A Novel Scheme for Energy-Balanced Data Aggregation in Agricultural Environment using WSN

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Abstract

Wireless Sensor Networks (WSNs) are thickly deployed sensor nodes in an application area for example agricultural monitoring, smart homes, automation, vehicular traffic management, environment monitoring , disaster finding and so on. In a typical cluster based routing protocols, few nodes are selected as Cluster Head(CH) nodes and these nodes form clusters with other nodes in the network called cluster members(CM). However, energy efficiency of a sensor nodes and communication overhead are the major concerns of WSNs. There are many challenges and research areas concerned in the literature, one of which is power consumption in the sensor nodes. Nodes in these networks have limited energy sources and generally consume more energy in long communication distances and therefore run out of battery very soon. Data aggregation is an efficient mechanism in WSN to prolong the lifetime of the network. Due to high node density in WSN, same data is sensed by many nodes which results in redundancy. This redundancy can be eliminated by using data aggregation approach by intermediate nodes while routing packets from source node to the base station (BS). In this paper, we introduce a super CH node inside the WSN. This node is in charge of all clusters belongs to WSN and also maintains energy information of all clusters. All CHs send their respective information to super CH node that eliminates redundant information and forwards the aggregated information towards BS. This mechanism increases the lifetime of the network by minimizing the number of communication between sensor node and BS. In order to evaluate the performance of our proposed system, we use various parameters like packet delay, communication overhead, number of live nodes, and number of packet received by the BS.

Keywords: Wireless Sensor Networks, Cluster Head, Data aggregation, Cluster Member

1. Introduction

A Wireless Sensor Networks is formed in agricultural environment by different kinds of sensor nodes such as temperature sensors, humidity sensor, soil moisture sensors etc to receive information from the environment and send data to the BS. Each sensor node consists of microcontroller, transceiver, external memory, power source and an electronic circuit linked with one or more sensors. Sensor nodes are limited in battery control, cost and storage capacity and physical size. The sensor nodes jointly perform the activities such as sensing information, communicating with other node and with BS through wireless medium. To do all such activities, each sensor node consumes a lot of energy which is supplied by non-replaceable battery. The practical problem of WSN is that the nodes are equipped with limited power supply and it is not feasible to replace the battery. Hence the major research work revolving around WSN is design of energy efficient protocols that help in prolonging the network. To increase the network lifetime, there are different mechanisms such as data aggregation schemes, designing efficient routing algorithms, and clustering techniques.

Data transmitted by sensor nodes might be duplicate and redundant. Moreover, the amount of produced data in large WSN may be too high for being processed in the BS. Sensor nodes in the network are divided into clusters, each cluster consist of cluster members(CM) and cluster head(CH). The CHs forward the information to the super node. The super node maintains individual cluster node's energy by proper monitoring the energy levels. The main purpose of data aggregation is to make sensor networks energy efficient so the network life time may be enhanced.

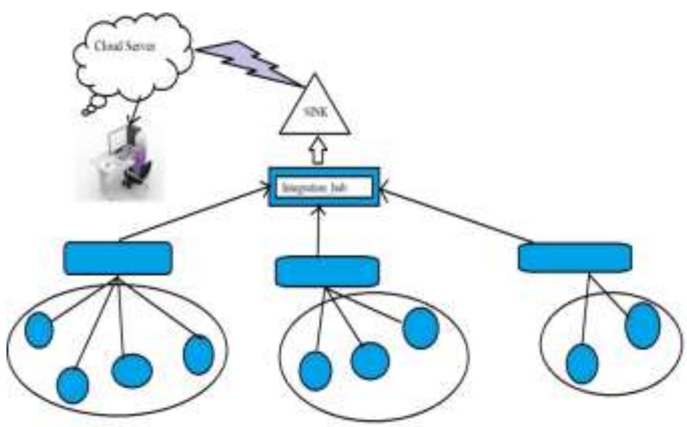

Figure 1: Architecture of the proposed system

In this work, we propose a new data aggregation mechanism that reduces the energy consumption by creating additional node called Super CH which is introduced before the BS. The rest of the paper is organized is as follows. Section 2 gives an insight on existing clustering protocols and aggregations methods. Assumptions and Network model used are mentioned in

During CH election, CH sends notification to the cluster members about the probability of becoming a CH based on the equation.

$$T(n) = \begin{cases} \dfrac{P}{1 - P[1 \bmod \left(\frac{1}{P}\right)]}, & n \dot{\in} N \\ 0 & \text{Otherwise} \end{cases} \quad (3)$$

Where p is the probability, n is any given node , N is set of nodes that are not selected as CH for the past rounds and T(n) is the predefined threshold. A node generates a random number between 0 and 1. A node can become CH for the current round if the number is below the T(n) value then node can become CH for the current round. T(n) is calculated in the above equation (3). After this process, CH advertises its status as CH to all cluster members (CM) of cluster. Then all CM will send the join messages to the CH about joining to the cluster. The CM who acknowledges first to the advertisement will become the Super CH node. Based on the energy levels, Super CH node is responsible for selecting CH in the next rounds. Super CH sends the broadcast messages to all the nodes in the network, in turn all the nodes sends their energy messages to the respective CH in the cluster. The energy message consists of initial energy level, residual energy level etc. CH sends these messages to the Super CH. Based on these information, Super CH is capable of assessing the priority among all the nodes. If CH is dissipated 25% of energy, then Super CH replaces CH to the node with maximum energy.

Super CH makes data transmission to the BS based on the TDMA mechanism[ ]. Each node communicates with their CH in their respective time schedule. All CHs forward the data and energy related messages to the Super CH. Super CH will aggregate the data and send the data to the BS.

4.1 EBDA Algorithm

Step1: Generate random number between 0 to 1
Step2: If the node's value is within the T(n) then node become CH for the current round.
Step3: CH broadcast to CM
Step4: CM send Join message
Step5(a): If the CM is first respondent to the advertisement, goto Step5(b) else Step8
Step5(b): Node become Super CH
Step6: Node broadcast residual energy message

Step7(a): If node is CH and energy<T(n) then update entry in energy table, assign new node as CH
Step7(b): If node is CM & energy>T(n) then Super CH sends ACK
Step8: CM sends data to CH
Step9: CHs forward the data to Super CH
Step10: Super CH aggregates the data and forwards it to BS

5. Performance Evaluation

In this section, comparative analysis of proposed algorithm is done with LEACH protocol. To analyze the performance of the proposed system with existing system by using various parameters such as active nodes, energy consumption, communication overhead and node decay rate. The simulation is carried out using Sensoria simulator.

It is observed that lifetime of the sensor nodes in the proposed model is better than the LEACH, deployed nodes remain alive for longer period of time. As super node is responsible of observing energy levels of all the nodes. If the energy level of CH reaches to the threshold level, it is replaced by a node with maximum energy level in order to keep the nodes alive for longer time, shown in figure 2.

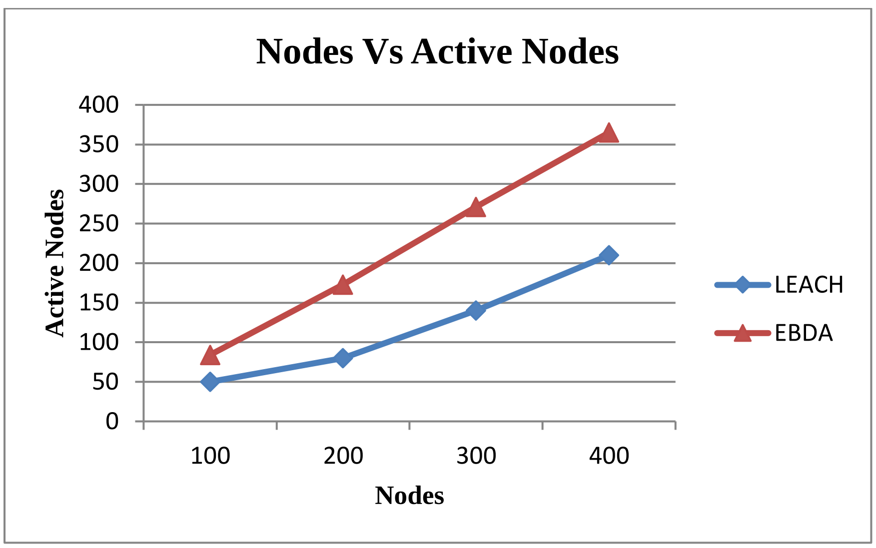

Figure 2: Evaluation of Number of Active Nodes

Energy consumption is highly depends upon distance between sensor node and BS. In the proposed system, sensor nodes forward the data to the respective CH which in turn forwards the data to the BS via the Super CH. This will save large amount of energy.

It can be observed that our proposed model is more efficient and consumes less energy compared to the LEACH protocol, shown in figure 3.

percentage. Due to more congestion, there is a gradual increase in the communication overhead in both algorithms which in turn increases node decay rate.

From figure 5, we can see that increase in the network size, sending rate also increases which results to more energy usage in network. Due to congestion in the network, each node consumes more energy for packet transmission; energy level of a node gets exhausted before packet reaches to the BS, and so node becomes dead. For instance when the number of nodes is 100, rate of node decay is 2.6% in case of proposed algorithm and 14.2% in case of existing algorithm. But in our proposed algorithm, due to less congestion in the network, node decay rate is minimum in the entire network life cycle compared to existing algorithm**.**

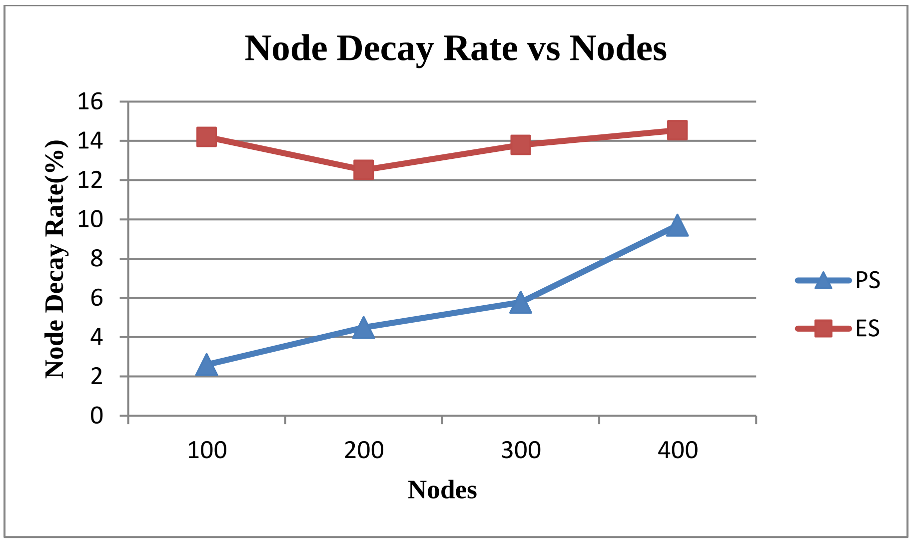

Figure 5: Evaluation of Node Decay Rate

6. Conclusion

Energy efficiency is very important aspect of the WSN during aggregation mechanism. In this paper, we have proposed a novel technique which introduces Super CH for data aggregation. This model can be implemented in an Agricultural field to monitor the environmental parameters such as temperature, humidity and soil moisture. Sensor nodes in the field will sense its environments and collects the data, creates data redundancy. Super CH collects the redundant information from the CHs and eliminates the data redundancy by aggregating mechanism before forwarding it to the BS. This will not only saves the nodes energy but also reduces the number of communication. From the experimental results, proposed model works better in terms of energy consumption, life time of the WSN and communication overhead when compared with the LEACH protocol.

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