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An Efficient Routing Algorithm to Lifetime Expansion in Wireless Sensor Networks

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Abstract

This paper proposes efficient network architecture to improve energy consumption in Wireless Sensor Networks (WSN). The proposed architecture uses a mobile data collector to a partitioned network. The mobile data collector moves to center of each logical partition after each decision period. The mobile data collector must declare its new location by packet broadcasting to all sensor nodes. However, packet broadcasting leads to increase in the network congestion as well as the network energy consumption. In this regard, this paper proposes an efficient routing algorithm to control number of packets broadcasting. The proposed algorithm declares the mobile data collector new location to sensor nodes within a special area. Special area has been considered around of the mobile data collector. Therefore, the proposed routing algorithm does not permit packets reaching to this special area. Indeed, the proposed algorithm directs data toward the mobile data collector by boundary sensor nodes. In fact, the proposed algorithm considers sensor nodes within special area have more traffic and energy consumption than other sensor nodes. Simulation results that have been implemented in ns-2 show the proposed algorithm increases the network lifetime as well as the sensor nodes energy consumption balancing.

Keywords: *Energy Consumption Balancing, Mobile Data Collector, Routing Algorithm, Wireless Sensor Networks.*

1. Introduction

Wireless Sensor Networks (WSN) are used in several aspect of human life such as environment monitoring [1], health care [2] etc due to low cost of design and implementation, ease of establishment, rapid development [3]. WSNs consist lot sensor nodes and one or several the base station. Sensor nodes are distributed at environment to detect occurred events. Sensor nodes are equipped with one or more sensor to sense and detect environmental changes such as humidity, pressure and temperature. WSNs act as real-time manner, so sensor nodes are activated when an event occurs, immediately. In this regard, they try to send an event occurrence report to the base station as real-time manner. Thus, event-driven and real-time manner is natural in WSNs. Of course, an occurred event is detected by several sensor nodes because WSNs are very redundant.

This phenomenon leads to many to one traffic pattern in WSNs. Therefore, to reduce sensor nodes energy consumption, researchers decrease sensor nodes transferring radius. Thus sensor nodes cannot communicate with the base station directly. In this regard, event occurrence reports are reached to the base station by several intermediate nodes [4], [5], [6].

Many to one and multi-hop traffic pattern leads to unbalancing in sensor nodes energy consumption [7]. In this regard, central and intermediate sensor nodes have more energy consumption than boundary sensor nodes [8]. Unbalancing in sensor nodes energy consumption leads to inefficiency in the network energy consumption. On the other hand, sensor nodes are very limited in power supply and they have limited lifetime. Sensor nodes energy consumption plays very important role in WSNs [9]. However, sensor nodes energy consumption must be balanced to improve energy efficiency and the network lifetime.

WSNs architecture with a stationary base station and lot sensor nodes leads to sensor nodes energy consumption unbalancing. Indeed, sensor nodes that are close to the base station have more energy consumption than other sensor nodes. Researchers with mobility of base station [10], optimal base station positioning [11], network clustering [12], multiple base stations [13], and multiple mobile base stations [14] try to increase sensor nodes energy consumption balancing. Recently researchers have attended to use mobile devices in WSNs [10], [14], [15]. Researchers use the mobile devices to data gathering from 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 energy consumption efficiency the mobile devices should move to an area of the network with more residual energy [16]. 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 energy consumption balancing enhancement, the mobile devices always should move to different parts of the network. After mobile device establishment at an assumed point of the network, it must declare its new location to all sensor nodes. This phenomenon increases the network congestion as well as the network energy consumption.

In this paper an efficient routing algorithm to a WSN with a mobile data collector has been proposed. For this purpose, the proposed algorithm divides the network to four logical partitions. To energy consumption balancing among sensor nodes, the proposed algorithm directs the mobile data collector toward logical partition with more residual energy as well as more density. The proposed algorithm does not require to new location of the mobile data collector broadcasting. In this case, the proposed algorithm prevents new location broadcasting of the mobile data collector to all sensor nodes. Therefore, the proposed algorithm declares the mobile new location of data collector to sensor nodes within special area of the network. Sensor nodes within the special area have knowledge about the mobile new location of data collector. To reduce energy consumption of central nodes, the proposed algorithm does not permit data reaching to special area. Indeed, the proposed routing algorithm distributes the network traffic to boundary sensor nodes.

The rest of the paper is organized as follows. Section 2 summarizes the background and related work. In Section 3 the proposed routing algorithm is explained. Simulation results are presented and discussed in Section 4. Finally, in Section 5 obtained results and future work are explained.

2. Related Works

Energy efficiency plays very important role in WSNs, because sensor nodes are very limited in their power supply and hardware resources [17]. Of course, maintenance and repairing of WSNs is impossible, due to a large number of sensor nodes and harsh environmental conditions [18]. Multi-hop communication from sensor nodes to a BS increases energy consumption of intermediate nodes [13]. Thus central and intermediate nodes have the lowest lifetime than other nodes. With 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 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 [19] 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 [20] a mobile BS moves at the network along a predetermined path. Sensor nodes are randomly distributed at environment, so predetermined path is not effective in WSNs. Paper [16] uses a mobile BS, and mobile BS moves toward sensor nodes that have the highest residual energy. Of course, paper [16] 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 [21] have proposed a Mobile sink based Energy-efficient Clustering Algorithm, MECA, for WSNs by using a mobile sink. The mobile sink moves around the square sensing field .

In [10] [22] authors have used of 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 [22] 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 [10], [22]. In this paper we use three type of nodes as sensor nodes, a base station and a mobile data collector similar to [10], [22]. However 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 mobile data collectors. A mobile data collector movement can be controlled by our proposed load-balancing method.

3. Proposed Algorithm

In this section, we introduce the wireless sensor network architecture, and our routing algorithm to sensor nodes energy consumption balancing, respectively. To energy consumption balancing we use a mobile data collector in WSN. The mobile data collector can move to across of the network and it can communicate with a BS directly. 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 resource such as bandwidth, energy supply, radio transfer radius and etc. Of course, the network users can repair and maintain mobile data collector. Figure 1 shows the network architecture.

The mobile data collector movement scheduling implies to sensor nodes energy consumption balancing. In this regard, the mobile data collector chooses and moves to its new location in a logical partition during the network lifetime. Therefore, the mobile data collector does not stay at a point of the network for long time. In [23] authors performs the mobile data collector movement programming that called Load-Balancing Enhancement method, LBE. The mobile data collector moves to center of a logical partition with more selecting chance parameter, SC_i. The mobile data collector makes decision about its new location at regular time interval. Equation (1) calculates selecting chance.

$$SC_i = PD_i \times RE_i \qquad 1 \le i \le 4 \tag{1}$$

Where PD_i is the logical partition density i and RE_i is the mean residual energy of logical partition i. PD_i has been calculated in Equation (2).

$$PD_i = \frac{Number\ of\ Node}{Partition\ Space} \qquad 1 \le i \le 4 \tag{2}$$

Where $Number\ of\ Node$ is number of sensor nodes per each logical partition and Partition $Space$ is space of each logical partition. This method requires more imposing energy consumption to declare the mobile data collector location to all sensor nodes. This strategy increases the network congestion as well as the packet lost probability. Thus, we have proposed an efficient routing algorithm to control number of packets broadcasting. Our proposed routing algorithm finds boundary paths to packets transferring toward the mobile data collector. Our proposed routing algorithm improves the network lifetime as well as the sensor nodes energy consumption balancing than LBE method.

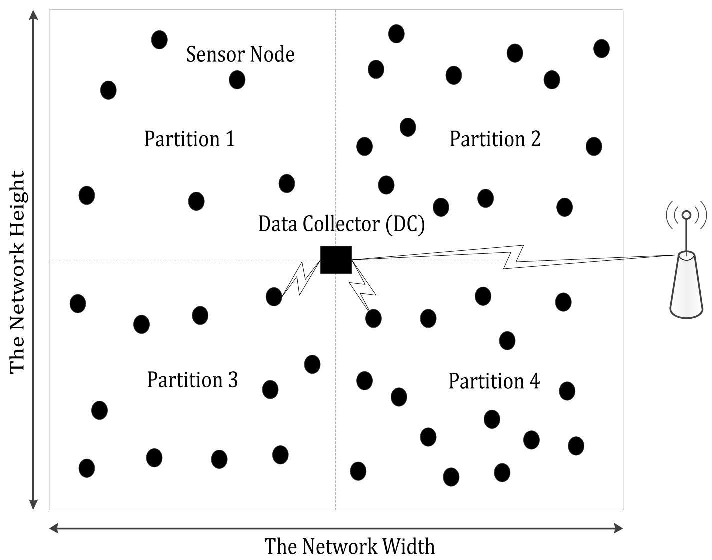

Figure 1. Wireless Sensor Network Architecture [23].

The mobile data collector must send its new location to all sensor nodes with packet broadcasting into the network. This phenomenon increases the network energy consumption as well as the network congestion. Our proposed routing algorithm controls the number of packet broadcasting. It does not send new location of the mobile data collector to all sensor nodes. The proposed routing algorithm chooses a candidate set of sensor nodes at a special area of the network. The special area of the network is denoted at center of the network with d radius according to Figure 2. The special area is a rectangle region at center of the network. All sensor nodes into the special area have knowledge about new location of mobile data collector. Indeed, the mobile data collector broadcasts its new location within the special area instead all sensor nodes.

Thus, sensor nodes into the special area know the mobile data collector location within the network and other sensor nodes consider the mobile data collector has been located at center of the network. The special area is a hot region with more traffic and energy consumption. However, in a stationary base station and LBE method, the sensor nodes within the special area have more energy consumption and low lifetime than other sensor nodes. Thus, the network traffic must be directed toward boundary sensor nodes. In this regard the proposed routing algorithm transfers data to the mobile data collector by boundary nodes of the network. Figure 2 shows the network traffic pattern to data transferring toward the base station in our proposed routing algorithm. This figure shows data traffic is made in boundary sensor nodes. Thus, data packets do no permit to reach in special area. Based on this figure, the proposed routing algorithm tends to forward packets toward the mobile data collector by boundary nodes. In WSNs boundary sensor nodes have usually the low traffic as well as energy consumption. This phenomenon increases the network energy consumption unbalancing. Thus, our proposed routing algorithm tries to traffic distribution to increase sensor nodes energy consumption unbalancing.

All sensor nodes in out of special area do not knowledge about the mobile data collector new location. However, they consider the base station is at center of the network. Thus, they direct packets toward center of the network. Boundary nodes of special area do not permit packets reaching to special area. Therefore, sensor nodes within special area know the base station location. In this regard, boundary nodes of the special area direct packets toward the base station by sensor nodes in out of the special area. The proposed routing algorithm increases the network energy consumption balancing in two way, 1) using a mobile data collector in the network architecture, 2) traffic distribution to boundary sensor nodes.

The proposed routing algorithm is established to a network with a mobile data collector in its architecture. Our proposed algorithm distributes the network traffic and schedules the mobile data collector movement. Figure 3 shows pseudo-code of the proposed algorithm. The proposed algorithm divides the network to four logical partitions. Therefore, the proposed algorithm directs the mobile data collector to logical partitions with more residual energy as well as more density. The mobile data collector can move to each logical partition. On the other hand, d parameter in the proposed algorithm is the mobile data collector movement radius. Therefore, the mobile data collector can lead away of center of the network at a distance of d parameter. The mobile data collector distributes the network traffic to boundary sensor nodes. In this regard, the proposed algorithm considers the central nodes have more traffic than boundary nodes. The proposed algorithm does not broadcast new location of the mobile data collector to across of the network. The new location of the mobile data collector broadcasting leads to increases in the network energy consumption. In this regard, the proposed algorithm broadcasts the mobile data collector new location to sensor nodes within special area. This strategy decreases the number of packets broadcasting as well as the network energy consumption. Thus, the proposed algorithm improves the network energy consumption than LBE method with decrease in the packets forwarding about new location of the mobile data collector.

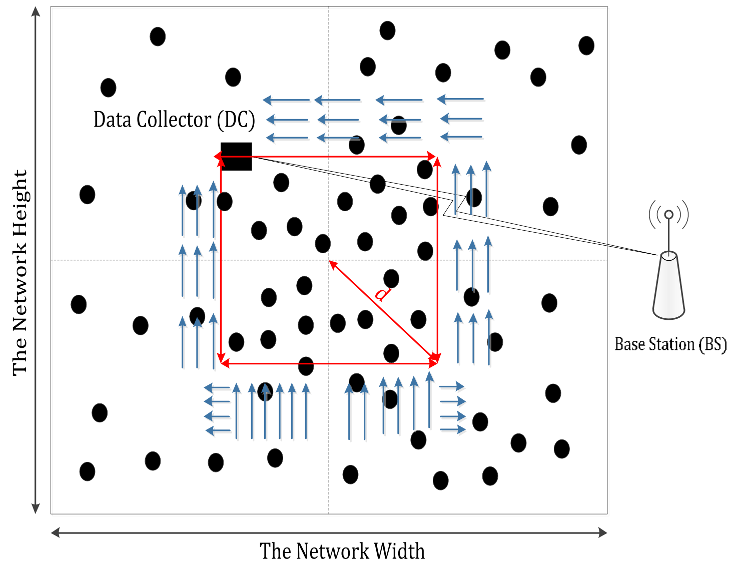

Figure 2.The proposed routing algorithm.

Input: The mobile data collector location
Output: The data packets routing
Step1: At the regular time interval do
Begin
    Make special area with d radius
    Broadcast the mobile data collector location to sensor nodes within special area
Case new packet received by a sensor node
    Sensor node is out of the special area:
        Direct packet to center of the network
    Sensor node is within special are:
        Transfer packet to left or right sensor node
End.

Figure 3. Pseudo-code of the proposed algorithm.

4. Experimental Results

In this section, the proposed algorithm performance has been evaluated via NS-2.35 simulator. Different parameters of simulation are presented in Table. 2. 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 sender node for forwarding one packet [24]. We have randomly distributed sensor nodes in terrain. BS is fixed and its location is out of the terrain. First, the mobile data collector is located at center of terrain. The mobile data collector broadcasts its new location to sensor nodes within special area after each period decision. Of course, to make the network traffic, sensor nodes transfer data to the mobile data collector every 2 second.

Figure 4 shows **d** parameter versus the network lifetime. In the proposed algorithm **d** parameter is special area radius or the mobile data collector movement radius. Based on this figure, $\boldsymbol{d}$ parameter equal 0 leads to make a stationary mobile data collector.

Therefore, a WSN with a stationary base station leads to increase in the network energy consumption unbalancing. On the other hand, when ***d*** parameter is logical partition's radius, the network has maximum lifetime. In this point the mobile data collector moves to center of each logical partition. This point balances the energy consumption imposing and the sensor nodes energy consumption balancing. In the proposed algorithm, energy consumption imposing is made with the mobile data collector location broadcasting to sensor nodes within special area.

Table 1. Simulation Parameters.

Terrain	$200m \times 200m$
Node Number	100
Radio Range	40 m
Topology	Grid
Mac Type	Mac/802_15_4
Initial Node Energy	$5\,J$
Propagation Model	
e	
e	

Figure 5 shows ***d*** parameter versus the network energy consumption. Based on this figure, ***d*** parameter has direct relationship with the network energy consumption. The sensor nodes energy consumption imposing to broadcast the mobile data collector new location is main reason to increase the network energy consumption. Thus, when ***d*** parameter increases, the mobile data collector' new location must be sent to more sensor nodes. In this regard, increase in ***d*** parameter leads to increase in the network energy consumption.

Figure 6 shows the number of activated sensor nodes in each logical partition. Our simulation scenarios continue until 30% sensor nodes have been deathbed. The proposed algorithm and LBE method consider the logical partition density and residual energy to choose the mobile data collector destination, so they balance the number of sensor nodes in logical partitions. In this regard, the mobile data collector moves toward logical partition with more density. Thus, more traffic and nodes death have been occurred in these logical partitions. This phenomenon leads to the network coverage efficiency as well as the logical partitions density balancing. Therefore, the mobile data collector stays in logical partitions with more residual energy. This strategy balances residual energy of logical partitions. However, the proposed routing algorithm does not broadcast new location of the mobile data collector to all sensor nodes. This strategy controls the network congestion. Therefore, our proposed algorithm distributes the network traffic to boundary nodes that have low traffic and energy consumption than central sensor nodes. Thus, according to Figure 6, the proposed routing algorithm improves the number of sensor nodes balancing as well as coverage efficiency than LBE method. Figure 7 shows residual energy of four logical partitions. The mobile data collector moves to across of the network to balance the sensor nodes energy consumption. Thus, based on this figure it can be seen that residual energy of logical partitions has been balanced. Using the mobile data collector and traffic distribution makes the network energy consumption balancing in our proposed algorithm.

Figure 8 shows the number of sensor nodes versus the network lifetime. The proposed algorithm balances the logical partition energy consumption. The proposed algorithm uses a mobile data collector to gather information from sensor nodes. With a mobile data collector, the energy consumption is distributed among sensor nodes. Therefore, the mobile data collector moves toward logical partition with more residual energy and density. Thus, increase in the network density leads to increase in the network lifetime in our proposed algorithm and LBE method. However, with traffic distribution in our proposed algorithm, the network lifetime improves than LBE method.

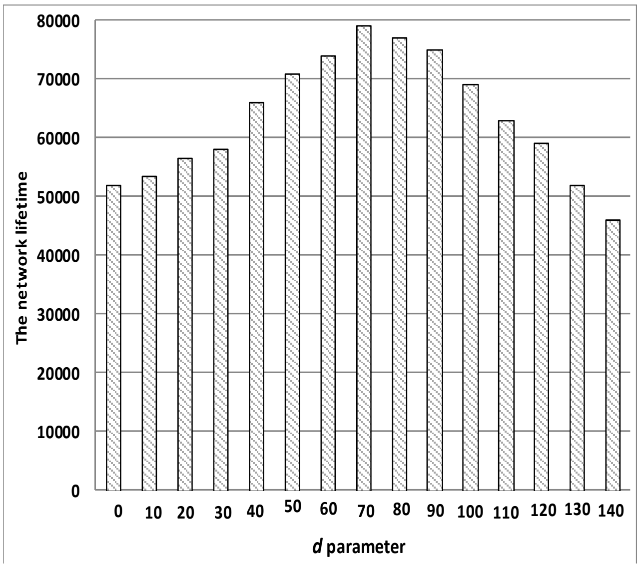

Figure 4. d parameter vs. The network lifetime.

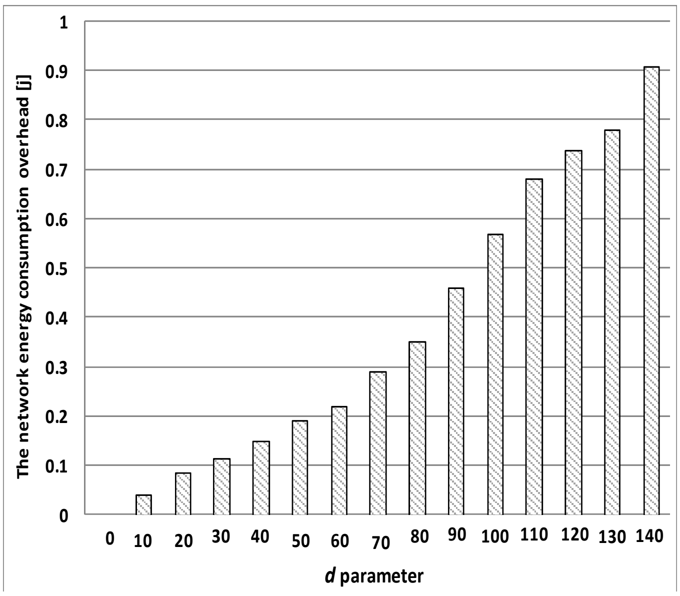

Figure 5. d parameter vs. The network energy consumption.

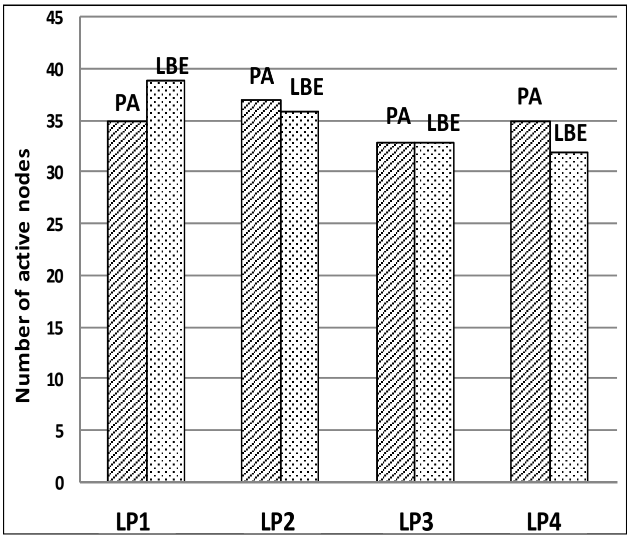

Figure 6. The number of activated sensor nodes in each logical partition.

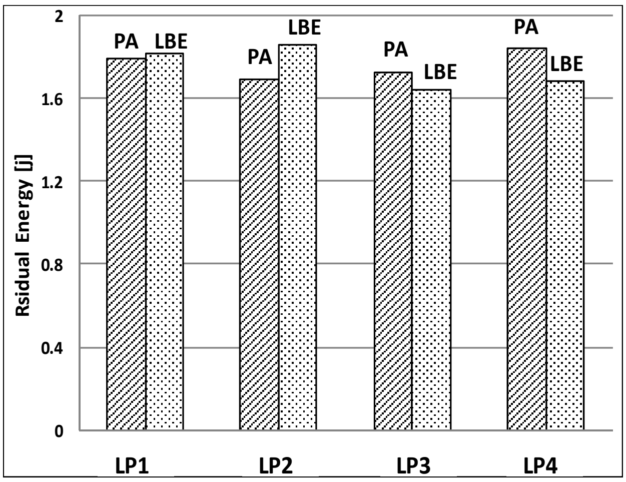

Figure 7. Residual energy of each logical partition.

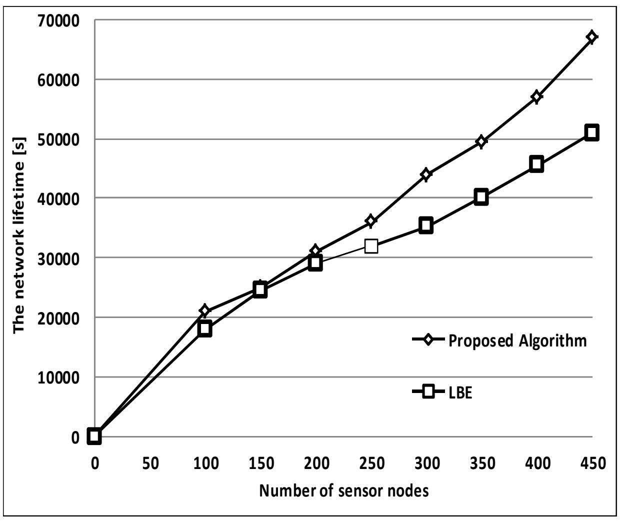

Figure 8. The network lifetime vs. The number of sensor nodes.

The mobile data collector makes decision about its new location at regular interval. More mobile data collector displacement increases the network energy consumption due to new location of the mobile data collector broadcasting. Figure 9 shows number of the mobile data collector displacement versus the network energy consumption by various d parameter. This figure shows that the network energy consumption increases when$d$ parameter increase too. However, more d parameter leads to more packets broadcasting within the special area of the network. Therefore, more mobile data collector displacement distributes energy consumption among sensor nodes. When the data collector displacement stays at new location of the network, it increases the partition energy consumption. This phenomenon decreases the standard deviation of logical partition remaining energy. Figure 10 shows the standard deviation of logical partition remaining energy versus number of the mobile data collector displacement. This figure shows, increase in number of mobile data collector displacement leads to decrease in the standard deviation. Therefore, when d parameter is equal half the network radius, the standard deviation of logical partition remaining energy has efficient result.

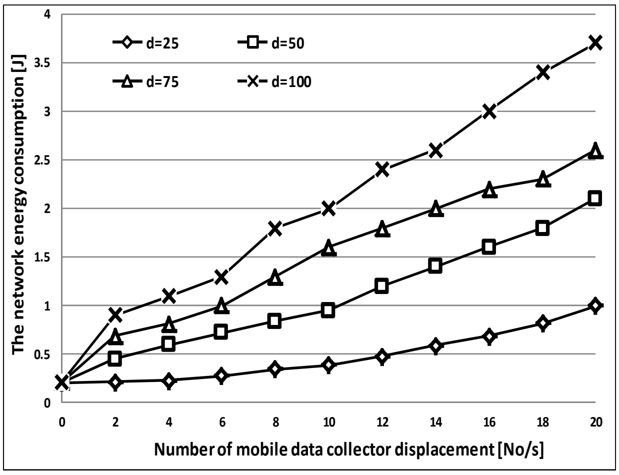

Figure 9. The mobile data collector displacement versus the network energy consumption.

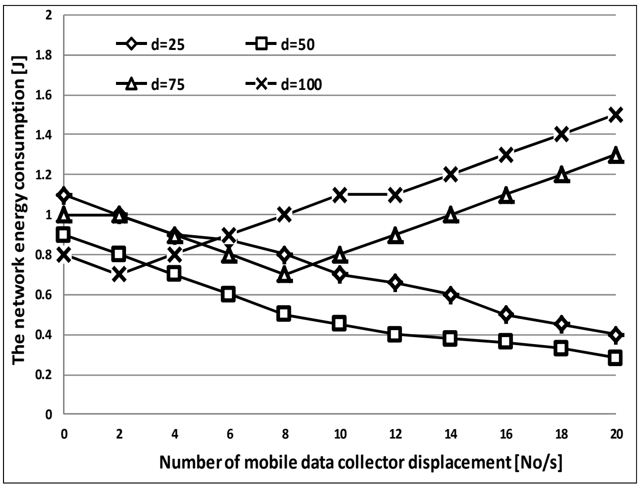

Figure 10. The standard deviation of logical partition remaining energy versus number of the mobile data collector displacement.

5. 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 algorithm to energy consumption balancing enhancement in wireless sensor network with a mobile data collector. On the other hand, when the mobile data collector chooses its new location, it must send its new location to all sensor nodes. Increase in number of packets broadcasting leads to increase in the network energy consumption. In this regard, the proposed routing algorithm does not require to broadcast new location of the mobile data collector to all sensor nodes. Therefore, in the proposed algorithm some sensor nodes know about the mobile data collector location and some sensor nodes do not know the mobile data collector location. This strategy decreases the number of packets broadcasting in the proposed algorithm.

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