A Novel Energy Aware Data Dissemination Routing Protocol for WSN

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Abstract
Typical wireless sensor networks consist of sinks, events, and a large number of tiny, multifunctional and battery-powered sensor nodes. In Wireless Sensor Networks, data dissemination to multiple mobile sinks consumes a lot of energy. Various grid-based data dissemination schemes have been proposed over the years to reduce the energy consumption in Wireless Sensor Networks. Energy is one of the most important aspects for designing a data dissemination protocol for the applications such as battle-field monitoring, habitat monitoring etc. We present NEADD, a Novel Aware Data Dissemination scheme for randomly deployed wireless sensor networks. The proposed scheme is energy-efficient for handling both sink and source mobility. NEADD relies on virtual grid-based infrastructure for data dissemination from multiple mobile sources to multiple mobile sinks. Furthermore we proposed a diagonal forwarding algorithm for query and data forwarding which ensures that only one dissemination node forwards the query and data at a time. In NEADD, alternate dissemination nodes are selected in advance during grid construction process and minimum threshold energy level is defined for dissemination nodes. As soon as the energy of a dissemination node reaches to the minimum threshold value, it is replaced by an alternate dissemination node. The simulation results and theoretical analysis show that the proposed NEADD scheme performs better than the existing data dissemination schemes such as TTDD.

KEY WORDS: Wireless Sensor Networks; Data dissemination; Dissemination nodes; Reference Coordinates; Residual energy; Expected zone; Minimum threshold energy; Sink manager.

1. INTRODUCTION
A large sensing and monitoring task spread over vast geographical region can now be accomplished by deploying large number of tiny low cost wireless sensor nodes which self-organize themselves to form a sensing network, known as wireless sensor network (WSN). Unlike address-centric approaches used in other networks, WSNs however use data-centric approaches for data dissemination from source to sink. This attributes to the fact that due to sheer number of sensor nodes and their random deployment, assigning unique identification numbers to individual sensor nodes has not been possible. Hence, any data dissemination method based on routing tables is not viable for WSNs and thus alternate data dissemination techniques become necessary. We have proposed a data dissemination scheme which makes use of a virtual grid infrastructure for query and data forwarding between source and sink. Virtual grid is constructed only by the first source appearing in the sensor field all other subsequent sources make use of the existing grid. We have used an expected zone for handling the uncertainty in sensor node location caused by the random deployment. Residual energy level of sensor nodes is used during the grid construction and also for handling dissemination node failure. We have proposed a network model which ensures a reliable and efficient data delivery to multiple mobile sinks.

The proposed Novel energy aware data dissemination scheme is a data dissemination scheme which solves the problem of scalable and efficient data dissemination in a large-scale sensor network from potentially multiple sources to potentially multiple, mobile sinks. In this work, a source refers to a sensor node that generates sensing data to report about a stimulus, which is a target or an event of interest. A sink is a user that collects these data reports from the sensor network. Both the number of stimuli and that of the sinks may vary over time. In this work, a network with stationary sensor nodes is considered, whereas sinks may change their location dynamically.

2. LITERATURE REVIEW
In 2002, Shim and Park [2] proposed a data dissemination model using geographic routing with locators that track the sink locations and the location query of the reply sinks from the sensors. These locators are selected using a deterministic geographic hash function and replicated uniformly into the whole sensor field. When a sink moves, an
update location message is sent to the closest four locators. To obtain the location of a sink, a source node requests recursively the location of the sink from the locators and then sends its data reports directly to the sink. Data dissemination with locators is scalable to the number of sources. It can avoid trajectory forwarding at the most of cases as sink’s frequent periodical location updates.

![Figure 2.1: Grid Construction in TTDD](image)

Virtual grid based data dissemination schemes are preferred for the applications such as battle-field monitoring, forest fire detection and habitat monitoring because it requires less energy in grid maintenance. Energy is the major concern in WSNs as sensor nodes are battery powered and energy constrained. Most of the data dissemination schemes use flooding which seems to be a good candidate for sensor networks because it does not involve costly topology maintenance and complex route discovery algorithms. However, the main problems with flooding are that it typically causes unproductive and often harmful bandwidth congestion, as well as inefficient use of node resources such as energy, which is scarce in resource-constrained sensor networks. Though several data dissemination schemes have been proposed specifically for sensor networks, research on finding a scheme that can strike a good balance among reliability, scalability, and energy efficiency is still lacking.

In section 2 we will discuss about the proposed data dissemination scheme as well as the terminologies used in this research. In section 3 we go through the NEADD Protocol and discuss about the determination of cell size of the grid. In section 4, we will discuss about the dissemination node failure of NEADD routing protocol. In section 5, we go through the simulation of NEADD protocol with the help of various parameters. In section 6, we conclude the paper.

3. A NOVEL ENERGY AWARE PROPOSED DATA DISSEMINATION SCHEME:

In the proposed data dissemination scheme, a virtual grid of square size is constructed for query and data forwarding. The proposed Novel Energy Aware data dissemination scheme solves the problem of scalable and efficient data dissemination in a large-scale sensor network from potentially multiple sources to potentially multiple, mobile sinks. In this work, a source refers to a sensor node that generates sensing data to report about a stimulus, which is a target or an event of interest. A sink is a user that collects these data reports from the sensor network. Both the number of stimuli and that of the sinks may vary over time. For example, a group of soldiers collect tank movement information from a sensor network deployed in a battlefield. The sensors surrounding a tank detect it and collaborate among themselves to aggregate data, and one of them generates a data report. The soldiers collect these data reports. In this work, we consider a network made of stationary sensor nodes only, whereas sinks may change their locations dynamically. In the above example, the soldiers may move around, but must be able to receive data reports continuously. Sink mobility brings new challenges to data dissemination in large-scale sensor networks.

3.1 Problem Statement

The main problems in data dissemination to mobile sinks in WSNs are:

1. The existing data dissemination schemes such as TTDD makes use of separate virtual grids for each source, which consumes a lot of energy in grid construction process.
2. There is no energy efficient scheme for handling dissemination node failure.
3. Energy of the sensor nodes is not considered during the grid construction process and data forwarding to the sinks.
4. Data dissemination to multiple mobile sinks from the mobile source of event.
5. Considering the random deployment of sensor nodes in grid construction process.

The main objective of the research is to propose a novel energy-aware data dissemination scheme for multiple mobile sinks in WSNs. It can be subdivided into smaller objectives

- To reduce the number of transmissions in data dissemination process.
- To enhance the virtual grid life time.
- Handling dissemination node failure in virtual grid.
- Taking the energy aspects into consideration while selecting the dissemination nodes for data dissemination.
3.2 PROPOSED SCHEME:

Novel energy aware data dissemination is a novel grid-based data dissemination scheme in which a virtual grid is constructed by the first source appearing in the sensor field. In the proposed NEADD scheme, a virtual grid of square size is constructed by the first source appearing in the sensor field. Cell size of the grid is determined by using the radio range R and radius of expected zone d. Query is forwarded by the dissemination nodes through the shortest path (diagonal forwarding). Query and data is forwarded by the dissemination nodes only. All other nodes do not participate in query and data forwarding but they are responsible for sensing the events. In the proposed scheme dissemination nodes are selected on the basis of their energy levels as we have assumed that the sensor nodes may have different energy levels. As it is not always possible to find a sensor node at the estimated crossing point or the sensor node at the estimated crossing point may have very low energy as compared to other neighboring sensor nodes. Thus the selection of the dissemination nodes should be done on the basis of their energy level and distance from the estimated crossing point. We have also proposed a query and data forwarding scheme which reduces the energy consumption in data dissemination process. In the proposed scheme the dissemination node which is closest to the source forwards the query and all other dissemination nodes discard query. Thus each time only one dissemination node forwards the query and query is forwarded by using the shortest possible path through the virtual grid.

3.2.1 GRID CONSTRUCTION:

The steps followed during grid construction are given below:

- The source node sends the calculated co-ordinates and a predefined distance (d) of the dissemination node from the crossing point with GCM. Where d is the radius of the expected zone.
- Each node, on receiving the GCM, calculates its distance from the co-ordinates of the crossing point received with GCM.
- If the calculated distance is less than d, then the node replies to the sender dissemination node with its co-ordinates, residual energy and the calculated distance di.
- The sender dissemination node arranges all residual energies in descending order and selects the node with the maximum residual energy within the expected zone as the next dissemination node.
- It sends the confirmation message to the selected node and designates it as the next dissemination node.
- The GCM message is recursively propagated in the entire sensor field so that each dissemination point on the grid is served by a dissemination node.

3.2.2 Determining the Cell size

Cell size is determined by using the radio range R of sensor nodes and the limiting distance d. We can determine the cell size α with the help of figure 2.

\[ AB = BC = CD = AD = \alpha \quad \text{(cell size)} \]
\[ AP = CQ = d \quad \text{(radius of expected zone)} \]

In triangle ABC,

\[ AC = \alpha \sqrt{2} \quad \text{(Applying Pythagoras Theorem)} \]

Radio range of the node should be equal to PQ.

\[ PQ = R \quad \text{(Radio range)} \]

![Figure. 2: Cell size for grid construction](image)

So,

\[ QC + CA + AP = R \]

Or \[ d + \alpha \sqrt{2} + d = R \]

Or \[ \sqrt{2} \alpha + 2d = R \]

Or \[ \sqrt{2} \alpha = R - 2d \]

Or \[ \alpha = \frac{(R - 2d)}{\sqrt{2}} \] (2.1)

So from the above derivation it is clear that the cell size \( \alpha \) should be equal to \( (R - 2d) / \sqrt{2} \).

3.3.3 DETERMINING THE RADIUS D OF EXPECTED ZONE

We will construct a circular expected zone with radius d. So \( \pi d^2 \) will be the area of the expected zone. Let there are n sensor nodes deployed in the sensor field and the area of the region is A. Then-

Area of finding 1 sensor node = total area/ total number of sensors
\[ d = \left( \frac{\pi A}{n^2} \right)^{1/2} \]

We will take the upper bound (floor value) of the calculated value, so that there will be the probability of finding more than one sensor nodes in that area.

\[ d = \left\lfloor \left( \frac{\pi A}{n^2} \right)^{1/2} \right\rfloor \]  

(2.2)

If we need \( m \) sensor nodes in the expected zone then radius \( d \) can be given as,

\[ d = \left\lfloor \left( m \frac{\pi A}{n^2} \right)^{1/2} \right\rfloor \]  

(2.3)

When we require only one dissemination node then radius of expected zone \( d \) is determined using formula 2.2 but if we need more sensor nodes to be used as alternate dissemination node then we use formula 2.3 and select a value of \( m \) as per the requirement. \( m \) is the number of sensor nodes required within expected zone.

### 3.3.4 QUERY FORWARDING

In this approach the query forwarding is based on the virtual grid infrastructure. Each data source has its own unique source id and the source id is known to all the dissemination nodes of the cell in which the data source is lying. The query from a sink includes reference coordinates of the source, and reference coordinates of the next dissemination node which is expected to forward the query. When a sink needs data, it floods a query within the local cell area. The query reaches to the local dissemination node of that cell. Now it is forwarded on the grid towards the source. Each dissemination node compares its reference coordinates with that of the next dissemination node in the query. If it matches, then the dissemination node forwards the query otherwise discards. If a dissemination node receives queries for the same data from different sinks, then it aggregates all these queries and sends only one copy to its upstream dissemination node. Each node maintains the information about all the queries received by neighboring nodes and when it receives the data then it forwards the data to all the nodes from where it had received the query for that data item (Figure 3.1).

- The query from a sink includes the sink id, source id of the source of interested data, reference coordinates of the next dissemination node.
- When a sink needs data, it floods a query within the local cell area.
- The query reaches to the local dissemination node of that cell.
- Now it calculates the reference coordinates of next dissemination node and updates the query packet and forwards on the grid towards the source.
- Each dissemination node maintains the information of the node from which it has received a particular query.
- If a dissemination node receives queries for the same data from different sinks, then it sends only one query.

**Figure 3.1:** Query and data forwarding from multiple sinks

#### 3.3.4.1 ALGORITHM

The algorithm for query forwarding is given below-

1: Create Query ( Source_id (Xs, Ys), C_Dnode (Xi, Yi), N_Dnode (Xn, Yn) )
2: Transmit (Query, Ni)
3: while (Xi!=Xs & Yi!=Ys)
   4: if (Xi = Xn & Yi = Yn)
      5: if ( Q_list (Source_id ) = TRUE )
         6: Update Q_list (Source_id, C_Dnode)
      7: else {
         8: Update Q_list (Source_id, C_Dnode)
      9: Update_query (Xn, Yn)
     10: forward the query
   11: else discard the query.
12: end

Where,
Ni: immediate neighbors of node i
C_Dnode: current dissemination node
N_Dnode: next dissemination node
Q_list: query list maintained by each dissemination node

3.3.4.2 Calculating the next dissemination node’ reference coordinates
\[ X_n = X_i + p \cdot a \]
\[ Y_n = Y_i + q \cdot a \quad (where \ a \ is \ the \ cell \ size) \]

3.3.4.3 Calculating p & q
(Xs, Ys) are the reference coordinates of the source node.
If (Xi = Xs)
p = 0 & q = (Ys - Yi)/|Ys - Yi|;
else if (Yi = Ys)
p = (Xs - Xi)/|Xs - Xi| & q = 0;
else
p = (Xs - Xi)/|Xs - Xi| & q = (Ys - Yi)/|Ys - Yi|;

If a node receives multiple query packets with same Source id and Source sequence number then it forwards only one query and stores the location of all the nodes from where it has received the duplicate queries. Thus it removes the probability of forwarding duplicate query packets.

3.3.5 DATA FORWARDING
Once the query is received by a dissemination node, it is forwarded to the data source. Data is forwarded to the sinks through the reverse path followed by the query. If a dissemination node had received queries from different neighboring nodes, it sends a data copy to each of them (Figure 3.2). Once the data arrive at a sink’s local dissemination node, trajectory forwarding [4] is employed to further relay the data to the sink.

Figure 3.2: Handling multiple source and sinks

3.3.6 HANDLING DISSEMINATION NODE FAILURE
The most important feature of the proposed scheme is to handle the dissemination node failure problem without excessive flooding in the entire sensor field. Minimum threshold energy level is defined for dissemination nodes. This scheme makes use of the circular expected zone with radius d. But it does not rely on forwarding query when the dissemination node fails instead it makes use of the priority list of nodes which is maintained during the grid construction process. During the grid construction process, all the nodes belonging to the expected zone will send their residual energies to the neighboring node from which the query is received. A priority list is maintained by that node based on the residual energy level of the nodes. Thus the sensor node with maximum remaining energy is selected as the dissemination node and the information about the remaining nodes is stored in the priority list. When a dissemination node reaches to minimum threshold energy level, then it selects the next node from the priority list as the dissemination node. In this way the proposed scheme reduces the energy consumption and handles the dissemination node failure problem in an efficient way.

3.3.7 HANDLING SINK MOBILITY
Sink mobility brings new challenges to the data dissemination process. Sink mobility can be classified into two categories:
- Within the local cell of grid infrastructure
- Outside the local cell i.e. the sink may move to some other cell in the grid

Local sink mobility can be handled by local flooding of data within the cell but inter-cell movement of the sink requires a mechanism to keep track of sink location in order to forward the data to the sink. In the proposed scheme an agent
node called sink manager (SM) is used for the mobile sink (MS) when it moves into another cell. Unlike other data dissemination schemes, we will not use a new node as sink manager instead the dissemination node itself will work as a sink manager when a sink moves away from the cell into the adjacent cell. When a mobile sink (MS) moves into the adjacent cell, it selects the common dissemination node of both the cells which is closest to the previous immediate dissemination node or sinks manager.

![Figure 3.2: Handling sink mobility](image)

The sink forwards the same query to that dissemination node with a flag indicating that the query is already forwarded from this mobile sink and the receiving dissemination node will forward the query to its neighboring dissemination node i.e. the original dissemination node. The data which is already at the IDN is forwarded to the sink manager and to the sink following the backward path to the sink.

3.3.8 HANDLING EVENT MOBILITY
In the proposed scheme, we make use of the storage capability of the sensor nodes for handling the event mobility. The immediate dissemination node of the event (source node) stores the sensed information as soon as it senses the event. Thus the source node does not need to track the event mobility. When a source node receives the query for a particular data, it forwards the stored information without caring about the mobility of the event.

4. SIMULATION RESULTS:
In this section, we evaluate the performance of A Novel energy aware data dissemination protocol through simulations. We first describe our performance metrics, simulation parameters, and methodology in section 4.1 and 4.2. Then we evaluate the performance of NEADD with varying number of sinks and sources in section 4.3. The results confirm the efficiency and scalability of NEADD to deliver data from multiple sources to multiple, mobile sinks. We also compare the performance of NEADD with TTDD.

4.1 Performance Metrics
We use following three metrics to evaluate performance of proposed data dissemination scheme.

- **Total Energy Consumption** is defined as an average of the total energy consumption of all sensor nodes during a round; the idle state energy is not counted because it related to the data generation interval and does not indicate the efficiency of data delivery.
- **Total Transmissions** is defined as total number of packet transmissions during query and data forwarding to the sink.
- **Data Delivery Delay** is defined as the average time between the moment a source transmits a packet and the moment a sink receives the packet, also averaged over all source-sink pairs.
- **Success Rate** is the ratio of the number of successfully received data packets at a sink to the total number of data packets generated by a source, averaged over all source-sink pairs.

4.2 Simulation Parameters
Sensor field is region of 1000 * 1000 square meters, with 200 sensor nodes deployed in it randomly. The sensor nodes can be in one of these modes: sleeping, sending message, receiving message. A sensor node’s transmitting, receiving and idling power consumption rates are set to 0.66 W, 0.395W, and 0.035W, respectively. Each query packet has 36 bytes and each data packet has 64 bytes. The mobile sinks can have maximum speed of 10 m/s. Each simulation run lasts for 200 seconds.

5. RESULTS:
5.1 Effect of Number of Sources and Sinks on Total Energy Consumption
Numbers of sinks and sources are varied from 1 to 5 to study their effect on overall energy consumption and delay. Sinks move randomly with a maximum speed of 10 m/s. Figure 5.1(a) shows how using NEADD total energy consumption varies with varying number of sinks and figure 5.1(b) shows overall energy consumption while TTDD is used.
5.1. Effect of Number of Sinks and Total Energy Consumption

Figure 5.1(a) and 5.1(b) shows the total energy consumption in NEADD and TTDD respectively. From the figures it is clear that energy consumption increases with the increase in number of sinks and sources. Total energy consumption for NEADD is less than that of TTDD because NEADD need not to construct a separate grid for each individual source.

5.2 Effect of Number of Sources and Sinks on Delay

Figure 5.2(a) shows the impact of varying number of sources and sinks on delay when NEADD is used and figure 5.2(b) shows delay when TTDD is used. NEADD shows lower delay as compared to TTDD which attributes to the fact that in NEADD, most of the time the data packet follows the shortes path between source and sink.

5.3 Effect of Number of sinks and Sources on Success Rate

Success rate of NEADD is better than that of TTDD (as shown in Figure 5.3(a) and 5.3(b)) because NEADD reduces the number of transmissions significantly which ultimately results in reliable data delivery.
Figure 5.3(a): Success rate vs. numbers of sinks and sources for NEADD

Figure 5.3(b): Success rate vs. numbers of sinks and sources for TTDD

6. CONCLUSION:

NEADD is a novel grid-based data dissemination scheme which makes use of virtual grid infrastructure for query and data forwarding. NEADD is an energy-efficient scheme for addressing the issues of dissemination node failure and excessive flooding of packets in WSNs. Virtual grid infrastructure constructed over randomly deployed large scale wireless sensor network has proven very useful for handling sink and event movements. The proposed scheme exploits location information of sensor nodes to build grid structure over entire sensor field. In the proposed scheme the random deployment of sensor nodes is considered during the grid construction. Dissemination nodes are selected on the basis of their residual energy levels. The proposed network model ensures query and data forwarding through the shortest path between source and sink. The proposed scheme is energy efficient and robust as it reduces the energy consumption in query and data forwarding and dissemination node failure handling.

REFERENCES:


