Dynamic Clustering Based on Location in Wireless Sensor Networks with Skew Distribution

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Abstract - Because of unreplenishable power resources, reducing node energy consumption to extend network lifetime is an important requirement in wireless sensor networks. In addition both path length and path cost are important metrics affecting sensor lifetime. We propose a dynamic clustering scheme based on location in wireless sensor networks. Our scheme can localize the effects of route failures, reduce control traffic overhead, and thus enhance the reachability to the destination. We have evaluated the performance of our clustering scheme through a simulation and analysis. We provide simulation results showing a good performance in terms of approximation ratios.

Keywords: Wireless sensor network, topology control, location control, clustering, life-time.

1 Introduction

A sensor network is composed of a large number of battery-operated sensor nodes, which are densely deployed either inside the phenomenon or very close it [1]. Sensor network is usually organized around one or more base stations which connect the sensor network to control and processing devices or to wired or wireless network. Another important requirement is that how to use the node battery resources fairly, when an event of interest occurs within the monitoring area of the sensor network [2, 3].

For these reasons, clustering is fundamental mechanism to design scalable sensor network protocols. Clustering splits the networks into disjoint sets of nodes each centering on a chosen cluster header [4]. Main function of the clustering is to minimize the exchange of flooding messages, there is no point in wasting valuable resources to pro-actively maintain such an elaborate structure between floods, when there is no traffic that can make use of it.

The position models described in this paper form a relatively skew distributed position. In Fig. 1, sensor nodes are concentrated on the right-hand or left-hand side in the sensor network topology. In this case, if the cluster headers rapidly deplete remained energy, the inter-cluster routing path may fail which can jeopardized the entire mission in some cases. The unbalance of energy depletion is caused by different distance from the sink.

To our best knowledge, although many clustering approaches in various contexts have been proposed, previous works [1, 2] have been aimed not at minimizing the energy spent in sensor node but at generating the minimum number of clusters, which implies that achieving multiple goals cannot always be guaranteed but can be approximated through intelligent local decisions. However, these mechanisms are mostly heuristic in nature and aim at generating the minimum number of clusters such that any node in any cluster in at most some hops away from the cluster header [5].

In this paper, we divide the whole network into a few clusters based on the distance from the sink and the strategy of routing. Our scheme use nodes with more energy than the nodes along the shorter routes. This scheme is helping avoid "*hot spots*" in the network. However, routing path may be more than longer.

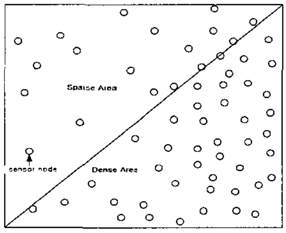


Fig. 1 Topology model with skew-distributed topology.

Our scheme validate through the simulation, which show that our scheme increase the network lifetime by reducing the senor energy consumption since cluster headers are uniformly distributed over the whole network.

The rest of the paper is organized as follows. Section 2 describes a preliminary works. Section 3 presents our scheme and argues that is satisfies its objectives. Simulation results are presented in section 4. Finally, Section 5 concludes the paper and discusses possible future research directions.

2 Preliminary Works

In terms of multi-hop transmission wireless sensor networks have a character that the forwarding nodes is clearly a balancing act between reduced transmission energy and increased receive energy. Hops that are too short lead to excessive receive energy, and then hops that are too long lead to excessive path loss.

Handy et al. [7] does not control the number of clusters in current round, since the sensor nodes elect themselves to be local cluster-headers. This scheme can not maintain optimal number of clusters so that it should consume much energy dissipation. The election of cluster header which does not consider the distance between one cluster and another cluster can cause inefficient deployment of the cluster header. SPIN [11] is earliest work to execute data centric routing methods. However, this approach based on data advertisement scheme cannot guarantee the delivery of data because of fail of an advertisement message. Directed diffusion [9] addresses this problem using opportunistic data aggregation. Sensor selection and tasking is achieved by naming nodes using geographic attributes. Youssef et al. [10] proposed routing approach which constraints the minimum transmission range in order to limit the delay. However, which might require the deployment of many gateways to guarantee high sensor coverage. Therefore, to meet needs of cluster formation in wireless sensor networks, we proposes a cluster formation scheme for energy-efficient clustering, in which the sink divides the network topology into several areas, and then only a single cluster header is selected for each area based on round-robin fashion.

Our goal is to devise dynamic clustering algorithm based on position that can form variable size cluster. In order to adapt the size of cluster in environment, the achieved cluster sizes should be as close as possible to the specified density. Therefore, once the cluster head is assigned to a cluster, the total number of message sent by each node to one of its neighbor implies that the total forwarding message reduced by at least a faction of neighbor.

3 Position Based Cluster Formation

In this section, we describe the position based clustering protocol. First, we define the models used in the clustering process and sensor capability. Second, we define the parameter used in the clustering process, and then we describe the protocol operation. Finally, we prove that the protocol meets its requirement.

3.1 Our Models

Consider a set of sensors deployed in a field. We assume the following properties about the sensor network.

1. All sensors are arbitrarily deployed in a two-dimensional plane, and have homogeneous capability, i.e., equipped with GPS-capable antennae. We show that location information (x_i, y_i) is available to node i, for all nodes in the network. However, node i is not aware of the locations of other nodes in the network.
2. Each node is equipped with omni-directional antennae with adjustable transmission power. When they are selected as the cluster header and the cluster member for node i, we use power level, $P_{i,head}$ and $P_{i,node,}$ respectively. When a header sends a packet in the network, it broadcasts the message at a specific power level, in the range of $P_{i,head}$.
3. The radios on every node are switched off when its does not need to participate in any communication. An energy consumption model can be founded in the Fig. 2.

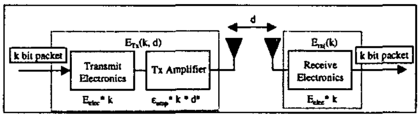


Fig. 2 Radio energy dissipation model

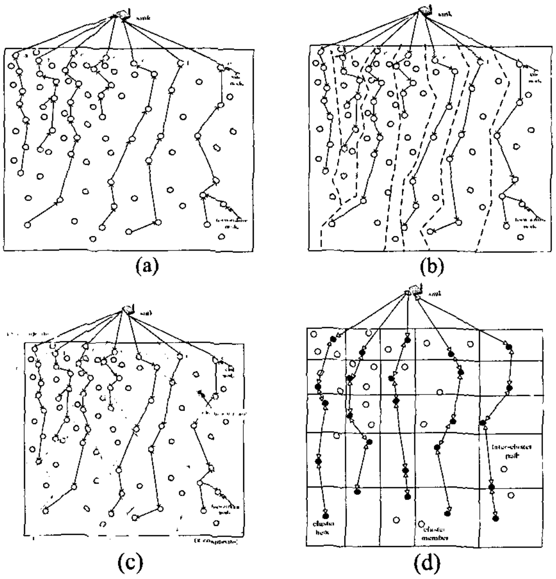
4. We assume that the radius of cluster is limited by node density. Prior to selecting cluster header, a sink parts the sensing field into $r \times r$ grid size with received location information from all sensors.
5. Synchronization is required among nodes in the network.

Let the clustering time to re-establishing a grid topology, τ_{grid} be the time interval taken by the sink. Clustering terminates within a fixed number of iterations without regard to cluster range. Assuming that the process for selecting head completed within τ_{head}, and we ensure that $\tau_{grid} \geq \tau_{head}$. Clustering and head selection process is triggered every $\tau_{grid} + \tau_{head}$ second to select new cluster heads. We consider a topology model for sensing field length, S_l in which n nodes are randomly distributed in square field.

3.2 Cluster Formation Algorithm

Our protocol uses two phases to prolong network life-time. In the position aware phase, our algorithm divides a sensing field into some grid areas; the second phase, referred to as the head selection, selects one cluster head on this grid topology. In Fig. 3, the process of position aware illustrated as follows. Position aware phase starts with the received position information from sensors. In Fig. 3(a) according to received information from each sensor, sink broadcasts an advertisement message using its maximum power range, referred to as the *cluster setup* (*ES*) message in Fig. 3(b), and the *ES* includes the location of each cluster number, C_i and (x_i, y_i) coordinates, where $i=1, 2..., n$. Upon receiving such an *ES*, each node

s_j , where $j=1, 2,..., k$ within C_i knows its cluster by receiving *ES* message from sink.



(a) (b) (c) (d)

Fig. 3 An example of position aware process. (a) Reporting phase *from sensor to the sink. (b) The sink broadcasts the* partition information to entire nodes. (c) Two hops distance based on (b). (d) After broadcasting information from sink, clusters of grid size appear.

4 Analysis and Simulation

For simulation, we used 100-nodes where nodes were randomly distributed *100 * 100* area and the sink with fixed location. Each data message was 500 bytes long and the packet header for each type of packet was 25 bytes long. We use the same radio model as discussed in [2].

$$E_{Tx}(l,d) = E_{Tx}(l) + E_{Tx-amp}(l,d) = \begin{cases} lE_{elec} + l_{e_{fs}}d^2, & d < d_0 \\ lE_{elec} + l_{e_{mp}}d^4, & d \geq d_0 \end{cases} \qquad (1)$$

and to receive this message, the radio expends:

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec} \qquad (2)$$

The electronics energy, E_{elec}, depends on factors such as the digital coding, modulation, filtering, and spreading of the signal, whereas the amplifier energy, $E_{fs}d^2$ or $E_{mp}d^4$, depends on the distance to the receiver and the acceptable bit-error rate.

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For each node, j located in $s_j \in T_{\ldots}$, to be included at each cluster, $s_j \in C_i$ :

for re-establishing cluster,
  if $\tau_{grid}$ fires then
    repeat
        send request_message from sink to node
        if sink receives information then
           compute grid topology for clustering
           send partition information to nodes
        end if
    until position_aware_time $\leq$ threshold;
  else
    repeat
       if one round is expired then
          get backoff time;
          broadcast remaining energy;
          select as a cluster head a node with the more remaining energy;
       else
          while all node have transmission energy do
              send its event to cluster head;
          end while
       end if
    until one_round_time;
  end if
end for
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Fig. 4 Pseudo-code algorithm for clustering

The transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in Fig. 2. For the experiments described here, both the free space (d^2 power loss) and the multi-path fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and receiver. Power control can be used to invert this loss by appropriately setting the power amplifier—if the distance is less than a threshold d_0, the free space (*fs*) model is used; otherwise, the multi-path (*mp*) model is used. Thus, to transmit an l-bit message a distance *d*, the radio expends

In LEACH, the cluster formation scheme was created to ensure that the expected number of clusters per round is *k*, a system parameter. We can analytically determine the optimal value of *k* in LEACH using the computation and communication energy models. Assume that there are *N* nodes distributed uniformly in an *M*M* region. If there are *k* clusters, there are on average *N*/*k* nodes per cluster (one cluster header and *(N/k)-1* non-cluster header nodes). Each cluster header dissipates energy receiving signals from the nodes, aggregating the signals, and transmitting the aggregate signal to the sink. Since the sink is far from the nodes, presumably the energy dissipation follows the multi-path model (d^4 power loss). Therefore, the energy dissipated in the cluster header node during a single frame is

$$E_{CH} = lE_{elec}\left(\frac{N}{k} - 1\right) + lE_{DA}\frac{N}{k} + lE_{elec} + lE_{mp}d^4_{toSink} \qquad (3)$$

where d_{toSink} is the distance from the cluster header node to the sink and we have assumed perfect data aggregation. Each non-cluster header node only needs to transmit its data to the cluster header once during a frame. Presumably the distance to the cluster header is small, so the energy dissipation follows the Friss free-space model (d^2 power loss). Thus, the energy used in each non-cluster header node is

$$E_{non-CH} = lE_{elec} + lE_{fs} d_{toCH}^{2} \qquad (4)$$

where d_{toCH} is the distance from the node to the cluster header. The communication energy parameters are set as: E_{elec} = 50nJ/bit, E_{fs} = 10pJ/bit/m2, and E_{mp} = 0.0013pJ/bit/m^4. The energy for data aggregation is set as E_{DA} = 5nJ/bit/signal. The cluster header probability k is set to 0.05 – about 5 nodes per round become cluster headers.

Fig. 5 shows total system dissipated in each round. In this figure, our scheme is denoted by "Det. Scheme." Our scheme is more efficient than LEACH and less variety of energy consumption. The remaining energy in all nodes keeps evenly. This is mainly due to the load balance algorithm used in Det. Scheme so that all nodes try to evenly share their lifetime.

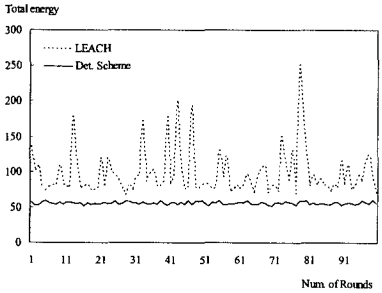

Fig. 5 Total system energy dissipated in each round

Fig. 6 shows the number of rounds completed at the FNA with various numbers of nodes. When the node density is high, Our Scheme still offers approximately two times longer life time than LEACH.

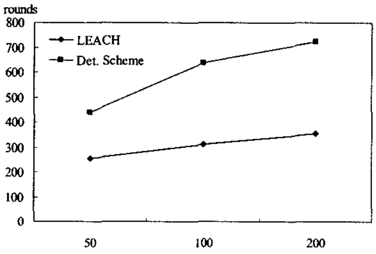

Fig. 6 Life time versus the number of nodes

Our scheme has a series of advantage for maintain the optimal number of cluster header and without any negotiation between the sensor nodes for the election of cluster headers. However, our scheme has scalability problems for large sensor networks or is not directly applicable to the support of variant data delivery models such as [9].

5 Conclusions

In this paper, we proposed a dynamic clustering scheme based on location in wireless sensor networks with skew distribution, cluster head works based on remaining energy. Simulation results show that our scheme provides a much longer network life time than the conventional one by reducing the senor power consumption since cluster headers are uniformly distributed over the whole network. Therefore, our future work will consider scalability for applicable in large sensor networks.

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