

Load-Balancing Enhancement by a Mobile Data Collector in Wireless Sensor Networks

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Abstract— Decrease in the time interval between the first node death and the last node death, due to the completion of their energy supply, is the main goal of load-balancing methods in Wireless Sensor Networks (WSN). This paper proposes a Load-Balancing Enhancement (LBE) method, in WSN. LBE method uses a mobile data collector to data gathering from sensor nodes. The mobile data collector can directly communicate with the base station. Indeed, the mobile data collector acts as an interface between sensor nodes and the base station. LBE method divides WSN to four logical partitions. Then, LBE method directs the mobile data collector to the center of each logical partition of the network with considering the density and the mean residual energy of the desired partition, i.e., the more the partition density and the mean residual energy, the more the obtaining chance of the desired partition. Simulation results that have been implemented with NS-2 software show LBE method achieves load-balancing in energy consumption for all logical partitions. LBE method also balances logical partitions density and it increases the network coverage efficiency.

Keywords- *Energy Consumption, Mobile Data Collector, Load-Balancing; Wireless Sensor Networks;*

I. INTRODUCTION

Wireless Sensor Networks (WSN) are real-time and event driven network [1]. These networks are established at environment to collect information about the specified environment by a large number of sensor nodes in a variety of scenarios including battlefields, forests, farmlands, and so on [2]. Sensor nodes report environmental conditions to one or more Base Station (BS) via wireless and multi-hop communications [3]. A BS is central data gathering and it acts as an interface between network's users and sensor nodes. Normally BS is a more powerful node and it is not limited in hardware resources [4]. Memory, energy supply, analog to digital unit (ADC), transceiver, processing unit and sensors are the main component of a typical sensor node (See Fig. 1) [5]. Sensor nodes may be equipped with several types of sensors to sense several environmental parameters [6]. Sensor nodes are tiny and inexpensive device, so they are

very limited in hardware resources [7]. Of course, sensor nodes are constrained in transceiver capacity, so they are unable to communicate with BS directly [8]. Therefore, multi-hop and many to one communication are the nature of traffic patterns in WSNs.

Traditionally, WSNs are established with a stationary BS and a large number of sensor nodes [9]. In these networks, sensor nodes transfer their sensed data to a BS by several intermediate nodes. Multi-hop communication between sensor nodes and a BS leads to intermediate nodes have the more energy consumption of other nodes. Because, sensor nodes lifetime is dependent on their power consumption, i.e., the more the power consumption, the less the sensor node lifetime [10]. The main components of power consumption in WSNs are power consumed for packets send/receive in transceiver unit and the power consumed for packet processing by processing unit respectively [11]. Sensor nodes that are in close to BS consume the more energy of other sensor nodes, so they have the lowest lifetime of other sensor nodes. Several methods which are known as Load-Balancing methods have been proposed to balance sensor nodes energy consumption [4] [12] [13]. Load-balancing methods attempt to decrease the time interval between the first node death and the last node death [14].

Load-balancing methods in WSNs can be considered in the mobility of BS [4], optimal BS positioning [15], network clustering [16], multiple base station [9], and multiple mobile base station [8]. Recently, researchers have attended to use mobile devices in WSNs [4] [8] [17]. Researchers are using the mobile devices to data gathering of sensor nodes in WSNs. When a WSN is established with one or more mobile devices, the mobile devices can freely and randomly move to across the network. For load-balancing enhancement the mobile devices should move to an area of the network with more residual energy [18]. Of course, staying the mobile device anywhere in the network leads to increase in energy consumption of sensor nodes that are close to the mobile device. Thus, to load-balancing enhancement, the mobile devices always should move to different parts of the network.

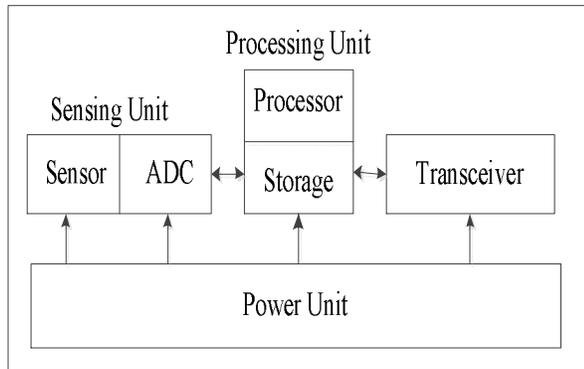


Figure 1 Structure of typical mobile sensor node [5].

In this paper an efficient method to Load-Balancing Enhancement, LBE, in WSNs is proposed. LBE method balances the network energy consumption by an efficient scheduling to a mobile data collector movement. LBE method first performs the network logical partitioning, and then it calculates partitions density to each logical partition. LBE method directs the mobile data collector to the center of each logical partition with considering of partition density and the mean residual energy of the desired partition. Because LBE method considers the partition density for scheduling of the mobile data collector movement, it balances the logical partition density as well as the network coverage efficiency.

The rest of this paper is organized as follows. Section II summarizes the background and related work. In Section III the proposed method is explained. Simulation results are presented and discussed in Section IV. Finally, in Section V obtained results and future work are explained.

II. RELATED WORK

Energy efficiency plays very important role in WSNs, because sensor nodes are very limited in their energy supply [19]. Of course, maintenance and repairing of WSNs is impossible, due to a large number of sensor nodes and harsh environmental conditions [20]. Multi-hop communication of sensor nodes with a BS increases energy consumption of intermediate nodes [9]. So, intermediate nodes have the lowest lifetime of other nodes. With the completion of intermediate nodes energy, BS communication with all sensor nodes is interrupted. In this regard, researchers have proposed several load-balancing methods to decrease the time interval between the first node death and the last node death in WSN as well as the network energy efficiency. Recently using mobile data collectors and mobile devices to load-balancing enhancement has been proposed by researchers.

Researchers in [21] have used a mobile BS which moves in across of the network to balance in energy consumption of sensor nodes that are in close to BS. In [13] a mobile BS moves on the network along a predetermined path. Sensor nodes are randomly distributed at environment, so predetermined path is not effective in WSNs. In paper [18] a mobile BS moves toward sensor nodes that have the highest residual energy. Of course, paper [18] considers only

residual energy to mobile BS movement and does not consider other parameter such as density, distance to BS and etc., to mobile BS movement. Authors in [22] have proposed a Mobile sink based Energy-efficient Clustering Algorithm, MECA, for WSNs by using a mobile BS. The mobile BS moves around the square sensing field.

In [4] [12] authors have used three types of nodes as sensor nodes, mobile agents and a BS. Sensor nodes transfer their data packets to nearest mobile agent, and mobile agents transfer received data to a BS. In [12] sensor nodes can directly communicate with mobile agents and authors do not consider multi-hop communication. Therefore, mobile agents should be coordinated with each other, due to using several mobile agents [4] [12]. In this paper, we use three types of nodes as sensor nodes, a base station and a mobile data collector similar to [4] [12], but to save energy we consider sensor nodes communicate with a mobile data collector as multi-hop communication. We also use a mobile data collector and a BS, so we do not need to establish coordination between several mobile data collectors. A mobile data collector movement can be controlled by our proposed load-balancing method.

III. PROPOSED METHOD

In this section, we introduce the wireless sensor network architecture, and our method to load-balancing enhancement, LBE, respectively. To load-balancing enhancement we use a mobile data collector in WSN. The mobile data collector can move to across of the network and it can directly communicate with a BS. BS has been located in out of the network area. Therefore, sensor nodes communicate with the mobile data collector as multi-hop manner. Indeed, the mobile data collector acts as an interface between BS and sensor nodes. The mobile data collector is powerful node and it is not limited in hardware resources such as bandwidth, energy supply, radio transfer radius and etc. Of course, network users can repair and maintenance of the mobile data collector. So, the mobile data collector can be replaced with a new mobile data collector. The mobile data collector movement can be controlled that in continuous of this section LBE method for scheduling of the mobile data collector movement is proposed.

LBE method divides the network to four logical and equal partitions as Fig. 2. After network partitioning, LBE method calculates the partition density as Equation (1).

$$PD_i = \frac{\text{Number of Node}}{\text{Partition Space}} \quad 1 \leq i \leq 4 \quad (1)$$

where *Number of Node* is nodes number per each logical partition and *Partition Space* is space of each logical partition. LBE method divides the network to equal partitions, so each logical partition space is calculated as Equation (2).

$$\text{Partition Space} = \frac{NH}{2} \times \frac{NW}{2} \quad (2)$$

where *NH* is the network height and *NW* is the network width. Partition space is constant in the network lifetime, but the number of nodes per each logical partition may be changed due to the sensor nodes death. So, LBE method gets the number of nodes per each logical partition in regular time

intervals. After the network partitioning, LBE method performs movement scheduling of the mobile data collector and it makes decision about the mobile data collector placement.

LBE method directs the mobile data collector to the center of each logical partition. LBE method considers the partition density and the mean residual energy of logical partition to movement scheduling of the mobile data collector. When the mobile data collector moves to each logical partition, energy consumption of the desired partition increases. Because, all sensor nodes transfer their data packets to a mobile data collector in its new location. On the other hand, the network coverage is one of the important issues in WSNs which has a large impact on the network performance [23]. So, the mobile data collector should not stay in the network partition with low density for long time. With considering the residual energy and logical partition density, LBE method calculates selecting chance, SC_i , for each logical partition to the mobile data collector movement as Equation (3).

$$SC_i = PD_i \times RE_i \quad 1 \leq i \leq 4 \quad (3)$$

where RE_i is the mean residual energy of logical partition i and PD_i is logical partition density that has been calculated in Equation (1). LBE method directs the mobile data collector to center of partition i with considering of selecting chance of partition i , SC_i . After calculation of selecting chances to each partition, LBE sorts these values as ascending. Then, LBE method selects a logical partition with the most selecting chances. Indeed, logical partition that has the more density and the mean residual energy has the most chance to select by LBE method. If selecting chance, SC_i , for two logical partitions be identical, then LBE method selects randomly one of them. Therefore, if selecting chance, SC_i , for three logical partitions be identical, then LBE method selects randomly one of three logical partitions. Also, if selecting chance, SC_i , for four logical partitions be identical, then LBE method directs the mobile data collector toward center of the network. For example, in Fig 2, if SC_2 and SC_3 be identical, then LBE method selects randomly partition 2 or partition 3, and if SC_2 and SC_3 and SC_4 be identical, then LBE method selects randomly partition 2 or

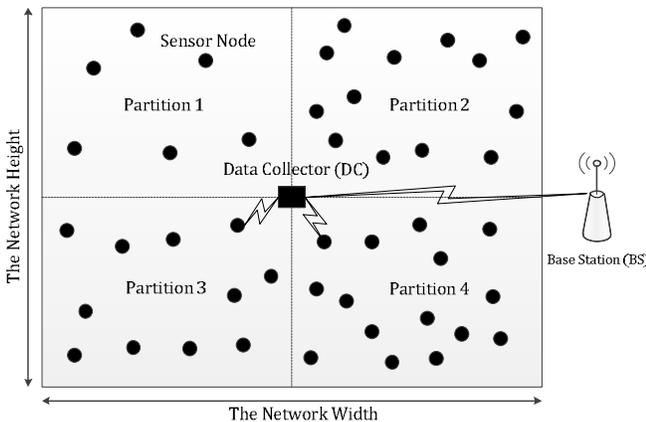


Figure 2. Proposed architecture of a Wireless Sensor Network.

partition 3 or partition 4. LBE method calculates logical partition density and the mean residual energy of each logical partition at regular time intervals by hello message broadcasting. Then, LBE method makes decision about the mobile data collector movement at begin of time interval.

Pseudo-code of LBE method is shown in Fig. 3. According to this figure, LBE method directs the mobile data collector toward desired logical partition at regular time intervals. First, LBE method broadcasts a hello message to calculate each logical partition density and the mean residual energy. LBE method directs the mobile data collector toward a logical partition with considering of partition density and the mean residual energy. Therefore, a logical partition with the highest density and the mean residual energy of other logical partitions has a greater chance of being selected by LBE method.

To load-balancing enhancement, LBE method uses a mobile data collector in WSN. The mobile data collector movement can be controlled by LBE method. LBE method directs the mobile data collector toward a logical partition with more residual energy and density. The mobile data collector establishment in each logical partition leads to increase in energy consumption of sensor nodes that are into the desired partition, i.e., the more the energy consumption, the more the node death probability. If a sensor node energy supply be completed then the network coverage may be compromised. So, selection chance of logical partitions with high density is the greatest of other partitions. In this regard, in a logical partition with high density, each point can be covered by more than one sensor node.

Input: The mean residual energy & density of four logical partitions
Output: The mobile data collector node direction
Step1: At the entire network lifetime do
 Begin
 Broadcast Hello Message to calculate the mean residual energy & density at regular time intervals
 For each partition i calculate
 $SC_i \leftarrow PD_i \times RE_i$
 Case: ($SC_i > SC_j$ for all $i \neq j$ that $1 \leq j \leq 4$)
 Directs he mobile sink node toward partition i
 Case: ($SC_i = SC_j$ and $SC_i \neq SC_k$ for all $i \neq j \neq k$ that $1 \leq j, k \leq 4$)
 Directs randomly the mobile sink node toward partition i or j
 Case: ($SC_i = SC_j$ and $SC_i = SC_k$ and $SC_i \neq SC_y$ for all $i \neq j \neq k \neq y$ that $1 \leq j, k, y \leq 4$)
 Directs randomly the mobile sink node toward partition i or j or k
 Case: ($SC_i = SC_j$ and $SC_i = SC_k$ and $SC_i = SC_y$ for all $i \neq j \neq k \neq y$ that $1 \leq j, k, y \leq 4$)
 Direct the mobile data collector toward center of the Network
 End.

Figure 3. Pseudo-code of LBE method.

IV. EXPERIMENTAL RESULTS

In this section, LBE method performance has been evaluated via NS-2.35 simulator. Different parameters of

simulation are presented in Table. 1. In Table. 1, e_{rx} is the energy consumed by electronic circuit for receiving or forwarding one bit of data, e_{tx} is the energy consumed by the sender node for forwarding one packet [24]. We have randomly distributed sensor nodes in terrain. BS is fixed and its location is at out of the terrain. First, the mobile data collector is located at center of terrain. The mobile data collector broadcasts a hello message for every 10 second. So, LBE method makes decision about the mobile data collector movement every 10 second. Of course, sensor nodes transfer data to the mobile data collector every 2 second.

TABLE I. SIMULATION PARAMETERS.

Terrain	200m x 200m
Node Number	100
Radio Range	40 m
Topology	Grid
Mac Type	Mac/802_15_4
Initial Node Energy	5 J
Propagation Model	Two Ray
e_{rx}	0.1 μ J
e_{tx}	0.33 μ J

Fig. 4, shows the mean residual energy of sensor nodes in four logical partitions, *LP*. The mean residual energy of sensor nodes has been calculated after the energy level becomes zero for 30% of total sensor nodes. Based on Fig. 4, it can be seen the energy consumption of all logical partitions have been balanced by using LBE method. Because, LBE method considers the logical partition density to the data collector movement, so the logical partition density is balanced. Fig. 5, shows the initial logical partition density, *ID*, and final logical partition density, *FD*. The final partition density has been calculated after the death of 30% of the sensor nodes. If the logical partition density be balanced, then all points of the network are covered by sensor nodes. Therefore, by considering the network coverage, the network Quality of Service (Qos) increases. Based on Fig. 5, it can be seen that the more node death has been occurred in logical partitions with high density. Because, these partitions have more chance to obtain by LBE method for the mobile data collector placement. Therefore, Fig. 5 shows that LBE method performs the logical partition density balancing as well as coverage balancing. Because, the logical partitions are equal, so partition density only decreases with the number of nodes reduction in each partition. Fig. 6, shows the number of nodes death in each logical partition. Based on this figure, the logical partition 2 has the more nodes death of other logical partitions. The logical partition 2 has the more density of other logical layers (See Fig. 5). So, the mobile data collector stays in this partition for a long time (See Equation (3)). Residence of the mobile data collector in a logical partition for a long time increases the logical partition energy consumption. On the other hand, the more the energy consumption, the more the nodes death probability. Fig. 7, shows the network lifetime by using a

mobile and stationary data collector. The stationary data collector has been placed in the center of the network and center of all logical partitions respectively. Network lifetime is defined as time passed of the energy level becomes zero for 30% all sensor nodes. In this figure *MD* is a mobile data collector, *SC* is a stationary data collector with location of center of the network and *SP_i* is a stationary data collector with location in center of *i*-th logical partition.

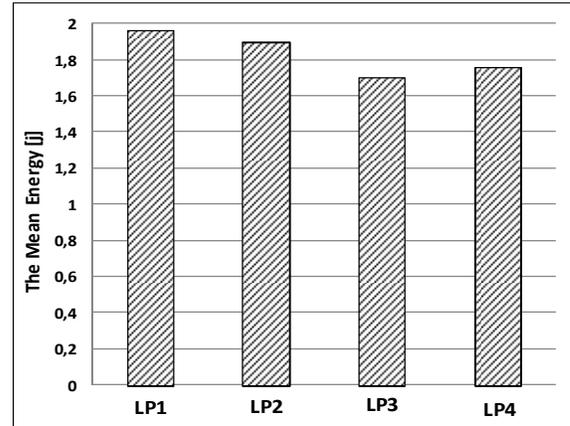


Figure 4. The mean residual energy of four logical partitions.

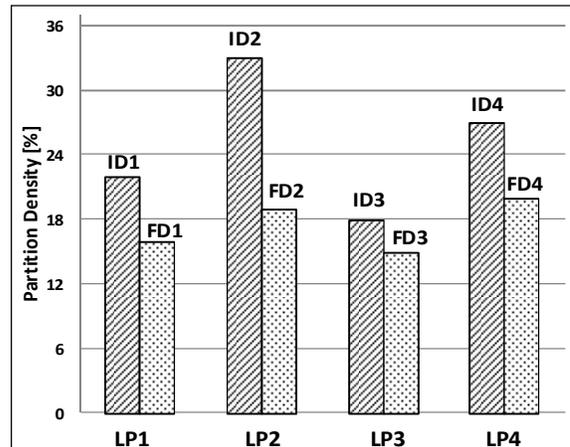


Figure 5. Initial partition density and Final partition density.

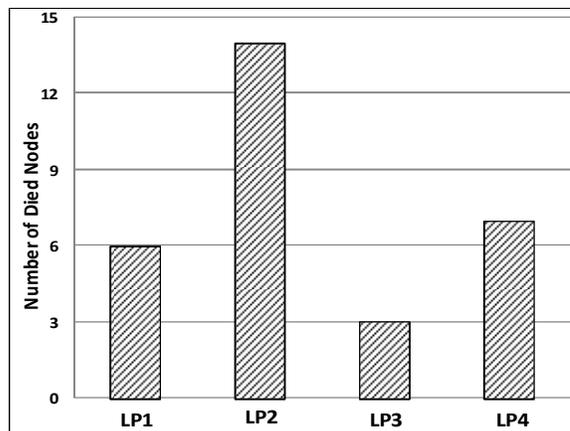


Figure 6. Number of died nodes in each logical partition.

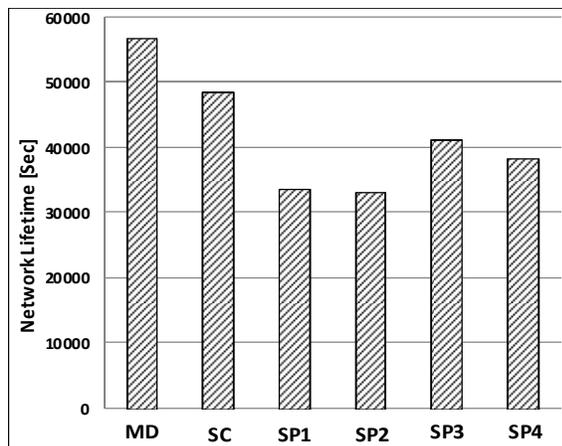


Figure 7. Network lifetime with a Mobile data collector and a Stationary data collector.

V. CONCLUSIONS

Energy efficiency plays very important role in wireless sensor networks. Due to multi-hop communications, sensor nodes that are close to base station have the more energy consumption of other nodes. This paper proposed an efficient method to load-balancing enhancement in wireless sensor network. Proposed method divides the network to four logical partitions and it uses a mobile data collector to data gathering from sensor nodes. The mobile data collector movement can be controlled by our proposed method. The proposed method directs the mobile data collector toward logical partitions with the more residual energy as well as the more density. Because, proposed method considers the logical partition density to the mobile data collector movement, it balances the partition density as well as partition coverage.

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