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Cluster based - SPIN Routing Protocol for Wireless Sensors Networks

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Abstract

There are many facets of Wireless Sensor Networks (WSN), which provoke research interest. One of the major being routing protocol, i.e. the task of transmitting data from source node to sink node. SPIN (Sensor Protocols for Information via Negotiation) being one of them, which efficiently disseminates information among sensor node in an energy-constrained wireless sensor network. Although in time constrained operation like war zone it is not suited because it take much more time to deliver information among sensor node, also it consume more energy to broadcast data among sensor node that results energy drain faster and node dead quickly. Hence we proposed a modified version of SPIN routing protocol with network being formed using clustering technique, called Cluster Based SPIN (CB-SPIN) routing protocol. For simulation of both protocols SPIN and CB-SPIN, MATLAB platform is used and result show that CB-SPIN gives better performance in terms of time and energy.

Keywords: Cluster, Energy, Lifetime, Routing Protocol, Sensor Node, SPIN, WSN

1. Introduction

A Wireless Sensor Network (WSN)[1,2] consists of light-weight, low power, small size of sensor node. The basic components of a node are sensor unit, ADC (Analog to Digital Converter), CPU (Central Processing Unit), power unit and communication unit[3]. Since a sensor node has limited sensing, storage, energy resource and computation capacities, a large number of sensor devices (thousands to million) are distributed over an area of interest for collecting information (like temperature, humidity, pressure, motion detection etc.). The base station collects data from all the sensors, and analyzes the data to draw conclusions about the activity in the area of interest, and further action takes place[4].

Since nodes in sensor networks have restricted power, to utilizing that power efficiently is very much important, because the power source is not replicable. Therefore choosing appropriate routing technique is one of the major tasks in WSN, to transfer data from source to sink while consuming minimum amount of energy.

There are several types of routing protocols available in WSN. SPIN[5,6] is one of the data centric routing protocols which disseminate data in the network through negotiation. However, this paper concerns about CB-SPIN protocols. The discussion is begun with basic data dissemination techniques in WSN like Flooding and Gossiping[7].

2. Flooding and Gossiping

In Flooding technique, any sensor node having new sense data to disseminate in the network, first it forward data to all of its neighbor nodes, then upon receiving the new data by neighbor node, all neighbor node transmit the data to its own neighbor nodes and this process will continues until the packet reaches the destination or throughout in the network or maximum hop count of the packet is not reached, in this way all nodes in the network updated with the new sense data. This technique is very simple to implement and does not require complex topology maintenance or route discovery algorithms[7].

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On the other hand, Gossiping technique is a slightly enhanced version of flooding that uses randomization to reduce the number of duplicates packets, where the node sends the data packet to few randomly selected neighbors, which picks another random neighbor to forward the packet and so on. There are three major disadvantages of classic flooding technique[8]:

2.1 Implosion

In classic flooding, a node always sends data to its entire neighbors node, regardless of whether or not the neighbor has already received the data from some another source i.e. duplicate message are sent to the same node. This leads to the implosion problem, illustrated in Figure 1. The protocol thus wastes resources by sending two copies of the same data to node D[8].

In Figure 1 node A starts by flooding its data to all of its neighbors. Two copies of the data eventually arrive at node D. The system wastes energy and bandwidth in one unnecessary send and receive.

2.2 Overlap

Sensor nodes often cover overlapping geographic areas, and same event may be sensed by more than one node due to overlapping of region. This results in their neighbors receiving duplicate reports of the same event. This leads to the implosion problem illustrated in Figure 2[8].

In Figure 2 two sensors cover an overlapping geographic region. When these sensors flood their data to node C, C receives two copies of the data marked r.

2.3 Resource Blindness

In classic flooding protocol, nodes do not modify their activities based on the amount of energy available to

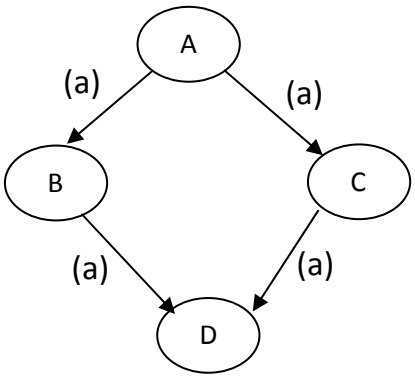

Figure 1. The implosion problem.

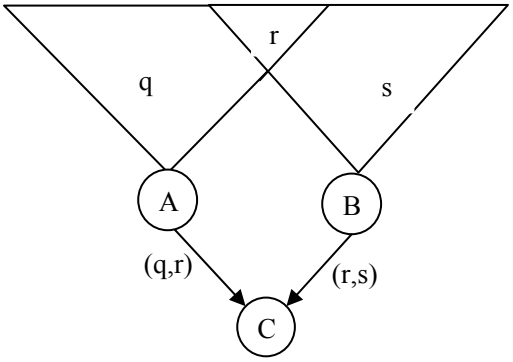

Figure 2. The overlap problem.

them at a given time and results in many redundant transmissions. So, it reduce network lifetime[8].

3. Sensor Protocols for Information via Negotiation (SPIN)

The protocol is a family of adaptive routing protocol called Sensor Protocols for Information via Negotiation (SPIN) that uses data negotiation technique and resource-adaptive algorithm, i.e. according to availability of resources it modifies some of its operation. It disseminates all the information at each node to every node in the network assuming that all nodes in the network are potential base stations. SPIN is a data centric routing protocol i.e. it give more emphasis to deliver the data in the network. Nodes in this network use a technique called meta-data to describe their collected data. Exchanging sensor data may be an expensive operation, but exchanging data about sensor data i.e. meta-data need not be[9].

Nodes of SPIN protocol use three types of messages for communication:-

- ADV - New data advertisement. When a SPIN node has a new sense data to disseminate in the network, it can advertise this by transmitting an ADV message to all its neighbors' containing meta-data.
- REQ - Request for data. When a SPIN node wishes to receive some actual data then it sends request message by sending REQ packets.
- DATA - Data message. It contains actual sense data that have to disseminate in the network, with a meta-data header.

The SPIN protocol starts when a sensor node sense a new data and it wants to disseminate throughout in the network, then it send advertisement message to all of its neighbors node by sending ADV packet. After receiving an ADV message, the neighbor node checks to see whether it has already received or requested the advertised data. If yes, then it simply neglects the ADV packet and don't send REQ packet back to original advertiser, If not, it responds by sending an REQ message back to the original advertiser for requesting the data. The original initiator of the SPIN protocol responds to the REQ message by sending actual data packet by DATA message[9,17].

ADV and REQ messages contain only meta-data i.e. information regarding data and are smaller in size than their corresponding DATA messages. Therefore ADV and REQ messages will cost less time and energy to transmit and receive than their corresponding DATA messages. Figure 3 shows an example of the SPIN protocol how information disseminates in the network.

Therefore, SPIN successfully eliminate the problem of blind use of resources and solving two major problem "implosion" and "overlap" in the Flooding and Gossiping protocol, but some problem in SPIN still exists.

The major drawbacks of SPIN are:-

- For data dissemination in network through SPIN protocol it takes long time, because at every step the neighbor node will get the data packet, so time to receive data at boundary node is much more. Therefore, it is not suited for time constrained operation.

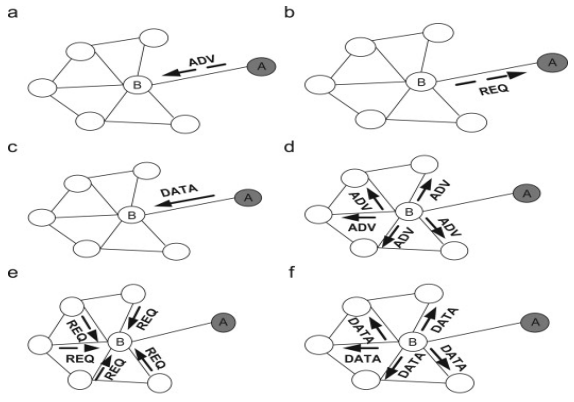

Figure 3. Node A send Advertisement ADV message to node B (a). Node B responds by sending a request REQ message to node A (b). After receiving the requested data DATA by node B (c), node B then sends out advertisements to its neighbor node (d), who in turn send requests back to B (e, f).

- In SPIN we only disseminate data message in the network, but in most of the time the information is send from source to sink node.
- Node with high degree consumes more power and drain faster.

We implement CB-SPIN protocol to overcome the above deficiency in SPIN.

4. Cluster based SPIN

In this proposed protocol we implement SPIN routing protocol in the clustered network.

4.1 Network Model

The network consists of 100 node distributed randomly throughout the region in the area of (100 m * 100 m). The whole network is divided into cluster using FCM (Fuzzy C-Means)[10] algorithms, which form cluster based on membership value. The formation of total number of cluster in network is based upon the degree of sensor node. Each cluster is having a Cluster Head (CH) with Cluster Member (CM)[11,16]. Any communication between two nodes is possible only through CH. Because the CH have to take more task so its energy drain faster, so to maintain the network and cluster we randomly rotate the CH, if any CH energy is reduced by 50 percent. After new CH being elected all CM are updated with the same[18,20]. Here network is divided into four clusters i.e. shown in Figure 4.

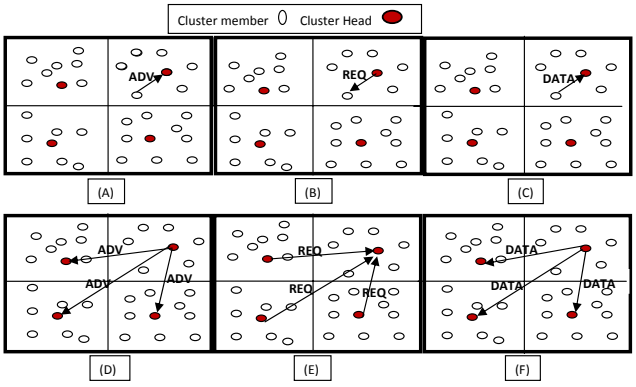

Figure 4. Network is divided into four clusters. (A) A node CM is having with new sense data send ADV message to CH. (B) CH is replied with REQ message. (C) The CM send data packet to CH by DATA message. (D) CH send ADV message to neighbor CH. (E) Neighbor CH reply with REQ message. (F) The initiator CH send data packet by sending DATA message.

4.2 Working Model

Step 1: When any sensor node has a new data and it wants to disseminate in the network, then it first advertises its data to its CH by sending ADV message, then CH request for that data by reply REQ message. After receiving of REQ message the cluster member replies with original data packet by sending DATA message.

Step 2: After getting data packet the CH, it sends request message to its neighbor CH and wait for request reply to come, after getting reply it sends data packet to the entire neighbor CH who sent reply message.

Step 3: when any CH gets new data then it disseminate throughout its cluster member in the manner of SPIN (all the member of cluster are the neighbor of CH).

Step 4: All the CH repeats the same operation.

Step 5: Check if any CH have remaining energy less than 50 percent, if yes then rotate CH and update CM with the same otherwise repeat steps.

In this manner data propagate in the network quickly, which is very useful in time constraint operation like war zone. Another advantage of CB-SPIN is that we can easily convert CB-SPIN into LEACH[12] by adding sink node in the network because in most of the time we need data to transfer from source node to sink node. If there is higher degree of node then we again divide into more number of clusters. By implementing CB-SPIN, we are able to remove all the deficiency in the SPIN protocol[19].

4.3 Energy Consumption Model

We uses first order radio model[13,14] for energy dissipation of sensor node. It is divided into two models, free space (fs) model and multipath model (mp) based on the distance between the sending node and receiving node.

Here transmitter dissipates energy to run the radio electronics; power amplifier and receiver dissipate energy to run the radio electronics only.

To transmit 'K' bit packet over a distance 'd' the radio energy dissipation is

$$E_{Tx}(K,d) = E_{elec}(K) + \varepsilon_{amp}(K,d) = \begin{cases} K * E_{elec} + K * \varepsilon_{fs} * d^2, d < d0 \\ K * E_{elec} + K * \varepsilon_{fs} * d^4, d < d0 \end{cases}$$

To receive 'K' bit data packet, the radio energy dissipation is

$$E_{Rx}(K) = E_{elec}(K) + K * E_{elec}$$

Where $d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}}$

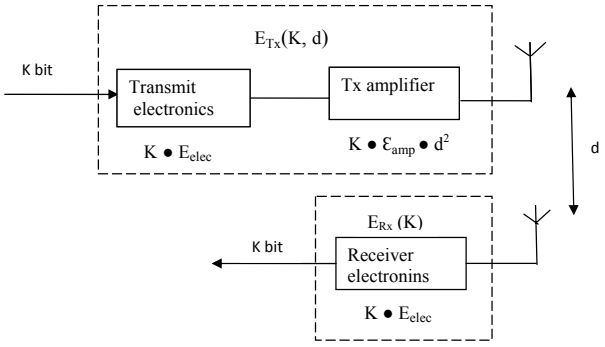

Figure 5. Radio energy dissipation model.

5. Simulation and Result

In order to evaluate the performance, we simulate SPIN and CB-SPIN protocol in MATLAB R2013a[15]. We consider a WSN with 100 nodes randomly distributed in the region of (100 m × 100 m) field. Table 1 shows simulation parameters used in the simulated network.

5.1 Number of Control Packet Transmitted

Figure 6 represents the number of control packet transmitted in SPIN and CB-SPIN in the network in

Table 1. Simulation parameters

Parameters	Value
Size of network	100m × 100m
Number of Nodes	100
Node distribution	Randomly distributed
Data packet size (DATA)	8000 bits
Meta data size (ADV, REQ)	400 bits
Initial Energy	0.5 j
E_{elec}	50 nj/bit
ε_{fs}	10 pj/bit/m^2
ε_{mp}	0.0013 pj/bit/m^4
E_{DA}	5 nj/bit
Network loss	Zero

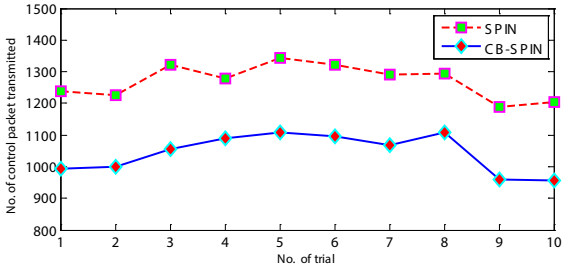

Figure 6. Control packet transmitted in each trial in SPIN and CB-SPIN.

each trial. Energy dissipation of sensor node is not only by sensing and transmitting data packet, but also by the number of control packet transmitted. If we minimize the number of control packet transmitted in the network then subsequently we save energy of sensor node.

5.2 Number of Dead Node

Figure 7 represents the number of dead node in SPIN and CB-SPIN. A sensor node is said to be dead if the energy level of node is reduced to minimum threshold value. The dead node will not participate in any type of event occurring in WSN, so we reduce the number of dead node.

We also run the protocol several times and compared the dead node between SPIN and CB-SPIN is shown in

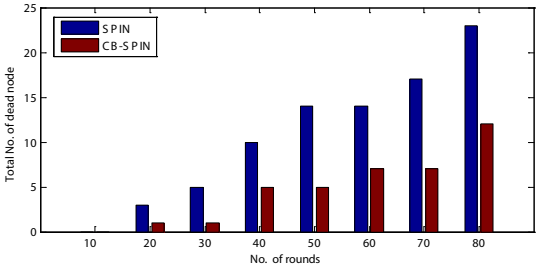

Figure 7. Number of dead node in each round.

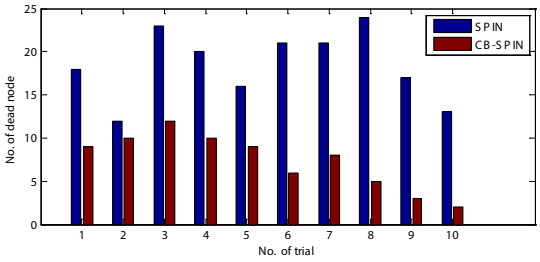

Figure 8. Number of dead node in different trial in two protocol.

Figure 8. In each trial number of dead node is less in CB-SPIN than SPIN protocol.

5.3 Energy Dissipation in the Network

In WSN it is difficult to recharge or replace the battery of sensor node, so we need to be more concerned with saving energy of sensor node so that the node lifetime enhanced. Figure 9 shows that average energy consumption of all nodes in each trial by CB-SPIN is less than SPIN protocol.

5.4 Propagation Delay in Network

Propagation delay is the total time to disseminate data in the network. In time constraint operation like war zone, propagation delay is very important, and we should mini-

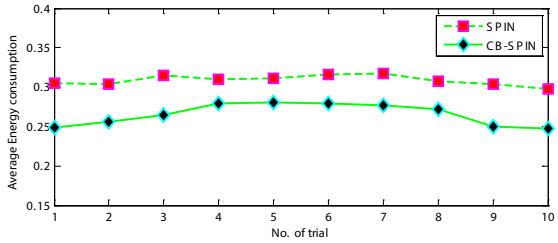

Figure 9. The comparison of energy consumption by the two protocol.

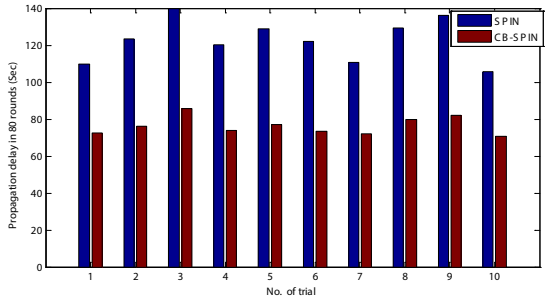

Figure 10. Propagation delay in two protocols.

mize the delay to perform desire task. Figure 10 show that our proposed protocol i.e. CB-SPIN take less propagation delay to disseminate information in compared to SPIN.

6. Conclusion

In this paper we modified the SPIN protocol to Cluster Based SPIN (CB-SPIN). By implementing CB-SPIN in the network any node can be accessible within one hop

distance from the cluster head. So that it disseminates information in the network very quickly along with conserving energy. If transfer only of data from source to sink is require then our protocol can be easily modified to LEACH by adding sink node.

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