ENERGY EFFICIENT HYBRID SCHEME FOR DATA AGGREGATION IN GRID BASED WIRELESS SENSOR NETWORKS

AMANDEEP KAUR AND DR.RAJNEESH GUJRAL
M.M.Engineering College/ Department of Computer Science andEngineering, Maharishi Markandeshwar University, Ambala, Haryana, India
Email: amanya3110@gmail.com, drrajneeshgujral@mmumullana.org

ABSTRACT: Large scale Wireless Sensor Networks (WSNs) will be enormously deployed in different kinds of applications. It is likely that redundant data will be detected by nodes when sensing an event. As energy efficiency is the critical issue in WSNs. Several aggregation, clustering and routing protocols have been developed in order to reduce the network traffic toward the sink and therefore prolong the network lifetime. An alternative of clustering is to build chains instead of clusters. Grid based WSNs have the advantages of dynamic topology management and flexible selection of routing path. In this paper we propose a hybrid grid and chain based data aggregation method based on sleep/awake mode to improve the lifetime of WSNs. Aggregated data moves from node to node along the chain, and finally reach to the BS. Further simulation results show that the proposed solution has better performance in terms of energy efficiency and number of dead nodes which increase network lifetime.

KEYWORDS: Data Aggregation, Network lifetime, Wireless Sensor networks.

INTRODUCTION

Recent advances in miniaturization and low-power design have led to the development of small-sized battery-operated sensors that are capable of detecting ambient conditions such as temperature and sound. Sensors are generally equipped with data processing and communication capabilities. The sensing circuitry measures parameters from the environment surrounding the sensor and transforms them into an electric signal. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor. Each sensor has an onboard radio that can be used to send the collected data to interested parties. Such technological development has encouraged practitioners to envision aggregating the limited capabilities of the individual sensors in a large scale network that can operate unattended [1–3].Data aggregation [4] is a key task performed within WSNs to fuse information from multiple sensors and deliver it to a sink node in a manner that eliminates redundancy and enables energy saving. As a popular approach for data aggregation such as LEACH [5], HEED [6] uses cluster head for communicating data to sink. If sink is far away, high energy will be required to successfully deliver the packet. Another approach PEGASIS [7] has a drawback that energy expenditure will be high in case the neighbours along the chain are too distant. This paper presents an Energy Efficient Hybrid Scheme for Data Aggregation (E^2HSDA) protocol which is based on sleep/awake mode pattern [20-22]. It focuses on eliminating these limitations by using multihop communication instead of single hop for improving the network lifetime. With this method, the nodes in the sensor network can be in one of the two states: sleep state and waking state. In the sleep state, the node turns off its transmitter so that it is unable to transmit packets thereby saving energy whereas in the waking state, the sensor can be in one of the other three operating modes, i.e., either make measurements, perform some computation or communicate information to the fusion centre. In the present existing data aggregation schemes perform in-network processing at arbitrary aggregation points whereas E^2HSDA performs the aggregation at reliable (node having sufficient amount of energy to perform data aggregation work) sensor nodes (SNs). Further existing data aggregation schemes utilize dynamic topologies with variable cluster sizes hence incurring higher overhead, while E^2HSDA uses a fixed and simple architecture that reduces routing overhead.

RELATED WORK

In typical WSN, nodes are usually resource constraint and battery limited. In order to save energy and resources data must be aggregated to avoid excessive traffic in the network. T H. Wang et al. in [3] organizes the SNs in a chain. Nodes send their data to chain leader which transmits it to the base station (BS)/sink. However the drawback of this scheme is that if the chain leader is far away from the sink (BS) much of energy would be wasted in transmission. Yu and Y. Song et al. [8] proposed an Energy-Efficient Chain-Based routing protocol (EECB) that is an improvement over PEGASIS. EECB uses distances between nodes and the base station and remaining energy levels of nodes to decide which node will be the leader that takes charge of transmitting data to the base station. Haiyun Luo et al. [9] proposed TTDD uses a grid based approach for routing data from a source to multiple, mobile sinks. Proactive grid construction is initiated by each source appearing in the sensing field and only the grid point's sensors need to acquire the forwarding information. Rabia Noor Enam et al.[10] presented Distributed Uniform Clustering Algorithm (DUCA) divides the sensor area into grids and then head are selected based on LEACH. Therefore this method does not give assurance that each grid must have atleast one head for data aggregation. Yung-Kuei Chiang et al. [11] have proposed CBDAS in which the whole sensor field is partitioned into a logical grid of M ×N cells, each has a head. All cell heads are further linked together to form a cyclic chain. Young-Long Chen et al. [12] proposed Intra-Grid PEGASIS topology architecture, which is an architecture based on PEGASIS topology; in this architecture, the sensor area is divided into several network grids, meanwhile, the nodes of each network grid is deployed in random, then the nodes within the network grid are connected, finally, all the network grids are connected. Mourad Hadjila et.al [13] proposed protocol is based on constructing multiple chains in the direction of the sink. In addition to forming multiple chains as previously, it constructs a main chain, which includes leader node of each chain. Since, initially all main chain nodes have the same amount of power, the nearest node to the sink aggregates data from others then transmits it to the sink. In the next transmission, main chain node having the higher residual energy performs this task. In ECBSN, S. Mahajan et al. [14] adopt 2-layer hierarchical chains. In low layer, ECBSN based on PEGASIS adopts multiple chains instead. Each chain has a leader, the node with the most remaining energy. ECBSN further links the leader of each low layer chain to form a single high layer chain. In the high layer chain, the node with the shortest distance to the BS is selected as high layer leader, responsible for transmitting the aggregated data finally to the BS. Neng-Chung et al. [15] presented GBDAS divides the sensor field into a grid of cells to minimize the amount of data transmitted to the BS. Each cell head aggregates its data with the data sensed by the other member nodes of the cell. Besides, GBDAS also performs data aggregation for each cell heads in the chain. In EEDD Z. Zhou et al. [16] also divides the whole sensor field into small virtual grids so that each grid has a head to forward data. Each grid is further divided into four sub-grids if an event is unceasing. Working nodes in the sub-grids are scheduled to stay active according to their corresponding sub-grid time slot. Y. Xu et al. [17], an algorithm, called Geographical Adaptive Fidelity (GAF) was proposed, which uses geographic location information to divide the area into fixed square grids. Within each grid, it keeps only one node staying awake to forward packets. N.C.Wang et al. [18] propose PBDAS for grid-based WSNs with a single chain, formed by repeatedly linking the cell heads from the farthest row left to right then the next farthest row right to left until the nearest row of the BS. In PBDAS, choosing a cell head according to the energy level increases the lifetime and robustness of the WSN. Neng-Chung Wang et al. [19] propose a dual-path-based data aggregation scheme (DPBDAS) for grid-based WSNs. The SNs are randomly classified as type A and type B. All SNs of type A and type B in the grid are further organized as group A and group B, respectively. Each cell has a head for each type. DPBDAS construct dual paths by linking each cell head of each group, respectively. Each group has a leader randomly chosen from cell heads on its own path, responsible for directly transmitting the data to the BS. For data gathering in each round, each cell head aggregates its own data with the data received from the other nodes of the same type in the cell and then transmits to the neighbouring cell head toward its own leader. In this paper, we propose E^2HSDA, a static and energy efficient aggregation in which chain is formed dynamically and improves the network lifetime by considering sleep/awake mode pattern. The E^2HSDA aggregation protocol relieves the network from clustering overhead and it ensures that the information will reach to BS anyhow by following a reliable path.

DATA AGGREGATION MODEL

It is assumed that the network consists of static, homogeneous and densely deployed SNs that are distributed uniformly in a randomized manner throughout a two dimensional square field. The sensing area is divided into equal size square grids. Sensor Network is modeled as a connected graph G = (V, E) where V represent set of all vertices in network, $n \subseteq V$ denote the number of nodes and E represents set of all links (i,j) where $(i,j) \in V$. An edge exists between two nodes if and only if they are neighbor of each other. The adjacency matrix representation of a graph G consists of |V|*|V| matrix.

$$A = a_{ij} = \left\{ \begin{array}{l} w_{ij} \ \forall \ (i, j) \in E \\ \infty \forall \ (i, j) \notin E \\ 0 \ otherwise \end{array} \right\}$$

Each sensor has a transmission range d meters and initial residual energy E_i . The SNs are assumed to be stationary but the sense information is allowed to move.

This aggregation protocol has the following assumptions.

- There exists a unique BS located at a fixed place outside sensing region.
- The SNs are unaware about their location.
- The SNs have unique identity.
- The SN can adjust its amplifier power based on its distance from receiver.
- Each node knows its neighbour. Finding neighbour cost is not included in E^2HSDA aggregation method.

In E^2HSDA, some nodes in every grid are in sleep mode and rest is in a awake mode. The sleep/awake mode pattern of nodes will change at regular intervals. The E^2HSDA protocol uses a multi-hop data communication scheme towards the BS.

DATA AGGREGATION ALGORITHM DESIGN

Formation of Grid

The first step in E[2]HSDA is to construct grid to perform aggregation as shown in Fig. 1. The sensor nodes are uniformly deployed in randomized manner throughout the region. Depending upon the number of nodes in every grid, approximately half of the nodes (red color) are in sleep and rest is in awake mode (green color) in order to minimize the energy consumption of the network. The sleep and awake pattern changes at regular interval to uniformly distribute the energy consumption all over the network. Also, the BS will have the information about all waking nodes in the network.

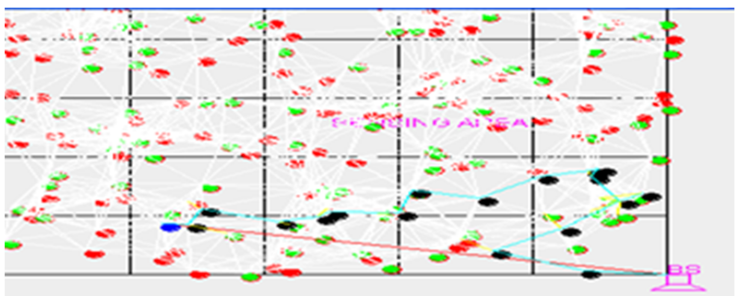

Fig. 1 grid to perform aggregation

Energy Efficient Hybrid Scheme for Data Aggregation (E^2HSDA)

The data gathering process is initiated by the BS and is illustrated by an algorithm as shown in algorithm1. BS broadcasts a query message that is received by all the nodes in WSN. The node whose ID matches with the request ID becomes the source node.

Optimal_path_aggregation (G, w)

Begin

1. Intialize_energy (G);
2. Broadcast (Query_message)
3. For all nodes {v|v V} do
4. Receive (Query message);
5. if (node_id[v]=Query_Message[source_id])
6. Set source=v;
7. Generate Optimal path (source);

End

Algorithm1. Optimal path aggregation

The source node finds the adjacent active node y of x which is nearest in its neighbor list, is in waking mode and has remaining energy above threshold value in algorithm 2. Threshold value is minimum energy required by a node for successful transmission of packet to neighboring node. When node x finds reliable node y, it forward sensed value of x to y and calculates Etrans which is the energy required to transmit sensed value from node x to node y.

Optimal_path (x)
Begin

1. Set min_dist=max_value;
2. While(x node_near_BS) do
3. For each y, y adj[x] do
4. If ((sleep[y] = false) &&(dist[x][y]<min_dist)
   && (E_{rem}[y]> Th))
5. Set min_dist=dist[x][y];
   [End of For loop]
6. Forward (sense_value[x], x, y);
7. Calculate E_{trans} (x,y)
8. Call Aggregate (sense_value_x, sense_value_y);
9. Call Optimal_path(y);
10. If(x=node_near_BS)
11. Send_packet (Aggr);

End

Algorithm2. Optimal path

At node y, the aggregation function upon receiving the sensed value of node x, compares its sensed value with sensed value of node x. In case both are equal, node y sense value is not added to aggregate packet to avoid redundancy as shown in algorithm 3and total number of send and received packet of node x and y are increased by 1(if values are not equal)as in algorithm 4. This process goes on until aggregated packet reaches to a node nearest to the BS that forwards aggregated packet to BS.

Aggregate (value_x, value_y)
Begin
Set Aggr [0] =sense_value[s];
If (value_x! = value_y)
Aggr [ ] = value_y;
Return Aggr;
End

Algorithm3. Data forwarding

Forward (sense_value v, x, y)
Begin

1. Send sense value v of x to y
2. send_packet[x] = send_packet[x] + 1;
3. receive_packet[y] = receive_packet[y] +1

Algorithm4. Aggregated output

Energy Calculations

Energy to Transmit & Receive a packet:

$E_{TX}(L,d)$ is energy consumed by a node to transmit L bit packet at distance D, E_{elec} is the electronic energy that depends on factors such as the digital coding, coding, and modulation or, is the amplifier energy that depends on the transmission distance and the acceptable bit-error rate. $E_{RX}(L)$ is energy dissipated by a node to received L bit packet .

$$L * E_{elec} + L * \in_{fs} * d^4 \;\; if \;\; d \geq d_0 \qquad (1)$$

$$E_{TX}(L,d) = L * E_{elec} + L * \in_{fs} * d^2 \;\; if \;\; d \leq d_0 \qquad (2)$$

$$E_{RX}(L) = L * E_{elec} \qquad (3)$$

Energy in Sleep Mode:

$$N_{awake} = (N - N_{path} - N_{sleep}) \quad (4)$$

$$EC_{sleep} = RE + (N_{awake} * time * E_{awake}) + (N_{sleep} * time * E_{sleep}) \quad (5)$$

3) Energy without Sleep/Awake mode:

$$N_{awake} = (N - N_{path}) \quad (6)$$

$$EC_{awake} = RE + (N_{awake} * time * E_{awake}) \quad (7)$$

where EC $_{sleep}$ =Energy consumed by network in sleep/awake mode, N=Total no. of nodes in the network, N_{path} =Total no. of nodes in routing path, N_{awake} =Total no. of awake nodes in network, N_{sleep} =Total no. of sleep nodes in network, E_{awake} =Energy consumed by awake mode for 1ms, E_{sleep} =Energy consumed by sleep mode for 1ms, Time=Time required for transferring aggregated information from source to BS in ms, EC_{awake} = Energy consumed by network without sleep/awake mode.

Network Lifetime

The network lifetime is defined in terms of number of rounds. Where E_i is the initial residual energy of sensor node, avg_{energy} is the average transmission energy for one round.

$$Numberofrounds = (N * E_i) / avg_{energy} \quad (8)$$

Effect of Aggregation:

$$Energy_{withouaggregation} = (n*(n+1)/2)*avg_{energy} \quad (9)$$

$$Energy_{aggregation} = n * avg_{energy} \quad (10)$$

SIMULATION AND PERFORMANCE ANALYSIS

We evaluated the performance of E^2HSDA protocol by providing a comparison with the existing protocols and simulating the results in JAVA. We analyzed energy consumed by the system in sleep mode vs. awake mode. Also the effect of aggregation is analyzed that shows the improved efficiency and increased lifetime of network. In addition, we compare our E^2HSDA aggregation protocol with PEGASIS protocol. The following simulation parameters are considered for the implementation of E^2HSDA.

- The size of data packet is 512 bytes

- The distance between the BS and the network is taken as 100m.
- The number of node 10-80
- The electronic power is 50 nJ/bit
- Free space attenuation coefficient is 12 pJ/bit/m2
- Multipath attenuation coefficient is 0.0012 pJ/bit/m4
- Nodes' initial energy is 0.5 J
- A node is treated as dead when its remaining energy is less than 0.002 J

For simplicity, error free communication links are assumed. We assume a square network field. Fig. 2 shows that average transmission energy decreases with the increase of node density. Because the node density increases, the average number of its neighboring nodes also increases. Thus, probability of seeking appropriate neighbors to join the path will enhance accordingly.

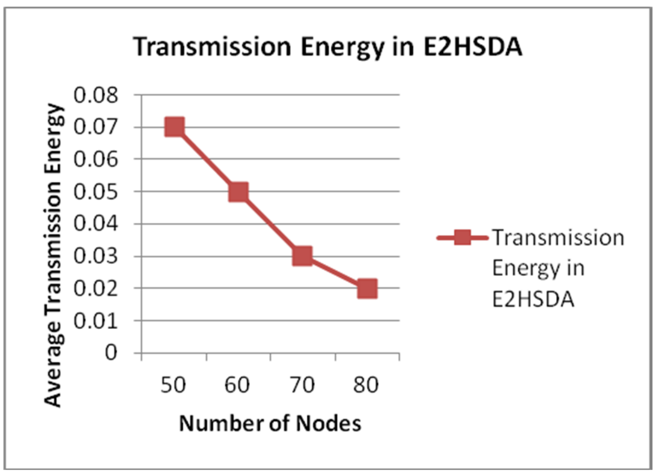

Figure 2. No. of nodes vs average transmission energy

Fig.3 illustrates that less energy consumption is required in sleep mode as compared to awake mode. The results show that for a large network with dense number of nodes, it would be useless to utilize all the nodes for sensing. Some nodes can be kept in sleep mode while aggregating data to be transmitted to sink Fig. 4 Shows the comparison of E^2HSDA protocol with PEGASIS that network lifetime will increase in case of proposed scheme because the total number of dead nodes gets reduced which directly impacts the transmission energy.

CONCLUSIONS

This paper presents an Energy Efficient Hybrid Scheme for Data Aggregation (E^2HSDA) protocol which is based on sleep/awake mode pattern. It focuses on eliminating these limitations by using multihop chain based communication instead of single hop for improving the network lifetime. In the present existing data aggregation schemes perform in-network processing at arbitrary aggregation points whereas E^2HSDA performs the aggregation at reliable (node having sufficient amount of energy to perform data aggregation work) SNs. Further existing data aggregation schemes utilize dynamic topologies with variable cluster sizes hence incurring higher overhead,

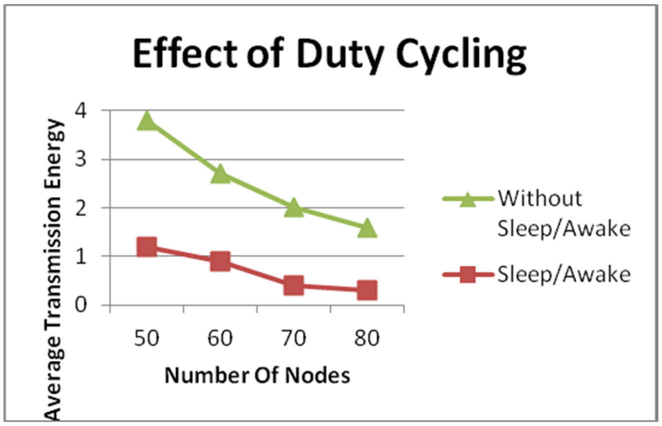

Figure 3.Energy consumption in sleep vs. awake mode

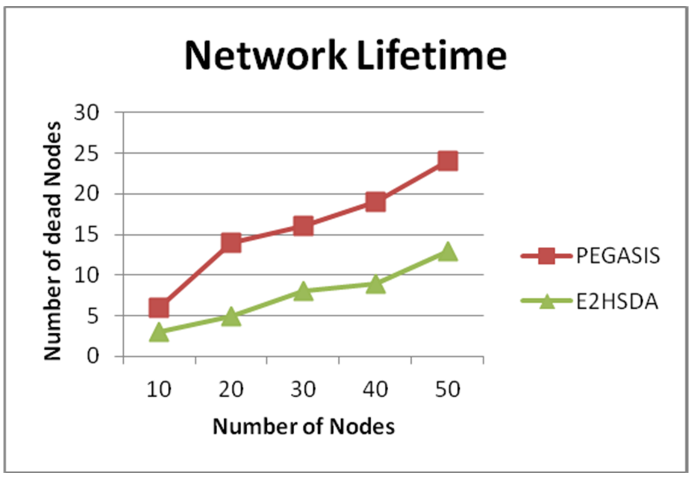

Figure 4.Network lifetime

while E^2HSDA uses a fixed and simple grid based architecture that reduces routing overhead. The proposal will be further improved in order to ensure a fault-tolerant aggregation process and to optimize its operation in the presence of collisions.

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