www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 03 Issue 07 July, 2014 Page No. 6996-7000

Energy-Efficient Attribute-Aware Data Aggregation Using Potential-Based Dynamic Routing in Wireless Sensor Networks

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Abstract: ***Sensor nodes gather data in Wireless Sensor Networks (WSNs), which is pieced together at the sink. Most of the energy of SNs is consumed in transmission and reception of the data packets. Reduction in transmission of data packets greatly improves the lifetime of WSNs as it not only reduces the energy of transmitting nodes but also of the receiving nodes. Since the network consists of low-cost nodes with limited battery power, power efficient methods must be employed for data gathering and aggregation in order to achieve long time network usage. Attribute-aware data aggregation uses the concept of packet attribute, can make the packets with the same attribute spatially convergent as much as possible and improves efficiency of data aggregation. To improve network efficiency, the proposed mechanism focuses on efficient data aggregation in tree based network by constructing energy efficient duty cycled data aggregation trees. In this method the number of transmissions is reduced and the energy consumption also get reduced.***

Keywords: Wireless sensor networks, Data aggregation, LEACH, PEGASIS, TEEN, EADAT, PEDAP, PEDAP-PA, DASDR, L-PEDAP, EEDGP, ADA, Dynamic routing

1. INTRODUCTION

With advance in technology, sensor networks composed of small and cost effective sensing devices equipped with wireless radio transceiver for environment monitoring have become feasible. The key advantage of using these small devices to monitor the environment is that it does not require infrastructure such as electric mains for power supply and wired lines for Internet connections to collect data, nor need human interaction while deploying. These sensor nodes can monitor the environment by collecting information from their surroundings and work cooperatively to send the data to a base station or sink for analysis.

Wireless Sensor Networks (WSNs) consist of several sensor nodes and one or more base station or sink. Sensor nodes have limited processing capability and low power battery. It has also a sensing element and a transceiver. Sensor nodes sense the physical environment and send the data in the form of signals to the base station. The sensor nodes are usually scattered in a sensor field as shown in Figure 1.1.

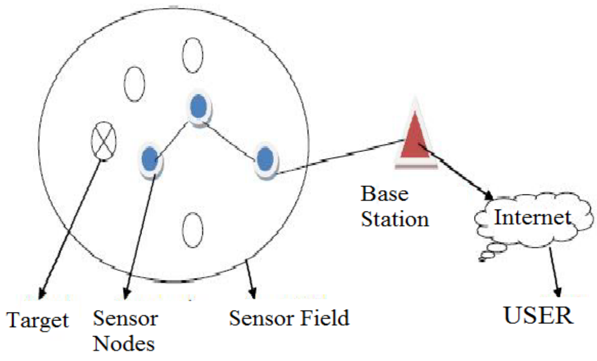

Fig. 1 Wireless Sensor Network

One of the most important constraints on sensor nodes is the low power consumption requirement. Sensor nodes carry limited, generally irreplaceable, power sources. Therefore, while traditional networks aim to achieve high quality of service provisions, sensor network protocols must focus primarily on power conservation. They must have inbuilt trade-off mechanisms that give the end user the option of prolonging network lifetime at the cost of lower throughput or higher transmission delay. Many researchers are currently engaged in developing schemes that fulfil these requirements.

1.1 Sensor Network Applications

Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar, which are able to monitor a wide variety of ambient conditions that include the following

- temperature
- humidity
- vehicular movement
- lightning condition
- pressure
- soil makeup
- noise levels
- the presence or absence of certain kinds of objects
- mechanical stress levels on attached objects

1.2 Data Aggregation

Data gathering is defined as the systematic collection of sensed data from multiple sensors to be eventually transmitted to the base station for processing. Since sensor nodes are energy constrained, it is inefficient for all the sensors to transmit the data directly to the base station. Data generated from neighbouring sensors is often redundant and highly correlated. In addition, the amount of data generated in large sensor networks is usually enormous for the base station to process. Hence, we need methods for combining data into high-quality information at the sensors or intermediate nodes which can reduce the number of packets transmitted to the base station resulting in conservation of energy and bandwidth. This can be accomplished by data aggregation.

Data aggregation is defined as the process of aggregating the data from multiple sensors to eliminate redundant transmission and provide fused information to the base station. Data aggregation usually involves the fusion of data from multiple sensors at intermediate nodes and transmission of the aggregated data to the base station (sink).. So we can conclude that data gathering is to collect the data from neighbour nodes to be sent to sink and data aggregation is process of removing redundancy among them.

1.3 Advantages of Data Aggregation

With the help of data aggregation process we can enhance the robustness and accuracy of information which is obtained by entire network, certain redundancy exists in the data collected from sensor nodes thus data fusion processing is needed to reduce the redundant information. Another advantage is those reduces the traffic load and conserve energy of the sensors.

2. RELATED WORK

Researches are always being conducted to improve the lifetime of sensor networks. Wendi Rabiner Heinzelman et al. [1] proposed a clustering-based protocol, LEACH (Low-Energy Adaptive Clustering Hierarchy), which is able to distribute energy dissipation evenly throughout the sensors, doubling the useful system lifetime for the networks.

Arati Manjeshwar et al. [2] modified the work of Huseyin Ozgur et al.[1] and proposed a hierarchical protocol, Threshold sensitive Energy Efficient sensor Network protocol (TEEN) that uses data-centric mechanism. TEEN is well suited for time critical applications and is also quite efficient in terms of energy consumption and response time. Stephanie Lindesy et al. [3] proposed a chain-base protocol, PEGASIS, which is able to increase the lifetime of the network twice as much the lifetime of the network under the LEACH protocol.

Min Ding et al. [4] suggested an efficient energy-aware distributed heuristic to generate the aggregation tree, EADAT. EADAT performs very well in terms of network lifetime, energy saving, data delivery ratio and the protocol overhead. Huseyin Ozgur et al. [5] proposed a Power Efficient Data gathering and Aggregation Protocol(PEDAP), which outperforms previous approaches, by constructing minimum energy consuming routing for each round of communication.

Huseyin Ozgur et al. [5] refined their work as PEDAP-PA, takes PEDAP further and tries to balance the load among the nodes. Minimizing the total energy of the system while distributing the load evenly to the nodes has a great impact on system lifetime.

Jiao Zhang et al. [6] proposed an effective data aggregation mechanism supported by dynamic routing (DASDR) which can adapt to different scenarios without incurring much overhead. DASDR is more effective in energy savings as well as scales well regarded to the network size. Huseyin Ozgur Tan et al. [7] modified their work, in [5] as a localized version of PEDAP (L-PEDAP), which tries to combine the desired features of MST and shortest weighted Path-based gathering algorithms. The main concern in this work is the lifetime of the network.

The method suggested by Siddhartha Chauhan et al. [8] describes an energy efficient data gathering protocol (EEDGP) which reduces the transmission of data packets thereby reducing the energy consumption of SNs (SNs). EEDGP significantly increases the life time of WSNs by reducing the transmission of redundant data.

Fengyuan Ren et al. [9] modified their work, DASDR in [6], and proposed an attribute-aware data aggregation (ADA) scheme, which can be used to aggregate data from heterogeneous sensors. ADA uses the concept of packet attributes. It improves the efficiency of data aggregation, scalable with respect to network size and adaptable for tracking mobile events. This mechanism can be used in a WSN with heterogeneous sensors.

In this paper, *energy efficiency problem in WSN* is investigated and proposed sleep wake scheduling scheme with the existing ADA mechanism to optimally choose the variable wakeup interval of the nodes based on node's dissimilar traffic loads.

3. ENERGY-EFFICIENT ATTRIBUTE-AWARE DATA AGGREGATION IN WIRELESS SENSOR NETWORK

3.1 Problem Definition

In this paper, *energy efficiency problem in WSN* is investigated and proposed sleep wake scheduling scheme with the existing ADA mechanism to optimally choose the variable wakeup interval of the nodes based on node's dissimilar traffic loads.

Energy efficiency is a major problem in wireless sensor networks. Various methods are developed to improve the efficiency by reducing the number of transmissions in the network, using the concept of data aggregation. Earlier methods aggregates data from homogeneous sensors and further developed methods for aggregating data from heterogeneous sensors. Data aggregation using dynamic routing mechanisms is more reliable than methods using static routing mechanisms. The method Attribute-aware Data

Aggregation is efficient to a certain extent, in which it improves the efficiency of data aggregation, but did not consider the energy utilization in nodes. In ADA a considerable amount of energy in sensor nodes is wasted due to idle listening, that is, listening to an idle channel in order to receive possible traffic. This will reduce the sensor lifetime, and hence lifetime of the network. In the proposed method energy-efficiency is achieved using dynamic sleep scheduling technique.

3.2 The Proposed Protocol Description

Following is the detailed explanation of problem statement and proposed protocol. The proposed method is named as Energy-Efficient ADA mechanism. This method should focus on efficient attribute-aware data aggregation. To improve network efficiency energy efficient duty cycled data aggregation trees could be introduced. Data aggregation concept is used while scheduling the information to the base station. The parent node while forwarding the data of its child nodes to base station append or aggregate its information along with its child information and send to its upper level node. In this method the number of transmissions will be reduced and the energy consumption also get reduced.

The proposed ADA mechanism contains the following phases.

1) *Set-up Phase:* During this phase all the sensor nodes in the whole WSN share control messages to know their neighbour nodes. It is further divided in to two sub-phases initialization and route update.

Setup Phase- Initialization: Each node determines its battery power and location in which it is located. It is very important information and is used in the proceeding phases for making important decisions like sleep/wakeup, route update and event report. Afterwards, each node sends control messages to maintain their first hop neighbour information. Once node has its neighbour information, then it decides whether it is connectivity critical node or not. This information is later used in making sleep scheduling decisions.

Route Update: In route update phase, nodes forms multi-hop path of sensor nodes to forward data to the base station. In sensor nodes to update these routes, the base station first generates a route discovery message that is broadcasted throughout the network. Upon receiving the broadcast message, each sensor node introduces a hop delay proportional to its cost before it forwards the route discovery message to nodes in its communication range. In this way a message arrives at each node along the desired minimum cost path and each node has minimum hop count path to the base station.

2) *Operation Phase:* In operation phase, nodes do the sleep scheduling and perform the event reporting. The route information determined and maintained in this phase is used in later phases for event reporting to the base station.

3) *Sleep Wake Scheduling:* In this phase, sleep-wake scheduling is done and based nodes connectivity importance and their proximity to the event occurrence different sleep/wake interval are defined. Sleep wakeup scheduling algorithm address delay minimization problem. It attempts to give longer sleep intervals to nodes, as per their traffic requirement. Traffic load of nodes differ according to their connectivity importance and their proximity to the event occurrence. Based on these factors each node determines its sleep wake pattern and accordingly switches between sleep/wake states. In each sleep/wake cycle, a node wake up in the set time intervals, waits for events to occur, listens the medium and send/receive data.

At the end of this phase, each sensor node has different sleep/wake interval to the cluster member nodes. It assigns longer wake interval to nodes nearer to BS and it assign longer wake interval to the connectivity critical nodes to minimize the delay.

4) *Event Reporting:* This phase is responsible for forwarding data to the BS on the occurrence of event in timely manner. In this phase, data is gathered from the sensor nodes and sent to the BS. When an event occurs near any node, that node will increase its wake interval for the proceeding time slot. Furthermore, it sends message to its neighbouring nodes to increase its wake interval to the handle the expected traffic burst.

4. SIMULATIONS AND RESULTS

To evaluate the performance of the proposed protocol, simulations are carried out using NS2. Performance of proposed protocol is compared with the existing ADA protocol. The following are the details of the simulation setup and discussion of the results.

4.1 Simulation Setup

Simulations were conducted in the sensing area of 1000x 1500m2 and number of sensor nodes is set to 50. Sensor nodes were randomly deployed and they are static. The BS is fixed and located at the centre of the network. Initial energy of nodes is taken as 100 Joules.

4.2 Results and Discussion

The performance of the proposed mechanism is compared against the existing ADA mechanism. Experimental parameters, such as average residual energy, packet delivery ratio, packet drop and throughput are used to measure the performance of the new protocol.

1) *Average Residual Energy :* Every node's initial energy is set as 100 joules. Average residual energy of nodes in existing and proposed methods are shown in Fig 2. Average residual energy in nodes is high in the implemented method compared to the existing method. This is because by using dynamic sleep scheduling the active duration of nodes are reduced while comparing to the existing method. So energy dissipation in sensors due to idle listening is decreased.

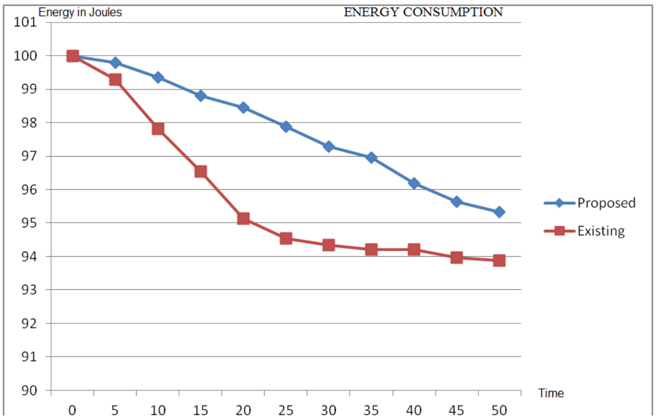

Fig. 2 Average Residual Energy

2) Packet Delivery Ratio : Comparison of Packet Delivery Ratio of existing and implemented methods are shown in Fig 3. PDR is comparatively better in the proposed method. This is because of the effect of sleep-wake scheduling. Here packets are delivered as part of the network is activated, at each round.

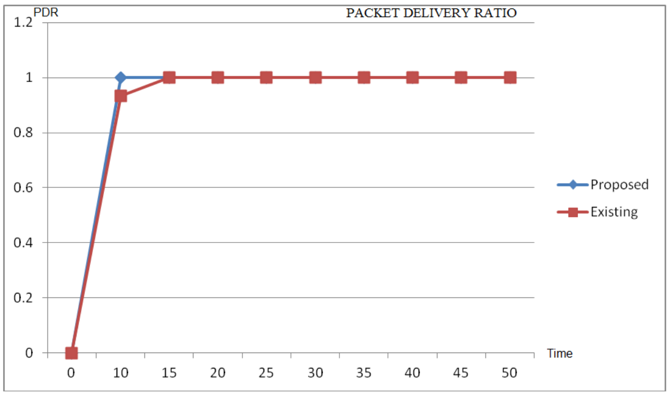

Fig. 3 Packet Delivery Ratio

3) Packet Drop : Packet drop is minimum in the implemented method compared to the existing method. In the existing method packet drop is high because of the initial broadcasting throughout the network for network initialization and rout set-up. It is shown in Fig 4.

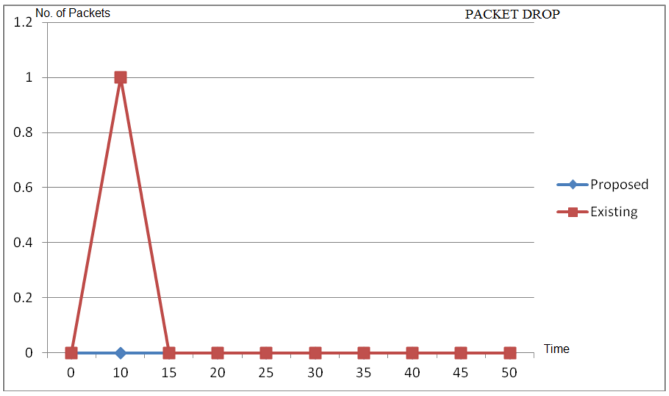

Fig. 4 Packet Drop

4) Throughput : Throughput comparison of the two methods are shown in Fig 5. Throughput is high in the proposed method while compared to the existing method. This is because of the delivery of packets in the network at different active interval periods.

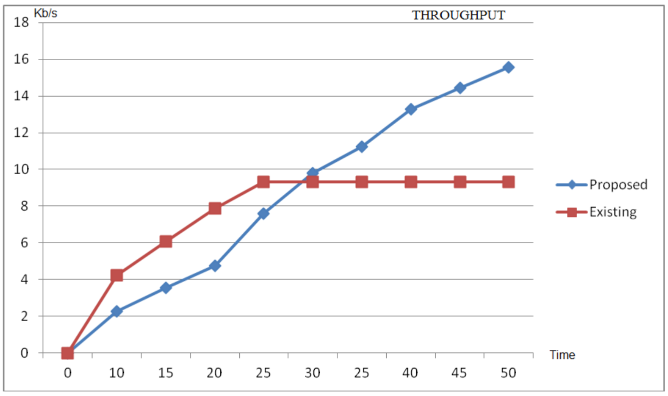

Fig. 5 Throughput

5. CONCLUSION AND FUTURE WORKS

Data aggregation is one of the main methods to conserve energy in Wireless Sensor Network (WSN). The existing ADA scheme aggregate data from heterogeneous sensors and make packets with same attribute convergent as much as possible to improve the efficiency of data aggregation but never consider the amount of energy dissipation in nodes. In the proposed method, an energy efficient duty cycled data aggregation mechanism is implemented. The proposed scheme is designed to have variable active duration of nodes according to their variable traffic load based on node topological importance, and occurrence of event in its vicinity. It improves the network efficiency and reduces the energy consumption in nodes compared with the formal approach. It also reduces the number of transmissions in the network and improves throughput.

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