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Energy Consumption Methods of Mobile Relay Configuration in Wireless Sensor Networks

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Abstract:-: Wireless Sensor Networks (WSNs) are increasingly used in data-intensive applications such as microclimate monitoring, precision agriculture, and audio/video surveillance. A key challenge faced by data-intensive WSNs is to transmit all the data generated within an application's lifetime to the base station despite the fact that sensor nodes have limited power supplies. We are study low cost disposable mobile relays to reduce the energy consumption of data-intensive WSNs. Our study focused on the problem of Optimal Mobile Relay Configuration (OMRC) in data-intensive WSNs. We study the effect of the initial configuration on the final result. We compare different initial tree building strategies and propose an optimal tree construction strategy. We develop two algorithms that iteratively refine the configuration of mobile relays. The first improves the tree topology by adding new nodes. It is not guaranteed to find the optimal topology. The second improves the routing tree by relocating nodes without changing the tree topology. Third algorithm improves the routing tree by relocating its nodes without changing its topology

Keywords:- OMRC,MS,MR,WSN,.

I. Introduction:-

Recent advancement in mobile sensor platform technology has been taken into attention that mobile elements are utilized to improve the WSN's performances such as coverage, connectivity, reliability and energy efficiency. The concept of mobile relay is that the mobile nodes change their locations so as to minimize the total energy consumed by both wireless transmission and locomotion. The conventional methods, however, do not take into account the energy level, and as a result they do not always prolong the network lifetime. Several different approaches have been proposed to significantly reduce the energy cost of WSNs by using the mobility of nodes. The mobile node may serve as the base station or a "data mule" that transports data between static nodes and the base station [3] [4]. Mobile nodes may also be used as relays [5] that forward data from source nodes to the base station. Several movement strategies for mobile relays have been studied in [5][6]. Although the effectiveness of mobility in energy conservation is demonstrated by previous studies, the following key issues have not been collectively addressed. First, the movement cost of mobile nodes is not accounted for in the total network energy consumption. Instead, mobile nodes are often assumed to have replenishable energy supplies [7] which is not always feasible due to the constraints of the physical environment. Second, complex motion planning of mobile nodes is often assumed in existing solutions which introduces significant design complexity and manufacturing costs. In [7] [8], mobile nodes need to repeatedly compute optimal motion paths and change their location, their orientation and/or speed of movement. Such capabilities are usually not supported by existing low-cost mobile sensor platforms.

II. Wireless Sensor Network:-

A wireless sensor network (WSN)[1][2] consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound , vibration , pressure , humidity, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. Figure 1 shows an example of a wireless sensor network.

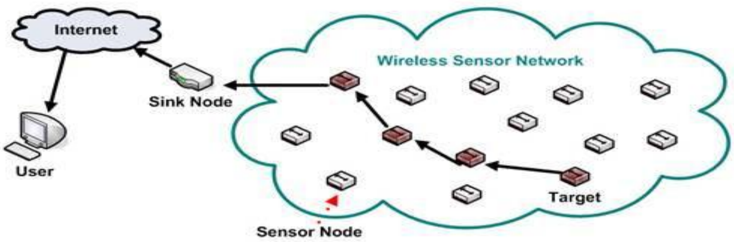

Figure 1: Wireless Sensor Network

III. Wireless Sensor Network Architecture

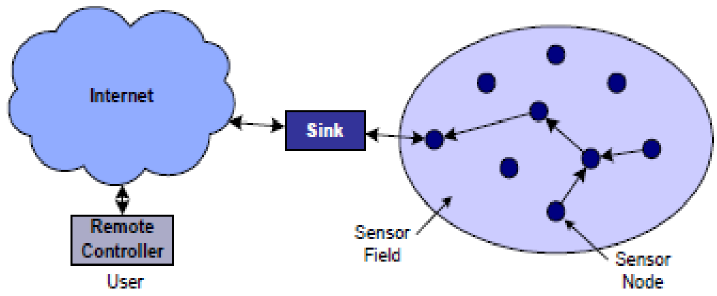

FIG. 2. Sensor Network Architecture.

In above FIG. 2 shows the architecture of a typical wireless sensor node, as usually assumed in the literature. It consists of four main components: (i) a sensing subsystem including one or more sensors (with associated analog-to-digital converters) for data acquisition; (ii) a processing subsystem including a micro-controller and memory for local data processing; (iii) a radio subsystem for wireless data communication; and (iv) a power supply unit. depending on the specific application, sensor nodes may also include additional components such as a location finding system to determine their position, a mobilizer to change their location or configuration (e.g., antenna's orientation), and so on. consisting of one sink node (or base station) and a (large) number of sensor nodes deployed over a large geographic area (sensing field). Data are transferred from sensor nodes to the sink through a multi-hop communication paradigm [5].

IV. ENERGY CONSUMPTION:

Energy Consumption Models Nodes consume energy during communication, computation, and movement, but communication and mobility energy consumption are the major cause of battery drainage. Radios consume considerable energy even in an idle listening state, but the idle listening time of radios can be significantly reduced by a number of sleep scheduling protocols. In this work, we focus on reducing the total energy consumption due to transmissions and mobility. Such a holistic objective of energy conservation is motivated by the fact that mobile relays act the same as static forwarding nodes after movement. For mobility, we consider wheeled sensor nodes with differential drives such as Khepera , Robomote , and FIRA. This type of node usually has two wheels, each controlled by independent engines. We adopt the distance proportional energy consumption model which is appropriate for this kind of node . The energy E consumed by moving a distance d is modeled as:MÐdÞ The value of the parameter k depends on the speed of the node. In general, there is an optimal speed at which k is lowest. In , the authors discuss in detail the variation of the energy consumption with respect to the speed of the mote. When the node is running at optimal speed, k ¼ 2 . An Illustrative Example We now describe the main idea of our approach using a simple example. Suppose we have three nodes located at positions x1;2;x, respectively (Fig. 1), such thats23is a mobile relay node. The objective is to minimize the total energy consumption due to both movement and transmissions. Data storage node needs to transmit a data chunk to sink s31through relay node s. One solution is to have sand node s1transmit the data from x2 relays it to sink 3. This will reduce the transmission energy by reducing the distances separating the nodes. However, moving relay nodes also consumes energy. We assume the following parameters for the energy models: k ¼ 2;a ¼ 0:6 _ 10_7;b ¼ 4 _ 10.

V. MOBILITY-BASED ENERGY CONSERVATION SCHEMES

Mobility-based energy conservation schemes can be classified depending on the nature of the mobile element, i.e. a Mobile sink (MS) or a Mobile relay (MR).

Mobile-Sink-based Approaches:

Many approaches proposed in the literature about sensor networks with mobile sinks (MSs) rely on a Linear Programming (LP) formulation which is exploited in order to optimize parameters such the network lifetime and so on. For example, in[13] the authors propose a model consisting of a MS which can move to a limited number of locations (sink sites) to visit a given sensor and communicate with it (sensors are supposed to be arranged in a square grid within the sensing area). During visits to nodes, the sink stays at the node location for a period of time . Nodes not in the coverage area of the sink can send messages along multi-hop paths ending at the MS and obtained using shortest path routing.

Mobile-Relay-based Approaches

The Mobile Relay (MR) model for data collection in multi-hop ad hoc networks has already been explored in the context of opportunistic networks [12]. One of the most well-known approaches is given by the message ferrying scheme [6], Message ferries are special mobile nodes which are introduced into a sparse mobile ad hoc network to offer the service of message relaying. Message ferries move around in the network area and collect data from source nodes. They carry stored data and forward them towards the destination node. Thus, message ferries can be seen as a moving communication infrastructure which accommodates data transfer in sparse wireless networks. A similar scheme has also been proposed in the context of sparse wireless sensor networks through the data-MULE system [6], [11]. In detail, the data-MULE system consists of a three-tier architecture (FIG 3).

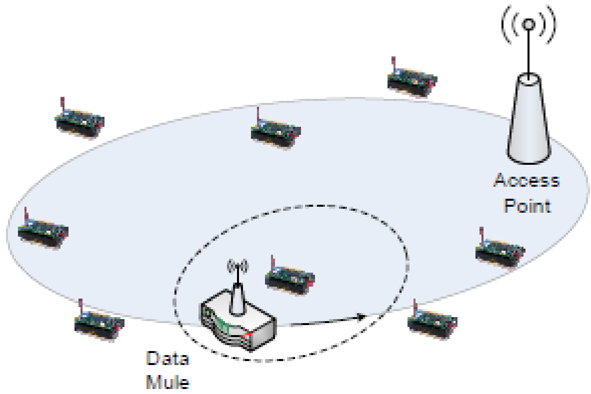

FIG. 3: System architecture of a wireless sensor network with mobile relays.

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VI. ENERGY OPTIMIZATION FRAMEWORK

The Optimal Mobile Relay Configuration problem is challenging because of the dependence of the solution on multiple factors such as the routing tree topology and the amount of data transferred through each link. For example, when transferring little data, the optimal configuration is to use only some relay nodes at their original positions. As the amount of data transferred increases, three changes occur: the topology may change by adding new relay nodes, the topology may change by changing which edges are used, and the relay nodes may move closer together. In many cases, we may have restrictions such as no mobility for certain relay nodes or we must use a fixed routing tree. These constraints affect the optimal configuration.

Assume the network consists of one source si−1, one mobile relay node si and one sink si+1. Let the original position of a node sj be oj = (pj , qj), and let uj = (xj , yj) its final position in configuration U. According to our energy models, the total transmission and movement energy cost incurred by the mobile relay node si is

$$c_i(U) = k\|u_i - o_i\| + am + b\|u_{i+1} - u_i\|^2 m$$

Now We need to compute a position ui for si that minimizes Ci(U) assuming that ui−1 = oi−1 and ui+1 = oi+1; that is, node si's neighbors remain at the same positions in the final configuration U. We calculate position ui = (xi, yi) for node si by finding the values for xi and yi where the partial derivatives of the cost function Ci(U) with respect to xi and yi become zero. Position ui will be toward.

$$\frac{\delta C_i(U)}{\delta x_i} = -2bm(x_{i+1} - x_i) + 2bm(x_i - x_{i-1}) + k\frac{(x_i - p_i)}{\sqrt{(x_i - p_i)^2 + (y_i - q_i)^2}}$$

$$\frac{\delta C_i(U)}{\delta y_i} = -2bm(y_{i+1} - y_i) + 2bm(y_i - y_{i-1}) + k\frac{(y_i - q_i)}{\sqrt{(x_i - p_i)^2 + (y_i - q_i)^2}}$$

VII. STATIC TREE CONSTRUCTION

Different applications may apply different constraints on the routing tree. When only optimizing energy consumption, a shortest path strategy (as discussed below) yields an optimal routing tree given no mobility of nodes. However, in some applications, we do not have the freedom of selecting the routes. Instead, they are predetermined according to some other factors (such as delay, capacity, etc.). In other less stringent cases, we may be able to update the given routes provided we keep the main structure of the tree. Depending on the route constraints dictated by the application, we start our solution at different phases of the algorithm. In the unrestricted case, we start at the first step of constructing the tree. When the given tree must be loosely preserved, we start with the relay insertion step. Finally, with fixed routes, we apply directly our tree optimization algorithm.

We construct the tree for our starting configuration using a shortest path strategy. We first define a weight function w specific to our communication energy model. For each pair of nodes si and sj in the network, we define the weight of edge sisj as: $w(s_i, s_j) = a + b\|o_i - o_j\|^2$ where oi and oj are the original positions of nodes si and sj and a and b are the energy parameters. We observe that using this weight function, the optimal tree in a static environment coincides with the shortest path tree rooted at the sink. So we apply Dijkstra's shortest path algorithm starting at the sink to all the source nodes to obtain our initial topology.We improve the routing tree by greedily adding nodes to the routing tree exploiting the mobility of the inserted nodes. For each node sout that is not in the tree and each tree edge sisj , we compute the reduction (or increase) in the total cost along with the optimal position of sout if sout joins the tree such that data is routed from si to sout to sj instead of directly from si to sj using the LocalPos algorithm described in algorithm 1. We repeatedly insert the outside node with the highest reduction value modifying the topology to include the selected node at its optimal position, though the node will not actually move until the completion of the tree optimization phase. After each node insertion occurs, we compute the reduction in total cost and optimal position for each remaining outside node for the two newly added edges (and remove this information for the edge that no longer exists in the tree). At the end of this step, the topology of the routing tree is fixed and its mobile nodes can start the tree optimization phase to relocate to their optimal positions.

```
Algorithm 1
function LOCALPOS(oi, ui, ui−1, ui+1)
  ▷ Consider case si moves right
  valid ← FALSE;
  xi ← 1/2 (xi−1 + xi+1) − Yi;
  if xi > pi then
        valid ← TRUE;
  else
        ▷ Consider case si moves left
        xi ← 1/2 (xi−1 + xi+1) + Yi;
        if xi < pi then
              valid ← TRUE;
        end if
  end if
  ▷ Record if new position is different from previous one
  if valid then
        yi ← (xi−1+xi+1−2pi)
             ------------------------ (xi − pi) + qi;
             (yi−1+yi+1−2qi)
        u'= (xi, yi);
        if ‖u'i – ui ‖ > threshold then
            return (ui, TRUE);
        end if
  end if
  ▷ not beneficial to move, stay at original position
  return (oi, FALSE);
  end function
```

Tree Optimization Algorithm

we consider the sub problem of finding the optimal positions of relay nodes for a routing tree given that the topology is fixed. We assume the topology is a directed tree in which the leaves are sources and the root is the sink. We also assume that separate messages cannot be compressed or merged; that is, if two distinct messages of lengths m1 and m2 use the same link (si, sj) on the path from a source to a sink, the total number of bits that must traverse link (si, sj) is m1 + m2. Let the network consists of multiple sources, one relay node and one sink such that data is transmitted from each source to the relay node and then to the sink. We modify our solution as follows. Let si be the mobile relay node, S(si) the set of source nodes transmitting to si and sdi the sink collecting nodes from si. The cost incurred by si in this configuration U is:

$$ci(U) = k\|ui - oi\| + ami + bmi\|ud - ui\|2$$

$$x_i = p_i + \frac{-Bx(\sqrt{pB^2_x + B^2_y} \pm k)}{A\sqrt{pB^2_x + B^2_y}}$$

$$y_i = q_i + \frac{-By(\sqrt{pB^2_x + B^2_y} \pm k)}{A\sqrt{pB^2_x + B^2_y}}$$

Where

$$A = mi + \sum_{s1 \in S(si)} ml$$

$$Bx = mixd + \sum_{s1 \in S(si)} mlxl + Api$$

$$By = miyd + \sum_{s1 \in S(si)} mlyl + Aqi$$

These values correspond to two candidate points moving in each direction (left/right). The optimal position is the valid value yielding the minimum cost. Our algorithm starts by an odd/even labeling step followed by a weighting step. To obtain consistent labels for nodes, we start the labeling process from the root using a breadth first traversal of the tree. The root gets labeled as even. Each of its children gets labeled as odd. Each subsequent child is then given the opposite label of its parent. We define mi, the weight of a node si, to be the sum of message lengths over all paths passing through si. This computation starts from the sources or leaves of our routing tree. Initially, we know mi = Mi for each source leaf node si. For each intermediate node si, we compute its weight as the sum of the weights of its children. Once each node gets a weight and a label, we start our iterative scheme. In odd iterations j, the algorithm computes a position uj i for each odd-labeled node si that minimizes Ci(Uj) assuming that uj i−1 = uj−1i−1 and uji+1 = uj−1i+1 ; that is, node si's even numbered neighboring nodes remain in place in configuration Uj . In even-numbered iterations, the controller does the same for even-labeled nodes. The algorithm behaves this way because the optimization of uj i requires a fixed location for the child nodes and the parent of si.By alternating between optimizing for odd and even labeled nodes, the algorithm guarantees that the node si is always making progress towards the optimal position ui. Our iterative algorithm is shown in algorithm.

```
Algorithm 2
procedure OPTIMALPOSITIONS(U0)
   converged ← false;
   j ← 0;
   repeat
         anymove ← false;
         j ← j + 1;
         ▷ Start an even iteration followed by an odd iteration
         for idx = 2 to 3 do
            for i = idx to n by 2 do
                  (uji ,moved) ← LOCALPOS(oi, S(si), sdi );
                  anymove ← anymove OR moved
                  end for
         end for
         converged ← NOT anymove
   until converged
end procedure
```

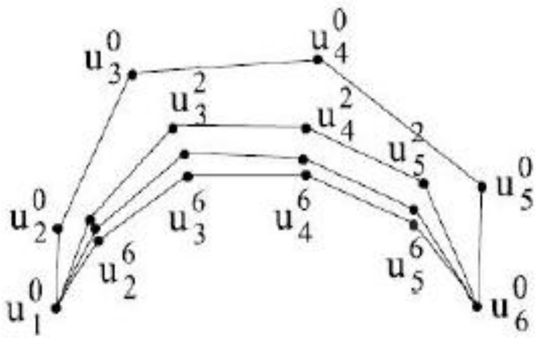

Figure 4: Convergence of iterative approach to the optimal solution

Figure 4 shows an example of an optimal configuration for a simple tree with one source node. Nodes start at configuration U0. In the first iteration, odd nodes (s3 and s5) moved to their new positions (u13, u15) computed based on the current location of their (even) neighbors (u02, u04, u06). In the second iteration, only even nodes (s2 and s4) moved to their new positions (u22, u24) computed based on the current location of their (odd) neighbors (u11, u13 , u15). Since s3 and s5 did not move, their position at the end of this iteration remains the same, so u13=u23 and u15 = u25. In this example, nodes did two more sets of iterations, and finally converged to the optimal solution shown by configuration U6.Even though configurations change with every iteration, nodes only move after the final positions have been computed. So each node follows a straight line to its final destination. As the data size increases, nodes in the optimal configuration get more evenly spaced. In fact, in any given configuration, the maximum distance travelled by a node is bounded by the distance between its starting position and its final position in the evenly spaced configuration.

VIII. Conclusion:-

In this paper, we are study a holistic approach to minimize the total energy consumed by both mobility of relays and wireless transmissions. Most previous work ignored the energy consumed by moving mobile relays. When we model both sources of energy consumption, the optimal position of a node that receives data from one or multiple neighbors and transmits it to a single parent is not them Id point of its neighbors instead, it converges to this position as the amount of data transmitted goes to infinity. Our approach improves the initial configuration using two iterative schemes. The first inserts new nodes into the tree. The second computes the optimal positions of relay nodes in the tree given a fixed topology. This algorithm is appropriate for a variety of data-intensive wireless sensor networks.

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