Data Gathering Protocol For Wireless Sensor Networks with Mobile Node

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Abstract— **Wireless sensor networks WSNs are emerging as a new paradigm which is used for a wide range of applications. The traditional architectures of WSN consist of a set of static nodes which are deployed over a geographical area in order to collect data. One of the major challenges in WSNs is the energy usage that has also a large influence on the lifetime of the network. Recently, a new WSN architecture based on mobile elements (MEs) has been proposed which introduces MEs to gather data from static sensors. In this paper, we propose a new cluster-based data gathering protocol in WSN-ME. To define the MEs path, we divide the network into several groups of sensors. Then, the ME visits the center of gravity of each group to collect data from static sensors.**

***Index Terms*— Data Collection, WSN, WSN-ME, Center of Gravity.**

I. INTRODUCTION

WSNs consists of a large number of autonomous static sensors which are in charge to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. One of the major challenges of WSN is reduction of power consumption because all sensor nodes are battery-powered tiny devices. More recently, the mobility has been introduced to WSNs (WSN-ME), to address the data gathering problem. In WSN-ME [1], the ME can visit different area in the network and spread the energy consumption even in the case of a dense WSN architecture. However, mobility in WSNs also poses some challenges which do not arise in static WSNs: the presence of a mobile node detection, Reliable data transfer since the duration of contacts is short, the ME path in order to maximize the network performance.

Usually, data collection process in WSN-ME comprises two main steps, ME discovery which is strongly linked to the ME path and aims to minimize energy consumption. Data transfer step which immediately follows the first one.

Several works have been proposed to offers an efficient ME discovery and to formulated the ME path. In [2] the Markov Decision Process (MDP) has used to formulate the movement of the mobile collector and to determine its path. In [3], the ME is assumed to be on board of public transportation shuttles which visit static sensors at specified moments. In [4], the ME sends wakeup messages to trigger the activation of the static sensor node. After the presence of an ME has been detected, the data transfer starts which consists of the communication process between the ME and its one-hop neighbors.

In this paper, we propose a new Center Gravity-based data gathering protocol (CGP) in WSN-ME. In CGP, the WSN is partitioned into several groups of static sensors before being visited by the ME. To ensure an efficient data collection operation and to minimize the energy consumption of sensors, the ME moves to the center of gravity of each group and gathers data from static sensors.

The rest of the paper is organized as follows. In section II, we expose our proposed protocol. The performances and the simulation results are discussed in section III. Finally, we conclude the paper in section IV.

II. CENTER OF GRAVITY-BASED DATA GATHERING PROTOCOL (CGP)

Before explaining the basis of CGP, we consider the following hypothesis:

- The network is homogeneous and all sensor nodes have the same initial energy level.
- The existence of one Mobile collector.
- The sensed area has a rectangular form.

The energy consumption during message transfer between two nodes is proportional to the distance between them, in other word, when we adapt the radio energy model,, the energy usage for transmitting k bits through distance d is expressed as:

$$E_T = kE_{elec} + kE_{ampl}d^2 \qquad 1$$

And to receive this message the radio expands in a free space model is:

$$E_R = E_{elec} * k \qquad 2$$

The energy is directly proportional to d^2, our goal is to minimize the distance between mobile collector and static sensor nodes. To achieve this goal, we use the center of gravity notion.

The center of gravity is a geometric property of any object. and the average location of the weight of an object (Cf. Fig.1).

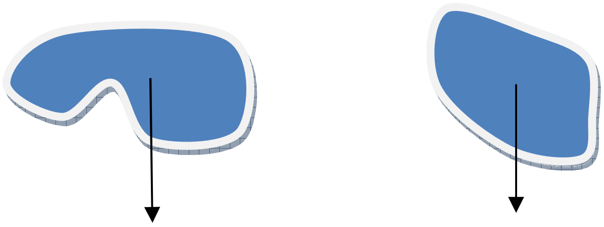

Fig.1. Center of Gravity of an object

Based on [5], let a system that consists of n particles with the position vectors r_v and the masses m_v for $v = (1, \dots, n)$. The center of gravity of this system is defined as point S with the position vector r_s:

$$r_s = \frac{m_1 r_1 + m_2 r_2 + \cdots + m_n r_n}{m_1 + m_2 + \cdots + m_n} = \frac{\sum_{v=1}^{n} m_v r_v}{\sum_{v=1}^{n} m_v} \qquad 3$$

$$r_s = \frac{1}{M} \sum_{v=1}^{n} m_v r_v \qquad 4$$

Where $M = \sum_{v=1}^{n} m_v$ is the total mass of the system and the moment mass is:

$$M r_s = \sum_{v=1}^{n} m_v r_v \qquad 5$$

For a system with uniform mass distribution over a volume V with the volume density, the sum $\sum_i m_i r_i$ becomes an integral as follow:

$$r_s = \frac{\int_V r Q(r) dV}{\int_V Q dV} \qquad 6$$

The individual components are:

$$x_s = \frac{\sum_v m_v x_v}{M}. \qquad y_s = \frac{\sum_v m_v y_v}{M}. \qquad z_s = \frac{\sum_v m_v z_v}{M}.$$

And for the continues mass distribution, we have:

$$x_s = \frac{\int_V Q x dV}{M}. \qquad y_s = \frac{\int_V Q y dV}{M}. \qquad z_s = \frac{\int_V Q z dV}{M}.$$

The center of gravity is described by the following equation:

$$\overrightarrow{OG} = \frac{1}{p} \sum_{i=1}^{n} p_i \overrightarrow{OC_i} \qquad 7$$

Where $C_1, C_2, \dots, C_n$ are the points in the plan having respectively $p_1, p_2, \dots, p_n$ as masses G is the center of gravity point, and p *is* the total masse.
The mobile collector visits the center of gravity of each group to collect data from sensors as illustrated in Fig.2.
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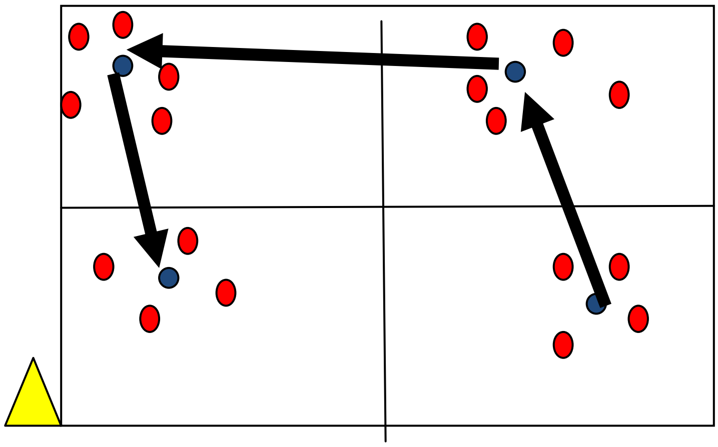

Fig.2. Center of Gravity-based data gathering scheme.
: sink.
: Sensor node.
: Center of gravity point.

The mobile collector is considered as a virtual cluster-head in the center of gravity point of each cluster. To gather data only from sensors which have a high level of energy, we use the following equation to compute p_i:

$$p_i = D + RE \qquad 8$$

With $D \in \{0,1\}$ and RE is the residual energy of static sensor node.

In this way the mobile collector moves near sensor nodes having data to send and more residual energy.
Our data collection algorithm comprises two main phases, localization and data collection phases (Cf. Algorithm 1).
During the localization phase, the mobile collector moves according the scheme shown in Fig.3:

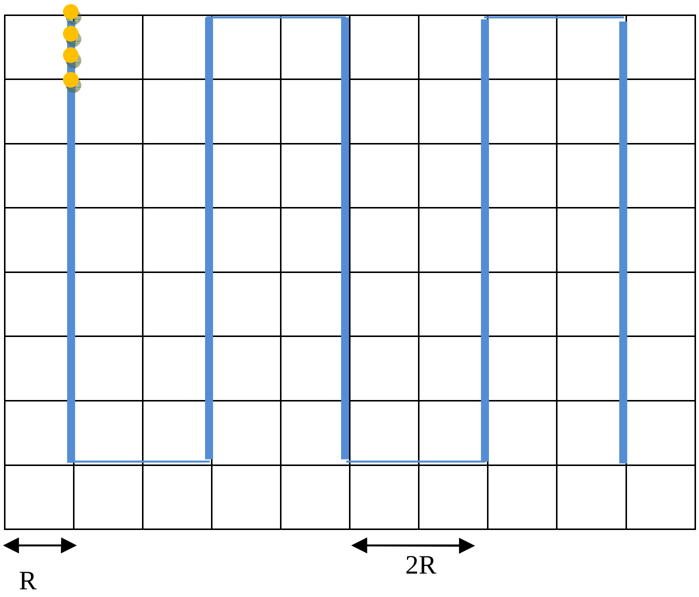

Fig.3. The mobile collector path.

Algorithm 1 Center of Gravity-based Data Gathering Algorithm;

Procedure LOCALIZATION PHASE

1: In this phase, the mobile collector move according the following rule(R,2R,2R,…,2R).

2: It moves R/3, then wait and broadcast a hello message.

3: Repeat this steep three times.

4: During the fourth time, the mobile collector receive the nodes coordinates with residual energy of the current cluster <P,RE>.

5: The mobile collector computes the center of gravity of current cluster and stores <CG,d> in its knowledge base for further use; where d is the density of cluster.

End procedure

Procedure DATA COLLECTION PHASE

1-The mobile collector moves towards a center of gravity.

2-The mobile collector broadcasts a REQ message.

3-Starts the data collection.

4-Repeat (1,2,3) for the next center of gravity.

End procedure

III. SIMULATION EXPERIMENTS

To evaluate the performance of our protocol, we have simulated our protocol and another protocol that use MDP [2].

A. The Simulation parameters

A network simulator is developed using C language and SDL (Simple Direct Media), and CODE::BLOCKS as integrated development environment (IDE).

To facilitate the simulation we consider a sensor network that contains 10-80 sensors randomly distributed in $100 * 100m^2$ square area, the radio range of each sensor is set to 20m. The moving speed of the mobile collector is 6m/s, the packet size is set to 2k bits

For energy consumption measurement, we adopt the first-order radio model [6]. So to transmit an k-bits message through a distance d using the radio model in equation (1) and (2)

Where E_{elec} is the necessary energy to handle bits before transmission such as the coding operation and the modulation. In our simulation, we assume that E_{elec} is a small value, thus the energy consumption is only related to the distance d and the energy of the amplifierE_{ampl}, . So this energy becomes:

$$E_T = E_{ampl} d^2$$

In our simulation we assume that $E_{ampl} = 100\ pJ/bit/m^2$.

The initial position of the mobile collector is (0, 0), and the Sink exists at (50,50), in the center of the network.

B. Simulation results

At this level, we analyze the results to show the performance of our proposed scheme, Center of Gravity-based Data Gathering protocol (CGP), and we compare these results with those obtained with MDP [2]. To do so, we chose the energy usage as criteria.

As it shown in the Figure 4, we observe that the energy consumption in CGP is better than in MDP, because the mobile collector in CGP visit the points that represent the centers of gravity of clusters, where the distances between the sensors and the mobile collector are small. Thus, the two energies consumption converge when the number of sensors is decreased, but when this number increases in the network theses energies will be diverge.

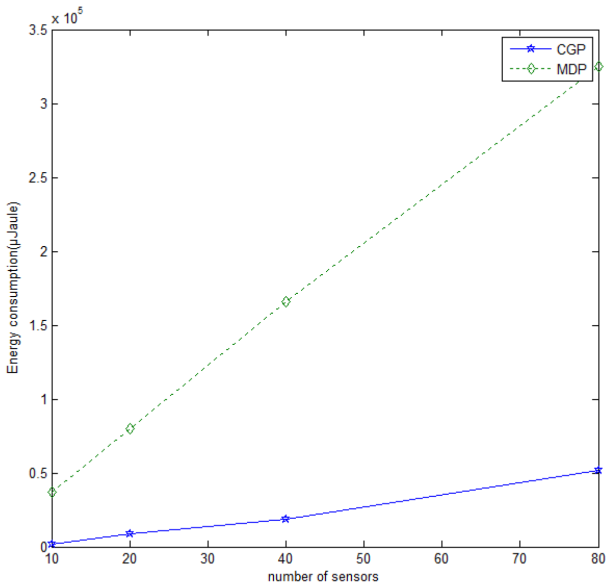

Fig.4. The Energy Consumption.

IV. CONCLUSION AND FUTUR WORKS

In this paper, we have presented our Center of Gravity Data Gathering protocol for Wireless Sensor Networks with mobile elements, the movement of the mobile collector is guided by the center of gravity of points, where the distances between sensor nodes and mobile collector are small, as future works, we aim to more evaluate our proposed protocol by simulating other data gathering protocols and using other criteria such as, the latency time, and the data gathering rate.

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