Event Based Energy Efficient Routing Protocol for Wireless Sensor Networks (WSNs)

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***Abstract*--Sensor nodes that are deployed in the wireless sensor field are equipped with limited energy power. The most important problem in the wireless sensor network is to develop the energy efficient, reliable and robust routing protocol. To achieve these targets, we have proposed a new Event-based Energy Efficient Routing Protocol (EBEERP). EBEERP is also concerned to the reliable data dissemination in the wireless sensor network. In this protocol, we have used the Tier based architecture for data dissemination among the sensor nodes. We have simulated the results of our protocol with LEACH and PEGASIS and observed that it is 7.5 times better than LEACH and 2 times better than PEGASIS.**

***Keywords*: Event driven, DGD node, Gateway node, DTC range, WSN.**

I. INTRODUCTION

A wireless sensor network is a network consisting of small and smart sensor nodes which can communicate each other via wireless communication network. WSNs have the self organizing ability that permits one to access data from dangerous and hostile environments. Wireless sensor networks are being used in many applications that include [1,2] agriculture, battle field and military surveillance, habitat monitoring, security intelligence, border patrol, health monitoring, early warns to natural disasters like wild life tracking, forest fire, industrial process controlling, smart transportation etc. Wireless sensor nodes are highly restraint to the amount of battery power which limits to the network lifetime [3,4,15]. With concerned to the limited battery power, it is quite necessary to design a protocol which saves more energy in receiving and transmission of data as most of the sensor nodes' energy is dissipated at dissemination of the data from one node to another[13,14]. In this paper, we have used Tier based architecture for designing an energy efficient protocol in respect to data dissemination through which we can prolong the network lifetime. The designed protocol also fulfills the requirement for the reliable and robust dissemination of data in the wireless sensor network.

II. RELATED WORK

LEACH [5] is the first cluster-based routing protocol in wireless sensor network, which is based on the formation of the cluster heads randomly and distributed the energy load evenly among the clusters. The cluster heads collect the data from their respective sensor nodes in their cluster, aggregates the data and send it to the sink. In case of LEACH, cluster heads are not selected statically, they will lose their energy and die rapidly [6]. Instead of this LEACH uses the rotational policy so that all the sensor nodes one by one will act as the cluster head by this the energy of every node will equally diminish and avoid the battery power depletion of an individual sensor node. In LEACH the selection of cluster heads is based on some probability and after selection CH broadcast their condition (status) to all the sensor nodes in the whole wireless sensor network. Without any negotiation among all sensor nodes, any sensor node can become cluster head (CH). A sensor can decide to be a CH on the desired percentage P of the cluster heads, the current round, and the set of sensors that have not become cluster heads in the past 1/P rounds. If the number of cluster heads is < T(n), a sensor node n will become a CH for the current round, where T(n) is a threshold as,

$$T(n)=\begin{cases}\frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} & \text{if } n \varepsilon G,\\ 0 & \text{otherwise}\end{cases}$$

The main restriction (limitation) of this protocol is that it does not fit for the non-occasional event delivery and the clusters can be again build within the range of another cluster that may cause uneven distribution of load [7,8]. PEGASIS is the another protocol proposed in [12] which is the improvement over the LEACH that allow only one cluster head in the wireless sensor network to transmit the data the sink in each round. PEGASIS is the chain based routing algorithms that can reduce the energy consumption, but it causes a longer delay of data transmission. In case of PEGASIS, a sensor node has to transmit its data to its local neighbor instead of sending the data directly to the cluster heads. However, sensor nodes in PEGASIS acts as the chain head in turn. The sensed data is forwarded and aggregated at each node. The chain head to transmit the aggregated data to sink. Direct Diffusion [9] is a data-centric and application based protocol in the sense that all the data generated by the wireless sensor nodes are named as attribute value pairs. The key idea of Direct Diffusion is to aggregate the data coming from different sources and to minimize the transmission loads by eliminating redundancy. HEED [10] is a distributed clustering approach in which cluster head nodes are elected on hybrid of available energy level and communication cost. Unlike LEACH, it does not select cluster heads randomly. The energy consumption is not assumed uniform in HEED for all the sensor nodes and that's why it is adaptive to the unpredicted traffic pattern. However, in HEED the routing is based on the greedy forwarding approach that may cause energy holes near the sink.

III. NETWORK AND RADIO MODEL

Let us assume that *N* sensor nodes are evenly distributed in the circular area *A* with a base station controller (BSC) at the center for the formation of the wireless sensor network. We denote *i* – th sensor by u_i and corresponding sensor node set $U = u_1, u_2, u_3, \ldots, u_N$ *where* $|U| = N$. We have organized the whole network into the Tier architecture centered with BSC (base station controller). In case of Tier architecture, the tiers are numbered 1,2,3……n as innermost is Tier 1 which is nearest to BSC. The radius of Tier 1 denoted by R from BSC. The Tier 2 is the next tier from Tier 1 whose distance from the inner tier is R and its radius from BSC is 2R and so on (as shown in fig. 1). All sensor nodes have the same capability of processing and communication. Sensor nodes can use power control to vary the amount of transmission power according to the distance of the recipient node. Sensor nodes are location aware through the Global Positioning System (GPS). The routing used in our approach is hop by hop, at each hop the sensor node has the tier number in its packet which is destined for the node of lower level tier. According to this way, the routing can be done at the level of addressing of the tier, which has much less overhead compared to have one routing address per node [11]. Our protocol is also using the RTR (Request to Relay) and CTR (Clear to Relay) messages concept discussed in AIMRP [11] for the communication among the sensor nodes within a Tier or between the Tier structure.

Our protocol is also equipped with the power saving mode to reduce the energy expenditure at the time of *idle listening*. According to our protocol, it is quite waste of energy for all the sensor nodes to keep their radio module on for all the time. Whenever, any event occurs the sensor nodes should listen that event and respond accordingly otherwise it should keep its radio module off. For this, our protocol relies on sleep and awake pattern at each sensor node. We have exploited the same radio model as discussed in LEACH [5] and PEGASIS [12]. According to these models, a radio dissipated $E_{elec} = 50$ nJ/bit to run the transmitter and receiver and $\varepsilon_{amp} = 100$ pJ/bit/m^2 for the transmitter amplifier.

The equations used for the calculation of transmission and receiving costs for a k-bit message at a distance d are given below:

For Transmission, the equation is:

$$E_{Tx}(k,d) = E_{elec}k + \varepsilon_{amp}kd^2 \quad (1)$$

For Receiving, the equation is:

$$E_{Rx}(k) = E_{elec}\, k \quad (2)$$

Other parameters such as Data bit are expressed in Table I.

TABLE I. VARIABLES USED FOR MATHEMATICALANALYSIS AND SIMULATION

TYPE	PARAMETER	VALUE
Transmitter amplifier	ε_{amp}	100 pJ/bit/m^2
Data bit	k	2000
Distance between sensor nodes	d	2m
Number of sensor nodes	n	100

IV. EVENT BASED ENERGY EFFICIENT ROUTING PROTOCOL (EBEERP)

Our protocol is designed for the event driven scenario, where ever any event occurs in the network, it should be responded. Firstly, we will discuss the Formation of Data Gathering & Dissemination Node, then the Formation of Gateway Node.

A. Formation of Data Gathering & Dissemination Node (DGD Node)

The formation of Data Gathering & Dissemination Node (DGD Node) is based on the power level factor of the sensor nodes. The sensor nodes in each tier whose power level will be greater than the neighboring sensor nodes in radius R will be elected as the DGD Nodes (as shown in fig.2). If more than one sensor nodes will be at same power level than anyone of them will be elected randomly for the DGD Node.

All the low power level sensor nodes in the Data Transmission & Collecting Range (DTC Range) of the Data Gathering & Dissemination Node will communicate to it. If any event is generated nearer to these regular sensor nodes, they will forward their data towards the Data Gathering & Dissemination Node. The DGD Node will receive all the data coming from all the neighboring sensor nodes (which are in the DTC Range of DGD Node), fuse their data along with its sensed data and make one packet and forward it towards BSC. The important feature of DGD Node is that it also stores the copy of the data packet which is forwarded to the BSC until its acknowledgment message is not received by it generated by the BSC.

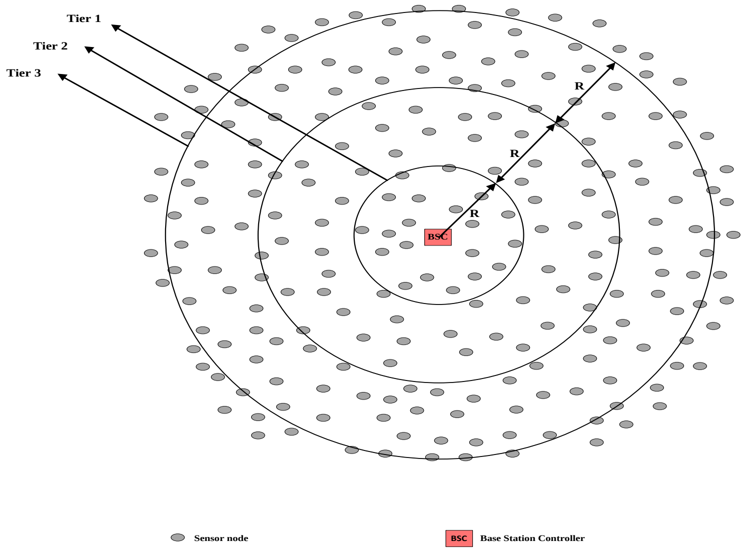

Figure 1. Network model consisting of Tier Architecture.

B. *Formation of Gateway Node*

The formation of the Gateway Node is based on the overlapping area of the two Data Gathering & Dissemination Node's communication radius of adjacent Tiers. The regular sensor nodes (falling in the overlapping area of two DGD Node's DTC Range of adjacent Tiers) in this area whose power level will be maximum will be elected as the Gateway Node (as shown in fig.2). If more than one regular sensor nodes have the same power level, anyone of them will be elected as the Gateway Node.

These Gateway Nodes work as the intermediate nodes for the data packet routing. The Data Gathering & Dissemination Nodes of two adjacent Tiers cannot communicate directly to each other. So, for building the communication channel between two DGD Nodes of adjacent Tiers, these Gateway Nodes work as the intermediate nodes.

All the data packets generated by the Data Gathering & Dissemination Node for BSC are first routed towards this Gateway Node in its path and this Gateway Node forwards the incoming data packets to its lower Tier level Data Gathering & Dissemination Node and so on until all the data packets are not reached to the Base Station Controller (as shown in fig.2).

C. *EBEERP Description*

Our protocol works in the situation when an event occurs in the Network field. Initially, all the sensor nodes are in the sleep state. When any activity or event occurs, the sensor nodes in that area will wake up, listen the event and transmit their data to their nearby Data Gathering & Dissemination Node. All the data will be send by regular sensor nodes will be fused by the DGD Node along with its sensed data. DGD Node will fuse all the data and generates one data packet. This data packet will be routed towards the Gateway Node in the DTC Range of DGD Node, then Gateway Node will forward this data packet to next lower Tier DGD Node until the data packet is not reached to the Base Station Controller (BSC). The DGD Node stores a copy of that data packet until its acknowledgment is not reached, generated by the BSC to acknowledge that the data packet is successfully received by the BSC. The same path in reverse direction is followed by the acknowledgment message to reach till that DGD Node where the event is occurred. If the acknowledgment is not received by the DGD Node, it means that the data packet is lost and not received by the BSC. Again, the DGD Node forwards that data packet following the same path.

For example, (in fig.2) initially, all the sensor nodes are in the sleep state. An activity or event occurs in area S (shown in the fig. by yellow color), all the sensor nodes sleeping in that area wake up and listen the event. They sense and transmit their data towards the DGD Node (of Tier 3) within the communication radius. The DGD Node A receives all the incoming data from its neighboring regular sensor nodes (sensor nodes in the DTC Range of DGD Node A) and fuses their data along its sensed data and generates a data packet and forwards that data packet towards the Gateway Node X in its communication radius. The path followed by the data packet forwarding from DGD Node A to BSC is shown by dark black arrows. Now, the Gateway Node X routes the data packet to the DGD Node B in Tier 2 until the data packet is not reached to the BSC.

If two events occur at different locations in the network, their data generated will be forwards to the BSC following the corresponding path. And if the two events occur at the same location one by one, their data will be forwarded to BSC one after another.

For example, (in fig.2) in Area V an event is also occurred, the sensor nodes will wake up, sense the data and forward their respective data to the DGD node which fall in the Data Transmission & Collecting Range (DTC Range) of DGD Node. The DGD Node will generate a data packet and forward that packet towards the BSC as described above following the path shown in fig. by dark black arrows.

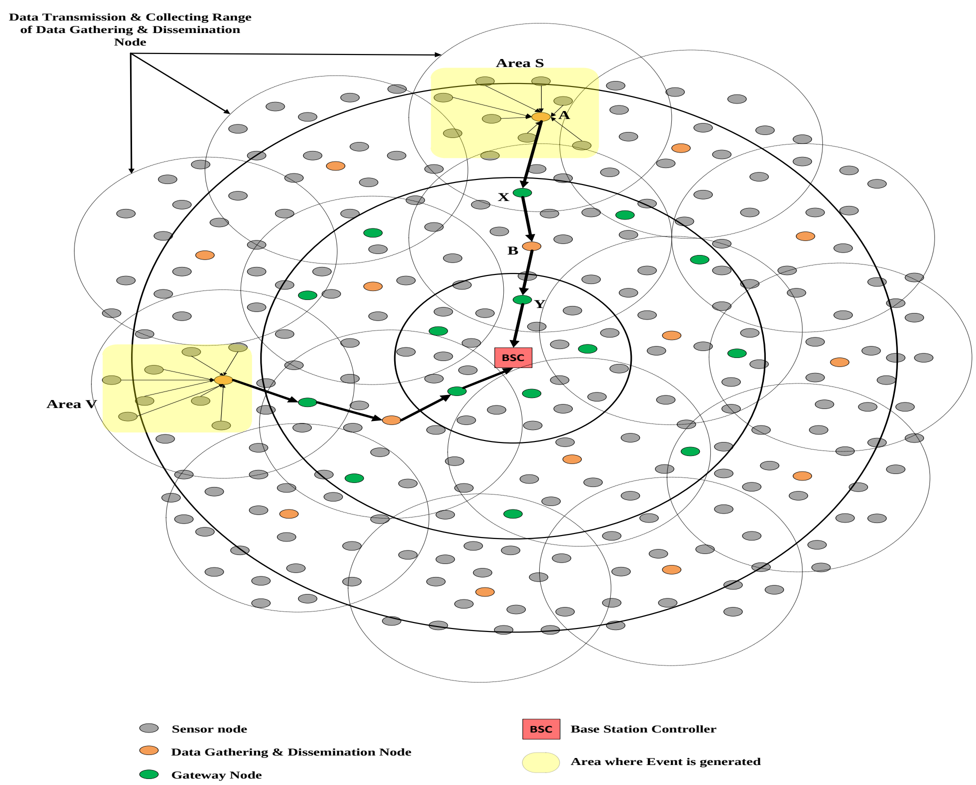

Figure 2. Event driven architecture.

V. EXPERIMENTAL RESULT

Figure 1 shows the randomly deployment of 100 sensor nodes in the network field. To evaluate the performance of our proposed model EBEERP, we have simulated its results with LEACH and PEGASIS protocols in 100 sensor nodes network. The Base Station Controller (BSC) is located at the center of the 100m X 100m field. We have simulated our experimental result to determine the number of rounds of communication when 1%, 25%, 50%, 75% and 100% of the nodes die using LEACH, PEGASIS and EBEERP with each sensor node having the same initial energy level. Figure 3 shows the number of rounds until 1%, 25%, 50%, 75%, 100% nodes die for 100m X 100m network with 0.25 J initial energy per node, 0.5 J per node in Figure 4 and 1.0 J per node in Figure 5. Figure 6 shows the simulation results for the total energy consumption over simulation time. Figure 6 shows that in the beginning, the total energy consumption of our proposed model EBEERP is somehow similar to the LEACH and PEGASIS. However, as the simulation time increases, EBEERP consumes less energy as compared to the other conventional routing protocols. The simulated result shows that our proposed model EBEERP is 7.5 times better than the LEACH and 2 times better than the PEGASIS respectively.

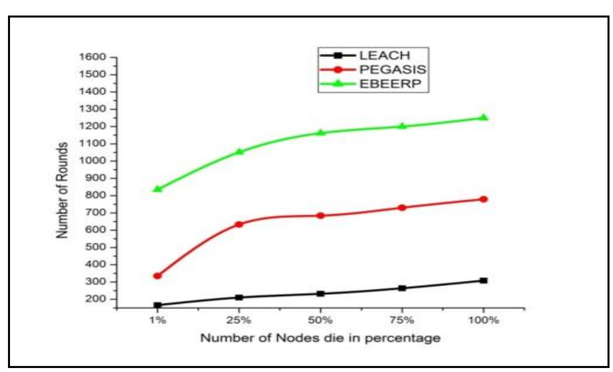

Figure 3: Experimental result for 100m X 100m network with initial energy 0.25 J/node

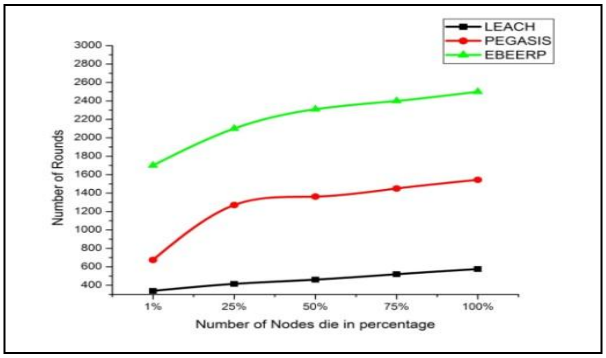

Figure 4: Experimental result for 100m X 100m network with initial energy 0.5 J/node

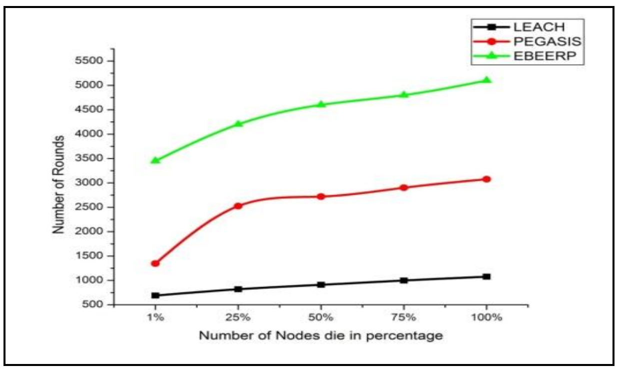

Figure 5: Experimental result for 100m X 100m network with initial energy 1.0 J/node

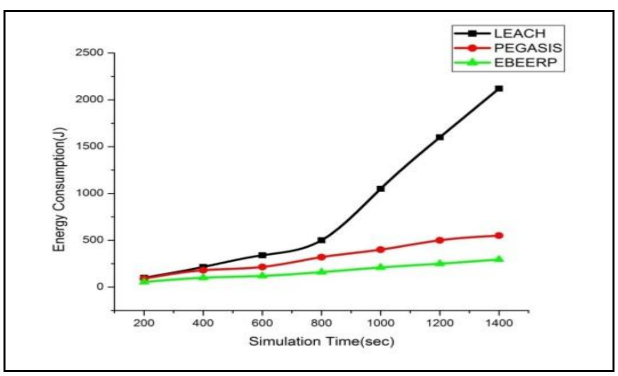

Figure 6: Experimental result showing Energy Consumption over Simulation Time.

VI. CONCLUSION

In this paper, we have proposed EBEERP scheme for energy efficient and reliable routing in WSN. Our experimental and simulation results shows that the proposed EBEERP scheme is 7.5 times better than LEACH and 2 times better than PEGASIS. Our main concerned of designing such a protocol is to run in a disaster management and surveillance system which is highly dense and non-uniform. EBEERP scheme is an energy efficient, reliable and robust protocol which has minimum delay and achieve highly reliable data dissemination in WSN.

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