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Mobile Sink Based Lifetime Optimization For Data Gathering And Forwarding In Wireless Sensor Networks

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Abstract

Energy efficiency and utilization is a key concern in Wireless Sensor Network. The energy depletion of sensor nodes causes major setback on performance and lifetime of WSN. Due to this problem, maximizing the data collection and delivery is one of the most challenging issues. In order to reduce the unwanted movement and energy depletion of sensor nodes for data gathering, mobile sink is employed with the controlled mobility pattern. ES-LEACH algorithm is proposed for Cluster Head selections. The lifetime of network is optimized by using mobile sink. LBESRP is sensing the coverage area of Wireless Sensor Network for analyzing the parking position of Cluster Heads. Using Random Way Point model, the mobile sink can flow and the data collection strategy is employed by MIN-MAX algorithm. The simulation result improves the performance by the use of mobile sink.

Keywords *– mobile sink, energy efficiency, MIN-MAX algorithm*

1. Introduction

Wireless Sensor Network is called as wireless sensor which is spatially distributed over the region. The autonomous sensors are used to monitor the physical and environmental conditions such as humidity, temperature, mobility of living or non- living things. Sensor Network is comprised of large number of different sensor nodes in a large area.

The sensor nodes are randomly deployed either inside or very close to the sensed circumstance. All sensors have cooperative capabilities that they perform wireless sensing, computing and act as a communication elements for gathering andforwarding data from one place to another in the network. The sensor node is the basic unit in the sensor network. The salient features of sensor nodes are self-organization, self-configuration, wireless infrastructure and ability to withstand in harsh environmental conditions. WSN system acts as a bridge which provides connectivity between virtual and physical world. It allows the ability to sense the unobservable node at a fine resolution over large spatial temporal scales. The potential applications are battlefield surveillance, nuclear, biological and chemical attack detection in military, monitoring of human physiological data and drug administration in hospitals, machine condition monitoring in industry, traffic management in transportation and civil infrastructure.

Every sensor node is filled with energy that should be used efficiently in both active and inactive state. The energy is utilized by minimizing energy consumption in each node and reducing the average communication distance over

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the area. This can be achieved using ES-LEACH by making cluster.

The random mobility pattern makes the sink to move autonomously and has no knowledge about mobility in terms of direction and speed. It is highly unpredictable. The proposed system uses controlled mobility and the mobile sink is guided based on residual energy of the nodes.

2. Energy Saving-Low Energy Adaptive Clustering Hierarchy Energy Model

2.1. Cluster Head Selection

Clusters are formed for reducing the energy consumption. Every cluster has its own cluster head. Before forming the clusters, there is a need to select the number of cluster heads. These cluster heads are likely to be an administrative head which they have an authority to control the normal sensor nodes and have a more energy than other sensor nodes. So these cluster heads help to utilize the energy efficiently and maximize the network lifetime of sensor nodes.

The packet format generated by each node for cluster head selection is packet type, number of neighbors, sequence number, source address, destination address, energy, X-position, Y-position and timestamp. Each node transmits its status to every sensor nodes.

The cluster head is selected based on two categories,

- If the sensor nodes have varied energy, the node with highest residual energy is selected as cluster head MAX (E_r).
- If the nodes have equal or full energy, then centrality is calculated for each node as the difference between the location of node (i) and the center of the cluster (j) of squared distances from other nodes to the candidate node using the following equation:

$$C(N_i) = \sqrt{\left(\left(x_{cc_j} - x_i\right)^2 + \left(y_{cc_j} - y_i\right)^2\right)} \quad \forall i \neq j \text{ where } i = 1....n_{CCj}, j = 1...k$$

where x_{cc_j} and y_{cc_j} is the center of a specified cluster j. N_i indicates selected neighbor node. The lower distance means higher value of centrality, resulting in the lower amount of energy required to transmit the data.

2.1.1. Set-up Phase

If the node is elected as a cluster head, it informs the other nodes by broadcasting advertisement message (ADT_msg) using Carrier Sense Multiple Access protocol (CSMA). This message contains Cluster Head_ID and header. The normal nodes in the network calculate the power value based on received signal strength of ADT_msg and the residual energy of cluster head. The normal node compares power value among the cluster heads in the network. The normal nodes send joint request message (JNT_REQ_msg) to the respective chosen cluster head using CSMA protocol. This message contains Cluster Head_ID and node's ID.

Once the grid is formed, the cluster head creates a Time Division Multiple Access (TDMA) and allocate this schedule to all the member nodes in the grid.

2.1.2. Steady State Phase

This phase is broken into frames where each node in the cluster or grid is allocated by the time scheduling for data transmission to the cluster head. It seems to be sequential pattern. So there is no collision occurred during transmission of data between cluster head and member nodes. The scheduling provides efficient bandwidth and low latency. Once all the

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data are aggregated into the cluster head, non-cluster head is getting into idle state. Only the cluster head is active. So less energy is consumed.

2.2. Algorithm for Energy Saving-LEACH Model

for all nodes N in network do
if (N have equal energy)
Calculate (C(S_i))
CH ← select MAX (C(S_i))
else
CH ←select MAX (E_r)
end if
end for
while
N ← Broadcast ADT_msg (CH_ID, E_r, hdr)
Calculate Power Value (ADT_msg)
CH ← Send JNT_REQ_msg (CH_ID, N_ID)
N ← Broadcast TDMA Schedule
CH ← Grid Nodes send data
end while

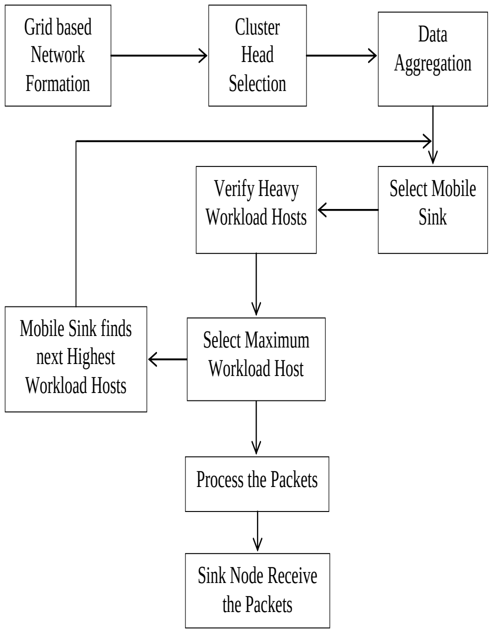

Figure 1: Data Collection of Mobile Sink

3. Mobile Sink Selection

Mobile Sink is used for gathering data from the cluster heads based on the load available in host. The host contains number of clusters otherwise called as grids. It enables hop by hop communication from cluster heads to mobile sink and from mobile sink to static sink. The nodes near to the sink drain its energy rapidly. So mobile sink is used to avoid the draining of energy and thus ensure balancing the energy consumption. It helps to prolonging the lifetime of network.

There are two mobile sinks. The sink have the highest residual energy is selected as primary mobile sink to continue processing the packets. The secondary mobile sink have the residual energy lesser than the primary mobile sink. So the secondary sink is recharging by harvesting energy from the surrounding nodes. It can be used when the primary sink losses its energy.

Once the cluster or grid is formed, the mobile sink initiates its work. The mobile sink follows the mobility model that is Random Way Point model based on the maximum workloads of group of cluster heads.

4. Load Based Data Collection

In Load Based Energy Saving Routing Protocol (LBESRP), the sensor nodes are partitioned into subsets for sensing transmission range and network connectivity. The problem with this approach is to find the existence of critical nodes. These nodes may be on all the time and the network will be partitioned if these nodes die.

This protocol divides the network into subsets for analyzing the workloads of cluster heads in each subset. Each group calculates workloads of cluster heads totally. The workload is determined by

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number of bits transmitted in period of time.

The load on each node is calculated by,

$$L_i = \sum_{i \in N} rx_{ij} \,.\, tx_i + rx_j, \forall\, L_i \in N$$

rx_{ij} is 1 if and only if node L_i transmits its data directly to node L_j

tx_i is total number of bits transmitted by sensor node $L_i \in N$

rx_j is total number of bits received by sensor node $L_i \in N$

The loads of each subset are calculated by adding all the cluster heads in the subset.

This MIN-MAX algorithm selects the maximum workload of host or group of grids which contains cluster heads within the transmission range of mobile sink because the cluster head consumes more energy than others. So the residual energy of this cluster head is very low compared to others. It leads to rapid draining of energy as the cluster head is active state. In order to save the lifetime of this cluster head, the mobile sink collects the data from this heaviest workload host. Once the mobile sink collects the data from the cluster heads, it is moved to idle state for energy conservation. Then the data is forwarded to static sink.

While selecting maximum workload clusters or grids, the mobile sink estimates its residual energy based on the load of cluster head. It is ready for the next process to find the next highest workload of host. Again the process starts from selection of mobile sink. If the primary mobile sink has sufficient energy to continue the process, it is selected again. Otherwise secondary mobile sink takes the place of primary mobile sink and continue the process.

Here, the mobile sink uses the controlled mobility as it is controlled and moved towards the maximum workload of hosts. It reduces data delivery latency. The route of sink is determined in off-line.

After the connectivity is provided by LBESRP, the mobile sink starts analyzing the workload of cluster heads. This group of cluster heads should be monitored by mobile sink. Each cluster head calculates its residual energy after grid formation. Each host calculates its loads by adding the loads of cluster heads.

The residual energy is calculated from the total energy consumed in cluster head. For residual energy calculation, the energy consumed between cluster head and normal nodes is taken into account.

The total energy consumed by a cluster head after cluster formation is

$$TE_c^{CH} = \sum_{i=1}^{n} E_c$$

n is the number of events occurred in cluster head.

The amount of energy used for an event to be occurred per unit of time is the energy consumed to be work done.

$$E_c = TR_e \text{ x t}$$

E_c is consumed energy, TR_e is the energy required for transmitting or receiving the message and t is the unit of time.

The residual energy of cluster head is calculated by difference between the initial energy of cluster head and total energy consumed by a cluster head.

$$E_r = E_i - TE_c^{CH}$$

Each cluster head calculates its own residual energy. Now the mobile sink verifies all the residual energies of cluster heads that fall within the range. The mobile sink selects least residual energy of cluster heads in the host and collects data simultaneously and forwards it to the base station.

The mobile sink is parked randomly for certain period of time based on the heavy workloads of host. The mobile sink is parked to collect data that the host which contains the cluster heads should be within the range. The parking position is generated randomly by Random Way Point model. This model does not consider the previous position to calculate the next

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parking position. It is used for sink mobility.

This protocol calculates the distance from parked position of mobile sink to cluster heads that should be in distance d. The cluster heads should be in the coverage area of mobile sink. The nodes beyond the transmission range are considered as orphaned nodes. While moving the MS starts sensing and communicating with CHs. If the cluster heads are within the transmission range of mobile sink, then the mobile sink broadcasts SNK_ADT_msg to the cluster heads. This message contains Mobile Sink_ID and location information. After receiving the message, the cluster heads send JNT_REQ_msg to mobile sink. This ensures network connectivity between mobile sink and cluster heads and then the communication starts.

The time is called as sojourn time for network connectivity and connecting cluster heads within the transmission range and collecting data from cluster heads simultaneously. The host with maximum workload of cluster heads is chosen by mobile sink to collect data MAX(L_H). The sojourn time is varied in each time because of load variation of hosts. This ensures the total amount of data collected from the cluster heads by the mobile sink is maximized.

4.1. Movement Model Algorithm

STEP 1: while (NETWORK IS ACTIVE)
//cluster formation phase
STEP 2: Determine sink position $P_{initial}(X,Y)$
Divide network into hosts
Calculate L_i
Calculate loads of CHs of each host
MS ← Select MAX (L_H) using MIN-MAX Algorithm
Find optimal path to locate sink
Determine $P_{final}(X',Y')$
STEP 3:MS ← gather data
end while

5. Performance Analysis

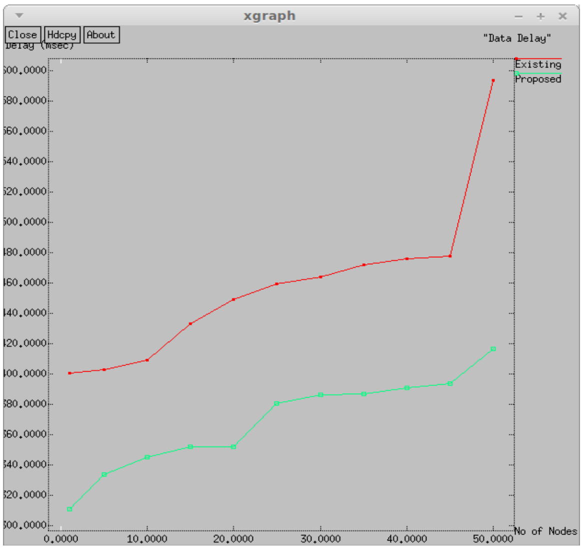

Figure 2: Data Delivery Delay

Figure 2show less data delivery delay compared to previous techniques that uses fixed mobility pattern. The mobile sink collects data from cluster heads without any interruption as it follows load based model to find out the heavily loaded host. The controlled mobility makes the mobile sink to analyze the senor nodes for data transmission.

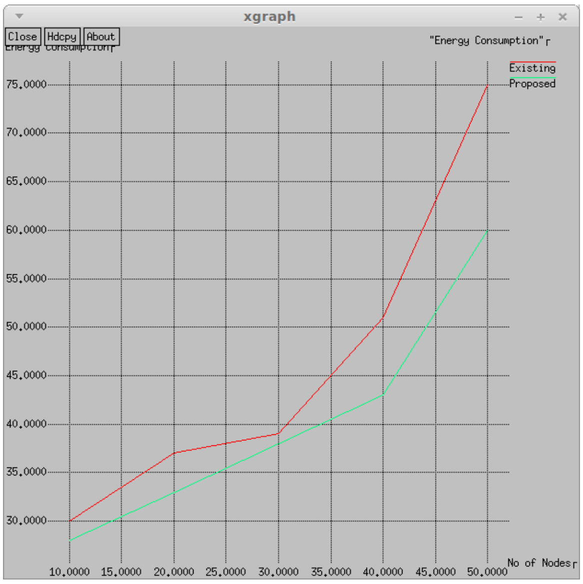

Figure 3: Energy Consumption

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Figure 3 show the results of energy consumption. Energy consumption occurs because of packet transmission, packet reception, and processing and sensing by each node during network operation. The packet transmission consumes more energy than reception which is less than sensing. The less energy is consumed as ES-LEACH model is used and controlled sink mobility based on heavy workload host.

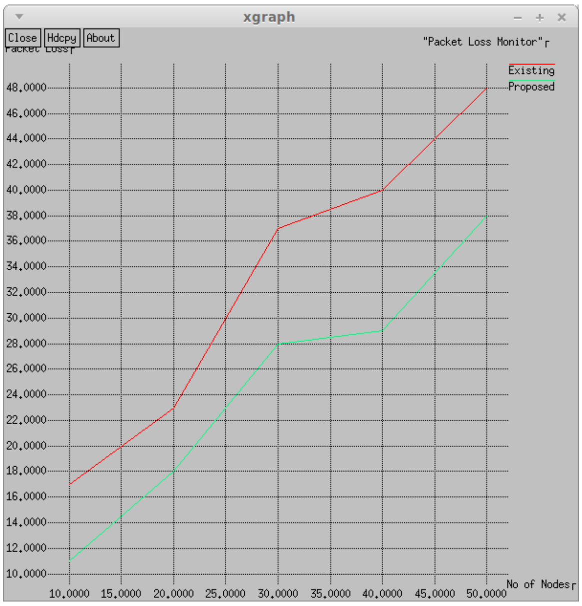

Figure 4: Packet Loss Monitor

Figure 4 show the results of packet loss, in which the loss is reduced because ES-LEACH eliminates network congestion in which the packets are sent from normal nodes to cluster head based on TDMA schedule and also mobile sink calculates its own energy level for maximizing data collection.

6. Conclusion

The lifetime of sensor nodes are focused where the information generated by the monitoring sensors needs to be routed efficiently to a mobile sink. The proposed model determines the optimal sink sojourn times at different locations, and the optimal rates at which the sensed data must be transmitted and collected by mobile sink. However, implementing this model implies that the information obtained by solving the linear programming problem must be flooded to the network, so that every sensor is aware of the sink sojourn times and of the rate at which it has to transmit data to its neighboring nodes.

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