Energy Efficient Centralized Hierarchical Routing Protocol for Wireless Sensor Network

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ABSTRACT
Wireless sensor network consists of hundreds or thousands of micro sensor nodes, networking together, allows user to accurately monitor a remote environment intelligently combining the data from the individual nodes. The main issue in WSN is energy limited characteristic of the sensor node. So the problem is to have the routing protocol in such the manner that it should be energy efficient in order to increase the life span of the whole WSN. One of the most critical issues in wireless sensor networks is represented by the limited availability of energy on network nodes; thus, making good use of energy is necessary to increase network lifetime. In this paper we design a routing protocol with named PECH. This protocol is base station assisted i.e. this protocol utilizes a high-energy base station to set up clusters and routing paths, perform randomized rotation of cluster heads, and carry out other energy-intensive tasks. However using a central control algorithm to form the clusters produces better clusters by dispersing the cluster head nodes throughout the network. So, in terms of power it will be highly power efficient. It is centralized since in this protocol, rather than self-configuration, base station is used (that is centralized located in the sensor field). Lastly, the new protocol PECH will be compared with centralized protocol SHPER

Keywords
Sensor, Sensor Network, Routing

I. INTRODUCTION
Wireless sensor networks consist of small battery powered devices with limited energy resources. Once deployed, the small sensor nodes are usually inaccessible to the user, and thus replacement of the energy source is not feasible. Hence, energy efficiency is a key design issue that needs to be enhanced in order to improve the life span of the network. Several network layer protocols have been proposed to improve the effective lifetime of a network

with a limited energy supply. A sensor node is a node in a WSN that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. In many application areas the wireless sensor network must be able to operate for long periods of time, and the energy consumption of both individual sensor nodes and the sensor network as a whole is of primary importance. Thus energy consumption is an important issue for wireless sensor networks.

Wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices called sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. However, wireless sensor networks are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, [4] healthcare applications, home automation, and traffic control. Wireless sensor networks have introduced a reliable monitoring, and they seem to be an interesting approach for emergency situations. Wireless sensors can be deployed in almost any environment where a disaster happened like earthquakes, flooding, urban fires etc. In wireless sensor network, User sends the request to the sink

node (gateway node), and gateway node access the source node to satisfy the request. There are intermediate nodes between source and sink node, information is sent back to the gateway nodes by using routing protocol. There are various routing protocol exists. Various routing protocol use energy differently.

II. BACKGROUND
Centralized Hierarchical Routing

In centralized routing, the base station is responsible for formation of cluster head.

I. LEACH-C
A centralized version of LEACH, LEACH-C, is proposed in [5]. Unlike LEACH, where nodes self-configure themselves into clusters, LEACH-C utilizes the base station for cluster formation. During the setup phase of LEACH-C, the base station receives information regarding the location and energy level of each node in the network. Using this information, the base station finds a predetermined number of cluster heads and configures the network into clusters. The cluster groupings are chosen to minimize the energy required for no cluster-head nodes to transmit their data to their respective cluster heads. Although the other operations of LEACH-C are identical to those of LEACH, results presented in [5] indicate a definite improvement over LEACH. The authors of [5] cite two key reasons for the improvement:

- The base station utilizes its global knowledge of the network to produce better clusters that require less energy for data transmission.
- The number of cluster heads in each round of LEACH-C equals a predetermined optimal value, whereas for LEACH the number of cluster heads varies from round to round due to the lack of global coordination among nodes.

II. SHPER
A hierarchical scheme used in SHPER [6] protocol in a similar way as in other protocols discussed earlier. However, contrary to other non-centralized routing protocols, the election of the cluster heads is not randomized rather it is based on the residual energy of the nodes. Cluster head selection is done by the base station itself. Base station asks

each node to send their residual energy initially. And based on the energy of each node and the predefined percentage of cluster heads, base station selects the cluster head.

The operation of SHPER [7] protocol may be divided in two phases: Initialization phase, and Steady state phase.

a) Initialization Phase

Initially, all the nodes switch on their receivers in order to receive TDMA schedule from the base station. The base station broadcasts TDMA schedule, the size of TDMA schedule depends on the number of the nodes in the network, to all the nodes for collecting the global information about the network topology

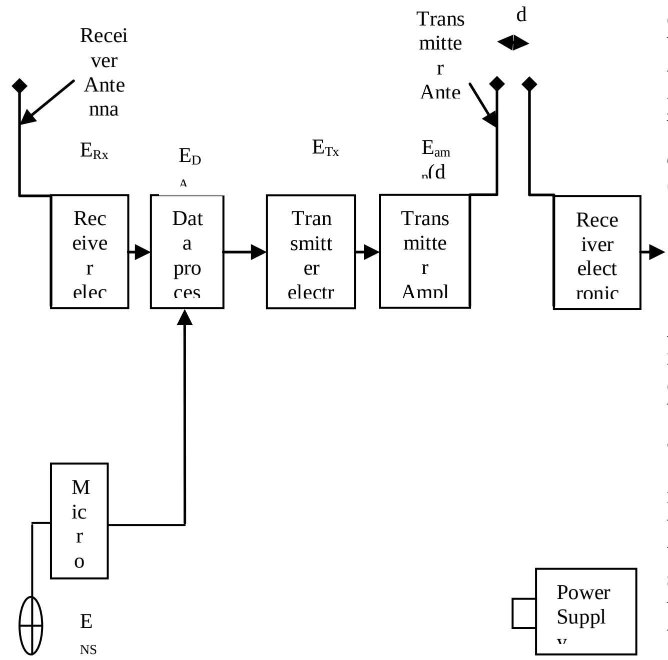

Figure 1: Energy Consumption Model

Table 1 demonstrates the TDMA schedule. According to this schedule each node advertises itself. Each time that a node advertises itself, the other nodes which hear this advertisement realize their relative distance from this node, according to the received signal strength of the advertisement.

Table 1: The Schedule Creation Scheme used in SHPER for a Cluster with Four Nodes

Cluster Head ID	Time Slot1	Time Slot2	Time Slot3
00	01	10	11
01	00	10	11
10	00	01	11
11	00	01	10

After the completion of node advertisement procedure, the base station selects the nodes as cluster head. The total number of cluster heads is predefined. The base station randomly elects some of the nodes as high level cluster head from which it has received an advertisement reply message and some of the nodes as low level cluster head from which it have not received message. The id's of the new elected cluster heads and the values of the thresholds are broadcasted by the base station. These thresholds used in this protocol are similar to the thresholds as described in TEEN and APTEEN [8-9]. The non-cluster head nodes decide as to which cluster they want to fit in. This assessment is based on the largest signal strength of the advertisement message heard previously. The signal to noise ratio is compared from various cluster heads surrounding the node. The non cluster-head nodes notify the respective cluster-head about the decision to join the cluster. In order to be able to indirectly route its messages to the base station, each lower level cluster head selects the upper level cluster node that it is going to belong to, in order to be able to indirectly route its messages to the base station. This selection is based on the discovery of the path *r= (c1. c2.....cn).* Between the source cluster head *c1* and the base station *cn* that spans *n-2* intermediate cluster head nodes *c2.....cn-1.* for which the Routing Index *RI(r)* shown in equation (1), is the maximum:

$$RI(r) = \sum_{i=2}^{n-2} E_r - \sum C_i C_{i+1}$$

After each node has decided to which it has to belong, it informs its cluster head that I will be a member of yours cluster. Each cluster head receives all the messages from the nodes that want to be included in its cluster and according to their number, generates a TDMA schedule of corresponding size as described in Table 1 .Each cluster head send transmission schedule (TDMA) to the nodes that are under its cluster that when to transmit data in order to avoid collision. Each node, during its allocated transmission time, sends to the cluster head quantitative data concerning the sensed events and using the hard and soft threshold values. Along with the data concerning the sensed attributes the node transmits the current value of its residual energy. The radio of each non cluster head node can be turned off until the node's allocated transmission time comes, thus minimizing energy dissipation in these nodes. In this way, each cluster head receives the data from its cluster nodes. Each cluster head aggregates the data it has received along with its own data and makes composite message. This composite message contains the id of the node which has highest residual energy among the cluster nodes, along with the most excessive (e.g. maximum) value of the sensed variable and the id of the corresponding node that has sensed it. Then, during its own time slot, each cluster head transmit its composite message to the base station either directly or indirectly via intermediate upper level cluster heads following the path suggested by the index calculation given in Eqn. 1. The base station collects all the messages that are transmitted to it.

b) Steady State phase

In this phase, by using the data of the received messages, the base station determines the new cluster heads. More precisely, the node which has the highest residual energy, in each cluster, is chosen as a new cluster head and the process continues again as given in the initialization phase. But in each time, the new hard and soft thresholds are defined.

III.ENERGY CONSUMPTION MODEL

Energy efficiency is one of the most important design constraints in wireless sensor network architectures [1]. The lifetime of each sensor nodes depends on its energy dissipation. A typical sensor node consists mainly of a sensing circuit for signal conditioning and conversion, a digital signal processor, and radio links [2-3].

Hence, during the life cycle of the sensor node, each event or query will be followed by a sensing operation, performing necessary calculations to derive a data packet and send this packet to its destination.

Thus, we divide the energy consumption model into the following sub models; the communication energy consumption model, followed by the computation energy consumption model and finally the sensing energy consumption model (As shown in Figure 1).Although energy is dissipated in all of the models of a sensor node, we mainly consider the energy dissipations associated with the

Station to control the coordinated sensing task performed by the sensor nodes. PECH is a wireless sensor routing protocol with the base station being an essential component with complex computational abilities, thus making the sensor nodes very simple and cost effective. PECH operates in two major phases: ***setup*** and ***data communication.***

a) Set up phase

In this phase, cluster set up, cluster head selection and Cluster head to cluster head routing path is to be set up. The steps involved in this phase are as follows.

Step 1: Initially, base station sends an START message to all the nodes in the sensor field , to acquire information about the node's residual energy and their neighbor list.

Step 2: After receiving the start "START" message, each node broadcasts the hello message "HELLO" as shown in Figure 3.

Step 3: Each node receiving hello message "HELLO" sends "REPLY" message containing its ID.

Step 4: When a node gets reply, it will note down the ID of the node from where the reply has been acknowledged. In this way each node will have their individual neighbor list.

Step 5: After receiving the information about their neighbors the nodes, for which the base station is within their range, sends a STATUS message to the base station. This STATUS includes ID, Neighbor list, and Energy of the node. This is shown in Figure 4.

Step 6: Base station sends an acknowledge (ACK) to all sending nodes.

Step 7: After acquiring acknowledge ACK, the nodes set their level to one which was initially zero and broadcasts a gateway advertisement GW_ADV to all its neighbors.

Step 8: Nodes receiving GW_ADV will check their level. If a node's level is zero (i.e. a node has not sent their status yet) it sends their STATUS to the node advertising gateway. In this case, a node can receive a GW_ADV from many of the nodes but it will reply only to that node from where it has received GW_ADV message first.

communication energy consumption since the core objective of algorithm is to develop an energy-efficient network layer routing protocol to improve networklifetime

The transmission and receive energy costs for the transfer of a k-bit data message between two nodes separated by a distance of d meters is given by Esq. 1 and 2, respectively.

$$E_T(k,d) = E_{TX}k + E_{amp}(d)k \quad (1)$$

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

Where ET (k, d) in Eq. 1 denotes the total energy dissipated in the transmitter of the source node, and ER(k) in Eq. 2 represents the energy cost incurred in the receiver of the destination node. The parameters E_{Tx} and E_{Rx} Esq. 1 and 2 are the per bit energy dissipations for transmission and reception, respectively. $_{Eamp(d)}$ is the energy required by the transmit amplifier to maintain an acceptable signal-to-noise ratio in order to transfer data messages reliably. As is the case in [2], we use both the free-space propagation model and the two ray ground propagation model to approximate the path loss sustained due to wireless channel transmission. Given a threshold transmission distance of d0, the free-space model is employed when d≤d0, and the two-ray model is applied for cases where d<d0. Using these two models, the energy required by the transmit amplifier $E_{amp}(d)$ is given by Eq. 3.

$$E_{amp}(d) = \begin{cases} \varepsilon_{FS} d^4 & , d \le d_0 \\ \varepsilon_{TR} d^4 & , d > d_0 \end{cases} \quad (3) \quad (3)$$

where ε_{FS} and ε_{TR} denote transmit amplifier parameters corresponding to the free-space and the two-ray models, respectively, and d_0 is the threshold distance given by Eq.

$$d_0 = \sqrt{\varepsilon_{FS} / \varepsilon_{TR}} \quad (4)$$

IV. ALGORITHM POWER EFFICIENT CENTRALIZED HIERARCHICAL: PECH

Energy efficiency is one of the most important design constraints in wireless sensor network architectures. The lifetime of each sensor nodes depends on its energy dissipation. In applications where the sensor nodes are totally dependent on no rechargeable batteries, sensor nodes with exhausted batteries will cease operation. A typical sensor node consists mainly of a sensing circuit for signal conditioning and conversion, a digital signal processor, and radio links hence, during the life cycle of the sensor node,

each event or query will be followed by a sensing operation, performing necessary calculations to derive a data packet and send this packet to its destination. Although energy is dissipated in all of the models of a sensor node, we mainly consider the energy dissipations associated with the communication energy consumption since the core objective of algorithm is to develop an energy-efficient network layer routing protocol to improve network lifetime. The foundation of PECH lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, PECH utilizes the base

Figure 2: Each node broadcast HELLO message

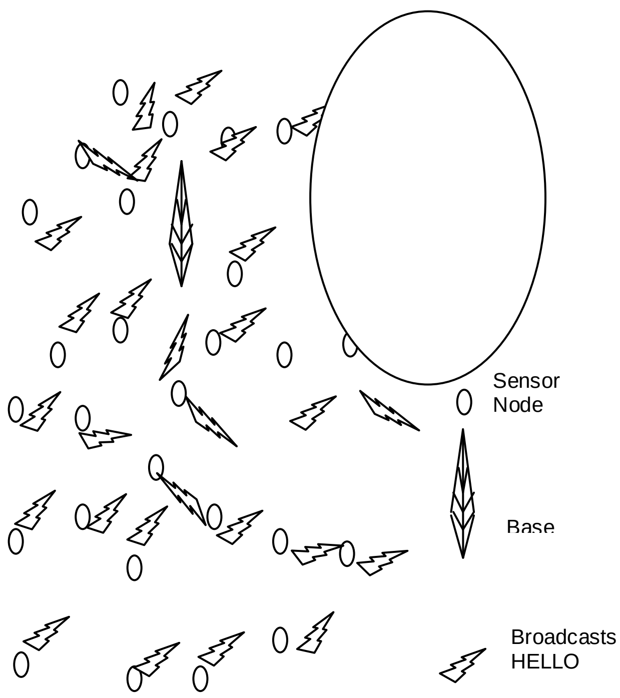

Table 2: Neighbor Information of each Node

Node No	0	1	2	3	4	5	6	7	8	9
0	0	1	1	0	0	0	0	0	0	0
1	1	0	1	1	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	0
3	0	1	0	0	0	1	0	0	0	1
4	0	0	0	0	0	1	0	0	0	0
5	0	0	0	1	1	0	1	0	0	0
6	0	0	0	0	0	1	0	1	0	0
7	0	0	0	0	0	0	1	0	1	1
8	0	0	0	0	0	0	0	1	0	0
9	0	0	0	1	0	0	0	1	0	0

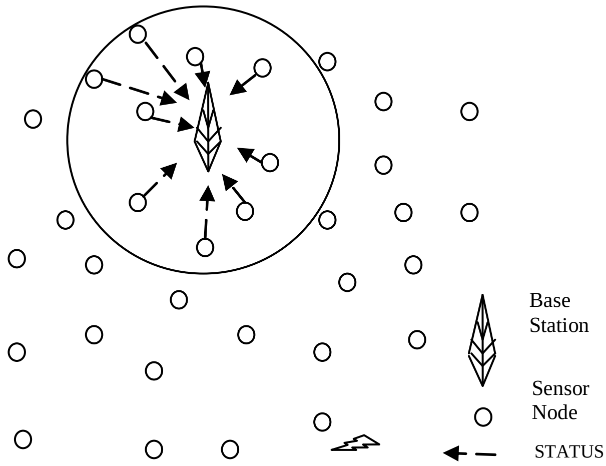

Figure 3: Sensor Node Sends their STATUS to Base Station

Step 9: After receiving the STATUS, gateway sends an ACK to the nodes, from where it has received the STATUS and forwards this STATUS to the other gateway or to the base station directly (if directly connected).

Steps 7 to 9 are continuously replayed until all the nodes send their STATUS to the base station, directly or via gateway. At this time base station has acquired all the information about logical structure of the sensor field. This can be shown in table consisting 10*10 cells for 10 nodes in the sensor field. This information is stored in status array of [10][10] size as shown in Table 2.

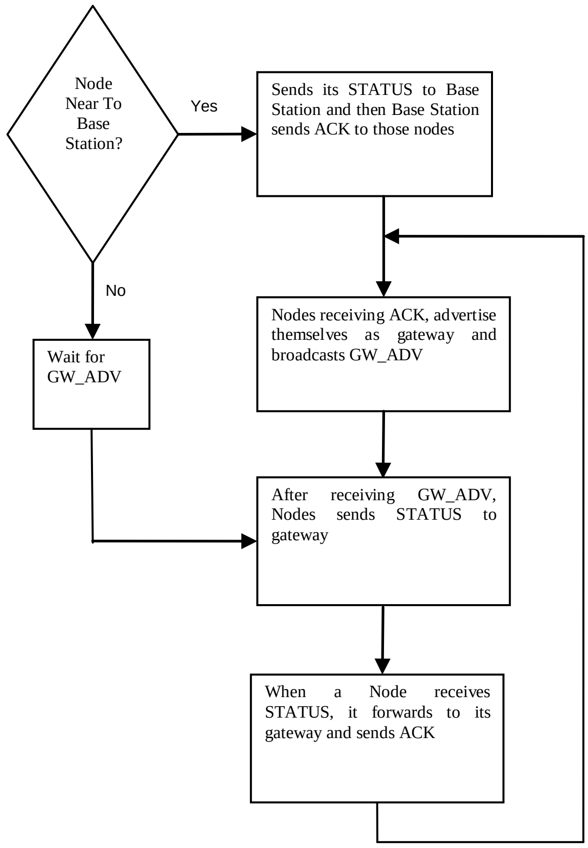

Figure 4: Nodes Sends their Status to Base Station

A value in cell status[i] [j] represents whether a node i is within the range of j or not. If it is, then its value is 1 else 0. The base station has information (in the energy table) about the residual energy status of the each node in the sensor network field as shown in Table 3.

	0	1	2	3	4	5	6	7	8	9
Energy	0.5	0.7	0.4	0.5	0.7	0.6	0.65	0.8	0.4	0.7

Table 3: Energy Information about each node

Step 10: Since the nodes, for which the base station is within the range, can send their data directly to it. For such types of nodes the base station is assigned as their cluster head.

Step 11: Base station computes the average energy level avgE for those nodes (let it be X) that have not been declared as cluster head themselves yet, but have been assigned with cluster head having their neighbors' count greater than zero.

Step 12: Out of X nodes, select a node N as a cluster head CH, whose energy is greater than avgE and has maximum number of neighbors.

Step 13: Assign selected CH as cluster head to the rest of unassigned neighbors as shown in Figure 4.7.

Steps 11 to 13 are repeated until X is greater than zero.

Data transmission phase

Step 14: Base station broadcasts cluster information that includes the ID's of the cluster head, non-cluster head nodes belongs to which cluster head in addition to hard and soft thresholds values similar to the way in TEEN and APTEEN .
Step 15: Every cluster head informs each one of its cluster nodes when it can transmit, according to the TDMA schedule which is broadcasted back to the nodes in the cluster.
Step 16: Each node, during its allocated transmission time, sends to the cluster head quantitative data concerning the sensed events. In a way similar to that proposed in TEEN protocol hard and soft thresholds are used in PECH too.
Step 17: Each cluster head receives the data from its cluster nodes. When all the data have been received, each cluster head performs signal processing functions to aggregate the data it has received along with its own data into a single composite message. This composite signal also contains the ids of the nodes. After each cluster head has created its aggregate message, it waits until its own time slot in order to transmit it to the base station, either directly (if this is possible) or via intermediate upper level cluster heads.
Step 18: The base station collects all the messages transmitted to it. The base station determines the new cluster heads by using the data of the received message. More precisely, the node having the highest residual energy and maximum number of neighbors, in each cluster, is elected to be the new cluster head transmitted to it transmitted to it. The base station determines the new cluster heads by using the data of the received message. Additionally, the new soft and thresholds are defined
The steps from 14 to 18 are continuously replayed of the procedure described above.

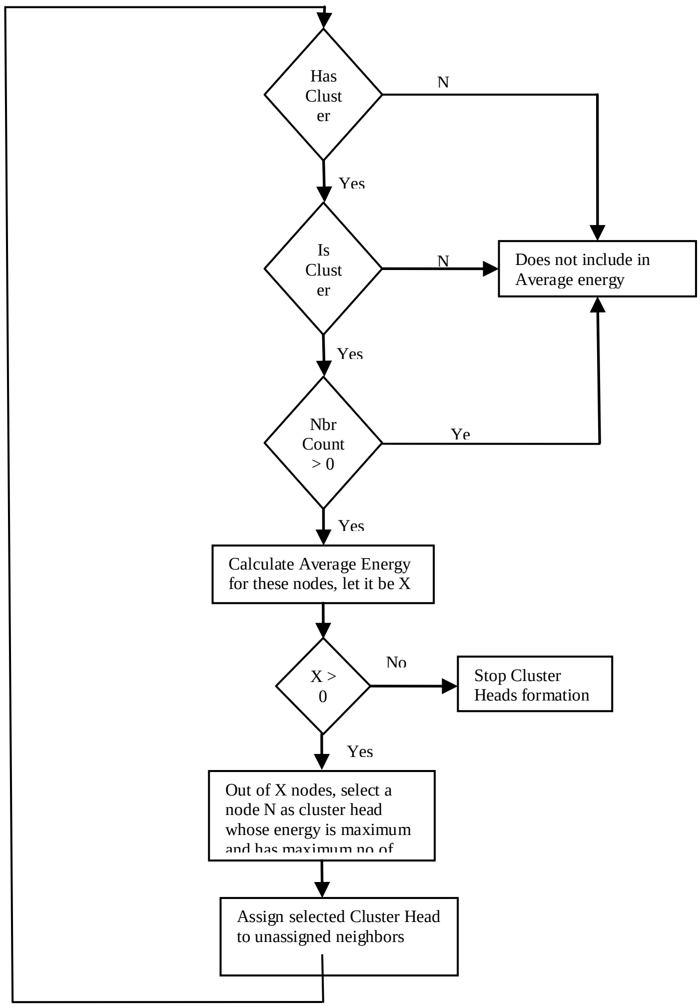

Figure 5: Cluster Head Formation by base station

V. PERFORMANCE

To access the performance of PECH, we simulated PECH using OMNET++ and compared its performance with other centralized based clustering routing protocol SHPER. Performance is measured by quantities matrices of average energy dissipation, system lifetime and number of nodes that are alive. Throughout the simulations we consider network node configuration with 100 nodes where, each node is assigned an initial energy of 2 Joules.

A) AVERAGE ENERGY DISSIPATION

Figure 8 shows the average energy dissipation of the protocols under study over the number of rounds of operation. This plot clearly shows that PECH has a much
more desirable energy expenditure curve than that of SHPER. On average, PECH exhibits a reduction in energy consumption of 30 percent to SHPER. This is because all the cluster heads in

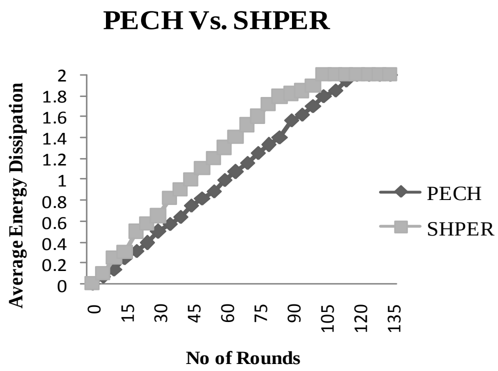

Figure 6: A Comparison of PECH's Avg Energy Dissipation with Centralized Clustering based SHPER Routing Protocol

SHPER transmit data directly to the distant base station, which in turn causes significant energy losses in the cluster head nodes. PECH alleviate this problem by having only multihop cluster head nodes to forward the data to the base station. This in turn increases the communication energy cost for those

SHP

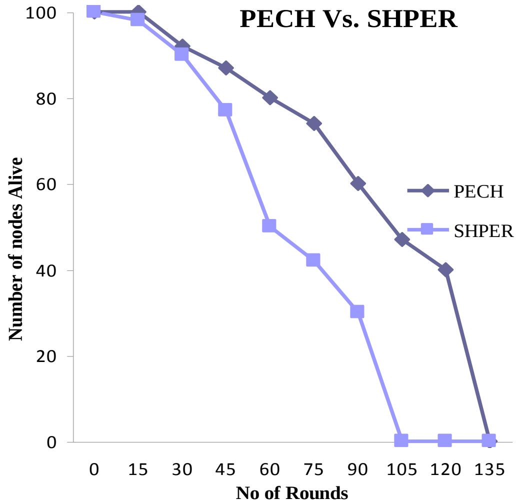

Figure 7: Comparison of PECH's System Lifetime with other Centralized Clustering based SHPER Routing Protocol

B) SYSTEMLIFETIME

The improvement gained through PECH is further exemplified by the system lifetime graph in Figure 9. This plot shows the number of nodes that remain alive over the number of rounds of activity for the 100 m × 100 m network scenario. With PECH, 82% of the nodes remain alive for 60 rounds, while the corresponding numbers for SHPER is 40%, respectively. And With this, 45% of the nodes alive for 105 rounds while the corresponding numbers for SHPER is 0 node alive i.e. all the nodes are dead for SHPER after 105 rounds. Furthermore, if system lifetime is defined as the number of rounds for which 75 percent of the nodes remain alive; PECH exceeds the system lifetime of SHPER and outperforms that of SHPER by 30 percent.

VI. CONCLUSION

As power source has limited power supply in sensor network.

In this paper, we have presented the energy efficient routing protocol which is Power Efficient Hierarchical Centralized (PECH) which is hierarchical routing based with the whole control to the base station or we can say that base assisted.

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