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Design of Mobile Relay in Data-Rigorous Wireless Sensor Networks

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ABSTRACT
Wireless Sensor Networks are widely used in variety of data rigorous application like traffic monitoring, agriculture, network centric warfare, forest area monitoring. The challenging task in WSN is to transmit the gathered data to the base station within the application's life time. In this paper we are proposing a concept on how to use mobile relay which have more energy than the static sensors to minimize the power consumption in data rigorous wireless sensor networks and this approach don't require complex movement of mobile nodes, so it can be effectively used with minimal cost.
***Keywords* –** Energy Optimization, Mobile node, Relay node, Wireless Sensor Networks

I. INTRODUCTION

Smart environments will be the next evolutionary development step in building, utilities, military, shopping mall, industrial, and home, shipboard, and transportation systems automation. Sensory data is generated from multiple sensors of different modalities in distributed locations. This information can be utilized to create smarter environment. But to achieve these challenges will be enormous like detecting the relevant quantities, monitoring and collecting the data, assessing and evaluating the information, formulating meaningful user information, and performing decision-making.
A WSN (WSN) consists of a set of sensors that are interconnected by a communication network. The sensors are deeply embedded devices that are integrated with a physical environment and capable of acquiring signals, processing the signals, communicating and performing simple computation tasks. While this new class of networks has the potential to enable wide range of applications, it also poses serious challenges like frequent network topology change, limited computational, memory and power supply. Sensors are more prone to failures. With all these constraints an efficient and effective method to extract data from the network is challenging task. Below Fig. 1 shows the scenario of WSN environment where sensors can be deployed for smarter computing.

In this paper, we make use of low cost disposable mobile relays to minimise the total energy consumption of data-rigorous WSNs.

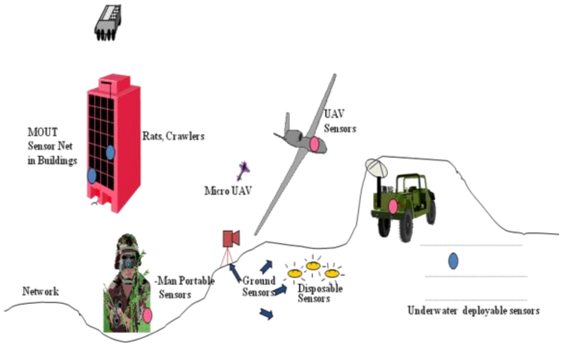

Fig. 1: Different Applications of Wireless Sensor Networks

Mobile relays do not carry the collected data at sensors instead they move to different locations and forward the data from source to the base stations. In this approach we can significantly reduce the delay occurring in communication process between the nodes and each mobile node performs a relocation only once unlike other approaches performs repeated relocations.

There are numerous low-cost mobile sensor prototypes such as Robomote [1], Khepera [2], and FIRA [3] are now available. Their manufacturing cost of static sensors had been compared with mobile sensors. As a result, they can be massively deployed in a network and used in a disposable manner. As the manufacturing cost of sensor nodes is low, hence mobile sensor platforms are powered by batteries and capable of less mobility. By considering these constraints, our approach only requires one relocation to the designated positions after deployment.

We design the Mobile Relay in data rigorous WSNs. Our goal is minimize the energy consumed by both mobility of relays and wireless transmissions, which is in contrast to existing mobility approaches that only minimize the transmission energy consumption.

II. LITERATURE SURVEY

Analyzing the three different approaches: Mobile base stations, data mules and mobile relays. All the three approaches use mobility to reduce energy consumption in wireless sensor networks.

1. MOBILE BASE STATION

A mobile base station is a sensor node collects the data by moving around the network from the nodes [4]. In some work, in order to balance the transmission load, all nodes are performing multiple hop transmissions to the base station. The goal is to rotate the nodes which are close to the base station.

Before the nodes suffer buffer overflows, the base station computes the mobility path to collect data from the visited nodes. Several rendezvous based data collection algorithms are proposed, where the mobile base station only visits a selected set of nodes referred to as rendezvous points within a deadline and the rendezvous points buffer the data from sources.

High data traffic towards the base station is always a threat to the networks life time. [5]. The battery life of the base station gets depleted very quickly due to the sensor nodes which are located near to the base station relay data for large part of the network. The proposed solution includes the mobility of the base station such that nodes located near base station changes over time. All the above approaches incur high latency due to the low to moderate speed of mobile base stations.

2. DATA MULES

Data mules are another form of base stations. They gather data from the sensors and carry it to the sink. The data mule collects the data by visiting all the sources and then transmits it to the static base station through the network. In order to minimize the communication and mobility energy consumption the mobility paths are determined.

In paper [6] the author analyses an architecture based on mobility to address the energy efficient data collection problem in a sensor network. This approach utilizes the mobile nodes as forwarding agents. As a mobile node moves in close propinquity to sensors, data is transmitted to the mobile node for later dumps at the destination.

In the MULE architecture sensors transmit data only over a short range that requires less transmission power. However, latency is increased because a sensor has to wait for a mule before its data can be delivered.

The Mule architecture has high latency and this limits its applicability to real time applications (although this can be mitigated by collapsing the MULE and access point tiers).

The system requires sufficient mobility. For example, mules may not arrive at a sensor or after picking the data may not reach near an access-point to deliver it. Also, data may be lost because of radio-communication errors or mules crashing. To improve data delivery, higher-level protocols need to be incorporated in the MULE architecture.

Data mules also introduce large delays like base stations since sensors have to wait for a mule to pass by before initiating their transmission.

3. MOBILE RELAY

In this approach, the network consists of three nodes such as mobile relay nodes along with static base station and data sources. To reduce the transmission cost relay nodes do not transport data rather it will move to different locations. We use the mobile relay approach in this work.

In [7] author showed that an iterative mobility algorithm where each relay node moves to the midpoint of its neighbors converges on the optimal solution for a single routing path

This paper presents mobility control scheme for improving communication performance in WSN. The objectives of the paper [7] are

1) Analyse when controlled mobility can improve fundamental networking performance metrics such as power efficiency and robustness of communications

2) Provide initial design for such networks.

Mobile nodes move to midpoint of the neighbours only when movement is beneficial [8]. Unlike mobile base stations and data mules, our approach reduces the energy consumption of both mobility and transmission. Our approach also relocates each mobile relay only once immediately after deployment.

The paper study the energy optimization problem that accounts for energy costs associated with both communication and physical node movement. Unlike previous mobile relay schemes the proposed solution consider all possible locations as possible target locations for a mobile node instead of just the midpoint of its neighbors.

III. PROBLEM STATEMENT

1. ENERGY CONSUMPTION MODEL

During the transferring of the data, computation and mobility the energy is consumed by sensor nodes but the large amount battery depletion takes place due to data transfer and mobility.

Even in the idle listening state Radios consumes more energy, but by using sleep scheduling protocols the idle listening time of radios is considerably reduced [9]. In this work, we mainly concentrate on decreasing the total power consumption due to data transmissions and movement. Such a holistic objective of energy conservation is motivated by the fact that mobile relays act the same as static forwarding nodes after movement.

We consider wheeled sensor nodes with differential drives such as Khepera, Robomote and FIRA for mobility. This type of node usually has two wheels, each controlled by independent engines. For this kind of node we adopt the distance proportional energy consumption model [10]. The energy EM (d) consumed by moving a distance d is modelled as:

EM (d) = kd

The factor k value depends on the speed of the node. In general, there is an optimal speed at which k is small. The variants of energy consumed with respect to mote speed are discussed by author in [10]. When the node is running at optimal speed, k = 2.

We evaluate the experimental results got by two radios CC2420 [11] and CC1000 [12] that are most commonly used on existing sensor networks platform to model the energy consumed by transmissions. The authors of [13], for CC2420 studied the transmission power level required for transmitting packets reliably (e.g., over 95% packet reception ratio) over different distances. Let ET (d) be the energy consumed to transmit reliably over distance d. It can be modelled as

ET (d) = m (a + bd^2)

Where m is the number of bits transmitted a and b are constants depending on the environment. We now discuss the instantiation of the above model for both CC2420 and CC1000 radio platforms.

We obtain a = 0.6 × 10−7J/bit and b = 4 × 10−10Jm^{-2}/bit from the measurements on CC2420 in [14], for received signal strength of -80 dbm (which corresponds to a packet reception ratio higher than 95%) in an outdoor environment. This model is constant with the hypothetical analysis discussed in [15]. We also consider the energy needed by CC1000 to output the same levels. We get lower consumption parameters:

a = 0.3 × 10^{-7}J/bit and b = 2 × 10−10Jm^{-2}/bit.

We note that although the mobility parameter k is approximately 1010 times larger than the transmission parameter b, the relays move only once whereas large amounts of data are transmitted. For larger data chunk sizes, the savings in energy transmission costs compensates for the energy expended to move the nodes resulting in a decrease in total energy consumed.

2. AN EXAMPLE

We now demonstrate the key idea of our approach using a simple example. Imagine that we have three nodes s_1, s_2, s_3 located at positions x_1, x_2, x_3, respectively (Fig. 2), in which s_2 is a mobile relay node. The aim is to reduce the total energy consumption due to both mobility and transmissions. Suppose the node s_1 needs to transmit a stored data chunk to sink s_3 through relay node s_2. This can achieved by one the way is to have s_1 transmit the data from x_1 to node s_2 at position x_2 and node s_2 forwards it to sink s_3 at position x_3, without s_2's movement. Another approach is in which it takes advantage of s_2's mobility as suggested in [16], node s_2 move to the midpoint of the segment x_1x_3. This approach will reduce the transmission energy by reducing the distances separating the nodes. Still, moving relay node s_2 also consumes energy.

We assume the following parameters for the energy models:

k = 2, a = 0.6 × 10−7, b = 4 × 10−10.

In this example, for a given data chunk mi, the optimal solution is to move s_2 to x^i_2 (a position that we can compute precisely). This will reduce the total energy utilization due to both transmission and mobility. For small chunk of data, s_2 moves very little if at all. As the size of the data increases, relay node s_2 moves closer to the midpoint. In this example, it is beneficial to move when the message size exceeds 4 MB.

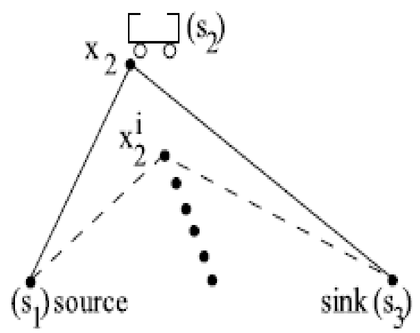

Fig. 2: Reduction in Energy Consumption due to Mobile Relay. As the Data Chunk Size Increases the Optimal Position Converges to the Midpoint of S_1 S_3.

We demonstrate in Table 1 the energy savings achieved using our optimal approach and the other two approaches for the significant range of data sizes. For large enough data chunks (≈ 13 MB), one relay node can reduce total energy consumption by 10% compared to the other two approaches. As the data chunk size increases further, the energy savings decrease, and the optimal position converges to the mid-point when the data size exceeds 43 MB. In general, by using multiple relay nodes the reduction in energy consumption increases.

TABLE. 1: ENERGY CONSUMPTION COMPARISON

Data Size (MB)	Costs at Original Pos.	Costs at Midpoints	Costs at Optimal Pos.	Reduction
5.00	42.78	70.71	42.04	1.73%
11.00	94.12	101.93	88.39	6.09%
12.00	102.68	107.13	94.71	7.75%
13.00	111.23	112.33	100.87	9.32%
14.00	119.79	117.53	106.89	9.06%
15.00	128.35	122.74	112.80	8.09%
16.00	136.90	127.94	118.62	7.28%
17.00	145.46	133.14	124.37	6.58%
18.00	154.01	138.34	130.06	5.98%
40.00	342.26	252.77	247.58	2.05%

The above example demonstrate the two interesting outcome. When both mobility and transmissions costs are taken into consideration the optimal position of a mobile relay is not only the midpoint between the source and sink. This is in contrast to the conclusion of several previous studies [6] which only account for transmission costs. Second, the optimal position of a mobile relay depends on not only the network topology (e.g., the initial positions of nodes) but also the amount of data to be transmitted. Moreover, as the data chunk size increases, the optimal position converges to the midpoint of s_1 and s_3. These results are mainly significant for reducing the energy cost of data-rigorous WSNs.

3. PROBLEM FORMULATION

In our definitions, we assume that all movements are completed before any transmissions begin. We also assume there are no obstacles that affect mobility or transmissions. In this case, the distance moved by a mobile relay is no more than the distance between its starting position and its corresponding position in the evenly spaced configuration which often leads to a short delay in mobile relay relocation. Furthermore, we assume that all mobile nodes know their locations either by GPS units mounted on them or a localization service in the network. We focus on the case where all nodes are in a 2-dimensional plane R^2, but the results apply to R^3 and other metric spaces.

Our problem can be described as follows. Given a network containing one or more static source nodes that store data gathered by other nodes, a number of mobile relay nodes and a static sink, we want to find a directed routing tree from the sources to the sink as well as the optimal positions of the mobile nodes in the tree in order to minimize the total energy consumed by transmitting data from the source(s) to the sink and the energy consumed by relocating the mobile relays. The source nodes in our problem formulation serve as storage points which cache the data gathered by other nodes and periodically transmit to the sink, in response to user queries. Our problem formulation also considers the initial positions of nodes and the amount of data that needs to be transmitted from each storage node to the sink. The formal definition of the problem is given below.

Definition 1: (Optimal Mobile Relay Configuration):

Input Instance: S, a list of n nodes (s_1,...,, s_n) in the network; O, a list of n locations (o_1, . . . , o_n) where o_i is the initial position of node s_i for $1 \leq i \geq n$; S sources, a subset of S representing the source nodes; r, a node in S, representing the single sink; M sources = {Mi | $s_i \in S_{sources}$}, a set of data chunk sizes for all sources in $S_{sources}$;

We define mi, which we compute later, to be the weight of node s_i which is equal to the total number of bits to be transmitted by node s_i. We define a configuration <E,U> as a pair of two sets: E, a set of directed arcs (s_i, s_j) that represent the directed tree in which all sources are leaves and the sink is the root and U, a list of locations (u_1, . . . , u_n) where u_i is the transmission position for node s_i for $1 \leq i \leq n$. The cost of a configuration <E, U> is given by:

$$c(\langle E,U\rangle) = \sum_{(s_i,s_j)\in E} am_i + b\|u_i - u_j\|^2 m_i + k\|o_i - u_i\|$$

Output: <E, U>, an optimal configuration that minimizes the cost c (<E, U>).

IV. OPTIMAL POSITION ALGORITHM

In this section, we consider the 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 (s_i ,s_j) on the path from a source to a sink, the total number of bits that must traverse link (s_i ,s_j) is m_1+m_2. The algorithm [4] converges to the optimal solution for the given tree given the topology is fixed.

procedure OPTIMALPOSITIONS(U^o)
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**
(u^j_i ,moved) ← LOCALPOS(o_i, $S(s_i)$, s^d_i);
anymove ← anymove OR moved
end for
end for
converged ← NOT any move
until converged
end procedure
Fig. 4: Algorithm to compute optimal position

V. SIMULATION RESULT

As in data-rigorous wireless sensor networks power management is challenging task so, mobile relay node is used to minimize the consumption of energy mobile relay node is used. The task of relay node is to forward the data which is gathered by sensor node to sink.

The simulation is carried out for the three pairs of static sensor node. Relay node computes the optimal position by comparing the size of the data at the sensor nodes rather than considering mid-point between two sensor nodes as optimal position. Relay node moves nearer to sensor node which has large size of data and forwards the data to the sink.

The below fig. 3 shows the energy optimization chart for three pairs of sensor nodes. The size of data in terms of KB at each node. Chart shows the energy consumed to transfer the data in the mid positions and optimal positions.

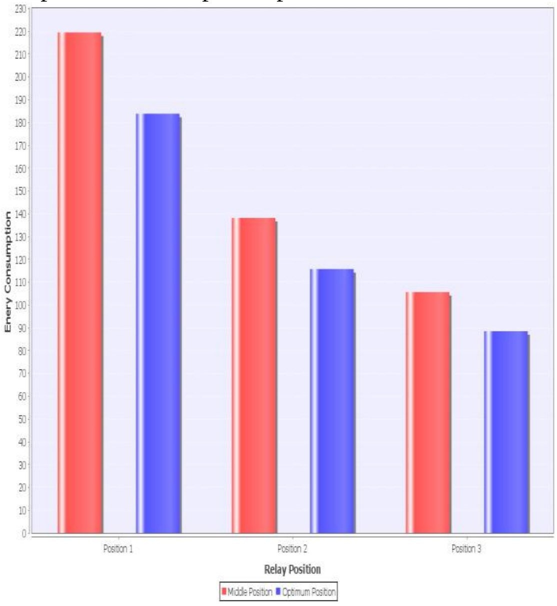

Fig. 3: Energy optimization chart

VI. CONCLUSION

In this paper we propose an approach to minimize the energy consumption of sensor nodes for transferring data to sink by using mobile relay node by taking cost of relay node mobility into consideration.

The optimal position of relay node which forwards the data from one or multiple sensor to sink is not only mid-point between two sensors .Depending upon the size of the data collected at each sensor node the optimal position is computed using optimal mobile relay position algorithm. Our simulation result shows decrease in energy consumed by sensor nodes for transferring of data.

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