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Power Efficient Routing in Wireless Sensor Networks

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***Abstract*—**The main issue in wireless sensor network is energy limited characteristic of the sensor node. The design of routing protocol should be in such a manner that it will increase the life time of the whole network. During the creation of network topology, the process of setting up routes in wireless sensor network is usually prejudiced by energy considerations, because the energy consumption of a wireless link is proportional to square or even higher order of the distance between the sender and the receiver. Hierarchical routing architecture in WSN divides the whole network in to a group of clusters and only cluster heads are responsible for forwarding the data to base station directly or via other cluster heads. 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 such as LEACH-C.

***Keywords*—** WSN, Hierarchical routing, Energy efficient routing, cluster based routing.

I. INTRODUCTION

The basic architecture of wireless sensor network is shown in figure 1. 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 which 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 proposed routing protocol will be compared with LEACH-C [4].

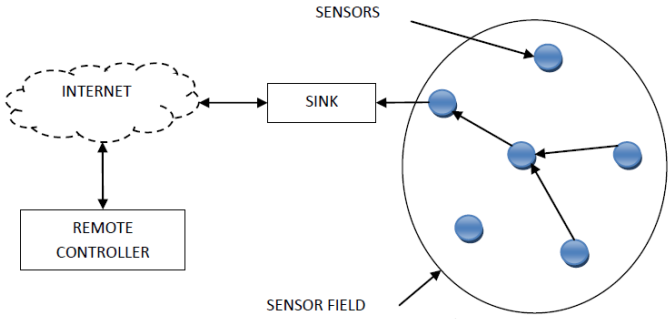

Fig. 1. WSN Architecture (redrawn from [2]).

1.1 Centralized Hierarchical Routing

In centralized routing, the base station is responsible for formation of cluster head. Cluster heads collects the data from nodes and after aggregating the data, the data will transmitted to base station as shown in figure 2.

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 has two characteristics [5-11].

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 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

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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 [7].

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.

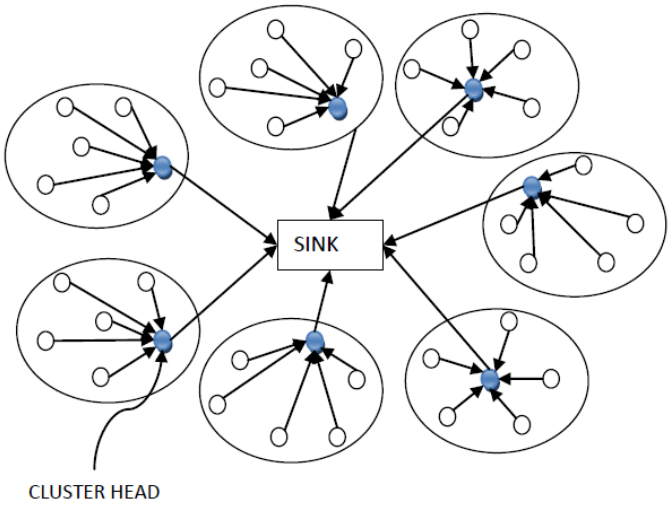

Fig. 2. Clustering schema for wireless sensor network (redrawn from [6]).

II. Issues of Wireless Sensor Networks

The main design goal of WSN is to not only transmit the data between source and destination but is also to increase the network lifetime; which can achieved by applying energy efficient protocols. The task of the protocol is not only to choose a path having lower energy consumption between sources to destination (BS), but also to find an efficient approach to prolong the network lifetime. But sometimes continuous use of low energy path may lead to energy depletion of sensor nodes in that path leading to network partition.

Performance of the routing protocol is calculated based on some terms which includes [1-7]:-

i. Energy per Packet: - the amount of energy required sending a packet from source to destination safely.

ii. Low Energy Consumption: - it includes such protocols that considers the remaining energy level of nodes and selects route accordingly for longevity of the network.

iii. Total Number of Nodes Alive: - It gives an idea of the area coverage of the network over time. This metrics is related to network lifetime.

iv. Average Packet Delay: - This metrics measure the accuracy of packet. This metrics is calculated as one way latency which is observed between transmission and reception of data packet at the sink.

v. 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.

vi. 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.

vii. Packet Size: - the lifetime of the network also depends on the packet size; it determines the time that a transmission will last. As it is effective in energy consumption so packet size should be reduced by combining large number of packets.

viii. 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.

III. Methodology

The foundation of proposed routing technique lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, proposed routing technique utilizes the base station to control the coordinated sensing task performed by the sensor nodes. In proposed routing technique 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.

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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:

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

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.

IV. Implementation And Results

4.1 Parameter Value

Network field: 400x400m
N (Number of nodes): 400
Initial energy: 1 Joule
Eelec (E.Dissipation for ETx&ERx):50 nJ/bit
ε fs (free space): 10 pJ/bit/m2
εmp (Multipath fading): 0.0013 pJ/bit/m4
EDA (Energy Aggregation Data):5 nJ/bit/signal
Data packet size: 4000 bits
Tool used for implementation: MATLAB 7.6.0

Figure 3 shows the comparison of routing protocols LEACH-C and Power Efficient Hierarchical Routing (proposed routing technique) in terms of Number of nodes dead. Figure 5.1 shows the overall lifetime of the network. Here, we can observe that proposed routing technique performs better as compared to LEACH-C.

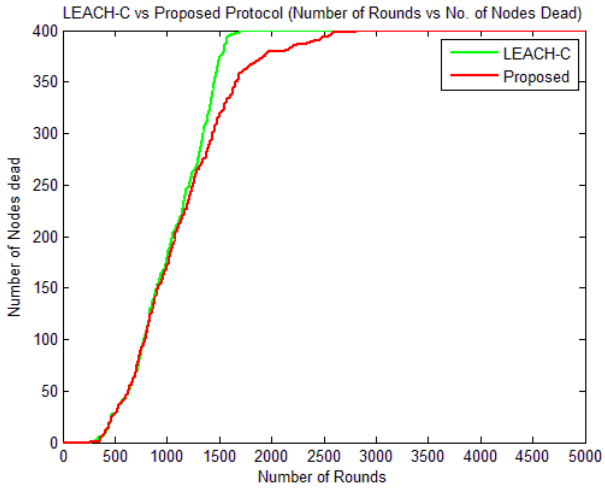

Fig. 3. Number of Rounds vs Number OF NODES DEAD.

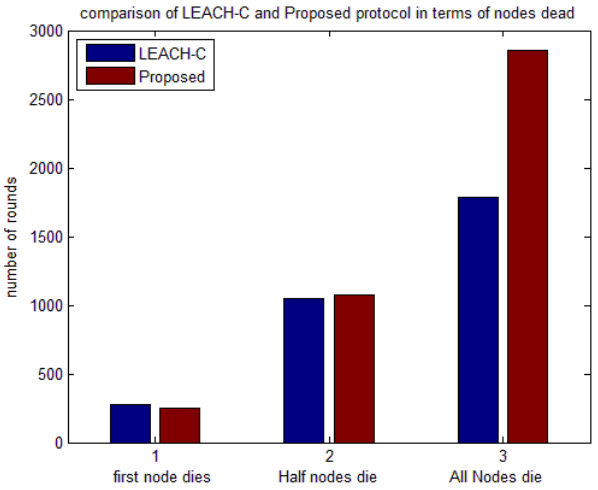

Fig. 4. Comparison of Network Lifetime LEACH-C and proposed routing technique.

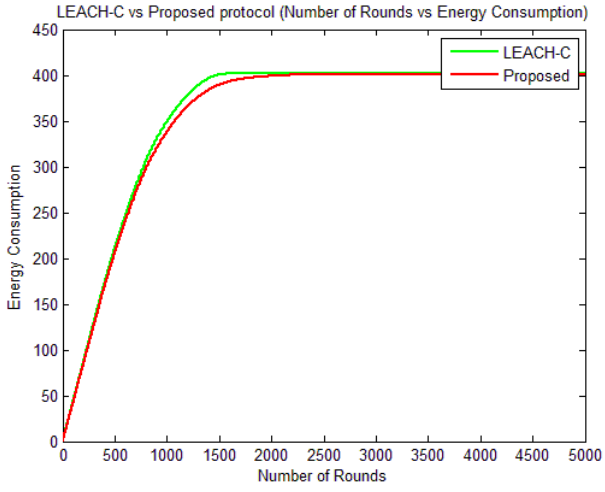

Fig. 5. Number of rounds vs Energy consumption.

Figure 4 also shows network lifetime with the help of BAR graph. Figure 4 shows exactly in which round the first node,

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tenth node and whole network dies. It can be observed from the figure 4 that proposed routing technique performs better as compared to LEACH-C.

Figure 5 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 5 that, proposed routing technique consumes less energy and sustain more number of rounds as compare to LEACH-C protocol.

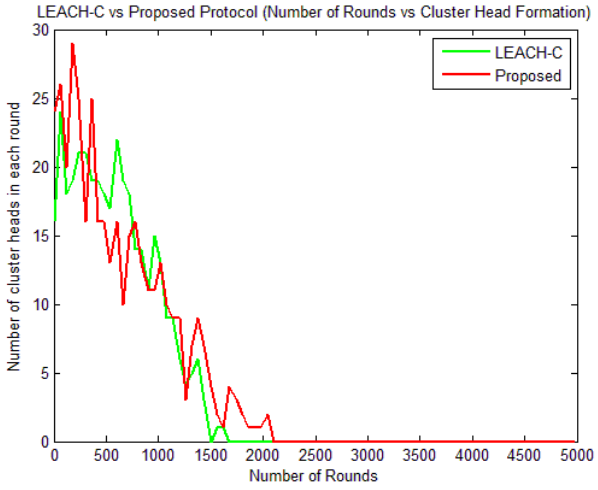

Fig. 6. Number of rounds vs Number of cluster head in each round.

Figure 6 shows the cluster head formation in each round. Overall, both protocols have comparatively equal number of cluster heads. But LEACH-C is showing more high spikes as compare to proposed routing technique. So, proposed routing technique will enhance the lifetime of the network.

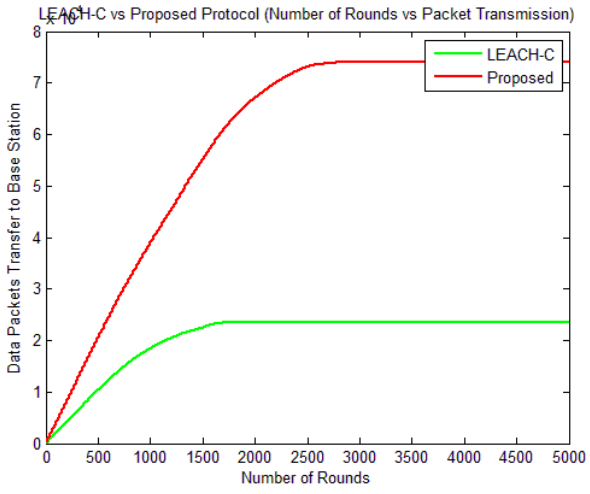

Fig. 7. Number of Rounds vs Data Packets sent.

Figure 7 shows how much data will be sent from nodes to SINK. From figure 7, we can observed that, in LEACH-C protocol data sent to base station is relatively less as compared to proposed routing technique.

V. Conclusion and Future Scope

This new routing protocol named Power Efficient Hierarchical Routing Protocol (proposed routing technique) which is hierarchical routing based with the whole control to the base station or we can say that base assisted. Basically, the question is how the cluster formation between the senor nodes will be?In non-centralized hierarchical routing, sensor nodes self configure them for the formation of cluster head. While self configuring, the nodes are unaware about the whole logical structure of the network. But in proposed routing technique, 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, proposed routing technique 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. System lifetime is basically for how long the system works.

In WSN, hundreds or thousands of sensor nodes are randomly scattered in the sensor field. These nodes sense the data and send this sensed data to the cluster head (in case of hierarchical routing) or directly to the base station according to the TDMA (time division multiplexing access) given by cluster head or base station respectively. But 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 proposed routing technique.

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