

Virtual Grid Based Data Collection for Wireless Sensor Network

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ABSTRACT: Due to sink mobility, network topology changes continuously in wireless sensor network. In order to deliver data efficiently, nodes need to rebuild their routes toward the recent position of the sink node. We propose Virtual Grid based Data Collection (VGDC) scheme, which allows sensor node to maintain best routes toward the recent position of the sink node. VGDC scheme introduces communication rules, so that only a few numbers of nodes have to adjust their data delivery routes toward the sink node. Simulation results demonstrate that VGDC scheme reduces overall energy consumption of the network and enhances network lifetime.

KEYWORDS: Wireless sensor network, Sink node, Virtual grid

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a wireless network consisting of randomly distributed sensor nodes using sensors to observe physical and environmental conditions. WSN measures environmental conditions like temperature, sound, pollution levels, humidity, wind speed and pressure. Sensor nodes make use of battery power for transmission and reception of data. Sensor nodes send observed data to base station or sink node for analysis and processing. Traditional sensor networks with static sink node deployment causes energy-hole problem. Therefore sink mobility is introduced in WSN to overcome energy-hole problem. Sink mobility also helps in balancing the node's energy dissipation. Even though sink mobility helps in overcoming energy-hole problem and improving overall network lifetime, it introduces new challenges while collecting data from the sensing area. Sink mobility causes continuous change in network topology. For efficient data delivery, sensor nodes should find the recent position of sink node. Since energy is scarce resource in WSN, regular transmission of sink location update will effect overall energy consumption of the network.

In this paper, we propose Virtual Grid based Data Collection (VGDC) scheme for collecting data regularly from WSN. VGDC scheme allows sensor nodes to maintain best routes toward recent location of sink node. Existing solutions makes use of several mobile sinks and super nodes for maintaining routes toward the mobile sink. But VGDC scheme does not have any such constraints. VGDC scheme makes use of a single sink node and it improves both data delivery performance and reduces overall energy consumption in WSN. VGDC scheme also minimizes network overhead. We initially partition entire sensing area into a virtual grid of K cells. All the cells in the virtual grid are of same size. Each cell consists of randomly distributed sensor nodes. From each cell, cell header node is chosen. Sensor node nearest to the midpoint of the cell is chosen as cell header. Cell header nodes gathers data from member nodes and deliver data to sink node. Sink node travels around the sensing area and collects data at regular intervals. In VGDC scheme, we introduce certain rules that help in routes re-adjustment process.

The paper is organized as follows: Section II deals with various related work carried on delivering data to the mobile sink. Section III provides detailed explanation of VGDC scheme. Simulation results are highlighted in section IV. We conclude the paper with section V.

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II. RELATED WORK

Various data distribution schemes uses mobile sink to overcome energy-hole problem and improve overall network lifetime. Existing data collection scheme are classified as path constrained, path unconstrained, and controlled sink mobility schemes [1]. In path constrained mobility scheme, sink node follows a predefined path. Sink node moves around a straight line or follows a circular path for data collection. In path unconstrained mobility scheme, sink node moves randomly without any restrictions. Sink node can contact any node in the sensing area for collection of data. In controlled sink mobility scheme, network or observer of the network controls the movement of sink node.

R. C. Shah et.al [2] proposed an architecture consisting of three tiers for collection of data from sparse sensor networks. In sparse sensor networks mobile entities called MULEs are responsible for collection of data. When MULES come in close range of sensor nodes, they capture data. Captured data is buffered and sent to wired access points. This will result in lot of power savings at the sensor nodes, because only short range transmission is needed for sensor node. Top tier, Middle tier and Bottom tier are the three tiers of MULE architecture. Top tier consists of access points. Access point collects data from MULE and sends it to WAN. Middle tier is made up of mobile transport agents. Bottom tier contains randomly scattered sensor nodes.

Heinzelman et al. [3] proposed Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol to distribute energy uniformly among the sensor nodes in the network. LEACH provides scalability and robustness for dynamic networks. For providing scalability, it makes use of localized coordination. In LEACH protocol, nodes are grouped to form cluster. Each cluster contains cluster head and member nodes. LEACH protocol consists of series of rounds. Each round contains two phase. Each round starts with a set up phase. During set up phase nodes are grouped to form cluster. In steady state phase, data transfer takes place between cluster head and base station. Steady state phase is kept long to minimize routing overhead.

A. Erman et.al. [4] proposed hexagonal based grid structure for timely delivery of real time data. Query and data rendezvous lines are defined by hexagonal cell based data dissemination (HexDD) protocol to prevent unnecessary transmission of sink's queries. Border line node receives data from sensor nodes and they propagate data to centre cell. Border line sensor node store and replicate data. Queries of sink node are relayed to centre cell and border line cell header deliver data to sink node. HexDD protocol helps in minimizing overall energy consumption of the network and improving the data delivery rate.

Oh et al. [5] proposed Backbone-based Virtual Infrastructure (BVI) scheme for distribution of data to mobile sink. BVI scheme employs single level multi hop clustering for data delivery. Multi-hop clustering helps in minimizing network overhead. BVI scheme tries to minimize clusters present in the sensor network. Cluster head is chosen based on remaining energy of the sensor nodes. In order to find sink node position, a cluster head is appointed as root of the tree. Agent node enables mobile sink to register towards cluster head. Route readjustment heavily depends upon root node and early energy depletion of route node causes decrease in lifetime of network.

Chen et al. [6] presented a novel Virtual Circle Combined Straight Routing (VCCSR) algorithm for mobile sink in order to collect data from WSN. The VCCSR algorithm is a structure based routing with a virtual backbone. Virtual backbone network contains group of cell header nodes. Mobile sink node moves across the sensor field and collects data from border cell header. VCCSR follows certain rules for routes re-adjustment process.

III. VGDC SCHEME

In this section we explain proposed VGDC scheme in detail. Initially we construct virtual infrastructure by dividing the sensing area. Later we introduce a set of rules that enable sensor nodes to find new routes toward recent position of sink node.

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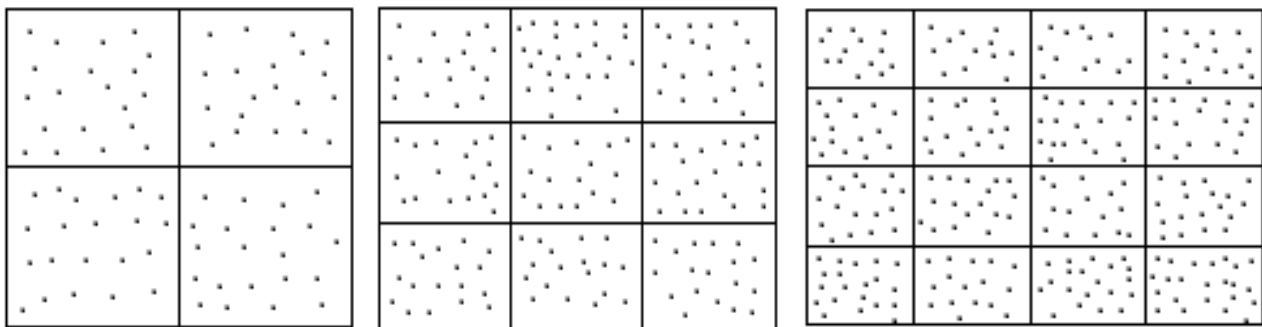
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A. Virtual Structure Construction

VGDC scheme divides entire sensing area into uniform sized cells and builds virtual grid. Partitioning of sensing area is done based on number of sensor nodes present in the network. Such partitioning helps in uniform distribution of workloads among sensor nodes. Heuristics used in LEACH protocol is used to find number of cells present in the network. According to LEACH protocol, number of cells in the sensing area is around 5% of total number of sensor nodes. If N numbers of nodes are randomly distributed in sensing area, then proposed scheme divides the sensing area into K cells of uniform size with the help of Equation 1. Each cell consists of randomly distributed nodes. From each cell a single sensor node is chosen as a cell header node. Total number of cell headers is always equal to number of cells present in the network.

$$K = \begin{cases} 4 & N * 0.05 \leq 6 \\ 9 & 6 < N * 0.05 \leq 12 \\ 16 & 12 < N * 0.05 \leq 20 \end{cases} \quad (1)$$



(a) K=4, when N<=100 (b) K=9 when 101<=N<=200 (c) K=16, when 201<=N<=300

Figure 1: Partitioning of sensing area into cells

Figure 1 shows the partitioning of sensing area into cells based on number of nodes present in the network. If numbers of nodes are hundred or less than that, sensing area is partitioned into 4 cells. If nodes vary from 101 to 200, sensing area is partitioned into 9 equally sized cells. If numbers of nodes are in between 201 and 300, sensing area is partitioned into 16 cells. Once network is partitioned, we choose cell header from each cell. In order to find cell header, midpoint of each cell has to be calculated. Using sensing area's dimension, midpoint of each cell is calculated. From each cell we choose a single node as a cell header. Sensor node nearest to the midpoint of the cell is chosen as cell header. Threshold based cell header selection is used to minimize the communication cost while choosing cell header. A threshold distance is chosen from midpoint of the cell, and nodes coming under the threshold distance are candidate nodes for cell header. Threshold distance is gradually increased if no node comes under threshold distance. Threshold based cell header strategy enables conservation of energy in the network. In VGDC scheme each cell header has got adjacent neighbouring cell header. Any border cell header can have maximum of 3 adjacent cell header whereas any non-border cell header can have maximum of 4 adjacent cell header.

B. Dynamic Routes Adjustment

Network topology changes continuously when sink node travels across the sensing area for data collection. For efficient data delivery cell header node has to find the recent position of mobile sink. Sending sink node's latest location information across the whole sensing area is one possible solution to keep track of mobile sink. But this solution violates energy conservation goal. In VGDC scheme only certain cell headers are responsible for finding routes toward recent position of mobile sink. Out of all cell header in the sensing area, one cell header act as originating cell header (OCH). Border cell header which is nearest to mobile sink acts as OCH. We follow set of rules for efficient data delivery to mobile sink. They are as follows

Rule 1: Find the distance between border cell header and mobile sink and choose OCH.

Rule 2: All cell headers alter their routes toward OCH. Cell headers deliver data to OCH.

Rule 3: OCH sends data to mobile sink.

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Algorithm: Dynamic Routes Re-Adjustment Using VGDC Scheme

1. Sink node moves around the sensing area and stops at regular intervals.
2. for each stopping location
3. {
4. find euclidean distance between border cell header and sink node
5. set nearest border cell header ←originating cell header(OCH)
6. set routes of all other cell headers ←OCH
7. set route of OCH ← mobile sink
8. }

Sink node travels across the sensing area and stops at midpoint of each cell. Whenever sink node stops, we find Euclidean distance between border cell headers and sink node as described in rule 1. Border cell header which has got minimum Euclidean distance towards sink is chosen as OCH. Cell headers follow rule 2 to adjust their routes toward OCH. Whenever OCH receives data from cell header node, it delivers data to mobile sink. OCH uses single hop for communication with mobile sink. Mobile sink communicate with border cell headers for collection of data. In VGDC scheme, only a few cell headers are involved in adjusting their routes. Hence this scheme reduces routes re-adjustment cost of the network. Figure 2(a) shows data delivery routes when sink node is situated near cell 2. Since cell header of cell 2 is nearest to mobile sink, it act as OCH. OCH present in the cell 2 delivers data to mobile sink. When sink node moves from cell 2 to cell 3 as in Figure 2(b), OCH changes. Cell header of cell 3 act as OCH and it delivers data to mobile sink.

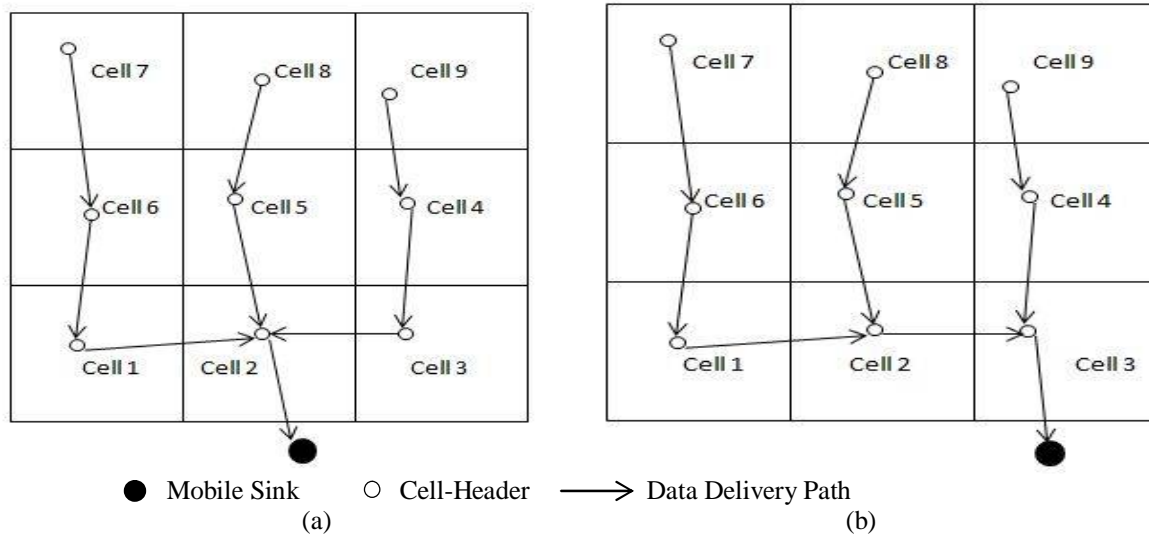


Figure 2: Routes Adjustment when sink node moves across the sensor field

IV. SIMULATION AND RESULTS

We simulate proposed VGDC scheme using NS-2 simulator. We created different topology of 100,150,200 and 250 nodes. We partitioned sensing area into virtual grid consisting of 4, 9 and 16 cells. Sink node move across the sensor field with a speed of 10 m/s and gather data from nearest border cell header. The details of simulation are given in Table I.

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Table 1: Simulation Parameters

Parameters	Values
Number of Nodes	100,150,200,250,300
Simulation area	500m*500m
Sensor node's energy	100J
Mobile sink's speed	5 m/s
Communication range	50m

In WSN, each sensor node has definite amount of energy. Sensor node loses energy when they transmit or receive packets. If node's energy reaches to zero, it cannot receive or transmit packets. The energy consumption of whole network can be determined by summing each sensor node's energy consumption. We calculated energy consumption of whole network, for topology of 100,150,200 and 250 nodes. The per round energy consumption is defined as energy consumed by sensor nodes during the sink movement of one round. We simulated VGDC scheme for different number of rounds. Figure 3 shows the network lifetime of different number of sensor nodes. Network lifetime is the time at which first node of sensor network dies due to absence of energy. We fixed a threshold value and calculated network lifetime of sensor network for different number of nodes. In VGDC scheme as the number of nodes increases network lifetime decreases very slowly.

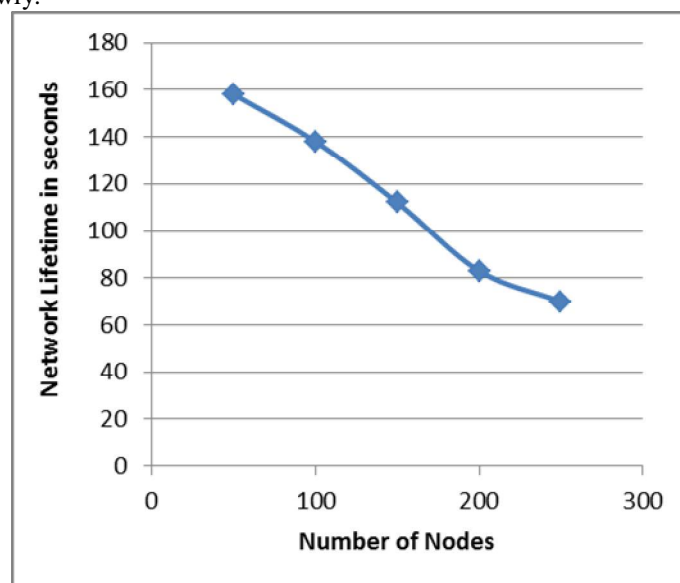


Figure 3: Number of nodes versus Network Lifetime

Figure 4 shows average energy consumption of sensor nodes for different number of rounds. As the number of rounds increases average energy consumption increases gradually. When sink covers more round it gathers more data and hence energy consumption increases. In our work sink node moves around the sensing area for 5 rounds.

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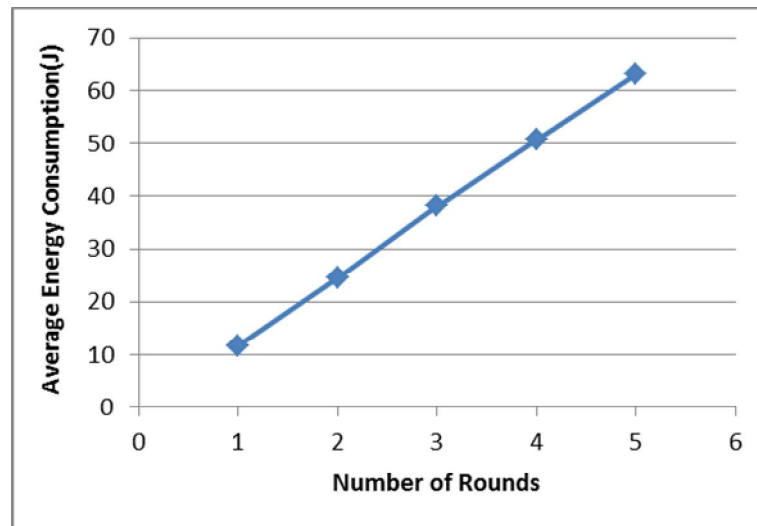


Figure 4: Per round energy consumption

V. CONCLUSION

In this paper, we proposed Virtual Grid based Data Collection (VGDC) scheme for regular data collection from wireless sensor network (WSN). VGDC scheme allows sensor nodes to keep best routes toward the recent position of the sink node. VGDC scheme initially divides sensing area into virtual grid and builds a virtual backbone structure using cell header nodes. Sink node moves along the sensing area and collects data from border cell header at regular intervals. A set of rules are followed by cell header in order to adjust routes toward the recent position of mobile sink. It is observed from simulation results that, proposed VGDC scheme reduces overall energy consumption of the network and helps in improving the network lifetime.

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