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Employing Sink Mobility for Energy Efficient Data Collection in Wireless Sensor Networks

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Research Article

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Abstract— Small, low-powered, self-organizing sensor nodes that are widely dispersed throughout the area to be monitored make up a wireless sensor network (WSN). WSN is a highly scalable network that is used for a variety of purposes across a wide region of interest. Since every sensor node has a limited amount of energy, it is much more crucial to minimize the energy depletion of those nodes nearer the sink since they are in the way of data transmission. Additionally, the nearby nodes of the sink would deplete their energy more quickly, resulting in a disconnected network. The nodes around a mobile sink constantly shift, balancing the network's energy usage and extending its lifespan. We assess the impact of sink movement in random walk and predetermined path on network lifetime in wireless sensor networks.

IndexTerms—Wireless sensor networks, Mobile sink, Network Lifetime, energy efficiency, Random Walk, Predefined path.

INTRODUCTION

Environment monitoring, object tracking, scientific observation and forecasting, industrial, security surveillance, medical, weather and environment monitoring, traffic control, and more are just a few of the many potential uses for wireless sensor networks, an emerging technology [1]. A WSN is made up of several dispersed nodes that band together to create a multi-hop wireless network. These nodes usually work together to accomplish a shared objective. Since battery-powered sensor devices make it impossible to replace the nodes' batteries in large-scale deployments, energy is a wireless sensor network's most valuable resource. Wireless sensor networks can be thought of as a vast array of tiny wireless devices with limited energy, processing, and communication resources that can self-organize into an ad hoc network and sense environmental conditions within their range. A sensor node must send the data it has sensed to a base station so that an application may process it. However, since a wireless sensor network often lacks infrastructure, sensor nodes must band together to establish pathways that end at a sink. Typically, sensors gather data by sending it to a static control center (sink). The fact that sensor nodes near sinks often use more energy than those further away is a significant problem. This is mostly due to the fact that they forward packets on behalf of other sensors that are further away in addition to sending their own packets. As a result, sensors near sinks often use more energy than those further away. The network will become disconnected and malfunctioning as a consequence of the sensor nodes nearer the sink using up their energy resources more quickly than other nodes. Therefore, if the energy used for data relaying to the sink is decreased, WSN lifespan may be greatly increased. The energy dissipation of nodes nearer the sink may be reduced by using a mobile sink that can gather data from the sensor network while moving within the monitored region. In addition to relieving the load on nodes near a sink, a mobile sink solution will increase network lifespan by offering a way to access and gather data from unconnected network locations. In this paper, we investigate the problem of extending network lifetime under predefined path mobility patterns and random walks using mobile sinks. Performance metrics like latency, success rate, and energy under various mobility patterns are used to examine how mobile sinks affect overall performance. The remainder of the document is structured as follows: Section II discusses related work; Section III discusses sink mobility models; Section IV discusses planned work; Section V discusses simulation findings; and Section VI concludes with conclusions and future work.

RELATED WORK

The relevant research on mobile sinks for WSN data collecting is reviewed in this section. Reducing the amount of energy used in data relaying, particularly for nodes nearer the sink, may greatly increase the network's lifetime. Using sink mobility is one approach to

prevent this. A sink may relocate to an area with higher sensor node energy when the energy of the nearby sensor nodes drops. This approach will increase network lifetime and achieve energy consumption balance. [4] discusses this method using a single mobile sink. When a sink is installed on a bus that moves according to a predictable timetable, another method [6] investigates the effects of predictable sink movement. The sink pulls data and, when it approaches the nodes, awakens them. The authors of [7] only take into account a single mobile sink that travels in a straight path while gathering sensor data.

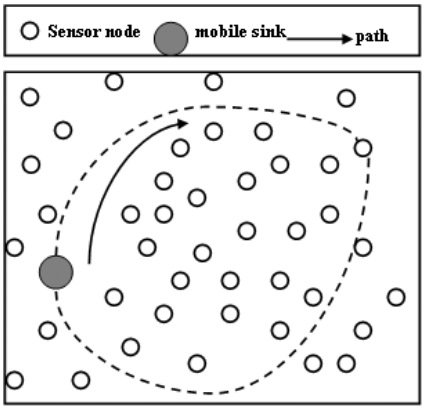
nodes. In addition to saving energy and extending network lifetime, this method minimizes the number of hops a packet must make before reaching the sink. Sink relocation strategies for energy efficiency in WSNs with several movable sinks are presented by Gandham et al. [3]. LP programming is used to determine the optimal locations for the mobile sinks. Similar to [3], Vass et al. [5] and Azad et al. [8] suggest centralized techniques based on mathematical programming to determine the optimal locations for the mobile sinks. The locations of all sensors and sinks are presumed to be known in advance because these techniques are centralized and offline. Adaptive sink mobility for energy efficiency in WSNs for event-driven applications is suggested by Vincze et al. [9]. The mobile sink's position is disseminated via network-wide broadcasting. The topological changes are updated via network-wide broadcasting in [10] and [11]. The impact of mobile sinks under random walk and random waypoint mobility patterns on network lifetime has been compared and examined in our proposed work. We have also investigated the effects of sinks moving along a preset route on performance parameters such as energy, delivery latency, and success rate.

SINK MOBILITY

A. Mobility pattern of the sink

The mobility pattern that the movable sink should adhere to may be approached in a variety of ways. various methodologies may provide various outcomes and have a significant impact on the resulting network performance, depending on the application situation, network size, and circumstances. Mobility models are often divided into two groups: group mobility models and entity mobility models. The movement of a single node, without any coordination with the movement of other nodes, is described by the entity mobility model. Conversely, the group mobility model synchronizes the nodes' collective movement. The Random Walk Mobility Model and Random Way Point are two distinct mobility patterns that the sink node in our method moves at random.

1) Random Walk Mobility Model: This simple mobility model uses random speeds and directions. A node in this mobility model [12] chooses a direction and speed at random to migrate from its present position to a new place. Both the new direction and speed are predetermined. The Random Walk Mobility Model calculates a new direction and speed once the movement takes place at either a fixed time interval (t) or a constant distance traveled (d). When a node moving in accordance with this model approaches a simulation boundary, it "bounces" off it at an angle that is determined by the incoming direction. After then, the MN keeps going in its new direction. This feature guarantees that the random walk is a mobility model that evaluates how entities move around their starting points without worrying about the entities straying and never coming back.



2)

Fig. 1. A mobile sink moving in a random motion

1) Predefined path: In this mobility model the sink traverses the same path through network area. The trajectory of the path could a straight line or a circle and is fixed. The movement of the mobile sink follows a certain pattern that can be compute. The sink broadcasts a beacon message continuously while traveling through the network. Sensor nodes listen to the wireless channel periodically in order to check if there is any sink nearby. Data is collected by the mobile sink when it traverses through the region by waking up the sensor nodes. This helps in achieving energy efficiency when the sensors operate between a low power sleep mode and normal operation. The sensor nodes could monitor network conditions, and adapt the length of each period accordingly so that energy savings are achieved even in a highly dynamic network.

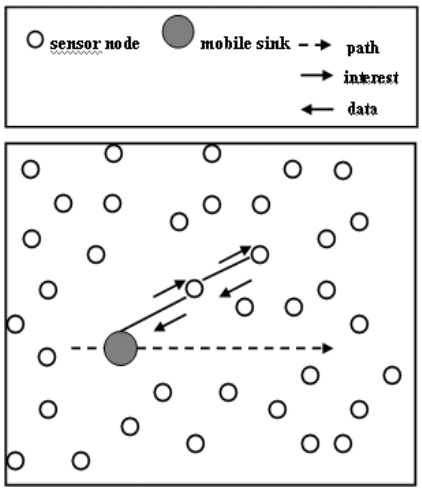


Fig. 2. A mobile sink moving along a straight line*Motivation*

WSN is a high scalable network deployed over a large area of interest for various applications. All sensor nodes are energy constrained. In a typical WSN scenario, all the data are routed back to the only static sink. Therefore, those nodes near the sink have to forward all the data from farther nodes and thus carry a heavier traffic load. This is the many-to-one traffic pattern of WSNs. Consequently, the nodes near the sink are more susceptible to energy exhaustion. When these nodes use up all their energy, no more data can be transmitted back to the sink, causing dysfunctional or disconnected network or premature lifetime ending of WSNs. In order to distribute the energy consumption uniformly across the network, using a multiple mobile sinks is a solution. The nodes near the sink change as the mobile sink moves.PROPOSED WORK

direction. In case the new position falls outside the network area, then S_{random} makes the position to fall on the boundary of the area. This is the simplest possible movement and also no

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A. Wireless sensor network model

We consider a scenario of deploying N wireless sensor nodes in a square area A. The sensor nodes are randomly scattered across the region A. There is mobile sink S which is responsible for collecting data from all sensor nodes and it acts as a gateway for the sensor network. A sensor node communicates with its one-hop neighbors using its wireless radio resources. The sensor nodes do not have global knowledge of the network. Each node and the sink are assumed to have transmission range R. The sensor nodes relay data to the sink in a multi-hop fashion. At any given time, each sensor node can be in one of three different modes, regarding the energy consumption: (a) transmission of a message, (b) reception of a message and (c) sensing of events. The energy model in our approach is as follows. The initial energy of each sensor node is α ($\alpha > 0$), while the sinks have no energy constraint. We assume that a sensor node consumes E_1 units of energy when sending one bit, while depletes E_2 units of energy when receiving one bit where $E_1 > E_2 > 0$. Therefore, for the case of transmitting and receiving a message, we assume that the radio module dissipates an amount of energy proportional to the message's size. For the idle state, we assume that the energy consumed is constant E_{idle}. We have made an assumption that the mobile sink is not resource constrained, i.e., it is assumed to be powerful in terms of computing, memory and energy supplies. *Network Lifetime* is defined as the duration from the very beginning of the network operation until the first node uses up its energy.

B. Data transmission scheme

In our work, we evaluate the performance metrics like delivery delay, energy dissipation and success rate of mobile sink under Random Walk and Random Way Point. First we consider the simplest of all possible mobility patterns i.e. random walk, wherein the mobile sink can move randomly towards all directions at varying speeds. We define S_{random} as a function that implements random walks in our scenarios. At each invocation S_{random} selects a random uniform angle in $[-\pi, +\pi]$ radians. This angle defines the deviation from the mobile sink's current direction. The speed of the movement is constant and predefined. The new position is

determined by S_{random} which selects a uniform randon[illegible] defined network knowledge is needed. This method is very robust, since it guarantees visiting all sensor nodes in the network and also collecting data even from disconnected areas of few/faulty sensors or under the presence of obstacles. However this model may become inefficient, mostly with respect to latency. Data is collected in a passive manner, sensors cache all recorded data. Periodically a beacon message is transmitted from the sink. Each sensor node that receives a beacon attempts to acquire the medium and transmit the cached data to the sink. Transmitted data is then removed from a sensor node cache to free the memory for storing incoming sensed data. This method may lead to many collisions, when the sink visits a dense area. Thus, an appropriate MAC layer protocol with an efficient back off function is essential for the proper deployment of this protocol. This approach minimizes energy consumption since only a single transmission per sensed event is performed. However latency may increase due to long intervals between visits to the sensors. Another mobility pattern Random waypoint is performed by using a pause time between changes in destination and speed. A node begins by staying in one location for a certain period of time (i.e., a pause time). Once this time expires, the node chooses a random destination in the simulation area and a speed that is uniformly distributed between the areas according to their connectivity. The speed of the movement is constant and predefined. In this model, because of the pause time , the mobile sink could collect more data as it gives more time for the nodes to propagate the data forwarded to the sink.

I. SIMULATION RESULTS

A. Simulation scenario and metrics

In order to evaluate and validate the performance of our proposed work we have implemented and carried out simulation in NS-2 [13]. We have scattered 100 sensor nodes across an area of 150×150 m. All nodes have radio range of R =25 m. The power dissipation of idle periods was set to zero to evaluate the energy consumption from the different approaches because idle time dissipation dominates the simulation and it would be difficult to compare the results. The number of data source nodes is set to 50, and they are chosen randomly from the sensor field. Each source node generates 2 packets per second during the entire simulation. The packet size is 32 bytes for all types of messages except DATA packets, which are set to 64 bytes. We have varied the number of Mobile sinks in multiplication of 2. A summary of our simulation parameters is shown in Table 1. The performance was evaluated from different aspects, but always focusing on end to end delay and energy consumption. The metrics used were:

1. Average End-to-End delay: The end-to-end packet delivery delay measured in seconds from the source node to the mobile sink.
2. Success rate: the ratio of packets received successfully at the mobile sink.
3. Average energy consumption: the energy dissipated per node in joules.

TABLE I
SUMMARY OF SIMULATION PARAMETERS

Parameter	Value
Number of nodes (N)	75
Simulation Area (A)	200×200
Wireless radio range	25m
No of source nodes	50
Source node data rate	2pkts/s
No of Mobile sinks	Variable
Mobile sink velocity	5m/s
Packet size	512Bytes
DATA packet size	64Bytes
TX power dissipation	0.660W
RX power dissipation	0.395W
Idle power dissipation	0.035W
Initial Energy	3.1 Joules

B. Simulation results

Our experimental results show the effect of sink mobility on end-to-end delay and energy dissipation of a node with respect to increase in the number of mobile sink. It is seen from Fig. 3 that as the number of mobile sink increases the end to end delay decreases in both random walk and in predicted path movement of sink. The reason is because the sensor nodes have various possibilities to send data packets to reach any one of the mobile sinks in a shortest path and in short duration. Also, more number of mobile sink makes the congestion less thereby reducing average end to end delay. An interesting observation i.e. found in Fig. 4 is that predefined path of sink takes more average end to end delay compared to random walk. The reason is that the nodes which have predetermined sink movement have to wait that much amount of time to again reach the same point in the network area whereas in random the sink could reach at any time to collect data. Also another important reason is random walk movement has more coverage area i.e. it could cover more area to collect data compared to predefined path whose coverage area is fixed. The slight increase in energy in random

walk could be attributed to the fact that as the number of mobile sink increases, the control packets in the network also increases. In case of predefined path the energy dissipation becomes lesser since the nodes have to deliver the data packets only when the sink node approaches and in the remaining time it could go into sleep mode thereby saving energy. Also in case of random movement the nodes have to spend more energy in finding routes to the sink since they constantly change their location. This is not the case with predefined path since they use proactive routing.

II. CONCLUSIONS AND FUTURE WORK

In a typical WSN scenario, all the data are routed back to a static sink. Nodes near the sink have to forward all the data from nodes that are away from the sink and thus carry a heavier traffic load. Therefore the nodes near the sink are more likely to use up their energy faster than other

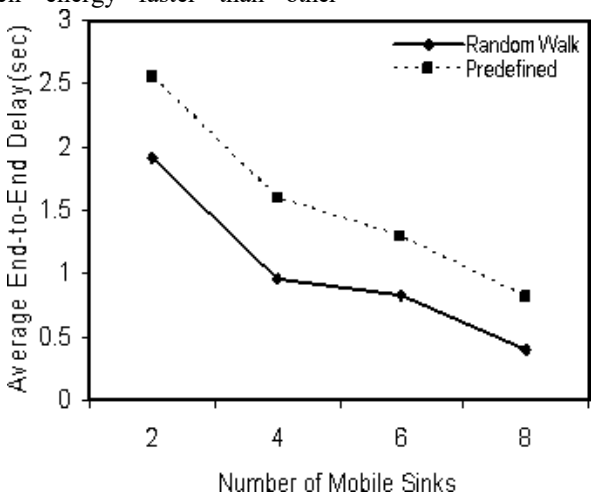


Fig. 3. Impact of mobile sinks on average end-to-end delay.

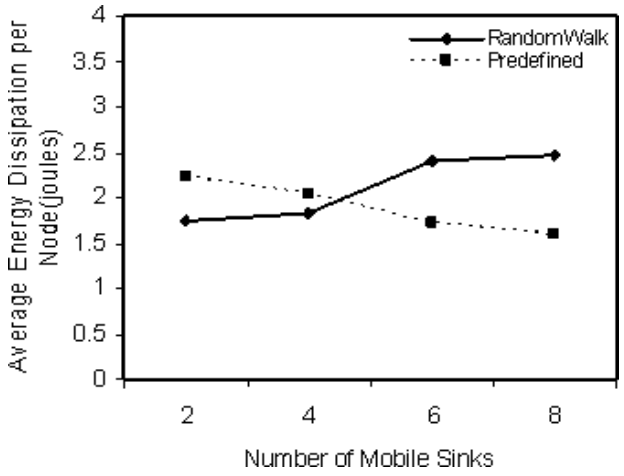


Fig. 4. Impact of mobile sinks on energy dissipation

nodes leading to dysfunctional and disconnected networks. With the introduction of mobile sink, the nodes around the sink always changes, thus balancing the energy consumption in the network and improving the network lifetime. In this paper, we investigate the impact of two mobility schemes Random Walk and Predefined models for mobile sinks in Data-collection sensor networks. Using mobile sink there is reduction in the number of hops that a data has to traverse to reach the destination. The experimental results also confirm that with more number of mobile sinks reduces the congestion at the nodes closer to the sink and thus reduces end to end delay. Also, we have found that among the two mobility schemes Predefined path performs slightly better than Random Walk in terms of less energy dissipation. End to end delay is more in predefined path than random mobility of the sink. We plan to further investigate the effect of the sink speed, network area sizes and sensor node densities on the performance of wireless sensor networks.