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EECPH: ENERGY EFFICIENT COOPERATIVE COMMUNICATION PROTOCOL FOR HETEROGENEOUS WIRELESS SENSOR NETWORKS

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Abstract: Typically, the energy consumption is the major issue in Wireless Sensor Network (WSN), and from past several years various clustering routing protocols are proposed to extend the lifetime of WSN. Sensor nodes can sense and sensed data will be forward to the Base Station (BS) in a cooperative manner. Hence, to transmit the data to BS a high amount of energy is required. To overcome this problem, the clustering approach is the key technique to reduce energy consumption. In this paper, we present an Energy Efficient Cooperative Communication Protocol for Heterogeneous (EECPH) Wireless Sensor Networks. Firstly, Cluster Head (CH) can be chosen according to the node initial energy, hop count, and remaining energy. Secondly, the introduction of cooperative node selection can reduce the uneven distribution of clusters. Finally, different levels of energy nodes are introduced namely normal, advanced, and super nodes to enhance the energy efficiency in heterogeneous WSN. Simulation results shows, the EECPH protocol outperforms with reference to network throughput, energy efficiency, and the network lifetime over EARPC, and LEACH protocol.

Keywords: cluster head; heterogeneous; residual energy; energy consumption; wireless sensor networks.

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1. INTRODUCTION

Wireless Sensor Networks (WSN) is one of the emerging fields in the scientific world. The recent technological development has brought less power consumption, least cost, and multifunction of sensor nodes. In WSN, consist hundreds of nodes are placed on the field to sense the surrounding environment such as fire detection, animal tracking, temperature measurement, and humidity, etc. These nodes will gather the sensed data and further it will transmit to the BS. The main aim of WSN is, to minimize energy consumption by selecting a suitable path from source to destination, and also extends the lifetime of sensor nodes. However, from the past several year's many authors proposed various techniques to minimize the energy consumption in case of constrained environment. Hence, an author's [1-4] present clustering is one of the key techniques to minimize the consumption of energy, and network load balancing in WSN. In WSN, a set of nodes will setup a cluster; in that one node can act as a cluster head (CH). A group of cluster members (CM) will elect one of the nodes as CH node. The CH node collect the information from the CM, and further aggregated data will be forwarded to the BS through direct communication or using relay nodes cooperatively. Furthermore, CH can perform channel allocation, relay node information, and also establish a route to BS in a cooperative manner. Hence, the clustering technique gives better energy efficiency in WSN. However, during the run-time scenario, the majority of the nodes with a different set of energy levels in the network. This type of network is called heterogeneous WSN. On the other hand, in case of Homogeneous WSN, equal energy levels are considered for all the sensor nodes in the network. Low Energy Adaptive Clustering Hierarchy (LEACH) [5], and Energy-Aware Routing Protocol for Cooperative MIMO Scheme in WSNs (EARPC) [6], are the examples of homogeneous cluster-based routing protocols in WSN. These protocols cannot perform well in heterogeneous networks. The node having less amount of energy will die quicker than the node having more amount of energy. In homogeneous WSN, the protocol does not consider when the nodes have

different energy levels. Thus, energy optimization approaches are required to prolong the life time of sensor nodes. In this paper, we propose Energy Efficient Cooperative Communication Protocol for Heterogeneous (EECPH) in Wireless Sensor Networks. In this protocol, the selection of CH formation is done on the following parameters, such as sensor node initial energy, number of hop counts, and node remaining energy. In the proposed EECPH protocol, sensor nodes are aware of its location at the time of deployment and further minimizing the energy consumption and network load balancing; divide the network into four subsections called zones [7].

An outline of the proposed EECPH is structured as follows: in section 2 presents literature review. Section 3 radio energy models are described, in section 4 system model is presented. In section 5 described about simulation results. The final summary is presented in section 6.

2. LITERATURE REVIEW

Designing an energy-efficient clustering technique is the solution to decrease the energy consumption in WSN. To enhance the lifetime of WSN, authors [3] proposed an energy-efficient protocol for load balancing. In this work, the authors proposed the CH node selection mainly depends on the route estimation energy cost calculated by the node with respect to BS node. However in their approach, for the selection of the least-cost route, Gaussian elimination technique is used. To reduce the energy consumption and internal overhead, authors [8] proposed a genetic algorithm for the selection of CH, and also A-star routing protocol is implemented to prolong the life of network. In their approach, sometimes less energy path is used for the selection of CH and frequently it updates the information about the energy for a further selection of the best routing path. However, the extra load will be imposed on the scalable network and if the CH node might be at a longer distance, further leads to higher energy consumption. To overcome the issues of load balancing and energy consumption, authors [5] proposed a cluster-based protocol that randomly rotates the CH, and this protocol evenly distributes the energy in WSN. In this protocol, the load balancing in the network can be maintained, by giving

chance to every node in the network will get a chance to become the CH. However, a node selected for CH in a particular round will never become a CH, irrespective of the node residual energy. Hence, the selection of CH is done on the set threshold $T(n)$ value. A node has less than the value of threshold that node can opt as CH for a particular round. Once a node becomes CH, it publishes advertise (ADV) message which consists of the node identity and associated parameter to the CM within the coverage area. Upon receiving the ADV from CH, the CM will reply to the ADV message with parameters such as acquired time slot, remaining energy level. Based on the CM reply, the CH allocates the TDMA schedule and forwards it to the nodes. With this, every sensor node knows its time slot for communication and other than this slot, the node will enter sleep state for saving the energy. However, the major drawback of this approach is, even though the node having low amount energy can be elected as CH. Hence the CH will die in a faster manner and further communication will be stopped. To minimize this problem, authors [9] proposed optimum number clusters based on available energy and the selection of CH node based on random approach, by considering the node remaining energy and dead node calculation from BS. This scheme reduces energy consumption and improves the network life. However, due to the because of extra load on the network and further utilization of energy is increased. In [10], the authors proposed an Extension of LEACH. To lower the energy consumption and to extend the lifetime of the WSN, in this protocol, residual energy, distance from CM, and distance from BS are the parameters to select the CH. In [11], the authors developed Stable Election Protocol (SEP). In this approach, two different energy nodes are implemented such as normal and advanced nodes in heterogeneous WSN. The CH formation is done according to the node's energy and the advanced node's energy levels are higher than normal nodes. The possibility of a node becoming the CH is independent in both the cases such as normal and advanced nodes. However, the advanced nodes will be having more chances to become CH rather than normal nodes. In their approach, the introduction of advanced nodes in the network can effectively increase the network performance in terms of overall throughput and lifetime of sensor nodes. Qing, Let al. [12] developed a Distributed energy efficient clustering approach (DEEC), where

the CH selection can be done according to the ratio of node available energy to the average network energy. In this approach, the authors found that the node having a higher energy level will have highest probability to become the CH than the nodes having a small amount of energy. In their study, for the selection of CH is depends on threshold by taking the ratio of node remaining energy and distance. In this approach, multiple levels of clusters are obtained when the network is scalable, and further, the unbalanced size of clusters is generated in the network. Hence, due to more number of clusters, its effects on the overall efficiency of the network in view of network lifetime and the stability of the network. Lloret, J et al.[13], proposed cluster-based architecture to find the optimal number of clusters in the wireless sensor networks with the same environment. The authors found that the sensor nodes with less distance will have better chances to become the CH. However, the selection of CH at the proximity level creates unnecessary energy dissipation, and also it affects the overall network efficiency. In [14], the authors proposed Energy-efficient hybrid routing protocol (EDHRP). In this protocol, the CH node can be selected depends on node's available energy on the routing path and the node has the highest energy on that particular path that node will be a suitable node for CH. Authors found that this protocol increases the sensor network life time by reducing the energy consumption. Hence, in recent years many authors proposed various techniques to prolong the network lifetime in heterogeneous WSN, but all these approaches somehow less faithful in terms of reducing the energy consumption in WSN without consideration of CH. Hence in this paper, a novel CH formation is implemented to improve the network lifetime and effective utilization of the energy in the network.

3. RADIO ENERGY DISSIPATION MODEL

The Communication system consists of transmitter and receiver section. Mainly the energy reduction in the WSN is, when the data communication happening between transmitter and receiver. Nodes consume a certain amount of energy to make the functioning of radio electronics circuit and amplification circuit in the transmitter side [5-15].

To send the K bit message with the distance d , the radio energy model is given by

$$E_{TX}(L, d) = \begin{cases} LE_{elec} + LE_{fs}d^2 & \text{if } d < d_0 \\ LE_{elec} + LE_{mp}d^4 & \text{if } d \geq d_0 \end{cases} \quad (1)$$

Where E_{elec} represents the amount of energy required to process one bit on transmitter (E_{tx}) section. E_{elec} depends on the type of modulation scheme is used, digital coding, and filtering. E_{fs} refers energy required for free space model and E_{mp} refers to the amount of energy required for the multipath model, and d represents the distance between the transmitter and receiver section. The threshold distance d_0 is given by equation 2

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad (2)$$

4. SYSTEM MODEL

In this section, we illustrate the EECPPH protocol. In the proposed EECPPH protocol n nodes are placed randomly on the $M \times M$ sensing area. We abstract the system model as follows.

- (1) Initially, the CH node can be chosen based on the node beginning energy level, number of hop count, and remaining energy. The CH node is responsible to send the collected data to BS. Initially, the network is divided into four zones, and BS is placed in the middle of the network area.
- (2) In each cluster, the introduction of cooperative nodes communication and further reduces the uneven distribution of clusters. The CH broadcasts the data to cooperative nodes and these cooperative nodes will transmit the information to BS node according to the TDMA schedule.
- (3) Finally, the energy communication model is presented different set of energy nodes, namely normal, advanced, and super nodes to enhance energy efficiency.

4.1 Cluster Head Selection

Our proposed protocol implements the Node Quality Index (NQI) for the selection of CH. The NQI can be estimated based on beginning energy levels, available energy during the execution scenario, and the number of hop count with respect to the BS. In this approach, for load

balancing, we apply LEACH principle to select the CH for the smaller number of rounds (25 rounds). The CH selection for the proposed protocol is given by

$$CH_i = \begin{cases} NQI > Avg_i & \text{for } i > 75 \\ NQI \frac{P_i}{1 - P_i(r \bmod \frac{1}{P_i})} & \text{for } i = 0 \text{ to } 25 \end{cases} \quad (3)$$

$$\text{Where } Avg_i = \left(\sum_{i=0}^n \frac{NQI}{|NQI|} \right)$$

4.2 Cooperative Node Selection

After the CH selection process, in every cluster few nodes can be chosen as cooperative nodes for sending the data to Base Station (BS). The CH node can select the cooperative node based on the node highest threshold value from all participating nodes. The threshold value to choose the cooperatives are expressed as

$$T(c) = \frac{E_{res}(i)}{d_i} \quad (4)$$

$$d_{min} \leq d_i \leq d_{max}$$

In equation (4), the node residual energy and distance parameters are taken to select the cooperative nodes in every cluster.

Where, $E_{res}(i)$ refers i^{th} node residual energy, d_i represents the distance between the CH node and cooperative node. Whereas d_{min} and d_{max} refers minimum and maximum distance.

4.3 Energy Consumption Model

In EECPPH protocol, we introduced three different levels of energy nodes are used such as Normal nodes having E_0 energy levels, advanced nodes with E_{Adv} energy level, and Super nodes with E_{Sup} levels. Energy calculation for three different nodes illustrated below [16],

The Energy contribution by a Normal sensor node is given by

$$E_{Norm} = nE_0(1 - b - b_0) \quad (5)$$

The Energy contribution by advanced sensor node is given by

$$E_{Adv} = nE_0(1 + m)b \quad (6)$$

Energy contribution by Super sensor node is given by

$$E_{Sup} = nE_0(1 + m_0)b_0 \quad (7)$$

Here m is the fraction of the total sensor nodes n , m_0 be total number of sensor nodes with b_0 times higher than normal nodes called super sensor nodes. E_0 is beginning energy level of normal sensor node with percentage factor as $n(1 - b - b_0)$ and eventually, the percentage factors for advanced sensor node and super sensor node are nb and nb_0 . The total energy of the network can be calculated as

$$E_{Total} = E_{Norm} + E_{Adv} + E_{Sup} \quad (8)$$

$$E_{Total} = nE_0 - nbE_0 - nb_0E_0 + nbE_0 + nE_0mb + nb_0E_0 + nE_0m_0b_0 \quad (9)$$

Hence, the equation (9) can be written as,

$$E_{Total} = nE_0 + nE_0mb + nE_0m_0b_0 \quad (10)$$

$$E_{Total} = nE_0(1 + mb + m_0b_0) \quad (11)$$

Hence, in equation (11), we found that, if we add heterogeneity up to level 3, it will increase the energy factor by $(1 + mb + m_0b_0)$ times. Hence to increase the heterogeneity to 'N' level more than level 2, the equation can be written as

$$E_{Total} = nE_0 \left(1 + mb + \sum_{i=0}^N (m_i b_i)\right) \quad i = 0, 1, 2, \dots, N \quad (12)$$

In equation (12), N refers integer number and heterogeneity of energy levels increases $(1 + mb + \sum_{i=0}^N (m_i b_i))$ times higher than the normal sensor nodes exist in the network. The total number of rounds can be calculated as given by

$$R = \frac{E_{total}}{E_{round}} \quad (13)$$

In equation (13), R is referred the total number of rounds. E_{round} refers the amount of energy needed by the network to complete the one round is expressed as

$$E_{round} = L(2nE_{elec} + nE_{DA} + kE_{amp}d_{toBS}^4 + nE_{fs}d_{toCH}^2) \quad (14)$$

In equation (14), k means the number of clusters in the WSN, E_{DA} refers energy required for data aggregation at the CH level, d_{toBS} refers CH to BS distance, and d_{toCH} refers the CM to CH distance. Then d_{toBS} and d_{toCH} are expressed as

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}}, d_{toBS} = 0.765 \frac{M}{2} \quad (15)$$

The suitable number of clusters that can be calculated is given by

$$k_{opt} = \frac{\sqrt{n}}{\sqrt{2\pi}} \sqrt{\frac{E_{fs}}{E_{amp}} \frac{M}{d_{toBS}^2}} \quad (16)$$

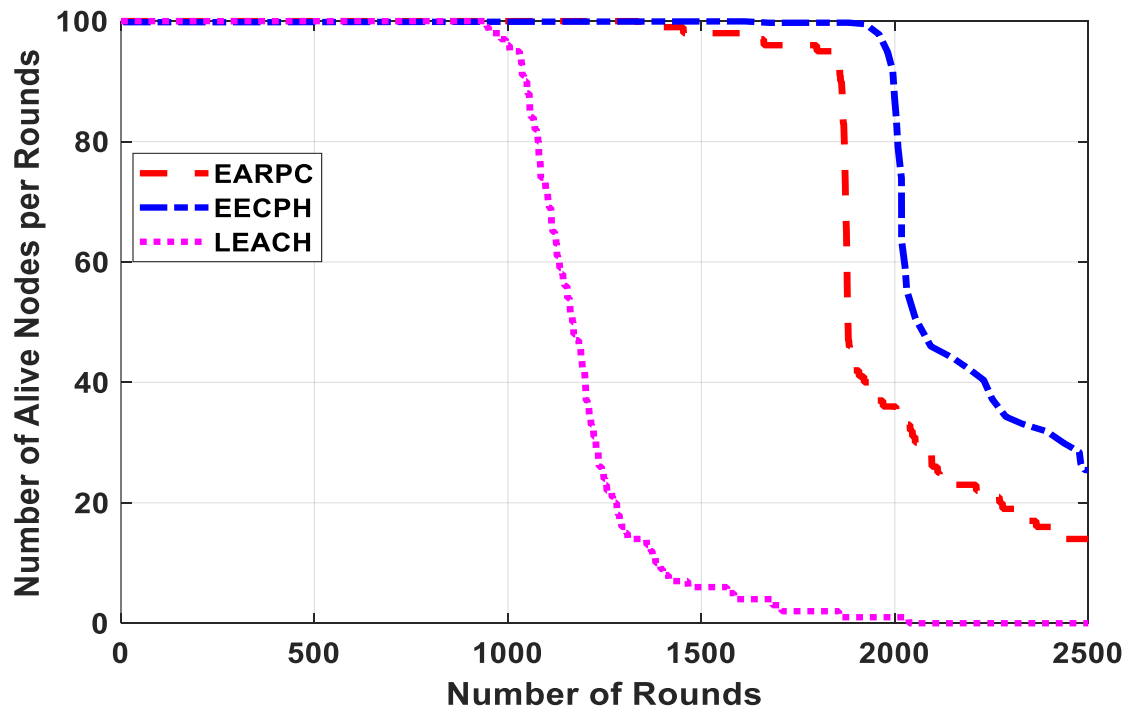
5. RESULTS AND DISCUSSION

In this section discusses the proposed EECPH protocol simulation results obtained using Matlab 18.0. The EECPH protocol has been assessed with EARPC [6], and LEACH [5] with respect to network lifetime, residual energy, and throughput. Table 1 shows the simulation parameters considered for the proposed EECPH protocol. In a 100 x 100m² network area, 100 nodes are randomly deployed and BS node is placed at the centre of the sensing area. The percentage fraction is b=0.1 and b₀ = 0.2 hence the advanced node energy level is twice that of normal node. The super node energy level is double over advanced node.

In the proposed EECPH protocol, we consider 20 normal nodes with E₀ energy levels, 32 advanced nodes having double energy levels than when compared to normal nodes, and the remaining 48 super sensor nodes energy levels are 3.5 times greater than normal sensor nodes. The simulation results of alive nodes versus the total number of rounds are shown in Figure 1. The results show that the lifetime of the EECPH protocol is extended over EARPC, and LEACH protocol. Figure 2 shows the network lifetime for EECPH, EARPC, and LEACH protocols. As a result, the EECPH protocol reduces the death rate over EARPC and LEACH. Figure 3 shows that the comparative simulation results with respect to number of data packets sent to BS. The simulation results show that the EECPH protocol sent more packets to BS. Figure 4 shows the residual energy versus the total number of rounds. The obtained results show that the residual energy depletes faster in the case of EARPC and LEACH than in the EECPH protocol. With this, the proposed EECPH protocol is most efficient in terms of a network lifetime, packets sent to BS, and residual energy.

Table 1: Simulation Parameters

Parameters	Value
Area of the network	100 x 100m ²
Number of Nodes	100 nodes
The total energy of the network (E_0)	50 joule
Size of the packet (L)	2000 bits
Energy amplification factor (E_{amp})	100/pj/bit/m ²
Energy data aggregation (E_{DA})	20nj/bit
Electronics energy (E_{elec})	50nj/bit
Threshold distance (d_0)	87-87.5 m
Base Station (BS)	(50,50)

**Figure 1: Number of alive Nodes v/s. Number of Rounds**

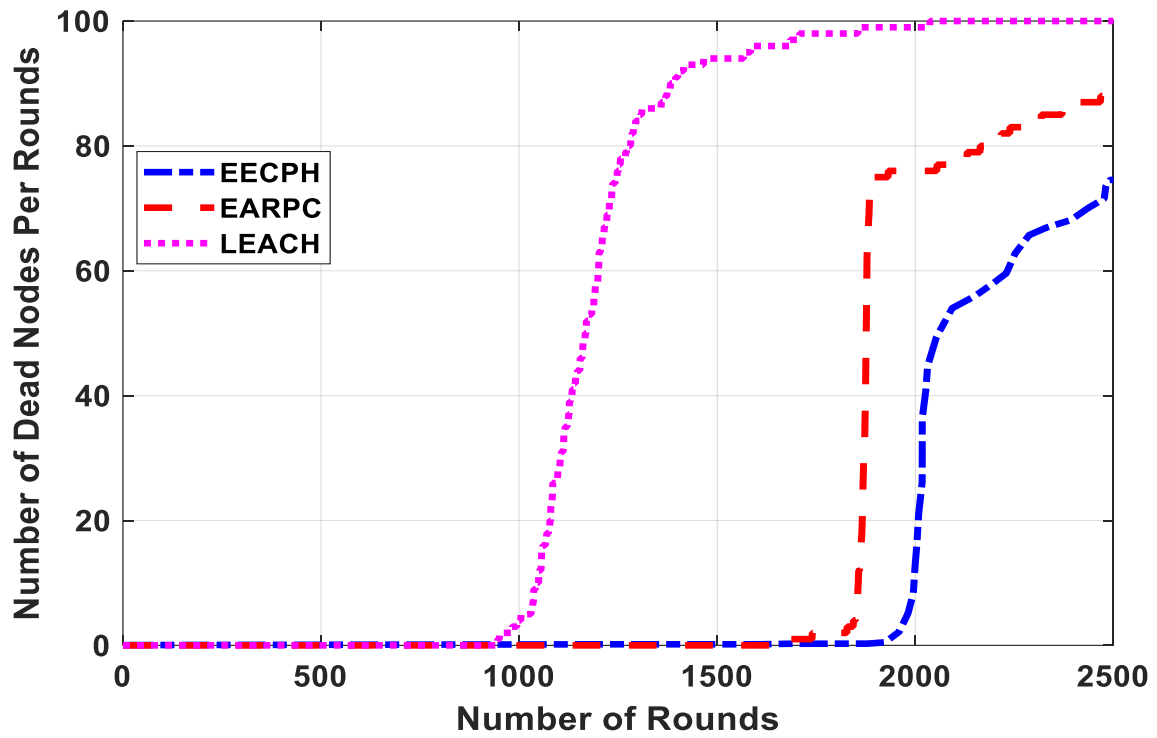


Figure 2: Number of Dead Nodes v/s. Number of Rounds

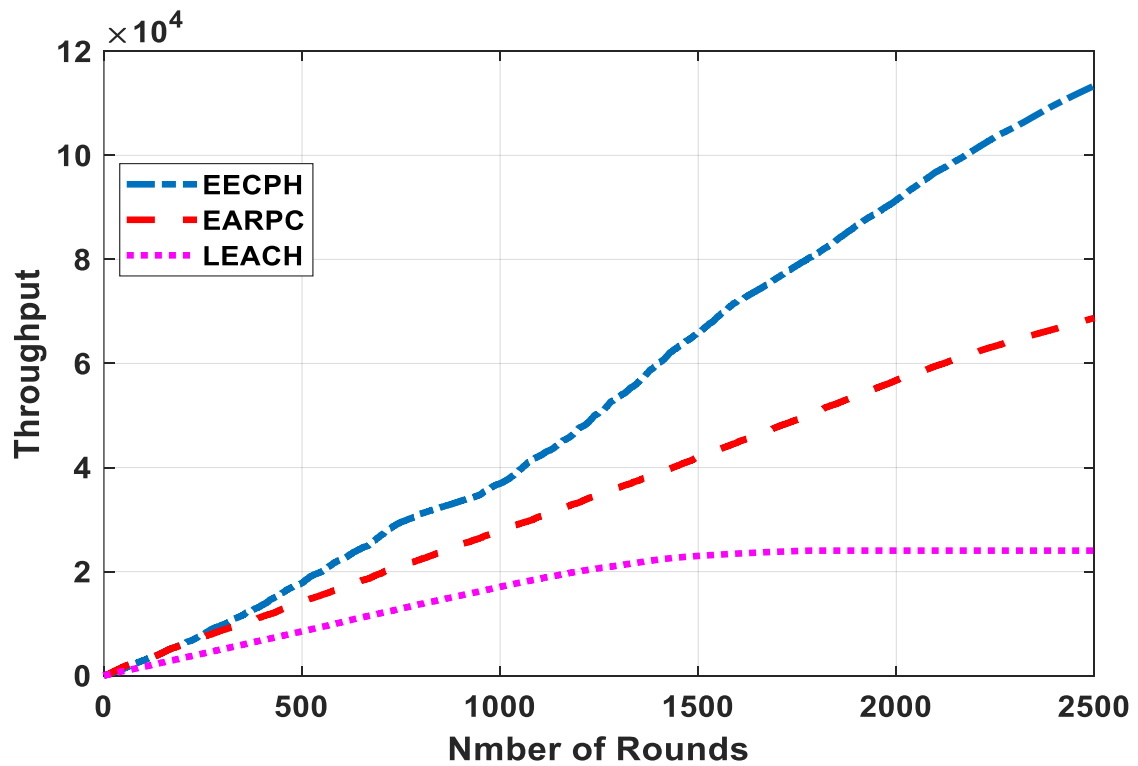


Figure 3: Network throughput v/s number of rounds

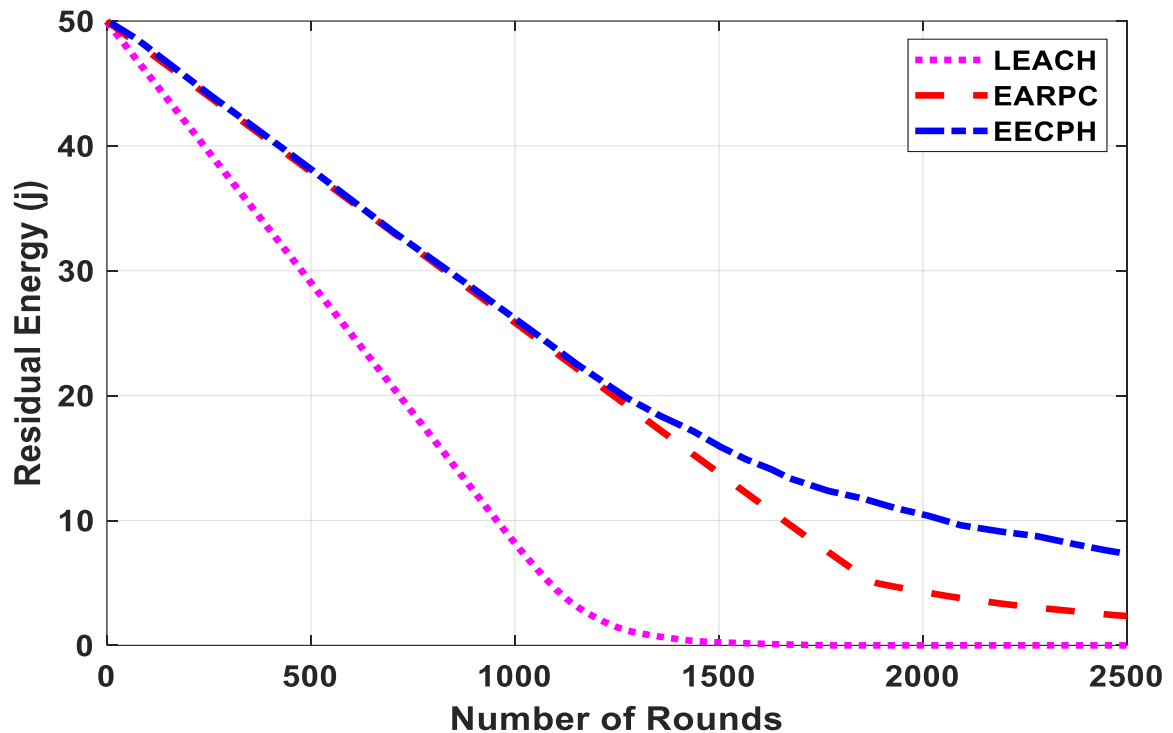


Figure 4: Residual Energy vs. number of rounds

6. SUMMARY

In the proposed EECPH protocol, the formation of CH can be done according to the node quality index (NQI). The NQI is estimated based on the node beginning level of energy, node available energy, and hop counts to the base station. The introduction of cooperative node selection can reduce the uneven distribution of clusters and further, we use different set of energy nodes such as normal, advanced, and super nodes to enhance the energy efficiency in heterogeneous WSN. Simulation results show the EECPH protocol out performs with reference to network throughput, Energy Efficiency, and the network lifetime over EARPC and LEACH protocols.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

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