Optimizing Mobile Sink Path in Wireless Sensor Networks

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Abstract - An important task of Wireless Sensor Networks (WSNs) is to gather environmental data. In WSNs, the data are collected by sinks from sensor nodes. When the data are sent to a sink via a multi-hop route the nodes closest to the sink will receive a heavy traffic. This results in early depletion of their energy which may result in "energy-hole problem". Earlier researches have concluded that the nodes farther away may still retain 90% of their initial energy, even when the one-hop surrounding sensors of a sink are depleted of their battery power. In this paper, we present a method to optimize mobile sink path which ensures equitable energy usage of all the nodes in network. It is proposed that for reducing the messages, which are received and sent by the nodes nearest to the sink, depending on the number of hops calculated from a sink, the mobile sink should follow an optimal path in an application area. Few nodes which are at a minimum distance from the sink path are selected. These will be called as receiver nodes. When the sink traverses via its optimal path, it collects data from these receiver nodes.

Keywords—Wireless Sensor Networks;Optimum Mobile Sink Path;Hops

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a group of sensor nodes scattered in a geographical area of interest [1]. These nodes are smaller in size and hence they are low power-devices. An important role of sensor nodes is to gather information from the monitored area and send this information to one or more mobile sinks. Sinks act as a gateway between outside world and sensor field. In WSN sensors have a finite amount of energy. The depletion of this energy disables the sensor nodes and results in decreased network lifetime of the whole network.

A WSN should be designed with an aim to increase the network lifetime. Energy management should be followed to prevent connectivity degradation while designing WSN. While the data are sent to a sink through a route, the nodes closest to the sink receive a heavier amount of messages and hence they are depleted of their battery soon compared to the other sensor nodes. When the sensors around a sink are exhausted of their energy, the sink will be disconnected from the network. This isolation of sink will result in network failure. Sink mobility can improve network lifetime and prevent network from connectivity problems [2]. Sink mobility prevents nodes close to a sink from having their energy depleted and hence it will increase the network-lifetime. Sink mobility is an important research topic in WSN. Introducing mobility for sinks has proven to be effective solution to reduce and balance the energy expenditure among sensors nodes [2].

In this paper finding an optimum path for a sink is presented. This optimum path will ensure a fair usage of all nodes while transmitting data to mobile sink. Based on the calculated number of hops from a sink, the mobile sink follows an optimum path in an application area and collects data from the nodes near the path. Only some nodes near the path are selected as receiver nodes. The nodes closest to the path are selected as receiver nodes to collect data from other sensor nodes. The nodes in an application area undergo clustering and send data to the receiver nodes.

Rest of the paper is organized as follows. Related work is discussed in section II. Section III explains problem definition. Section IV discusses the approach. Section V discusses the simulation result. Finally Section VI concludes the work.

II. RELATED WORK

According to the research by Somasundara et al[3] the consumption of energy in a network using a mobile sink is significantly lesser than that of static network. Moving the base station around an application area is proposed by the authors. Sensed data from the sensors is collected by the sink when it is within the range of sensor nodes. Even though this solution is useful in delay tolerant applications, it is not an optimum solution because before transmitting the sensed information, the sensor nodes will have to wait for the sink arrival.

The optimum path to move sinks and to improve the lifespan of large-scale sensor networks, a multi-sink heuristic algorithm (HOP) is proposed by Ben Saad and Tourancheau. Relocation of sinks to nodes which are located at the maximum number of hops from a sink is done, since these nodes have a higher residual-energy. As a result re-transmission of messages to the sink is not required by these nodes [4].

Brewer, Gu, and Bozdag [5] proposed a partitioning-based algorithm in reducing the loss of data due to buffer-overflow while anticipating for the arrival of the sink and the mobile sink movements are scheduled to achieve reduction in data loss. Cluster based and combination hierarchical scheme to group sensors and to transmit messages to cluster head which in turn transmits messages to the sink has been proposed by Chandrakasan, Balakrishnan and Heinzelman [6].

According to Rachuri, Ram Murthy and Vupputuri [7] mobile data collectors can be used to achieve reliable and energy efficient data communication. The main intention of the authors is to ensure energy efficient and reliable event reporting by ascertaining a mobile strategy for data collectors but optimizing the changing locations of data collectors is not considered in their approach.

III. Problem Definition

The aim is to find optimal path for the sink move to gather the data such that

a) the path minimizes the number of hops for a packet to reach the sink,

b) the number of messages to be exchanged between nodes is minimized,

c) the node nearest to the path is selected for collecting the data from other nodes and

d) the overall lifetime of the WSN is enhanced by eliminating energy–hole problem

Optimizing mobile sink path ensures equitable energy usage of all nodes to transport messages to the sink. It is proposed that for reducing the messages, which are received and sent by the nodes nearest to the sink, the mobile sink should follow a path in an application area depending on the number of hops calculated from a sink. When the sink traverses in this path, it collects data from the receiver nodes which are at a minimum distance from the sink path.

IV. Optimizimg Mobile Sink Path in WSNs

The number of hops from a sink is calculated and based on the calculated number of hops from a sink the mobile sink follows a path in an application area. Table I defines the variables used in the calculation of the path.

Table I. Variables used in Calculation of Path

Variables Used	Definitions of Variables Used
X_W	Width of an application area
Y_L	Length of an application area
R_G	Range of the nodes
X_{Start}	Starting point for X in the sink path
X_{End}	Ending point for X in the sink path
Y_{Start}	Starting point for Y in the sink path
Y_{End}	Ending point for Y in the sink path
H_N	Number of hops

The calculated path should be at equal distance from any further nodes in an application area. We consider a single sink which moves along the calculated optimal path. The maximum distance from a node within the range of the sink to the node at the center of an application area must be same as the maximum distance a message from a node on the perimeter of an application area travels before reaching a node in the sink range.

For a rectangle or square shaped area, if sink is centered in an application area then the number of hops a message has to travel, in order to reach the sink from a node which is at the farthest end of an application area is approximated as follows [1]:

$$Hrs = \left(\frac{X_W}{2*R_G}\right) + \left(\frac{Y_L}{2*R_G}\right) \qquad (1)$$

Here H_{rs} is the number of hops for rectangle and square shaped area. In order to maintain equal distance between the nodes at the perimeter of an application area and nodes at the center of an application area, the number of hops should be approximately same, i.e. $\frac{H_N}{2}$.

The width of an application area i.e. X_w and length of an application area i.e. Y_L and the range of the nodes i.e. R_G are known. Hence the maximum number of hops for a message to be re-transmitted can be calculated. To re-transmit a message the maximum number of hops can be calculated as follows [1]:

$$Hrs = \left(\frac{X_W}{4*R_G}\right) + \left(\frac{Y_L}{4*R_G}\right) \qquad (2)$$

Once the calculation of number of hops is completed, the path for the mobile sink is calculated. The starting and ending points of the path are calculated as follows [1]:

$$X_{Start} = R_G * \left(\frac{H_{rs}}{2}\right) \qquad (3)$$

$$X_{End} = X_W - \left(R_G * \left(\frac{H_{rs}}{2}\right)\right) \qquad (4)$$

$$Y_{Start} = R_G * \left(\frac{H_{rs}}{2}\right) \qquad (5)$$

$$Y_{End} = Y_L - \left(R_G * \left(\frac{H_{rs}}{2}\right)\right) \qquad (6)$$

Consider the WSN as shown in Figure 1 where nodes are placed in 360×200 application area. Each node is placed 40m from the previous nodes and the nodes range is assumed as 40m. The path for the sink is calculated based on equations [3], [4], [5], and [6]. Figure 1 shows the path. This path has equal number of further nodes from it. Hence number of hops the message has to travel to reach the sink is reduced as the sink moves in the path.

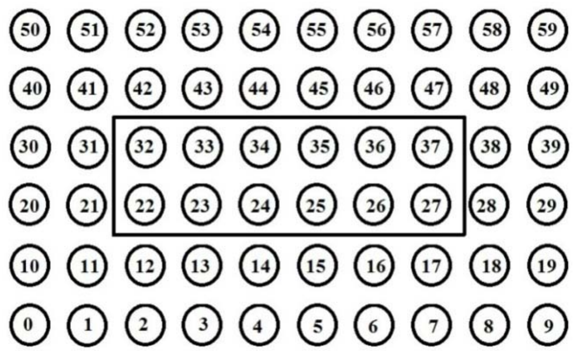

Figure 1. Sink node path for a 360×200 application-area

Some of the nodes closest to the sink path are selected as receiver nodes. When the sink passes along this path, these receiver nodes send data to the sink. Clustering is done

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based on number of neighbours and minimum distance and then the data is sent from the sensor nodes to the receiver nodes. To reduce the delay between the time the sink will receive the message and the time the event occurs, the nodes near the path are used as receiver nodes.

V. SIMULATION RESULTS

Network Simulator (NS-2) is used to carry out the experiments. This approach is implemented for different topologies with 20, 40, 60, 80 and 100 nodes. The average throughput and average residual energy is calculated for different topologies and the graph is plotted for the same. Table II lists the various simulation parameters set to implement the approach.

TABLE II. SIMULATION PARAMETERS USED

Number of nodes	20, 40, 60, 80 and 100
Communication range	40m
Type of the channel	Wireless
Packet size	512 bytes
Speed of the mobile sink	5m/s
Traffic source	CBR

Figure 2 shows the simulation of the 60 nodes in 360×200 application area. The 60th node is selected as the sink node. This sink node moves in the calculated path and collects data from the receiver nodes. Some of the nodes which are selected as receiver nodes are shown in the Figure 2.

The graphs plotted for average residual energy and average throughput are shown in Figure 3 and Figure 4. Graph is plotted by taking number of nodes along X-axis and average throughput and average residual energy along Y axis. Average throughput is measured in kbps and average residual energy is measured in Joules (J).

Figure 2. Simulation of 60 nodes in 360×200 simulation area

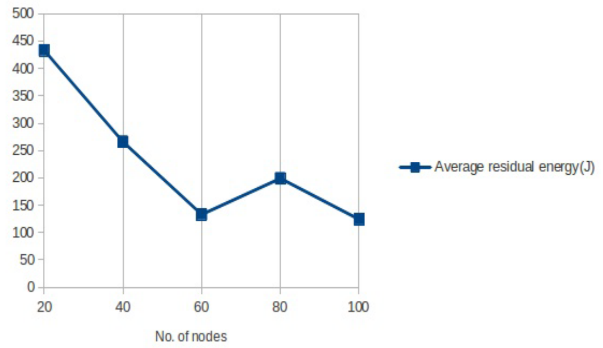

Figure 3. Number of nodes vs. average residual energy

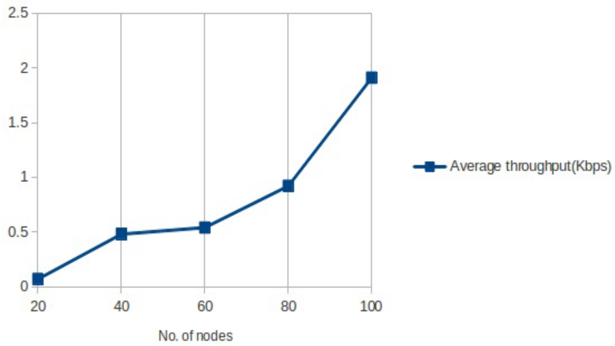

Figure 4. Number of nodes vs. average throughput

VI. CONCLUSION

Energy optimization using mobile sink in WSNs is a critical area of research. This paper presents an approach in which the sink is allowed to move along the calculated optimal path which aims to reduce the multi-hop transmission thereby reducing the energy consumption in the whole network. The messages received by each node can be reduced by using an optimum path for the mobile sink. Only the nodes which are at a minimum distance from this optimum path send data to sink.

Restriction of nodes which re-transmit messages to nodes with three or more neighbours, result in further reduction in the messages received by each node.

The path for a mobile sink is optimized for the message to be re-transmitted with lesser number of hops. Optimization of the path ensures equitable energy usage of all the sensor nodes thus increasing the node lifespan. Thus increased node lifespan can be achieved by optimizing the mobile sink path and by reducing messages received by each node.

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