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Hierarchical Energy Efficient Routing Protocol (HEERP) for Wireless Sensor Networks (WSN)

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***Abstract*– Wireless Sensor Network consists of an enormous number of small disposable sensors which have limited energy. These sensors cannot be replaced once they are deployed, as the users usually have no access to these nodes. In many situations like battle field monitoring, rescue operations, the battery operated nodes usually have no accessibility and thus its battery can't be replaced. Hence, energy efficiency is the key research question in wireless sensor networks that is required to be fingered sensibly in order to prolong or improve the life time of the network. An extensive amount of energy is consumed during routing operations; because of this it is the hottest research area in WSN. In the proposed mechanism, the operations of network are divided into different phases. These are cluster setup, intra cluster communication, and Cluster Head-Base station communication phase. In Cluster Head-Base station communication phase, the base station construct a shortest path rooted at base station discussed in algorithm 1. The data is sent to BS via these paths. The Hierarchical Energy Efficient Routing Protocol (HEERP) distributes the energy load in such a way that every sensor node will consume its minimum average energy to improve the network lifetime. Simulation results show that the life time of the proposed model is competent as compared to existing techniques.**

***Index Terms*– Routing, WSN, Cluster-based Routing, HEERP, Wireless Sensor Network and Energy Efficient Routing**

I. INTRODUCTION

THE WSN is composed of sensor nodes - starting from few to hundreds or thousands where each node has connectivity to one or more sensor nodes. In WSN each sensor node is composed of radio transceiver, processor, memory and charged battery with some optional components such as GPS. A sensor node might have vary in size that can be so small which we can't see on human eyes and can also big enough i.e. sensors used in home automation and hotel etc. The sensor nodes cost can also vary ranging from tens to hundreds of dollars depend on how much an individual use sensors for complex tasks. This size and cost restrictions on sensor nodes effect the resources of sensors such as memory, energy, computational and processing speed and bandwidth. The topology of the WSNs uses different topologies ranging from a simple star networks to a complex mesh networks. The transmission and receiving method between the network hops can be routing or broadcasting.

A wireless sensor network is composed of small dispersed randomly deployed devices that have the ability to monitor environmental and physical conditions in real time such as pressure, light, temperature and wetness; the ability to control the operations of devices like switches and motors and provide efficient and reliable communication through wireless network.

WSNs are usually self-healing and self-organizing. Self-organizing networks are those networks which have the capability to permit a new node to join the network automatically without requiring any manual work for joining the network. Self-healing networks have the capability to let nodes to configure and reconfigure their bond associations automatically if needed and find substitute or alternative paths around powered-down or failed nodes. The capabilities may be applied depends on network topology and a protocol which manage the network, and as a result the network scalability, flexibility and performance cost will be measured.

A wireless sensor network uses the basic topologies like point-to-point, star topology (Point-to-multipoint) or mesh topology. Point-to-point network topology simply uses dedicated link between two nodes and possibly it is not a network at all. Star networks are the combination of point-to-point links with a master node at center that manages the fixed amount of nodes and assign channels to nodes for communication. Star network can be extended by linking the master nodes that can form cluster-tree networks or simply clusters. The main drawback of star topology is that the failure of single master node will fail whole network, if the central master node fails, the entire network will fails.

In mesh topology, every node has connection to every other node with multiple pathways providing flexibility and elasticity. The failure of single node doesn't disturb the whole entire network because every node is independent and have multiple paths to another node in the network. Most useful mesh networks use a kind of pseudo-mesh that support routing with peer-to-peer communication links. Since in mesh each node must aware and maintain knowledge of other nodes in the network with routing tables, the processing and memory requirements related with each node is higher in

mesh topology, because every node in the network retains a routing table of all other neighboring nodes.

The main purposes of Hierarchal routing protocols are to increase life span of the network. In these protocols the CHs communicates with the base station directly which in result failure of nodes quickly due high energy use. The CHs are selected based on nodes average maximum energy or can be randomly selected from the network. So it is possible that the CH,s may selected from one part of the network, which can affect network lifetime. Another protocol was introduced called Base-station Controlled Dynamic Clustering Protocol (BCDCP) which divided the network into different clusters where each cluster have approximately equal number of nodes to avoid CH load [4]. But the problem with this protocol was that all the CHs transmits data directly to the controller or BS and the CHs which was far away from the BS required maximum energy to send data, due to which CHs loss their energy quickly and affects the life span of the network.

To address the above problems we propose Hierarchical Energy Efficient Routing Protocol (HEERP). In the proposed mechanism, the operations of network are divided into different phases. These are cluster setup, intra cluster communication, and Cluster Head-Base station communication phase.

II. RELATED WORK

In simplest case of direct communication routing protocol, the sensor node in WSN communicates directly to base station. In most cases the distance is large and sensor nodes consume energy quickly. Direct contact with Base Station spent a high amount of energy on activities such as application, advertising, and installation of the gradient. In addition, excessive time spent on these activities could not apply to some applications that require quick respond to an emergency.

Low Energy Adaptive Clustering Hierarchical (LEACH) is one of the first hierarchical routing approaches for sensor networks [4]. In LEACH each node transmits data directly to the CH and BS using single-hop routing. Therefore it is not capable for large network. In addition, the dynamic clustering scheme brings extra overhead e.g. advertisement and head changes etc. which can reduce the gain in energy utilization [4], [6]. The improve version of LEACH is PEGASIS in which sensor nodes make a chain, so that every node receive from and transmit data to its close neighbor [6], [8]. Though from certain limitations, first is too much delay which is produced by remote nodes on the chain. Another drawback is that the only leader can become a bottleneck for the network [3], [7], [8].

The BCDCP makes use of high level of energy base station for the setup of clusters and routing path. The key idea in BCDCP is to make use of clusters where every cluster has approximately same number of nodes serve by a cluster head. To avoid overloading the head, the positioning of cluster head is changed in the whole sensor field and to use the entire cluster-head to cluster-head routing to transfer data to the base station [1].

An Energy-Efficient Hierarchical Routing Protocol (EEHRP) is another hierarchical routing protocol which splits the network into different clusters on the bases of energy. It divides the whole network by balancing the energy of each cluster rather size distribution which result in unequal load on Cluster Head [7].

III. PROPOSED MODEL

In proposed model the operation of network is divided into different phases (Fig. 1). These are Cluster setup and selection of cluster head and data communication between CH to its nodes and with BS.

A) Cluster Setup Phase

In this phase we mainly focus on the formation of cluster. In Cluster setup, the deployed nodes in the network are divided into different regions called clusters and nodes start communication with Base Station. In region setup, the network nodes are first divided into different regions by the help of an algorithm which splits the network using divide and conquer strategy. To achieve this task, the whole entire network is divided into two sub parts; each sub part is then divided further into two sub parts and so on. This dividing of regions into sub regions will continue until the optimal numbers of regions are found. Each region is considered as a cluster after the completion of the above task.

This divides and conquers strategy warrants almost equal amount of nodes in every region as adopted in [2] which uses the balance clustering technique. The distance between the cluster head nodes are maximized by each splitting step of this technique. After formation of clusters every node broadcast there energy level. The Base Station then receive energy information from every node in the network for current round on the basis of this energy information, the Base Station then calculates the energy level of every node and the node with high energy is selected as CH in each

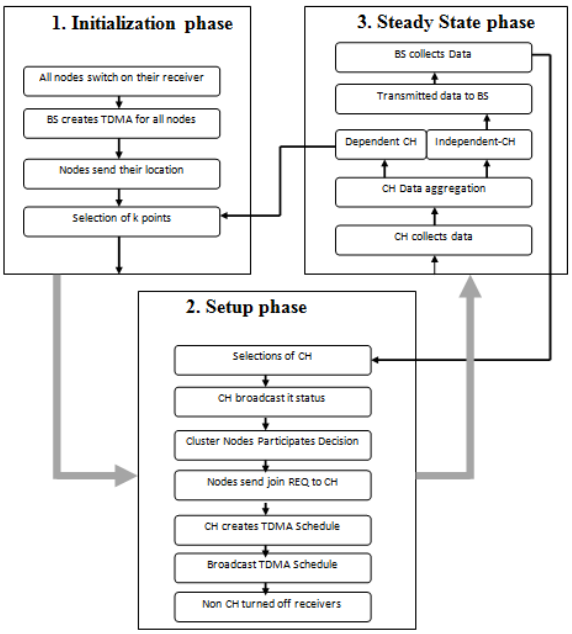

Fig. 1: Model of HEERP Technique

cluster. The CH can only be selected for the current round which ensures that CH can be selected on basis of sufficient energy and the node with low energy can perform tasks which require least energy to increase the life span of the network.

B) Communication between CH-BS

For communication with BS the cluster-head nodes are divided into two levels. That are, Independent CHs and Dependent CHs. The Independent clusters head are closed enough to base station and communicate directly to the base station while on other hand Dependent CHs are far from base station and they are incapable to transmit data directly to the base station. These cluster heads use multi-hop mechanism to communicate with BS through Independent cluster head. By using the algorithm, the BS find shortest path between all dependent cluster heads. The independent cluster heads receives data from dependent cluster heads through their designated path and then forwards the data to base station.

Algorithm 1

Value [Sink] ← 0// SINK is the sink node or base station
for each C-H ∈ M –{ SINK}// M is the sum of C-H s plus SINK
do value [C-H]← ∞ // initially each Cluster head is assigned ∞.
Known-C-H ← ∅
P-Queue ← M-SINK //total cluster heads except from base station
While P-Queue ≠ ∅
do
Optimum-C-H ← EXTRACT-MIN (P-Queue)
Known-C-H ← Known-C-H ∪ {Optimum-C-H } //concatenation of new C-H to the list
For each
C-H ∈ Adjacent [Optimum-C-H]
do if Value[C-H] > value[Optimum-C-H] +distance (Optimum-C-H , C-H)

then

Path-update [C-H] ← Optimum-C-H
Value [C-H] ←Value [Optimum-C-H] + distance (Optimum-C-H , C-H)

Thus to find a path to the cluster head, pick the value from path array and can be done with the following algorithm
p=0
Root = path-update [ID]
While root ≠ 0
do
if root ≠ 0
Route[p]=root
Root=path-update [root]
} p++

Fig. 2: Algorithm for shortest paths from each source to the sink

The direct communication between independent CHs and BS reduce traffic load on cluster head near to base station. The shortest paths from each source to the sink can be calculated using the following algorithm (Fig. 2).

C) Algorithm

Initialization:

Step 1: The sink is assigned the value null as its distance from itself is 0; the algorithm starts its operations from the sink node.

Step2: All other nodes are assigned the value ∞ in the network.

Step 3: Sink is designated as start of the network.

D) Intra-Cluster Communication

In this technique, each neighbor node takes its turn to transmit data to the CH. The nodes which are closer to each other and are able to communicate directly are known as neighbor(s). The nodes form a chain using greedy approach starting from any random node in the cluster. The data which a node receives from its neighbor is fused with its data and is transmitted to another neighbor in the chain. Finally, the data is transmitted to the CH by a single node. This process continues in each cluster while transmitting data to their CHs.

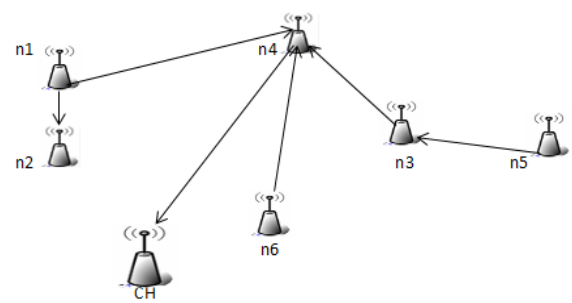

Fig. 3: Data Passing Technique

As shown in Fig. 3, node n2 passes its data to node n1. After receiving data from n2, node n1 fuses its own data with n2 data and transmit it to node n4. Node n4 then pass token to n5 and node n5 send its data to n3. The node n3 fuses its own data with node n5 and transmit it to node n4. On this way the node n4 then passes token to n7 for sending data, node n7 then transmit data to node n6 and which fuses n7 data with its own and send it to n4. Finally node n4 waits for receiving data from all neighbors and fuses its neighbors data to its own data and finally one message is transmitted to CH.

IV. SIMULATION RESULTS

The simulation setup is composed of 100 static sensor nodes deployed in sensor field randomly. More specifically, the sensor nodes are distributed in the area randomly, which is an area of side L = 900m. The BS is sited at a distance D from

the point closest to the target area. In each simulation tests D gets one value between 100m-1000m.The nodes send sensed data during their own specific time frames (Table 1). It is also supposed that every node in the network will send information to the base station about their current energy status. In conclusion, without any complications there is free space communication environment. During simulation tests the parameters adopted along with their values respectively.

Table 1: Simulation Parameters

Parameters	Values
Number of sensors	100
Network Area	100 x 100
Distance between Sensor field and BS	100 to 1000m
Data Packet Size	4000bits
Node Original Energy	0.5 joule

To evaluate the performance of HEERP, we simulated proposed technique with LEACH and BCDCP [2], [4] using 100 nodes network. The results have been compiled and then compared with popular existing techniques. The result show that the HEERP technique is more energy efficient than other techniques.

The most important factor in WSN is network lifetime, which has been increased by proposed technique. The graph in Fig. 4 clearly shows that as compared to other techniques the nodes death occurred earlier than HEERP thus help to prolong the life span of the network. Lifetime of the network can be determined from deaths of the nodes in the network. In proposed technique the nodes death occurs after the LEACH and BCDCP techniques which is good achievements of HEERP.

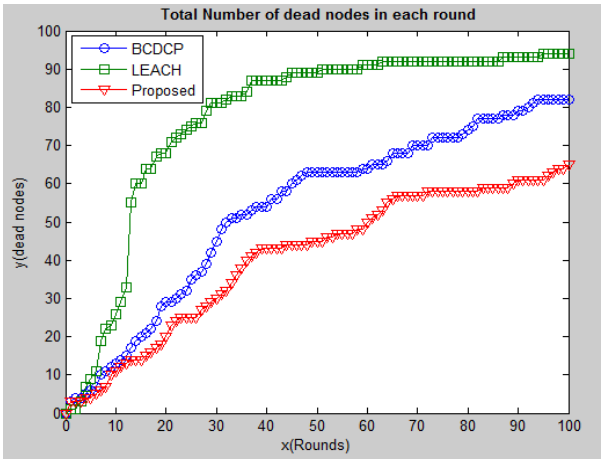

Fig. 4. Comparative results of HEERP with LEACH and BCDCP, the result of dead nodes after 100 rounds

Fig. 5 shows the result of alive nodes after each round. The results of graphs clearly indicate that the number of active nodes in HEERP is greater than LEACH and BCDCP. In HEERP the simulation is run for 100 rounds.

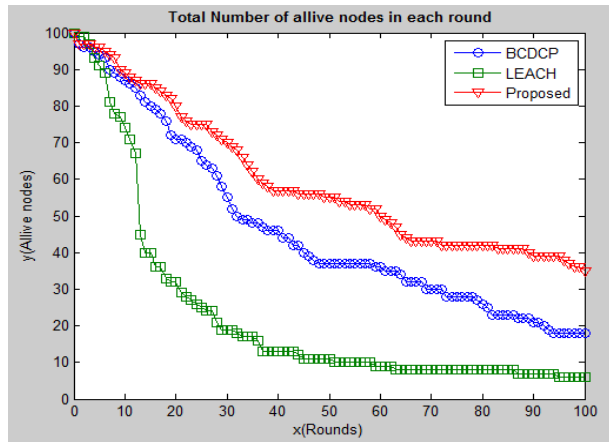

Fig. 5. Comparative descriptions of [2], [4] vs. HEERP, the remaining alive nodes after each round over 100 nodes

Fig. 6 shows the transmitted packets to the base station. The graph clearly illustrate that the effectiveness of HEERP of sending data packets is greater than LEACH and BCDCP. The HEERP performance in terms of alive nodes is greater than LEACH and BCDCP or we can also say that in HEERP the number of dead nodes in each round is less than [2], [4].

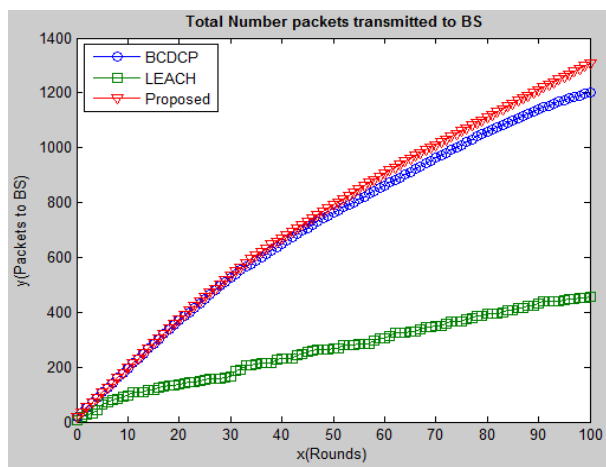

Fig. 6. Total number of packets sends to the base station after each round

V. CONCLUSION

This work focuses on sensor hierarchical routing by using a new reactive protocol named improved HEERP, which aims to save energy with energy efficient routing. This work focuses on hierarchical energy efficient routing. This can be attained by dividing the nodes into different clusters which have approximately equal number of nodes. The base station

then receives energy information from all nodes and a cluster head is selected based on maximum energy for current round. The cluster head receive data from every node within cluster, fused the data and then fused data is transmitted with the help of other cluster heads or directly to the base station. Unlike other protocols which directly communicate with the base station, HEERP uses Dependent and Independent cluster heads for the transmission of data to the base station. As in result this approach prolong the life time of the network proved in simulation results.

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