Energy Efficient Routing Protocol for Wireless Sensor Networks with Multiple Sinks

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***Abstract*- Wireless sensor network is a network of self-directed tiny sensor devices. Sensor nodes collect data from their surrounding environment and send these data to sink for post data analysis. The current popular application domains of sensor networks are environment, health, home, military, security and commercial areas. In this paper we have proposed an energy efficient routing protocol for wireless sensor network with multiple sinks. This proposed protocol ERPWSN works on the concept of optimal energy consumption. The ERPWSN has four phases as Updating Information, Selection of Cluster Head, Labeling and Data Routing. The cluster formation based on energy of sensor nodes and path switching. The CH forwards collected data to the sink which is at minimum distance from CH. If two sinks are at same distance then we consider energy of sinks.**

We have compared this proposed protocol ERPWSN with the standard routing algorithm LEACH and Multi Sink routing algorithm ERMSS. In the simulation result, it states that our proposed protocol has better performance.

Keywords- ***Wireless sensor network (WSN); Single Sink; Multi sink; Hotspot Problem; network lifetime; energy efficient routing; Cluster Head (CH)***

I. INTRODUCTION

Wireless sensor networks are one of the most rapidly developing information technologies. It consists of a collection of static sensors that monitor the physical environment. Wireless sensor network consists of a large number of sensor nodes, each equipped with three basic functional components: a sensing unit, a processing unit and a transceiver unit. Sensor networks can be potentially used for a broad spectrum of applications across various domains. We hope that in future everything is connected via wireless sensor networks using internet. Wireless sensor networks are powered by battery and generally deployed in dangerous regions. In these regions it is very difficult to change the battery of sensor nodes. Early deployments of wireless sensor network were based on many to one. Example for habitat monitoring a single sink collects environmental data from large number of sensor devices. Now a day if same wireless sensor network serving multiple applications then there is need of multiple sinks. Since the sensor node has limited battery, weak capability of storage then some problem may occur. The node which is closer to sink has to transfer more data. These nodes consume more energy than the node which is in remote areas. To overcome all these problem multi sink have advantage of dispersion, stability, battery power consumption and robustness. Multi sink can balance energy consumption and increases the network life time. Compared to single sink topology multi sink allows sensor nodes to choose different sink node based on their own situation. Due to this it will reduce average transmission distance between sensor nodes and sink node. In this way energy consumption is balanced.

We have compared this proposed protocol ERPWSN with standard routing protocol LEACH [1] and a multi sink routing protocol ERMSS [6]. We have compared average remaining residual energy of the sensor nodes of our proposed algorithm (ERPWSN) with LEACH [1] and ERMSS [6]. We have also compared network lifetime of the sensor nodes of our proposed algorithm ERPWSN with LEACH [1] and ERMSS [6]. This algorithm considers efficient energy consumption and ensures the optimal path from sensor nodes to sink.

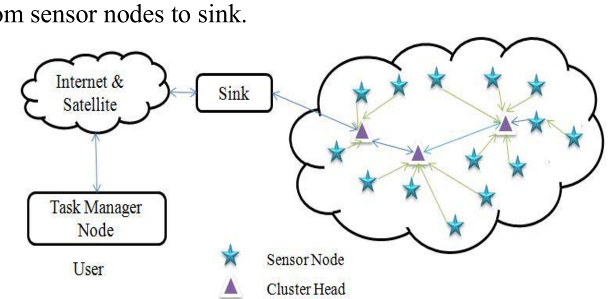

Figure 1. Architecture of Wireless Sensor Network

II. BASICS OF WIRELESS SENSOR NETWORK

A. Limitations of Wireless Sensor Network

One of the major limitations of Wireless sensor network is that it lies on the complexity of logistics involving selective replacement of sensors that have run out of energy .Wireless sensor network does not reduce the cost for installation of sensor. In WSN it is difficult to change battery of sensor nodes in remote areas. If sensor nodes are deployed in sea then it is difficult to change battery of sensor nodes. In battle field also it is quite difficult to change battery of sensor nodes [14]. Limited battery power is main challenge for the deployment of sensor nodes.

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B. Applications of WSN

In future, we hope that wireless sensor network will be used in every field of human life and everything will be connected via internet using WSN. WSNs are used in industrial applications to monitor information that would be complicated to monitor using wired sensors. Typical applications of WSNs include monitoring, tracking and controlling. Some of the specific applications are habitat monitoring, object tracking, nuclear reactor controlling, fire detection and traffic monitoring [15]. In a typical application WSN is scattered in a region where it is intended to collect data through its sensor nodes. Some more applications of wireless sensor networks are in civil structural health monitoring, monitoring groundwater contamination, rapid emergency response, industrial process monitoring, perimeter security surveillance, automated building climate control, habitat monitoring and environmental monitoring.

C. Routing with Single Sink

If routing is done by using single sink then sensor nodes have to wait to send data to that sink. In multi sink with fixed trajectory the choice of mobility path influences energy efficiency is possible. On the other hand in single sink applications sensor nodes spend a rather large fraction of their total lifetime in waiting to send data to sink.

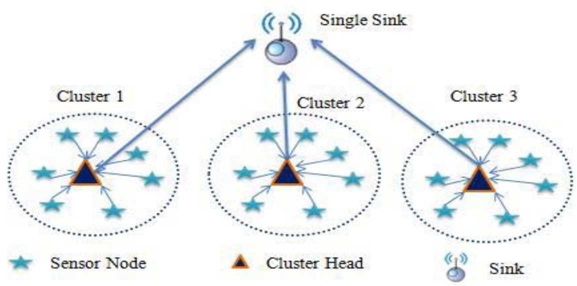

Figure 2. Single Sink Wireless Sensor Network

d) Hot Spot Problem in Single Sink

In single sink the node which is nearer to sink is busy in sending it's own data and also it's preceding sensor nodes data, due to this the energy of these nodes decreases rapidly. Hence it creates holes in the network. This problem is called hot spot problem. In particular we are interested in the isolation of the sink node caused by the depletion of the energy of the sensor nodes to their surroundings. Multi sink minimizes this problem.

e) Why Multi-Sink?

Multi Sink routing is generally needed for distant sensor nodes from the sink to save energy. The nodes nearer to the sink can be burdened with relaying a large amount of traffic from other nodes. This phenomenon is called as energy hole problem or crowded center effect problem. It results in energy depletion at the nodes near the sink too soon which leads to the separation of the sink from the rest of the nodes that will have plenty of energy.

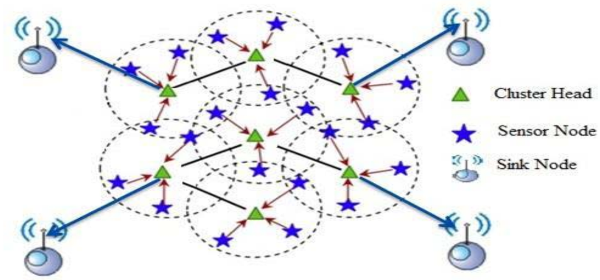

Figure 3. Multi Sink Wireless Sensor Network

In this work of Energy efficient routing protocol for wireless sensor network with multiple sink (ERPWSN) this paper is organized as follows: Section III - briefly reviews some of the related work, Section IV- describe system model, Section V- has proposed protocol, Section VI- presents experimental results and Section VII -conclusion.

III. RELATED WORKS

There exist many routing protocol for wireless sensor network. In the area where we are deploying sensor nodes, there is a possibility to deploy more than one sink to collect data from the sensor nodes. The collected data forwarded to the nearest sink available from the cluster head based on our proposed protocol which are discussed in section v.

A. Single Sink Problem

The sink acts as an association between the network and the outside world such as Internet. In many applications sensor nodes are deployed in hostile areas, battlefields, remote geographic region and toxic urban locations. Recharging the batteries of the sensor nodes manually in such places is extremely complicated. It also requires that the network should operate autonomously for a long period of time under energy constraints. Therefore energy consumption of the sensor nodes is the major challenge for long run of the WSN [6]. In single sink the main problem is data transmission delay and energy of sensor nodes. It is difficult to change battery of sensor nodes in remote places.

B. Multi sinks

In WSN multi sink overcomes the problem on single sink. Multi sink technique minimizes the energy consumption of sensor nodes. One of the most important design criteria in wireless sensor network is energy efficiency .The system designer would always consider the limited battery power of the sensor nodes at each network decision. In this proposed algorithm we are finding level based on the minimum distance from sink. The Proposed algorithm ERPWSN for multi sink not only considers distance between nodes well manner but also considers the energy of the sensor nodes and selects appropriate sink based on distance. Moreover, it ensures the load of CHs with respect to their residual energy.

C. Some existing routing protocol is as follows

i.) LEACH

LEACH [1] is a hierarchical routing protocol in WSN. In LEACH protocol selection of CH is random and each node has a chance to become CH. The energy consumption of sensor nodes is different. The operation in LEACH is divided into rounds. Each round contains a set-up stage, where each sensor node picks a random number between 0 and 1 to decide whether it will become a cluster-head or not. If a node of very less energy becomes CH then network lifetime of network reduces.

ii.) TEEN

TEEN [2] stands for Threshold sensitive Energy Efficient sensor Network protocol. TEEN has developed for reactive networks. TEEN is threshold sensitive hierarchical routing protocol. In this protocol CH sends a hard threshold and a soft threshold to its members. TEEN provides efficient energy consumption of time critical sensing applications.

iii.) HEED

HEED [5] is a distributed clustering algorithm. It distributes energy consumption in whole networks to increase the entire network lifetime. At the time of CH selection HEED also consider residual energy of the sensor nodes in the WSN.

iv.)PEGASIS

PEGASIS [3] is improvement of LEACH. PEGASIS is using greedy algorithm to form a shortest distance between neighbor nodes such that each node can send information at lowest cost. CH selection in PEGASIS is random.

v.)ERMSS

ERMSS [6] minimizes the number of links by maximizing the overlapping of the paths along which data is routed from a given source to a given sink. For high degree of overlapping among source-sink paths, this protocol uses adaptive scheme.

IV. SYSTEM MODEL

In this paper, we assume that a set of uniform sensor nodes are deployed arbitrarily in some regions. It is very difficult to recharge the battery of sensor nodes in remote areas. Multiple sinks are located outside the area under observation. Nodes are left unattended after deployment. Therefore, battery recharge is not possible. Initially, all the sensor nodes are charged with same amount of energy. The Link is symmetric and bidirectional. All the sensor nodes are organized into distinct clusters. The data sensed by sensor nodes transmits to their corresponding CH. The work of Cluster Head is to collect the data from sensor nodes and send these collected data to the sink for post data analysis. CH sends the aggregated data directly to the sink via shortest path.

Let we want to transmit k bit data to distance d then the ratio of hardware energy consumption is given as

$$E_{Tx}(k,d)= E_{Tx\_elec}(k) + {}_{ETx\_amp}(k,d)$$

Where E_{elec} is the factor of energy consumption.

We make basic assumptions as follows:

a. After deployment all sensor nodes are static.
b. Each sensor node knows distance to its neighbors.
c. Each sensor node knows the distance to each other.
d. We assume ideal MAC layer conditions.
e. The communication links are symmetric.

V. PROPOSED PROTOCOL

The proposed algorithm is divided into following phases: updating information, cluster Head Selection, labeling and data routing. They are subsequently described in the following Algorithm sections

ALGORITHM

Step 1: Each sensor nodes i=1 to n broadcasts a control message to all of its neighbor sensor nodes to convey its existence in the wireless sensor network.

Step 2: The message contains its identification number and locality information. If some other sensor node receives the message then it updates its neighbor routing table.

Step 3: The timer *t* (*i*) of node *i* is derived as

$$t(i) = \left(\frac{E_r(i)}{E_m(i)} \right) \times T_{CH}$$

Where $E_r(i)$= Residual energy of sensor node
$E_m(i)$= Maximum energy of sensor nodes

If timer expires, the node selects itself as a CH and broadcasts a CH advertisement message within its cluster radius in wireless sensor network.

Step 4: The whole region of the WSN is divided into various levels. Each node has to find its sink, which is decided based on the distance of the nodes from the sinks.

```
if(s[i].isCh==1)
L1= sqrt(pow((s[i].x-(A/2)),2) + pow((s[i].y),2))/rad
L2= sqrt(pow((s[i].x-(A/2)),2) + pow((s[i].y - (A)),2))/rad
L3= sqrt(pow((s[i].x),2) + pow((s[i].y - (A/2)),2))/rad
L4= sqrt(pow((s[i].x-(A)),2) + pow((s[i].y - (A/2)),2))/rad
```

Step 5: Let $L(CH_i)$ denote the level of the cluster head i. Then $L(CH_i)$ is calculated as follows

$$L\,(\text{CHi}) = \left\lceil \frac{D_{(CH\ ,\ \sin\ k)}}{R_c} \right\rceil$$

Step 6: In Data Routing phase we have considered number of cluster member and energy of the node. Each CH selects a higher level CH from which it receives the acknowledgment. If CH receives acknowledgment from (H_1, H_2...H_n), now among these nodes it selects the one having same sink id as well as least number of cluster member, if the number of cluster member is same then it selects the one having more energy. Data is send via those nodes which have less number of CH.

Step 7: By doing this all the CHs provides a path to their corresponding sink, thereafter the packets can be relay to the sinks.

VI. SIMULATION

Performance Evaluation

We compared the proposed algorithm in terms of network lifetime and the residual energy with the single sink [1] and multi sink routing algorithms [6]. In our experiments, we compute the network lifetime in 1000 rounds. To support network lifetime, we too measured amount of average residual energy of the sensor nodes per round. Simulation run was carried out using Dev C++ and Matlab. The parameters with their emblematic values used in the simulation run are listed in Table 1.

TABLE I. PARAMETERS AND THEIR VALUES

Parameter Name	***Notation***	***Value***
Target area	A	40 ×40 m sq.
Sink location	S	(0,0)
No. of sensors	N	60 – 100
Residual energy	E_r	0.02 Joules
Tx range	R	5m
Control packet size	C_p	100
Data packet size	D_p	500
Free space (ε_{fs})	ε_{fs}	10pJ/m^2/bit
Multi-path fading (ε_{mp})	ε_{mp}	0.0013 pJ/bit/m^4
Tx or *Rx* electronics	α_{tx} or α_{rx}	50nJ/m^2/bit

a) Network Lifetime:

From fig. 4 we can see that our proposed algorithm ERPWSN has better performance with respect to single sink [1] and multi sink [6] algorithm. In single sink as the load on the nodes are higher as it has to send data to a fixed sink that may be further away from the CH. But in multi sink approach, data are distributed among the sinks based on the sink which is nearest to the CH. These clearly justify our success over the single sink approach. Then, we have selected the cluster head based on energy that balances the load among the sensors. Data is routed via least number of neighbors.

Simulation Results of the comparison between ERPWSN, LEACH [1] and ERMSS [6] for the Network Lifetime:

Pseudo Code:
Step1: rounds = 1: 1000
Step2: ERPWSN = [150 ... 150 ... 100 ... 8 ... 1]
Step3: LEACH = [150 ... 143 ... 137 ... 55 ... 0]
Step4: ERMSS = [150 ... 125 ... 4 ... 2 ... 0]
Step5: graph

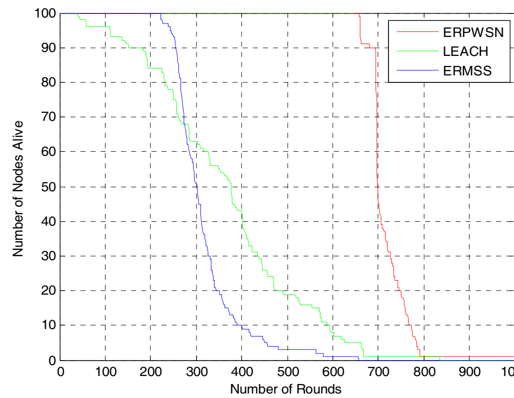

Figure 4. Network lifetime of various algorithms (n = 100)

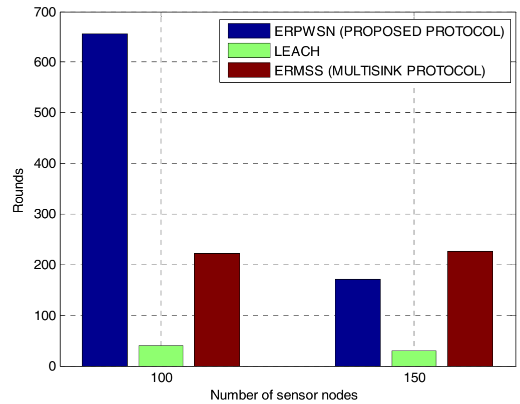

Figure 5. Network lifetime (FND)

b) Energy Efficiency

We also considered the average residual energy of the sensor nodes in the network to justify the lifetime of the sensor nodes. As shown in Fig. 5 we find that the proposed algorithm ERPWSN performs much better as [1],[6] because we are taking energy into consideration while selecting CH that balances the energy, again while selecting the routing node we are considering the number of neighbors of parents that also balances load among the regions of the wireless sensor networks.

Simulation Results of the comparison between ERPWSN, LEACH [1] and ERMSS [6] for the Network Lifetime:

Pseudo Code:
Step1: rounds=1:1000
Step2: ERPWSN = [0.049929 0.049859 ... 0.000670]
Step3: LEACH = [0.049823 0.049665... 0.000000]
Step4: ERMSS = [0.049826 0.049651 ... 0.000000]
Step5: Graph

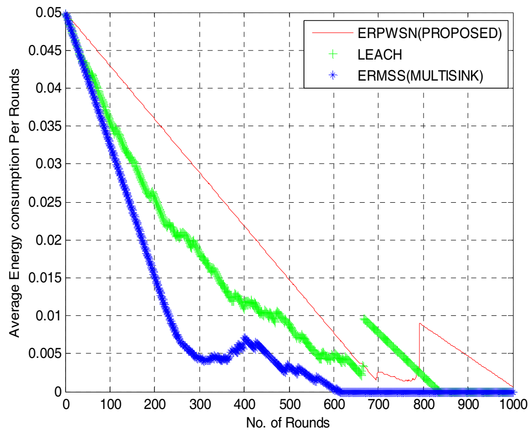

Figure 6. Average remaining residual energy of the sensor nodes

VII. CONCLUSION

The Multi Sink Protocol helps to solve the Hot Spot problem in wireless sensor networks. The energy problem in sensor nodes can be optimized by using more than one sink in the area of wireless sensor networks. We have proposed an Energy efficient Routing protocol for wireless sensor network with multiple sinks. The result of ERPWSN clearly shows that multi-sink approach can overcome the energy problem of sensor nodes in WSN, as the nodes can route their packets to a shorter distance. Clearly proposed algorithm has better average remaining residual energy and network lifetime.

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