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# A Novel Improved Energy-Efficient Cluster Based Routing Protocol (IECRP) for Wireless Sensor Networks

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## Abstract

Wireless sensor networks (WSNs) require an enormous number of sensor nodes (SNs) to maintain processing, sensing, and communication capabilities for monitoring targeted sensing regions. SNs are generally operated by batteries and have a significantly restricted energy consumption; therefore, it is necessary to discover optimization techniques to enhance network lifetime by saving energy. The principal focus is on reducing the energy consumption of packet sharing (transmission and receiving) and improving the network lifespan. To achieve this objective, this paper presents a novel improved energy-efficient cluster-based routing protocol (IECRP) that aims to accomplish this by decreasing the energy consumption in data forwarding and receiving using a clustering technique. Doing so, we successfully increase node energy and network lifetime. In order to confirm the improvement of our algorithm, a simulation is done using matlab, in which analysis and simulation results show that the performance of the proposed algorithm is better than that of two well-known recent benchmarks.

**Index Terms**: Cluster head, Energy efficiency, IECRP, Residual energy, Wireless sensor networks

## I. INTRODUCTION

Wireless sensor networks (WSNs) are used to oversee harsh environments and collect information from both reachable and unreachable locations [1]. The nodes of WSNs sense variables in the target domain and deliver data to a base station (BS) [2]; they fulfill many needs in the environmental, health, military, and industrial fields. The growth potential of WSNs is of particular importance for distributed terrain monitoring, especially for terrains that are inaccessible, hostile, or physically isolated. Recent advances in WSNs have decreased implementation costs and increased functionality [3]. However, the sensor nodes (SNs) are battery-driven and possess limited available energy. It is generally impossible to recharge or replace sensor batteries, owing to the costs and resources required to access the harsh geographic areas. The low-range communication processing capability, scalability, restricted memory, and deployment in unfriendly environments are further challenges.

When a node drains its energy completely, it fails to function and is considered a dead node. Then, target areas that are serviced by those nodes are neglected, even if nearby nodes have sufficient energy to operate. Furthermore, in addition to coverage, maintaining network connectivity is important so that every sensor can send data to the next node, a cluster head (CH), or a BS, depending on the network topology [4]. Hence, while tracking targets, enhancing the network lifespan and sustaining connectivity are crucial tasks.

SNs spend more energy during communication (i.e., send-

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ing and receiving data) than during routine computation processes [5]. With indirect communication, SNs dissipate more energy, owing to transmission distances. By contrast, multi-hop communication saves energy by relaying data via the nearest nodes or CHs to the BS. With multi-hop communication, SNs near the sink/BS have extreme communication overhead, resulting in power issues in the target area [6][7].

To overcome battery issues and enhance network lifespan, numerous clustering techniques have been proposed for WSNs [8-11] to prolong the life of the network [12-15]. The low-energy adaptive clustering hierarchy (LEACH) protocol improves network lifespan over direct or multi-hop transmissions, but it still has limitations. The CH is chosen randomly, which does not guarantee sufficient node dispersal and optimal performance. Sensors having low or high residual energy enjoy an equal chance of becoming the CH. Hence, those with low residual energy will quickly die as a CH, thereby shortening the life of the network [16].

The load-balancing energy-efficient sleep–awake aware (EESAA) protocol [17] considers multiple parameters, such as stability period, throughput, and network life, by enhancing and examining the clustering algorithm performance of WSNs. The CH collects data from the cluster nodes, fuses them, and sends them to the BS. However, the EESAA does not guarantee an even distribution of CHs across the network.

A stable energy-efficient network (SEEN) was also presented [18] in which the CH selection is based on the node residual energy and distance parameters. With this, a few SNs are facilitated by the best communication and processing competencies. Srivastava et al. [19] presented the optimized zone-based energy-efficient routing protocol (OZEEP) in which node density, residual energy, distance, and node mobility are used as input parameters for a fuzzy inference system to select an appropriate CH. However, it is the BS that stipulates all network controls and operations, which leads to poor scalability.

The problems with WSN routing schemes from the literature can be summarized as follows:

- Reselecting the same node as CH quickly drains its energy.
- The CHs are not evenly distributed across the network.
- Multiple CHs in the same cluster result in additional collisions that lead to increased energy consumption.

To resolve these complications, we propose a novel improved energy-efficient cluster-based routing protocol (IECRP) that is designed for useful clustering, which includes CH selection based on residual energy, neighbor distance, and number of neighbors. The significant contributions of this paper are as follows:

- We evaluate and increase clustering algorithm performance in terms of network lifetime, throughput, and stability period for WSNs.
- To ensure uninterrupted and collision-free communication, we focus on time-division multiple-access (TDMA)-based node transmissions.
- CH selection is based on current residual or maximum average energy.
- Active nodes transmit packets to other nodes or the BS, whereas the rest remain in a sleep state.

## II. LITERATURE REVIEW

Many clustering algorithms have been proposed to increase network lifespan, such as LEACH [20], kernel-based fuzzy C-means clustering [21], and dual-cluster heads technique based on Krill herd optimization [22]. WSN cluster routing emerged from these three protocols. The initial cluster routing technique for WSNs was LEACH. This algorithm presented the notion of rounds, which reflects the periodic implementation of cluster-based routing. A node is nominated based on its remaining energy during CH selection and whether it was nominated as a CH earlier.

The SN generates a random number between zero and one. It is selected as the CH if the number is smaller than T(n), after which the node broadcasts the information over the network. Every cluster member receives information from the other CHs. Afterward, the cluster member joins the CH with a strong signal and sends a join request to the CH. Upon receiving the request (approval), the CH assigns time slots using TDMA and codes using code division multiple access.

The probability of a node being selected as a CH based on each node's residual energy was later modified by Thein et al. [23], enhancing network lifespan by 40–50 %. In [24], another CH selection scheme was proposed for data aggregation, also enhancing the network lifetime by eliminating redundant data. The protocol considers a hotness factor to modify the threshold value, which describes a specific node's relative hotness in the network.

The CH selection in [25] focused on particle swarm optimization (PSO). The parameter selection is based on the residual energy, node degree, quantity of optimal CHs, and distance from the intra-cluster. This technique achieves better efficiency in different network metrics when assessed with other routing algorithms. A PSO based on energy-efficient CH selection was implemented in [26], where the CH is chosen based on the PSO by considering the residual energy, distance from the BS, and node-to-node distance. Using an optimization scheme (i.e., clustered gray-wolf search optimization), a security-aware CH is selected to increase the lifespan of the network in [27].

CH selection based on residual energy was then proposed as a LEACH improvement [28]. A modest multi-hop technique to LEACH was also introduced, and it was found that both algorithms enhanced the network lifetime better than LEACH after a given period. A non-probabilistic multi-criteria approach was presented for CH selection in [29], where the entire network is divided into different zones. The decision tool analytical network process is used to select the CH, and the best parameters are selected from a set of collected parameters for CH selection.

## III. NETWORK MODEL

To continuously monitor the environment, nodes are organized randomly in a network-targeted region/area. The total number of nodes is represented by $N$, where $N = \{n_1, n_2, n_3, \ldots\ldots, n_n\}$. The network model assumption is promulgated into the sensing area by deploying nodes to design the IECRP protocol.

- A single BS is placed above the sensing area.
- The SNs and the BS are static in the network region.
- At the time of deployment, all nodes have the same energy; therefore, uniformity is sustained.
- After acknowledgment, the BS interacts with the CH.
- Depending on the distance of the receiver, the transmission power is adjusted.

The architecture of IECRP is shown in Fig. 1. In each round, a new CH is selected based on its residual energy. Communication takes place based on the near-optimal path technique.

## IV. ENERGY CONSUMPTION MODEL

The energy required for data transmission depends on the transmission range of the transmission circuit. Similarly, the energy needed to receive the data also relies on the same factors. The energy necessary to transmit a data packet is

$$E_{Tr}(l, d) = E_{ele}(l) + E_{amp}(l, d), \tag{1}$$

$$E_{Tr}(l, d) = \{lE_{ele} + l\varepsilon_{fs}d^2 \, ; \, d < d_0\}, \tag{2}$$

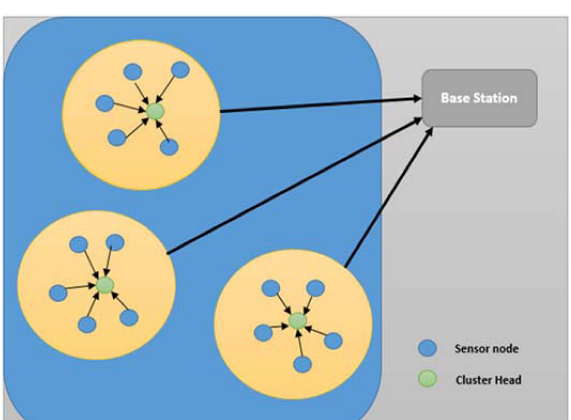


**Fig. 1.** Network structure.

$$E_{Tr}(l, d) = \{lE_{ele} + l\varepsilon_{mp}d^4 \, ; \, d \geq d_0\}. \tag{3}$$

The energy needed to receive a data packet is

$$E_{Rr}(l) = E_{ele}(l) = lE_{ele}, \tag{4}$$

where $E_{ele}(l)$ is the per-bit energy dissipated by transceiver circuitry. The free space ($d^2$) or multipath ($d^4$) propagation is used, depending on the transmission range. $E_{amp}$ $(l,d)$ is the amplification energy of the data at distance $d$.

## V. IECRP PROTOCOL

In this section, we propose the IECRP load-balancing technique, which improves the CH selection procedure by considering the node residual energy, node locations, and the number of neighbors.

### *A. Coupling in the Network*

At the start of CH selection, the SNs use carrier-sense multiple access (CSMA) with collision avoidance to broadcast the *HELLO* message with its residual energy to its neighbors. The *HELLO* message is used to determine the number of neighbors, the distance between them, and the neighbors' energy levels. Initially, the SNs broadcast their location information to the BS; after finding their positions, the BS estimates the related distance between the SNs. Nodes having minimum distance between them join the BS. Subsequently, the BS transmits the location information of each node in the network. The nodes that take part in the communication process change from the sleep state to an active state for the current round. The nodes that do not communicate with other nodes or the CH will remain in a sleep state, minimizing power consumption.

### B. Network arrangement

In this section, the distributed algorithm is used for an optimal number of CH selections. Initially, the network is homogeneous in energy with the same level. After the first round, the CH selection is based on each node's residual energy [30]. For the CH selection process, active nodes participate. Initially, nodes having the same initial energy, $E_0$, use a distributed algorithm. The SN of the active state chooses itself as the CH based on the selection probability. The random value of each node is in [0, 1] and is compared with the threshold value, $Th$, as follows:

$$\begin{cases} Pd/\ 1\text{-}Pd\_(\text{first round } mod\ 1) \text{ if } n \in A \\ 0 \quad Otherwise \end{cases} \tag{5}$$

Item $A$ is the group of active SNs during the first round, and if the threshold value, *Th*, is greater than the selected random number of the SN, then the SN elects itself as the CH.

### C. Data Transmission

The SNs send their sensed data in dedicated time slots during the assigned TDMA method. During the transmission phase, the nodes are not affected by the sleep state. The CH gathers data from each node and sends the aggregated data to the BS. During aggregation, the data are compressed, and redundant data are removed. Using a data aggregation scheme, a significant amount of battery usage can be minimized. Thus, to send packets, a non-CH SN consumes the $E_{amp}$ in transmission amplification and $E_{TX}$ in the transmitter circuits to achieve a tolerable signal-to-noise ratio. Therefore, the energy spent during the transmission of a non-CH $L_c$-bit message is calculated as

$$Enon - \mathrm{CH} = (\mathrm{N/K} - 1) \times \mathrm{ETX} \times \mathrm{Lc} \times Eamp \times Lc \times d2 - \mathrm{CH}. \tag{6}$$

In each cluster, the CH receives data from a cluster member, and the energy is calculated as follows:

$$Erec = (Erx \times Lc)\ (N/K - 1), \tag{7}$$

where $Erx$ represents the receiver-circuit dissipation of the energy for data reception. The data received by the CH to aggregate the data from the cluster members and the energy dissipated by data aggregation is calculated as

$$E_{AGR} = (E_{DA} \times Lc)\ (N/K). \tag{8}$$

The battery energy used by the CH to send the gathered data to the BS is

$$E_T = E_{TX} \times L_A \times E_{amp} \times L_A \times d^2 - BS, \tag{9}$$

where $L_A$ represents aggregated data, and $d^2$-$BS$ represents the distance between the CH and BS. The total CH dissipated energy is calculated as

$$E_{CH} = E_{rec} + E_{AGR} + E_T. \tag{10}$$

The overall energy consumed by the CH is the energy consumed during data reception, data aggregation, and data transmission to the BS.

## VI. RESULTS WITH DISCUSSION

To simulate and analyze performance, MATLAB 2017a was used for the proposed IECRP protocol, comparing it with two other benchmarks: SEEN and OZEEP. Table 1 lists the proposed IECRP simulation scheme.

**Table 1.** Simulation Setup

| Parameters | Values |
|---|---|
| Targeted area | 100×100 m |
| Sensor nodes initial energy ($E_0$) | 1 J |
| Energy cost during data aggregation ($E_{DA}$) | 5 nJ / bit/ signal |
| Total number of sensor nodes | 100 |
| Size of packet | 4,000 bits |
| Energy cost during transmission (*EelectTx*) | 50 nj/bit |
| Energy cost during receiving (*EelecRx*) | 50 nj/bit |
| Transmit amplifier ($E_{amp}$) | /bit /m$^2$ |

### A. Network Lifetime

Fig. 2 shows that the proposed method ensures that the life cycle of SNs is longer than the other two protocols (i.e., SEEN and OZEEP), because the proposed clustering method ensures that well-distributed CHs throughout the network achieve a balanced load. Moreover, CH selection relies on the nodes' residual energy to ensure the equal distribution of sensor energy depletion and avoid early battery consumption. From simulation results, an optimal number of SNs remains active until the end of battery life.

Network lifespan is essential to WSNs and is enhanced by the proposed method. Fig. 3 illustrates that SEEN and OZEEP node deaths occurred prior to those of IECRP. The lifetime of a network can be inferred from the death of its nodes.

### B. Quantity of Packet Delivery to the BS

Fig. 4 shows that the packet delivery to the IECRP BS was superior to SEEN and OZEEP. IECRP provides a significant improvement in data-packet transmission, and as it sends packets to the BS, the BS assigns different time slots to the

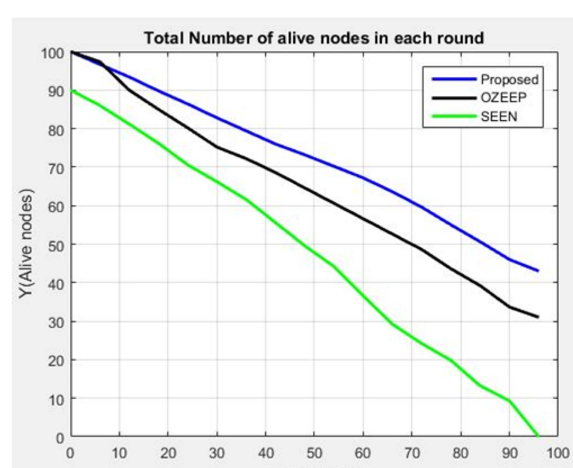


**Fig. 2.** Alive nodes in each round.

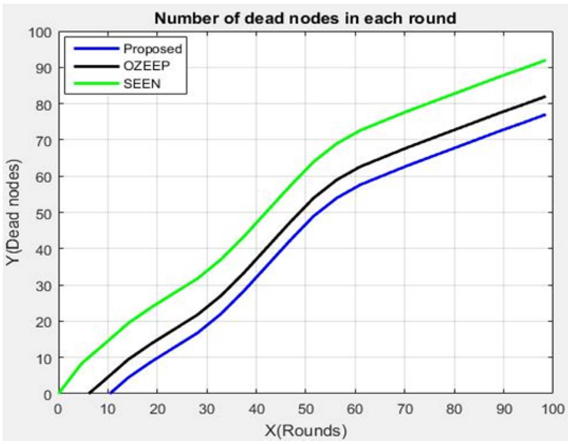


**Fig. 3.** Number of dead nodes in each round.

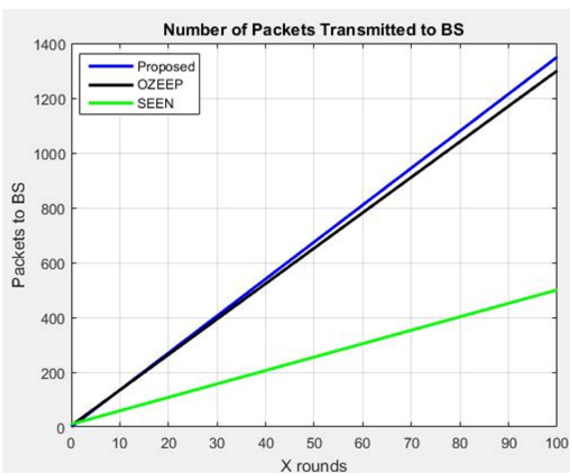


**Fig. 4.** Number of packets transmitted to BS.

CHs for data collection and transmission back to the BS. When the remaining CH energy is lower than the threshold level, the proposed algorithm selects a new CH.

## VII. CONCLUSION

We introduced a new load-balancing protocol, IECRP, which ensures efficient energy depletion and enhances the network lifetime of WSNs. The proposed method minimizes energy consumption, which leads to an increased network lifespan. Using this protocol, the live node concentration is increased and the dead node concentration is decreased. In terms of CH election, network stability, and network lifetime, the IECRP protocol was found to offer better efficiency than SEEN and OZEEP.

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