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Power Efficient Routing in Wireless Sensor Networks

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Abstract: 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 time of the whole WSN. Hierarchical routing architecture divides the whole network in to a group of cluster and only cluster head is responsible to forwarding the data to base station directly or via other cluster heads. In location based architecture of routing, localization of the sensor node is to be used to compute the path to the sensed data. During the creation of network topology, the process of setting up routes in WSNs is usually influenced by energy considerations, because the power consumption of a wireless link is proportional to square or even higher order of the distance between the sender and the receiver. Hierarchical routing can be centralized or non- centralized. In non-centralized hierarchical routing, the sensor nodes self-configures for the cluster head on the basis of selecting a random number. They don't consider the case of residual energy. But in centralized routing the base station is responsible to create cluster. In hierarchical routing architecture, sensor nodes self-configure themselves for the formation of cluster heads. The proposed work is to design a routing protocol which is energy efficient and the results will be compared with other routing protocols of same category.

Keywords: WSN, Hierarchical routing, Energy efficient routing, cluster based routing.

1. INTRODUCTION

In wireless sensor network, routing protocols generally classified into three categories, direct communication, flat and clustering protocols. In direct communication protocols, a sensor node sends data directly to the sink. Under this protocol, if the diameter of the network is large, the power of sensor nodes will be drained very quickly. Furthermore, as the number of sensor nodes increases, collision becomes a significant factor which defeats the purpose of data transmission [1]. Under flat protocols, all nodes in the network are treated equally. When a node needs to send data, it may find a route consisting of several hops to the sink. Normally, the probability of participating in the data transmission process is higher for the nodes around the sink than those nodes far away from the sink. So, the nodes around the sink could run out of their power soon. In the clustered routing architecture, nodes are grouped into clusters, and a dedicated cluster head node collects, processes, and forwards the data from all the sensor nodes within its cluster [2]. One of the most critical issues in wireless sensor networks is represented by the limited availability of energy on network nodes [3]; thus, making good use of energy is necessary to increase network lifetime. In hierarchical routing architecture, sensor nodes self configures them for the formation of cluster heads. In this paper, we have design a routing protocol with named Power Efficient Hierarchical Routing Protocol – PEHR. 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. 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 routing protocol PEHR will be compared with LEACH-C [4].

1.1 Centralized Hierarchical Routing

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

1.1.1 LEACH-C: 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 non-cluster-head nodes to transmit their data to their respective cluster heads. LEACH-C have two characteristics [8].

1. The base station utilizes its global knowledge of the network to produce better clusters that require less energy for data transmission.

2. 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

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to round due to the lack of global coordination among nodes.

1.1.2 Base station Controlled Dynamic Clustering Protocol (BCDCP) : A centralized routing protocol called Base-Station Controlled Dynamic Clustering Protocol (BCDCP), which distributes the energy dissipation evenly among all sensor nodes to improve network lifetime and average energy savings. 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. The key ideas in BCDCP are the formation of balanced clusters where each cluster head serves an approximately equal number of member nodes to avoid cluster head overload, uniform placement of cluster heads throughout the whole sensor field, and utilization of cluster-head-to-cluster head (CH-to-CH) routing to transfer the data to the base station.

1.1.3 Scaling Hierarchical Power Efficient Routing (SHPER): A hierarchical scheme used in SHPER [1,7] 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.

2. IMPORTANT TERMS IN WSN

There are some terms related to the energy efficiency on WSNs that are used to evaluate the performance of the routing protocols and here are the most important ones [5-7]:

- *Energy per Packet.* This term is referred to the amount of the energy that is spent while sending a packet from a source to a destination.

- *Energy and Reliability.* It refers to the way that a tradeoff between different application requirements is achieved. In some applications, emergency events may justify an increased energy cost to speed up the reporting of such events or to increase the redundancy of the transmission by using several paths.

- *Network Lifetime.* There is none universally agreed definition for the network lifetime. In many cases the term network lifetime corresponds to the time when the first node exhausts its energy, or when a certain fraction of the network's nodes is dead, or even when all nodes are dead. In some other cases it may be reasonable to measure the network lifetime by application-specific parameters, such as the time when the network can no longer relay the video. However, the importance of a WSN is to be operational and able to perform its tasks during its use. In WSNs, it is important to maximize the network lifetime, which means to increase the network survivability or to

prolong the battery lifetime of nodes. The common practice in networks is to use the shortest routes to transfer the packets. This could result the death of the nodes along the shortest path. Since in a WSN every node has to act as a relay in order to forward the message, if some nodes die sooner, due to the lack of energy, it is possible that other nodes will not be able to communicate any more. Hence, the network will get disconnected, the energy consumption is not balanced and the lifetime of the whole network is seriously affected. Therefore, a combination between the shortest path and the extension of the network lifetime is the most suitable routing metrics to be used in WSNs. Moreover, the lifetime of a node is effectively determined by its battery life. The main drainage of battery is due to transmitting and receiving data among nodes and the processing elements.

- *Average Energy Dissipated.* This metric is related to the network lifetime and shows the average dissipation of energy per node over time in the network as it performs various functions such as transmitting, receiving, sensing and aggregation of data [1].

- *Low Energy Consumption.* A low energy protocol has to consume less energy than traditional protocols. This means that a protocol that takes into consideration the remaining energy level of the nodes and selects routes that maximize the network's lifetime is considered as low energy protocol.

- *Total Number of Nodes Alive.* This metric is also related to the network lifetime. It gives an idea of the area coverage of the network over time [1-3].

- *Total Number of Data Signals Received at BS.* This metric is equivalent to the energy saved by the protocol by not transmitting continuously data packets (hello messages), which are not required.

- *Average Packet Delay.* This metric is calculated as the average one-way latency that is observed between the transmission and reception of a data packet at the sink. This metric measures the temporal accuracy of a packet [1].

- *Packet Delivery Ratio.* It is calculated as the ratio of the number of distinct packets received at sinks to the number originally sent from source sensors. This metric indicates the reliability of data delivery.

- *Time until the First Node Dies.* This metric indicates the duration for which all the sensor nodes on the network are alive. There are protocols in which the first node on the network runs out of energy earlier than in other protocols, but manages to keep the network operational much longer.

- *Energy Spent per Round.* This metric is related to the total amount of energy spent in routing messages in a round. It is a short-term measure designed to provide an idea of the energy efficiency of any proposed method in a particular round.

- *Idle Listening.* A sensor node that is in idle listening mode, does not send or receive data, it can still consume a substantial amount of energy. Therefore, this node should

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not stay in idle listening mode, but should be powered off [1].

- *Packet Size.* The size of a packet determines the time that a transmission will last. Therefore, it is effective in energy consumption. The packet size has to be reduced by combining several packets into one large packet or by compression.

- *Distance.* The distance between the transmitter and receiver can affect the power that is required to send and receive packets. The routing protocols can select the shortest paths between nodes and reduce energy consumption [1,9].

3. Proposed Algorithm (Power Efficient Hierarchical Routing Protocol- PEHR)

The foundation of PEHR lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, PEHR utilizes the base station to control the coordinated sensing task performed by the sensor nodes. In PEHR the following assumption are to be considered.

- A fixed base station is located far away from the sensor nodes.
- The sensor nodes are energy constrained with a uniform initial energy allocation.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Each node senses the environment at a fixed rate and always has data to send to the base station.
- All sensor nodes are immobile.

The radio channel is supposed to be symmetrical. Thus, the energy required to transmit a message from a source node to a destination node is the same as the energy required to transmit the same message from the destination node back to the source node for a given SNR (Signal to Noise Ratio). Moreover, it is assumed that the communication environment is contention and error free. Hence, there is no need for retransmission.

3.1 Algorithm

1. Initially, base station is centralized and 100 nodes are setup in a particular region (100 x 100) and each node has equal energy (0.5 joules).

2. In round 1, Cluster Head will be created according to probability condition.

3. The decision of each node to become cluster head is taken based on the suggested percentage of cluster head

nodes p . A sensor node chooses a random number, r , between 0 and 1. If this random number is less than a threshold value, $T(n)$, the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last $(1/P)$ rounds, denoted by G . $T(n)$ is given by:

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

Optimal number of cluster heads is estimated to be 10% of the total number of nodes.

4. Then, Nodes sends the data to their respective cluster heads and energy consumption will be calculated.

5. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated for each node and cluster heads.

6. In round 2, the nodes will become cluster heads according to probability condition i.e. according to minimum distance from base station and threshold energy.

7. After selection of cluster heads, Nodes sends the data to their respective cluster heads, that will be selected according to the minimum distance of a particular node from cluster heads and energy consumption will be calculated.

8. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated.

9. This process will be repeated until the whole network gets down or number of rounds finished.

10. Performance will be evaluated according to parameters like network lifetime, energy dissipation, no. of data packets sent etc.

4. Implementation and Results

Parameter Value

Network field:	100x100m
N (Number of nodes):	100
Initial energy:	0.5 J
Eelec (Energy Dissipation for ETx&ERx):	50 nJ/bit
ϵ_{fs} (free space):	10 pJ/bit/m ²
emp (Multipath fading):	0.0013 pJ/bit/m ⁴
EDA (Energy Aggregation Data):	5 nJ/bit/signal
Data packet size:	4000 bits
Tool used for implementation :	MATLAB 7.6.0.

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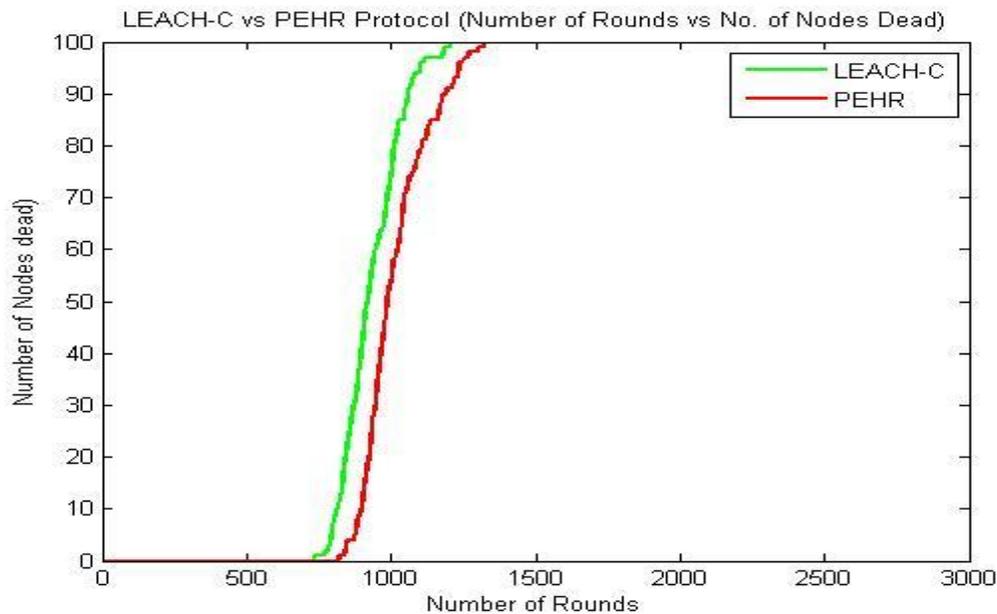


Figure 1: Number of Rounds vs Number of Nodes Dead

Figure 1 shows the comparison of routing protocols LEACH-C and Power Efficient Hierarchical Routing (PEHR) in terms of Number of nodes dead. Figure 1

shows the overall lifetime of the network. Here, we can observe that PEHR performs better as compared to LEACH-C.

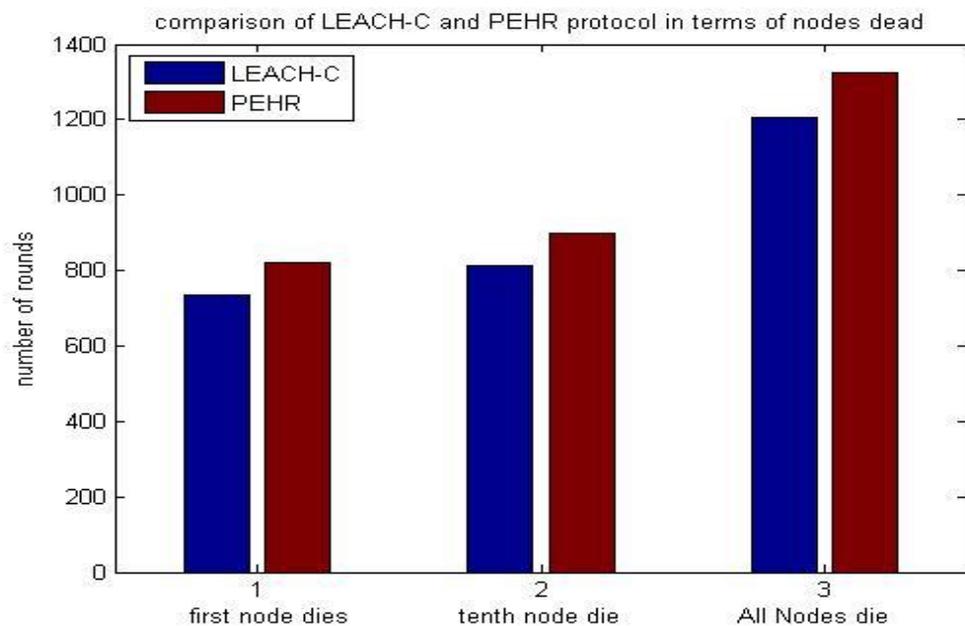


Figure 2: Comparison of Network Lifetime LEACH-C and PEHR

Figure 2 also shows network lifetime with the help of BAR graph. Figure 2 shows exactly in which round the first node, tenth node and whole network dies. It can be

observed from the figure 2 that PEHR performs better as compared to LEACH-C.

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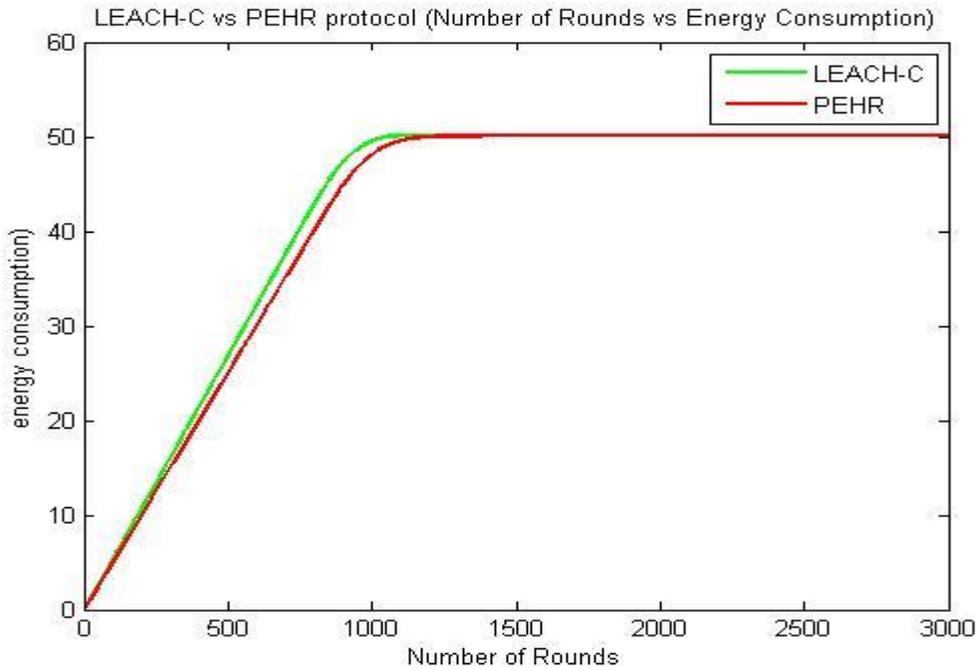


Figure 3: Number of Rounds vs Energy Consumption

Figure 3 shows the lifetime of the network. It shows that how energy of the network consumes step by step and finally whole network goes down. It can be observed

from the figure 3 that, PEHR consumes less energy and sustain more number of rounds as compare to LEACH-C protocol.

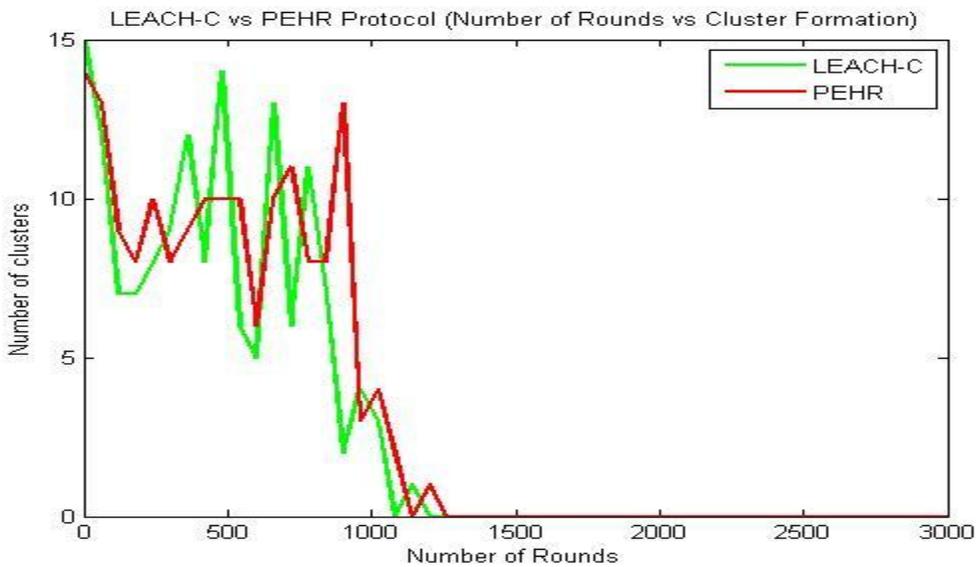


Figure 4 Number of Rounds vs Number of Cluster head in each round.

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Figure 4 shows the cluster head formation in each round. as compare to PEHR. So, PEHR will enhance the lifetime of Overall, both protocols have comparatively equal number of the network. cluster heads. But LEACH-C is showing more high spikes

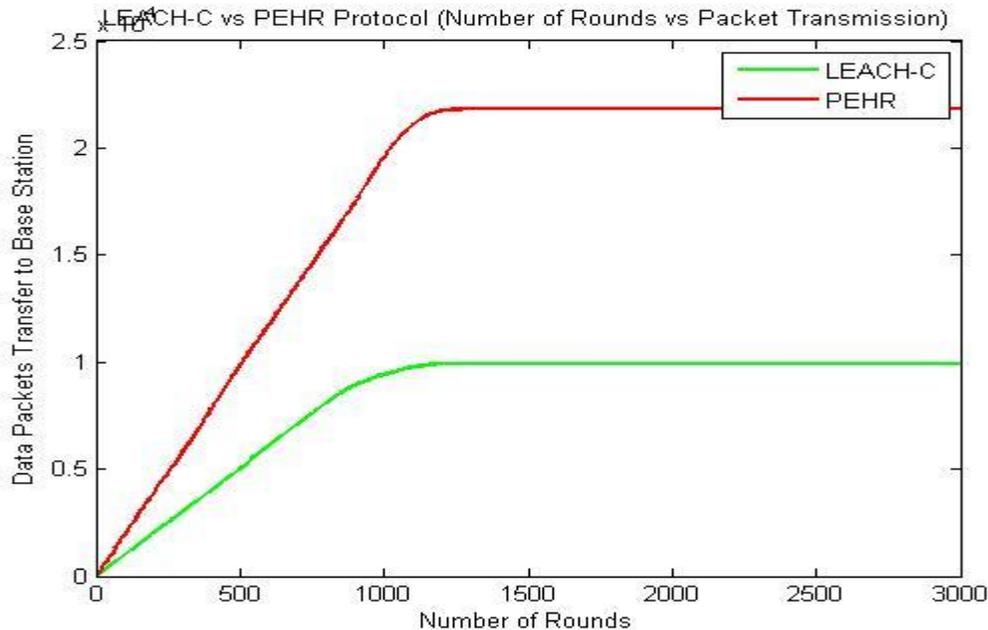


Figure 5 Number of Rounds vs Data Packets sent

Figure 5 shows how much data will be sent from nodes to SINK. From figure 5, we can observed that, in LEACH-C protocol data sent to base station is relatively less as compared to PEHR.

5. CONCLUSION AND FUTURE SCOPE

This new routing protocol named Power Efficient Hierarchical Routing Protocol (PEHR) which is hierarchical routing based with the whole control to the base station or we can say that base assisted. In PEHR, the base station first collects information about the logical structure of the network and residual energy of each node. So, with the global information about the network base station does cluster formation better in the sense that it has information about the residual energy of each node. Finally, PEHR is compared with already developed routing protocol Low Energy Adaptive Clustering Hierarchy-Centralized (LEACH-C) by the help of MATLAB. A comparison between two is done on the basis of energy dissipation with time, data packet sent and the system lifetime of network. There is no security and authentication while communicating. So this can be another research area where this can be considered. So in future, security can be applied to PEHR.

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