$$x_{id}^{\text{new}} = x_{id}^{\text{old}} + V_{id}^{\text{old}} \hspace{1cm} (7)$$

I is assumed that the positions of all the nodes are known in terms of x and y coordinates. So the distance $d_{ij}$ between the nodes i and j is calculated according to the following formula:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \hspace{1cm} (8)$$

Considering $d_{tr}$ as the threshold transmission distance for all the nodes, node j is said to be the neighbour of node i if and only if

$$p_i = \{ j : d_{ij} \leq d_{tr} \} \hspace{1cm} (9)$$

As the location of the sink b is $(X_b, Y_b)$, therefore the distance from the node i to the sink b is:

$$d_{bi} = \sqrt{(x_b - x_i)^2 + (y_b - y_i)^2} \hspace{1cm} (10)$$

Thus we can evaluate the set of neighbours for the sink b by the following equation:
The hop count, \(h_{ri}\), of node \(i\) is calculated using the following formula where hop count distance is expressed as \(d_i\):

\[
h_{ri} = \begin{cases} h_{fi} & \text{if } h_{fi} \neq 0 \\ 1 & \text{if } h_{fi} = 0 \end{cases}
\]

(12)

The \(h_{fi}\) in the above equation can be written as follows where \(d_i\) is the hop count distance:

\[
h_{fi} = \frac{d_{h_{fi}}}{d_{i}}
\]

(13)

In order to find the optimal link for each node to the sink, we have used the concept introduced in Minimum Transmission Energy (MTE) routing [16][17], and the link \(L_i\). For the node \(i\) is given by:

\[
L_i = \{i, j; h_{ji} = n, n \text{ is an integer, and } 1 \leq n \leq h_{ai} - 1\}
\]

(14)

As in a link, the first node consumes energy on transmission only and other nodes consume energy for both transmission and reception, so energy consumption of each link is:

\[
E_{lij} = h_{ai} \times E_{lx} + \left( h_{ai} - 1 \right) \times E_{Rx}
\]

(15)

Therefore, if a node is used to receive \((n - 1)\) times, it should transmit \(n\) times. Hence the energy consumption of each node is:

\[
E_{total,i} = n \times E_{Rx} + \left( n - 1 \right) \times E_{Rx}
\]

(16)

But if a relay node transmits \(n\) times it also receives \(n\) times. So the energy consumption of each relay node is given by:

\[
e_{total,i} = n \times E_{Rx} + n \times E_{Rx}
\]

(17)

The lifetime \(l_{(i,j)}\) node \(i\) at \(j\) particle is expressed by:

\[
l_{(i,k)} = \frac{e_{initial}}{e_{total}}
\]

(18)

The fitness function for each particle has been used as:

\[
fitness(k) = \min_{i=1}^{N} \left\{ l_{(i,k)} \right\}
\]

(19)

TABLE I. LIST OF VARIABLES

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p_{Best,sl})</td>
<td>Particle's best position</td>
</tr>
<tr>
<td>(g_{Best,sl})</td>
<td>Global best position</td>
</tr>
<tr>
<td>(W)</td>
<td>Inertia weight</td>
</tr>
<tr>
<td>(X_{sl})</td>
<td>The particle position</td>
</tr>
<tr>
<td>(V_{sl})</td>
<td>The particle velocity</td>
</tr>
<tr>
<td>(d_{h_{fl}})</td>
<td>Distance from node i to the sink</td>
</tr>
<tr>
<td>(P_{b})</td>
<td>Set of neighbours for the sink</td>
</tr>
<tr>
<td>(D_{hj})</td>
<td>Distance between node i and node j</td>
</tr>
<tr>
<td>(P_{t})</td>
<td>Set of neighbours for the node i</td>
</tr>
</tbody>
</table>

5. ENERGY-BALANCED TRANSMISSION ALGORITHM FOR WIRELESS SENSOR NETWORKS

In a wireless sensor network, nodes are battery powered and maximising the system lifetime is an important design goal. At the hardware level, this translates to developing techniques for low power circuit design. Motivated by finding a method to distribute equitably the energy over nodes for data transmission, we suggest a new method that combines transmission energy reduction and the distribution of this energy over the entire network. The technique that we have investigated is based on finding the minimum transmission energy for each transmission. Only the nodes having their energy greater than the network energy average can contribute to relay the data packets. So, before each data transmission round, the whole network energy state must be calculated by each networks nodes[16][17]. The proposed Energy-Balanced Transmission Algorithm for Wireless Sensor Networks (EBTAWSN) is a routing protocol where optimal routes are chosen based on the energy at each node along the route and the total transmission energy cost. In this algorithm, the path selection for multi-hop transmission is done using the minimum energy transmission over network nodes with a remaining energy greater than the average network energy. The target is to balance the transmission energy consumption over the entire network avoiding the energy depletion of the shortest routes nodes[16].

The EBTAWSN algorithm is given bellow:

- Start algorithm EBTAWSN
- Step 1: Each node broadcasts a Message of its Residual Energy to the network
- Step 2: For each alive node \(ni\) do:
  - For each node \(nj\)
    - If the Residual Energy of the node \(nj\) \(\geq\) the network Residual Energy Average
      - Add the distance between nodes \(nj\) and \(ni\) to the distance matrix
      - End if
Using distance matrix, find the path with minimal sum of square distance to the sink
• Do the transmission and update nodes path energy
• While existing living nodes go to the Step 1
• End algorithm

Periodically, the active nodes in the network broadcast a message frame containing its remaining battery energy. Based to this later, each node calculates the network energy average. This value should be used to determine the set of nodes which are allowed to act as relays[19]. In the transmission and reception of this broadcast message, the node uses a low energies[17] because this message contains only a few information(Energy information) and so it have a reduced length. And using the Dijkstra algorithm, it determines the routes that can use to transmit[15][18]. As result of not acting as relay when the node has its energy lower than the average, the energy depletion of all nodes in the network decreases uniformly. Therefore, the lifetime of the network increases[18].

6. ENERGY DISSIPATION RADIO MODEL

We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics (the same model used in [16][19]), as shown in the figure 1. For the experiments described here, the free space (d 2 power loss) channel models is used. Thus, to transmit an l – bit message a distance d, the radio expends the energy given in the equation 20.

\[
E_{TX}(l, d) = E_{TX-\text{elec}}(l) + E_{TX-\text{amp}}(l, d)
\]

\[
E_{TX}(l, d) = l.E_{\text{elec}} + l.E_{\text{amp}}.d^2
\]

The electronics energy (E_{elec}) depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal[19][20], whereas the amplifier energy, E_{amp}d^2, depends on the distance to the receiver and the acceptable bit-error rate. To receive an l – bit message, the radio expends the energy given in the equation 21:

\[
E_{RX}(l) = E_{RX-\text{elec}}(l) = l.E_{\text{elec}}
\]

Figure 2. Radio model

7. CONCLUSION

In this paper, we have proposed a simple scheme where relay nodes are used to collect data from the sensor nodes to pass them to the sink and the optimal location of the sink is determined with respect to those relay nodes. We will get Results of our experiment, the combination of the optimal location of the sink and relay nodes improve the network lifetime significantly. And We described our proposed routing protocol named EBTAWSN (for "Energy-Balanced Transmission Algorithm for Wireless Sensor Networks"), we note that this protocol outperforms largely the Direct Transmission and the MTE protocols. Therefore, these schemes can be used for designing a wireless sensor network of longer lifetime.

REFERENCES


