Dynamic Cooperative Routing (DCR) in Wireless Sensor Networks

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Abstract. Wireless Sensor Networks(WSNs) have micro sensors connected in a network with processing capabilities for communications. It is subjected to a set of resource constraints such as battery power, bandwidth and lifetime. The existing cooperative routing is addressed to reduce the energy consumption. We propose Dynamic Cooperative Routing (DCR) to conserve energy and maximization of lifetime with a static and mobile sink. A mathematical model is developed for the best placement of the sink in the deployment to reduce the distance between sources and sink . A comparative study of DCR algorithm with the existing algorithm is obtained for a static and mobile sink. In case of mobile sink, Comparative analysis shows the improvement in lifetime and energy conservation by 70% and 65% respectively over the existing algorithms.

Keywords: Cooperative Routing, Energy Efficient, Static Sink, Mobile Sink, and Wireless Sensor Networks.

1 Introduction

Wireless Sensor Networks(WSNs) are deployed with hundreds or thousands of computable and low cost sensors. Once the battery of sensor node gets discharged completely, then network fails. It is essential to preserve the energy of the sensor nodes, since it is very difficult to recharge or replace the battery of the sensor nodes. The effective deployment of nodes, efficient routing technique, memory management technique, better query processing technique, reduction of cost for transmission and reception of data etc.. are the different techniques used to reduce the energy consumption. To reduce energy consumption, finding the best location for sink is another issue in WSNs. If data does not reach through direct transmission then data transmission takes place through cooperative routing. Nodes located nearer to the sink deplete their energy faster due to the large and continuous data transmission to the sink. The successful transmission of data to the sink is addressed in this paper by implementing Dynamic Cooperative Routing with a static and mobile sink.

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2 Literature Survey

Mohamed et al., [1] proposed energy aware routing for wireless sensor networks. Gateway node acts as a centralized network manager. Failure of the gateway and the mobility of the sink is not considered. Sikora et al., [2] have considered a communication network with a single source node, a single destination node and N − 1 intermediate nodes placed equidistantly. Single hop transmission is more suitable for the bandwidth limited regime especially when higher spectral frequencies are required. The gap between single-hop and multi-hop is bridged by employing Interface Cancellation. Madan et al., [3] formulated a distributed algorithm to compute an optimal routing scheme. The algorithm is derived from the concept of convex quadratic optimization and time constraint to maximize the lifetime of network. Ahmed et al., [4], [5] proposed distributed relay assignment protocol for cooperative communication in wireless Networks. The relay is selected from the nearest neighbour list to the base station. Simulation results show that, significant increment in gain of the coverage area for the cooperative routing than direct routing.

3 Problem Definition and Mathematical Model

Given a set of Wireless Sensor Nodes $S_i \in V$ where $i = 1, 2, . . . , n$. we consider different type of sinks for the simulation. A Single Static Sink (z) is located with coordinates (x_z, y_z) and a Single Mobile Sink (z_m) with the coordinates (x_{zm}, y_{zm}). The objectives are to reduce the energy consumption and to maximize the lifetime of the network. The assumptions are (i) All source sensor nodes are static. (ii) Links in between the nodes are bidirectional. (iii) Sink has long communication range and energy than the source sensor nodes (iv) In the case of mobile sink, sink moves in the predetermined location with respect to global information timer. (v)Path loss exponent (α) = 1 to 4. (vi)Threshold value for SNR_{min} is constant.

3.1 Mathematical Model

We assume that power consumption is directly proportional to distance d_i. The power consumption for transmission of data is proportional to the distance between the nodes. As Signal to Noise Ratio increases the amount of power consumption decreases and therefore Power consumption is inversely proportional to $SNRmin(\gamma)$ which is given by .

$$power\ \alpha\ \frac{d_i}{\gamma} = \beta \frac{d_i}{\gamma} \quad (1)$$

where the proportionality sign is removed by the constant β.

Theorem: Distance between the source and the sink is minimized to conserve energy.

Proof: The entire network is mapped as graph G, node $i \in V$ with the coordinates of (x_i, y_i). Let z and z_m be the static sink and mobile sink with the coordinates of (x_z, y_z)

*a*nd $(x_z(_{mt}), y_z(_{mt})$ at time t respectively. d_i is the minimum distance between source and the sink. By partial differentiation of the distance equation and equating to zero, we obtain the best location of the sink with minimal distance with respect to all other nodes present in the network is given by

$$\sum_{i=1}^{n} d_i \rightarrow min \ . \tag{2}$$

$$d_i = \sqrt{(x_i - x_{z)}{}^2 + (y_i - y_{z)}{}^2}. \tag{3}$$

Partial differentiation of distance d_i with respect to x and y for static sink is given by

$$\frac{\partial}{\partial \psi_z} \sum_{i=n}^{n} d_i = \sum_{i=1}^{n} \frac{\psi_z - \psi_i}{d_i}. \tag{4}$$

Partial differentiation of distance d_i with respect to x and y for mobile sink is given by

$$\frac{\partial}{\partial \psi_{z_{mt}}} \sum_{i=n}^{n} d_{it} = \sum_{i=1}^{n} \frac{\psi_{z(mt)} - \psi_i}{d_{it}}. \tag{5}$$

where ψ is either x or y. Total power consumption of the path becomes the additive power consumption at each link present in the path, where path comprises of many links. Total energy consumption is computed as given by

$$E = \sum_{i=1}^{L} (pc^{\frac{C}{D}})(l_{i)}. \tag{6}$$

where l_i is the total number of links present in the path. Energy conservation is improved thus by reducing the distance between Source and destination node.

4 Dynamic Cooperative Routing Algorithm (DCR)

Sensor nodes are deployed randomly in the given area. Dynamic Cooperative Routing algorithm checks for the presence of void node in the network. Sensor nodes first need to identify or select the sink and then forward the data to the desired sink. We consider static and mobile sink. In the case single static sink, all sensor nodes have the global information about the sink location and hence source nodes can route the data to the destination sink. Source node first identifies the set of reachable nodes i.e., the neighbour vectors. It selects one source node from the neighbour vector to forward data. Later the receiver node calculates strength of the received signal and compares it with minimum threshold value i.e., SNRmin. Source node applies the shortest path algorithm and finds the next hop to which data can be sent. After sending data to the next node, receiver node calculates the strength of received signal r_s. If the received signal strength is less than the minimum fixed threshold value , receiver node then re-requests the relay node to send data through cooperative communication. If the relay node has received the data correctly, then it cooperatively transmits the data to the next node. The procedure is repeated until the sink node is encountered.

Table 1. Dynamic Cooperative Routing Algorithm (DCR)

```
The Subgraph G′ ∈ G, ∀ n ⊂ N, initial iteration C_t = 0. Type_of_sink are taken as the input
to the algorithm. p = type_of_sink, Set timer t = 0;
begin
.     while void node is false do
.      while(!event) do nothing;
.       if(event)   then C_t = C_t + 1;
.         Source node closest to event senses the data, min = 1;
.          for (i = 1; i ≤ num; i++) do
.           if(dist(event, i) _ min) then min = dist (event, i); u = i;
.           endif
.          endfor
.        Source s = u;
.    Phase 1: Algorithm Routing Towards Sink(RTS)
.      After selecting the destination sink dest source node s
.      forwards the data cooperatively using shortest path algorithm
.       while (s! = dest) do
.        Find the neighbours of the source s node, j = 0;
.        for(i = 1; i ≤ num; i + +) do
.          if(dist(s, i) ≤ range && i! = s) then
.           neighbour[j] = i;
.           j = j + 1;
.         endif
.        endfor
.       endwhile
.     select a node from neighbour vector i.e.,    σ_any (next hop ⊂ {neighbour})
.   Phase 2 : Algorithm for Selection of Destination Sink(SDS)
.    switch (type_ of_ sink) then
.     case 1 Static_ Sink:
.      Globally collect the information about the location of the static sink.
.       dest   =   Z;
.      break;
.     case 2 Mobile _Sink:
.        t = get (timer of sink node) ;
.         if   t ∈ event's quadrant then      dest = Z_mt;
.        else       dest = Z;
.        endif
.      break;
.    endswitch
.      for   i = 0 to num do
.      if   ∃ atleast   i ∈ V such that E_(i) = = 0 then   void node is true;          return;
.      endif
.     endfor
.    endif
.   endwhile
. endwhile
End
```

5 Simulation and Performance Analysis

In the setup of MATLAB simulation, a 100m X 100m region is considered with 100 sensor nodes. All sensor nodes have equal amount of energy initially with 50 joules.

Radio model is lossy in nature and communication range is 150m, energy consumption per bit is 60pJ. All the links are bi-directional., it transmits data at the fixed rate. Figure 1 shows the graph between the energy consumption versus the number of links for the WSN with static sink. The proposed algorithm DCR consumes less energy than the existing protocols Shortest Non Cooperative Path(SNCP), Cooperative Along Shortest Non Cooperative Path(CASNCP), Minimum Power Cooperative Routing algorithms(MPCR). The energy saving is less for sparse network, but energy saving increases to 33% with the increase in density of the network. The energy saving is much higher in the case of Mobile sink (Figure 2). Figure 3 and Figure 4 depicts the lifetime of the network with static and mobile sink. It is observed that our algorithm performs better in denser networks. In case of the static sink the lifetime is 10% while it is 70% higher in the case mobile sink.

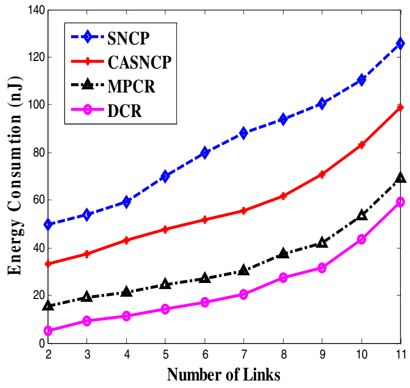

Fig. 1. Energy Consumption versus Number of Links for Static Sink

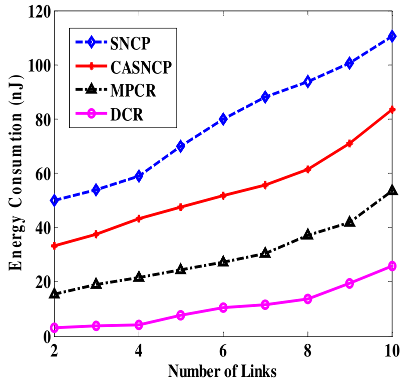

Fig. 2. Energy Consumption versus Number of Links for Mobile Sink

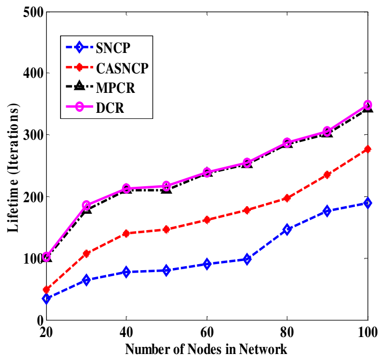

Fig. 3. Lifetime versus Number of Nodes for Static Sink

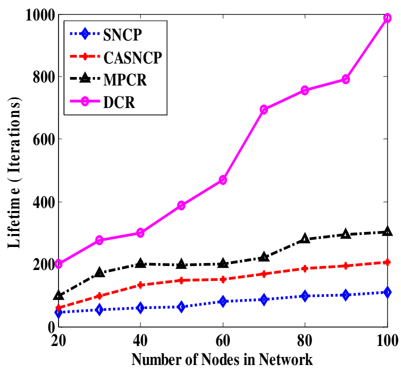

Fig. 4. Lifetime versus Number of Links for Mobile Sink

6 Conclusions

Wireless Sensor Networks operate under limited energy resources and hence with reduced lifetime. We propose Dynamic Cooperative routing to conserve energy and maximize the lifetime of the network. In the case of direct transmission only one node has an opportunity to transmit the data, and therefore the continuous participation of same node drains it's energy and reduces lifetime. In the second scenario, mobile sink moves to predefined locations. All sensor nodes participates for the communication evenly in data transmission and thus energy consumption is uniform across all nodes. The DCR algorithm implemented shows that there is 70% and 65% improvement over the existing MPCR algorithm with respect to lifetime and energy conservation respectively. This work can be enhanced in future with multiple static and multiple mobile sinks.

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