An Event Driven Energy Efficient Data Reporting System for Wireless Sensor Network

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Abstract

In Wireless sensor networks (WSN), researchers are showing tremendous interest because of their potential usage in various applications. Sensor nodes are inexpensive and portable devices with some constraints of limited processing power and energy resources. Sensor nodes are deployed in the form of network to collect information from the environment, after collecting data they process this data and transmit the processed data to the user. As sensor devices are battery driven therefore power conservation is important in order to extend the life time of the sensor network. Nowadays, Clustering in wireless sensor network, which enables a group of sensors to work closely to form a single cluster head, has been a flourishing research field. When sensor nodes forward their data to base station (BS) via cluster heads, it may happen that the cluster heads closer to the base station are burdened with heavy relay traffic and which may results into early death of the node, leaving areas of the network uncovered and network partition. To address the problem, we are proposing an event driven redundant data elimination system which uses in-network data processing before transferring data to cluster head (CH) or sink (BS). Our simulation results shows that our data reporting system along with routing scheme reduces the transmission loss and increase the network life time.

Keywords- *portable, cluster, event, sink, transmission.*

1. Introduction

Wireless Sensor Networks (WSNs)[1]-[2] is emerging as research area with huge effect on practical application developments. They allow fine grain observation of the environment at minimal cost. In hostile environments where human intervention can be dangerous, there sensor networks can provide a robust service. Sensor networks are designed to transmit data from an array of sensor nodes to a data repository on a server. The advances in the integration of micro-electro-mechanical system (MEMS), microprocessor and wireless communication technology have enabled the deployment of large-scale wireless sensor networks. WSN has potential to design many new applications for handling emergency, military and disaster relief operations that requires real time information for efficient coordination and planning [2].

Sensors are devices that produce a measurable response to a change in a physical condition like temperature, humidity, pressure etc. WSNs [3] may consist of many different types of sensors such as seismic, magnetic, thermal, visual, infrared, acoustic and radar, capable to monitor a wide variety of ambient conditions. Though each individual sensor may have severe resource constraint in terms of energy, memory, communication and computation capabilities; large number of them may collectively monitor the physical world, disseminate information upon critical environmental events and process the information on the fly [4].

The network lifetime and data availability are extremely important issues in WSN due to their deployment in unfavourable environment. The wireless sensor nodes are mostly battery driven and due to their deployment in harsh environment, their battery is usually un-chargeable and cannot be replaceable. Moreover, their sizes are too small to accommodate a large battery; they are forced to operate using an extremely limited energy. The total energy stored in a smart dust mote, for instance is only 1Joule. Since this small amount of energy is the only power supply to a sensor node, it plays an important role in determining lifetime of the sensor networks. Therefore, all the research work has a common concern of minimizing energy consumption and it is a significant issue at all layers of the WSN.

Nowadays, Clustering in wireless sensor network, which enables a group of sensors to work closely to form a single cluster head, has been a flourishing research field. When sensor nodes forward their data to base station (BS) via cluster heads, it may happen that the cluster heads closer to the base station are burdened with heavy relay traffic and which may results into early death of the node, leaving areas of the network uncovered and network partition. To address the problem, we are proposing an event driven redundant data elimination system which uses in-network data processing before transferring data to cluster head (CH) or sink (BS). When this method was proposed few goals were set, as follows:

1. Minimize the energy dissipation of the network.
2. Increase the network life time.

In this paper, we analyse an event driven energy efficient data reporting system for the wireless sensor network (WSN). We first describe the system and then simulation results in MATLAB. Further, the performance analysis of the proposed system is compared with benchmark clustering algorithm LEACH.

The remainder of this paper is organized as follows: Section 2 describes the related work. Section 3 describes the Sensor Network Model used. Section 4 describes proposed An Event Driven Energy Efficient Data Reporting System. Simulation results are discussed in section 5 and conclusions are drawn in section 6.

2. Related Work

In recent years, many data aggregation and reporting algorithms have been devised and proposed for wireless sensor networks in recent years; weave reviewed some of the research papers. WSNs are mainly deployed in those areas where humans cannot reach, to collect relevant data and report it to Base Station (BS) or sink after in-network processing of the data. In Event-driven data reporting, when sensor nodes sense some event, then they immediately report that event to the base station. The literature [5], has proposed a data collection strategy by using network coding for efficient data collection in event driven WSNs, In this paper, they have presented HTDC, which leverages mobile sinks to significantly extend the lifetime of the sensor network through the use of a two-tier geographic hash table. The proposed mobility-management method moves the sink node only upon the occurrence of an event according to the evolution of current events to minimize the energy consumption incurred by the multi hop transmission of the event-data.

TEEN is an event-driven routing protocol, where each node will decide whether to report data or not based on the threshold values [6]. If the sensed value and a change in value are beyond the threshold, the node must switch on its transmitter and report it. TEEN is well suited for time critical applications and is also quite efficient in terms of energy consumption and response time. It also allows the user to control the energy consumption and accuracy to suit the application. ESRT is a novel transport solution developed to achieve reliable event detection with minimum energy expenditure and congestion resolution functionality [7]. Energy Efficient Clustering Algorithm for Event-Driven Wireless Sensor Networks (EECED) extends the network lifetime of a sensor network by balancing energy usage of the nodes. AEEC improved the energy efficiency of WSNs:

- CHs have higher burdens than member nodes; therefore, rotating the role of the CH shares the burden and thus extending the useful lifetime of those clusters.
- If nodes have different amounts of energy, then the nodes with more energy should be cluster heads more often than the nodes with less energy [11].

Clustering sensors into groups, so that sensors communicate information only to cluster heads and then the cluster heads communicate the aggregated information to the processing center, may save energy, for that efficient Cluster Head Selection Scheme for Data Aggregation in Wireless Sensor Network [15] can be used, in which no need to select cluster head periodically, so lots of energy is saved in the wireless sensor network.

Low-energy adaptive clustering hierarchy (LEACH) is a popular energy-efficient adaptive clustering algorithm that forms node clusters based on the received signal strength and uses these local cluster heads as routers to the base station [16]. LEACH is an application-specific data dissemination protocol that uses clusters to prolong the life of the wireless sensor network. LEACH utilizes randomized rotation of local cluster heads to evenly distribute the energy load among the sensors in the network [4]. LEACH uses three techniques namely (i) randomized rotation of the cluster heads and corresponding clusters, (ii) localized coordination and control for cluster set-up and operation, and (iii) local compression to reduce global communication. LEACH clustering terminates in a finite number of iteration, but does not guarantee good cluster head distribution and assumes uniform energy consumption for cluster heads.

3. Sensor Network Model

3.1. Radio Model

We are using the same condition in LEACH with the simple model for the radio hardware energy dissipation, as a shown Fig.1. L is the number of bits per packet transmission and d is distance between the sender and the receiver [11]. Electronics energy consumption is same for transmitting and receiving the data, is given by,

$$E_{TX\text{-}elec}(L) = E_{RX\text{-}elec}(L) = E_{elec} * L \qquad (1)$$

E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit.

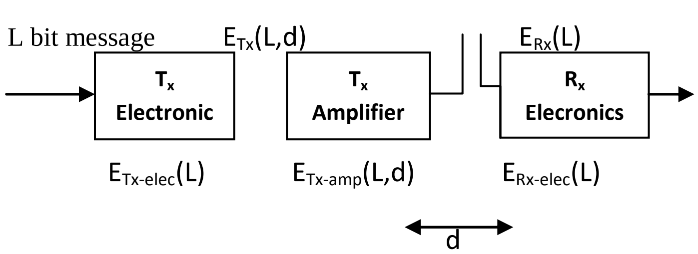

Figure 1. Radio energy dissipation model

Transmission cost to transmit L-bit message between any two nodes over distance d is given by the following equation:

$$E_{TX}(L, d) = E_{TX\text{-}elec}(L) + E_{TX\text{-}amp}(L,d) \qquad (2)$$

$E_{Tx\text{-}amp}(L, d)$ is the amplifier energy consumption and it can be further expressed in terms of ε_{fs} or ε_{mp}, depending on the transmitter amplifier mode that applied. They are power loss factors for free space (d^2 loss) when $d < d_0$; and multipath fading (d^4 loss) when $d \geq d_0$, respectively. The threshold d_0 can be determined by equating the two expressions, resulting:

$$d_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}} = 87.7m \qquad (3)$$

Thus, to transmit L-bit message within d distance, a node expends:

$$E_{TX}(L, d) = L*(E_{elec} + \varepsilon_{fs} * d^2) \qquad \text{if } d < d_0 \text{ or}$$
$$E_{TX}(L, d) = L*(E_{elec} + \varepsilon_{fs} * d^4) \qquad \text{if } d \geq d_0$$

To receive L-bit message within d distance, a node expends:

$$E_{Rx}(L) = E_{Rx\text{-}elec}(L) = E_{elec} * L \qquad (4)$$

4. Proposed System

4.1. Assumptions

In this paper we are proposing an energy efficient event-driven data collection scheme in a cluster based wireless sensor network. Event detection and data collection are the means to identify environmental events by randomly deployed and cooperatively working sensors. Following are the assumptions of wireless sensor network:

- Nodes are uniformly distributed in network and they are stationary after deployment.
- Each Sensor node has the same initial power.
- Sensor nodes are organized into clusters and it has cluster head (CH) and cluster member.
- The Base Station (i.e. data sink) located far away from the sensing field and it is stationary after deployment.
- The Base station (BS) has the information about the location of each node and the location of gateway nodes.
- Clustering is performed after every predefined interval (T_{Intvl}) to distribute the load on overall network.
- The communication range of the sensors is fixed.

- All nodes consume same energy for transmission and reception.
- Energy of transmission depends on the distance (source to destination) and data size.

4.2. Proposed Algorithm

4.2.1. Selection of node for detecting and reporting the event

- When an event occurs, sensor nodes which have that event in their sensing range will detect it.
- Each sensor node has a fixed communication range i.e. Fixed coverage area.
- All the detector nodes start the in-network data processing to select the node which will transfer the data to sink node based on the residual energy and distance to the base station. Sending the sensed data by all the detector nodes may lead to network congestion along because of redundant data.
- For example, A cluster is consisting of a CH, Cs (C1, C2, C3…) which are at a distance (d1,d2,d3… respectively) from cluster head(CH). When an event occurs, all the C1, C2, C3 which have that event in their sensing range will detect it. If all the Cs transmits the detected event to CH, then this will results in data redundancy and energy depletion.
- For above problem we have proposed an approach that is, the Cs will perform an in network data processing which will helps in finding, which C is having maximum residual energy and at the shortest path to CH . Thus the node is selected to communicate the event to CH which will avoid data redundancy and energy depletion.
- Calculate the energy required to transmit the event data to the CH from the detector nodes using the energy model. The sink node is assumed to know all sensor nodes in fixed location that are having a limited energy. Also calculate residual energy after transmitting the data, to find out the node with the maximum residual energy after transmitting the event data to CH.

4.2.2. Energy efficient Routing

- One of the detector node checks the distance from other detector nodes to CH and residual energy of neighbouring node.
- Compute the possible shortest path from the elected node to CH.
- Compute the total energy required to transmit the data from elected node to CH.

Total remaining energy after transmitting the data using first shortest path $E_{fs} = E_{trfs} - E_{rfs}$. E_{trfs} is total residual energy of first shortest path, E_{rfs} total residual energy required to transmit the data using first shortest path.

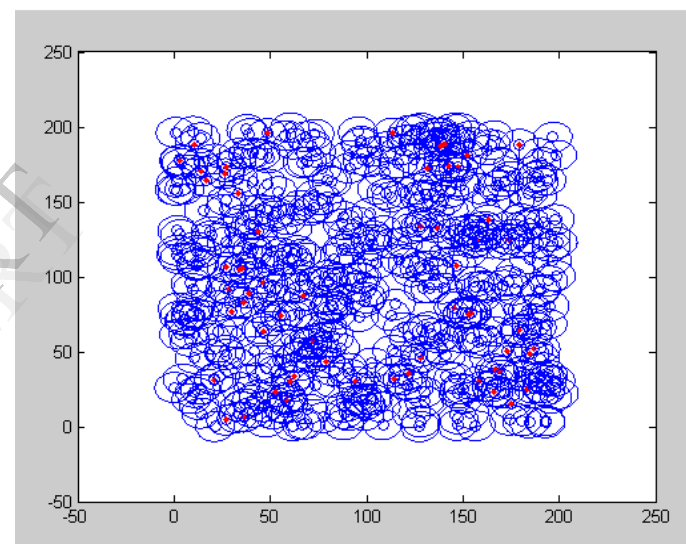

Figure 2. Sensor node deployment with dead nodes and the area covered by each node

4.3. Pseudo codes

4.3.1. Pseudo code for node deployment

1. N: no. of nodes
   S: array to store the node's location
   XR: array to store values of X co-ordinates for N nodes

   YR: array to store values of Y co-ordinates for N nodes
   $X_m = 200$, $Y_m = 200$ /* Field Dimension*/
2. For i=1 to N
3. XR(i)=random(1,1)* X_m
4. YR(i)=random(1,1)* Y_m
   /*initially there are no cluster head*/

5. S(i).Type='N'
6. temp_rnd = i
7. if (temp_rnd>m*n+1)
8. S(i).E=E_o /*initial energy E_o=0.5*/
9. Plot normal nodes.
10. End
11. End

/*plot base station with following co-ordinates.*/

12. S(N+1).xd=0.5* X_m
13. S(N+1).yd=0.5* Y_m

4.3.2. Pseudo code for finding the node at which the event occur

1. RandNode<- random(1,500)
2. RNode <- int8(100*RandNode)
3. Node= RNode(1)

4.3.3. Pseudo code for finding point of coverage

1 s_range: Range of Sensor Node
N: No. of nodes
2 set s_range
3 for i =1 to N
4 theata equals to 0 to 2*pi
5 node co-ordinate x is assigned to XR(i)
6 node co-ordinate y is assigned to YR(i)
7 xp = 2*s_range*cos(theata)
8 yp = 2*s_range*sin(theata)
9 display the points
10 end
11 extract first value from node co-ordinate x
12 extract first value from node co-ordinate y
13 call circlepoints (x,y,2*s_range)
14 For i= 2 to N
15 x1 ← XR (i)
16 y1 ← YR (i)
17 call circlepoints (x1,y1,2*s_range) for n node
18 end

4.3.4. Pseudo code for cluster head selection

1 For each round
2 Threshold is set to (P / (1 – P * (round% 1/P)))
3 if all nodes have been cluster heads
4 For each node
5 Reset used to '*' /* meaning the node can be used as cluster head*/
6 Reset node renewal to 0 /*start count of nodes that have been elected over*/
7 end
8 while Cluster Head count < Needed cluster heads
9 Reset node count /*start at the beginning of nodes
10 while (Cluster Head count < Needed Cluster heads) && (node < the total number of nodes)
11 Assign a random number
12 if (random number < threshold value) && (the node has not been cluster head)
13 Node is Cluster head /*assign node id to cluster head list*/
14 Set coordinate x /*assign all of node members to cluster head id*/
15 Set coordinate y
16 et energy amount
17 Set node as been used /*node id has been marked used */
18 Increment cluster head count /*a new cluster head has been added*/
19 go to the next node
20 end
21 else go to the next node
22 end

4.3.4. Pseudo code for generating clusters

1 For each node
2 if node is a cluster head
3 go to next node
4 else
5 for each cluster head
6 node coordinate x is assigned to x1
7 node coordinate y is assigned to y1
8 cluster head coordinate x is assigned to x2
9 cluster head coordinate y is assigned to y2
10 if it is the first cluster head
11 the distance between node and cluster head is the least distance
12 cluster head id is assigned as closest cluster head to node
13 end
14 else
15 Distance between node and current cluster head is current distance
16 if current distance < least distance

17 Current distances is now assigned to least distance
18 cluster head id is assigned as closest cluster head to node
19 end
20 end

4.3.5. Pseudo code for transmission and simulating reception

1 if distance between detectnode and cluster head is <= the transmission range
2 If d(detectnode1, CH) >= d(detectnodenext,CH)
3 Transmission cost is
E_{TX} (L, d) = L*(E_{elec} + ε_{fs} *d^2) if d < d_0 or
E_{TX} (L, d) = L*(E_{elec} + ε_{fs} *d^4) if d ≥ d_0

4 Reception cost is E_{RX} (L) = Eelec * L
5 Subtract the transmission cost from the sending node
6 if remaining energy <= 0
7 display node has died
8 exit the program
9 end
10Subtract the reception cost from the receiving node
11 if remaining energy <= 0
12 display node has died
13 exit the program
14 end
15 return the sum of transmission cost and reception cost
16 end
17 end

5. Simulation and Performance evaluation

All simulations have been implemented using MATLAB. Assuming that 500 nodes are randomly distributed in field of 200x200. The simulation parameters are given in Table 1. The performance of the proposed protocol scheme is compared with that of the Leach protocol.

5.1. Simulation Parameter

Table 1. Simulation Parameters

Simulation Round	500,1000,1500,2000
Sink Location	(100,100)
Network Size	200*200
Number of nodes	500
CH probability	0.05
Initial node power , E_o	0.5 Joule
Nodes Distribution	Nodes are uniformly distributed
Data Packet size	4000
Energy Dissipated per bit, E_{dpb}	50nJ/bit
Constant for amplifier energy consumption. E_{fs}	100pJ/bit/m^2

5.2. Simulation Results

5.2.1. Network Life Time

When a node is dead, it will not be the part of the network. If a dead node occurs in early rounds, this may affect lifespan of the network or results into early dead of all nodes. Table 2 shows the simulation results of the two schemes. Figure 3 concludes that in the proposed algorithm, the first node dies later in the network.

Table 2. Network Life Time (First node dead)

No. of rounds	LEACH	PROPOSED PROTOCOL
500	367	0
1000	345	683
1500	338	741
2000	346	723

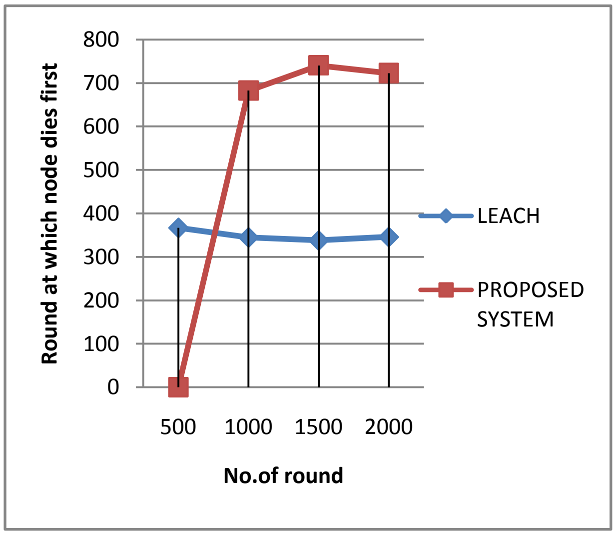

Figure 3. Network Life Time (First node dead) v/s No. of Simulation runs

5.2.2 Network Lifetime with Number of Dead nodes

More dead nodes show the decrease in network life time. Table 3. show the number of nodes dead in the network with the increase in number of rounds. It is very clear from the results that the lifetime of WSN using proposed scheme is better compared to Leach Protocol.

Table 3. No. of dead nodes vs. Rounds

No. of rounds	LEACH	PROPOSED PROTOCOL
500	341	0
1000	499	62
1500	500	494
2000	500	498

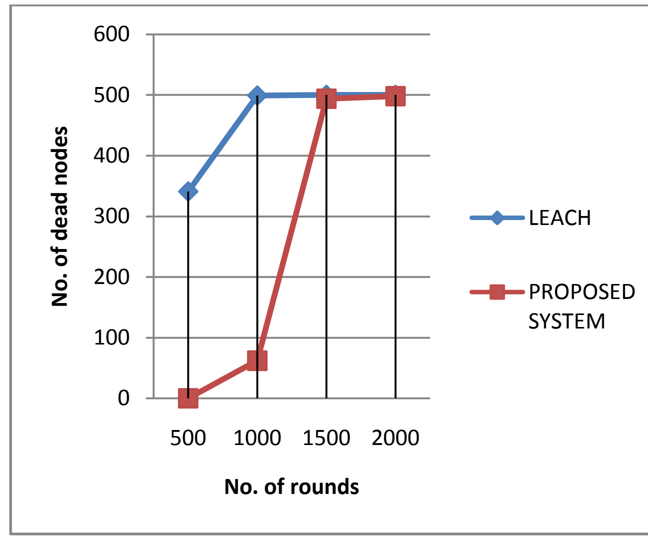

Figure 4. Network Life Time (Dead nodes) v/s Number of Rounds

5.2.3. Maximum residual energy versus Simulation runs

As shown in the Figure 5, the total residual energy of the nodes decreases in small stages. But comparing to LEACH, an Energy efficient clustering approach, the proposed approach makes sure that more residual energy persists with sensor nodes.

Table 4. Maximum residual energy

No. of rounds	LEACH	PROPOSED PROTOCOL
500	0.042241	0.36016
1000	0.041365	0.19006
1500	0.037083	0.079736
2000	0.036713	0.041122

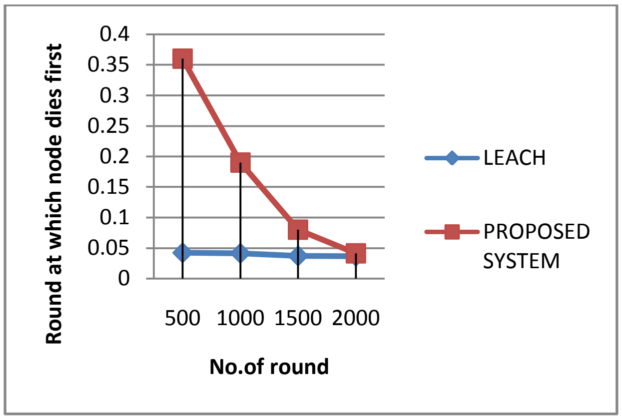

Figure 5. Maximum residual energy versus Simulation runs

6. Conclusion

There are many methods for event driven data collection and reporting system that are basically designed for achieving the energy efficiency using routing protocols but mostly they emphasize on the data redundancy before communicating to the base stations. The redundant data communication results into the loss of large amount of transmission energy. By the use of in-network processing, our proposed system reduces energy depletion, reduces data redundancy at the same time increases the energy efficiency.

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