International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-11 Issue-6, March 2023

Energy Efficient Multi-Hop Multipath Sub Clustering Routing Protocol for Wireless Sensor Network

Kirti Bazar, Kanika Sharma

Abstract: *This paper aims to design an energy-efficient multi-hop Multipath sub-clustering routing Protocol for Wireless Sensor Networks. This paper presents a routing protocol for heterogeneous WSNs that selects cluster heads based on the highest remaining residual energy in a node using an optimal probabilistic equation. The heterogeneous technique involves the multi-hopping of inter-cluster communication and connectivity among the remaining sensor nodes using a sub-clustering technique. The sensor nodes with high residual energy will become cluster heads and send data packets to the base station. After conducting successive simulations of this routing protocol using MATLAB 2022b software, it was found that the protocol improves the number of alive nodes, the number of data packets transmitted to the sink in a network, and also increases the network lifetime by 75%-80% compared to other protocols. The simulation results were obtained by comparing the proposed method with O-LEACH, EEE-LEACH, Z-SEP, and LEACH. The results show that our proposed method is more stable and energy-efficient than the other routing protocols.*

Keywords: *Wireless Sensor Networks (WSNs),* **Sub-Cluster** *based routing, Multipath routing for communication, alive active nodes, Network Lifetime.*

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of densely deployed wireless nodes that are used to sense information with the help of sensors placed in the desired area and communicate accordingly with the system. There are two types of sensor nodes, one is a source node and the other is a sink node. The fundamental task of the network system is to gather data from all sensor nodes [1-4]. The wireless sensors are generally operated with batteries, but in large areas, it is not possible to use as many batteries to collect data as batteries are needed to be replaced when they get discharged, so in large areas, batteries are not suitable to collect a massive amount of data [5]. WSNs are used in many applications, whether it is natural or man-made applications like climate change, weather forecasting, soil monitoring, Health monitoring, military surveillance, business, traffic, etc. WSN has manifold significant applications [6]. Therefore, this paper aims to design a routing protocol of this kind, which can collect data from all cluster heads and send the data to the base station in a more efficient manner. Data loss during wireless communication is a common problem in WSNs. Therefore, backing up overall data is a challenging task. To obtain the data, one must minimise power consumption within the network by ensuring data is delivered securely to the base station. Then, an encryption method can be used to maintain the secrecy of the data. The three different levels of scheduling the packet are priority queue, real-time, and non-real-time data packets [7-11]. In the field of wireless sensor networks, sensor nodes have limited power, which is used for transmitting information to the base station. The basic architecture of a "Wireless Sensor Network" has been mentioned below:

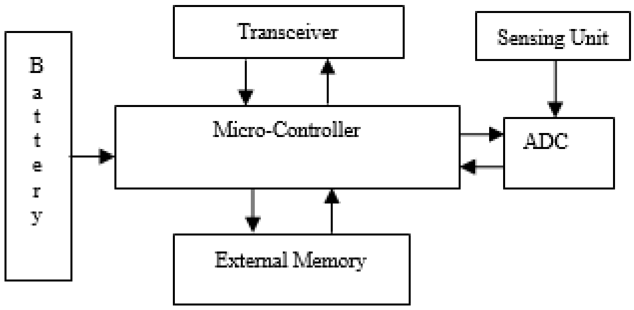

Fig. 1. Architecture of Wireless Sensor Network

Sensor node enables lifetime determination of battery, development of power management strategies, minimize latency and design and development of energy using protocols [12]. Many features and applications related to wireless sensor network are presented in paper which are described as, Energy Efficiency, Data aggregation process which is used for collecting data packets from all cluster heads and an aggregated data or fused data being sent at the base station, power consumption as it is main parameter in WSN because sensor nodes depleted at a fast rate when they tend to transmit or receive data from cluster head to base station, Mobility of nodes increases the efficiency of the network and sink mobility is the most effective means of load balancing, Scalability and Reliability which is ability of WSN to grow by number of nodes in a network and to maintain reliability of system is the critical task in the field of wireless sensor network [13-23].

Manuscript received on 24 January 2023 | Revised Manuscript received on 02 February 2023 | Manuscript Accepted on 15 March 2023 | Manuscript published on 30 March 2023.
*Correspondence Author(s)
Kirti Bazar*, Department of Engineering, Central Government, New Delhi, India. E-mail: kirti.id.1991@gmail.com, ORCID ID: https://orcid.org/0000-0002-5202-6689
Dr. Kanika Sharma, Assistant Professor, Department of Electronics and Communication, National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh, India

Retrieval Number: 100.1/ijrte.F74550311623
DOI: 10.35940/ijrte.F7455.0311623
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The use of a routing scheme in a network increases the network life as it provides a route to sensor nodes, which pass the data to the sink [24]. The effective use of routing is dependent on the network structure, which can be classified into three types. Data-centric routing, also known as query-based routing, originates from the sink side, where it requests data and then waits for a response from sensor nodes. Cluster-based routing: A combination of sensor nodes is used to form a cluster, and a cluster head is selected to transfer the data to the base station. It is helpful for Mobile Ad-hoc networks, which distribute data among nodes. Data aggregation at the cluster head also results in minimising energy consumption during data transmission. Location-Based Routing: Data is collected for sensor nodes. This comes under the example of Energy Aware Greedy Routing (EAGR) [25-30]. Clustering of sensor nodes is an effective method for achieving goals in wireless sensor networks. The clustering technique helps reduce power usage among networks and also reduces the time required. The clustering consists of two steps, which can be described as intra-cluster-based routing and inter-cluster-based routing. Intra-cluster-based routing can be used between a cluster member and a cluster head, or in inter-cluster-based routing, clustering occurs between a cluster head and a base station. In this paper, a multihop communication method is preferred over the distance between the cluster head and the base station. The threshold value of the network also increases in this type of communication. The sensor nodes are designed to be mobile, collecting information from the cluster head and transmitting it to the base station. The energy level of all sensor nodes is set as usual, intermediate and advanced nodes. Many challenges need to be overcome for implementing an energy-efficient network so that it can increase network lifetime and the number of alive nodes [31-36].

The proposed work is based on the Energy Efficient Multihop Multipath Sub Clustering Routing Protocol (EEMMSCR), which improves the overall performance of the network and increases the network lifetime, the number of alive nodes in the wireless sensor network, the number of data packets transmitted to the sink, and the network lifetime for FND, HND, and LND. The selection of the cluster head is dependent on an optimal probabilistic equation, which will be explained in this paper later. Also, it depends on the residual energy of the sensor nodes. A sub-clustering method is also introduced in this paper, and its use in wireless sensor networks enables sensor nodes to combine and form a cluster head, thereby increasing the network's connectivity. Multihop communication is a process that optimises energy consumption in a network, and combining it with multipath routing ensures that data is transmitted more efficiently. The use of multipath communication is reliable, as data can be transmitted through multiple paths within the network, providing redundancy and increased reliability.

II. LITERATURE WORK

There is a rapid increase in the number of routing protocols in wireless sensor networks. Various papers utilise different routing protocols and clustering methods, demonstrating that the use of such protocols increases network lifetime and reduces energy consumption through clustering. The clustering process consists of two types: homogeneous and heterogeneous. In the homogeneous process, all sensor nodes are deployed, and some initial energy is initialised to them. In the heterogeneous clustering process, sensor nodes are categorised by energy levels. We review some of the papers related to the proposed work. Kiran Maraiya et al. [37] introduced the selection of cluster head for aggregating the data in a wireless sensor network system, in which the data aggregation process has been implemented to achieve effective clustering and to avoid traffic amount in the network. The way of processing sensor data at the base station is an effective technique that aims to provide fused or aggregated data to the sink. Then, a re-clustering process is used to reduce the load on the cluster head, which sends data with limited energy. The ECHSSDA approach works well in several rounds and sets up a set of clusters in a structured manner, tracked by a cluster steady phase.

Ahmed Al-Baz et al. [38] has implemented the selection of cluster head algorithm for LEACH protocol. When sensor nodes are limited in resources, such as battery power and inbuilt memory, a cluster-based protocol is used, which balances the energy level at all nodes and gives them a chance to become a cluster head. A node-ranked LEACH algorithm has been proposed, which improves the overall network lifetime. The node that contains higher energy is highly prone to becoming a cluster head. Proposed algorithm based on two basic parameters: one is the path cost, and the other is the number of communication links between sensor nodes for the selection of the cluster head. The selection of a cluster head is based on ranking, where nodes with high rankings are selected to perform specific tasks in a wireless sensor network. The problem of random selection of the cluster head is being overcome in this method.

In [39], Bhawnesh Kumar et al. has used selection of cluster head algorithm based on distance which improves the network lifetime in wireless sensor network and balances the overall load of energy over sensor node. Cluster head selection is based on the residual energy of sensor nodes, calculated using the Euclidean distance between the centroid of the cluster and the base station. Multihop routing has been selected to determine the shortest path for transmitting data to the base station. This method conserves a sufficient amount of residual energy in sensor nodes, thereby extending the network lifetime.

In [40], Nadeem et al. have proposed energy-efficient distributed cluster algorithm mainly for heterogeneous networks. It is dependent on three primary energy levels, which are described as “Probability of sensor node for becoming a cluster head by estimating residual energy in every round”, “Number of adjacent sensor nodes and their distance to the destination. This concept selects the best possible sensor nodes to become cluster heads and enhances the stability period of the network by utilising different energy levels within the network.

The researchers Sehar et al. in [41] are using a load balancing method which improves the network lifetime by solving the problem of inadequate CH selection, fixed clustering, and static rounds, energy-efficient mobility of the cluster head selection algorithm. The

Retrieval Number: 100.1/ijrte.F74550311623
DOI: 10.35940/ijrte.F7455.0311623
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

process to select CH depends upon factors like node mobility, Sensor node residual energy, distance from CH to Base Station (BS), Neighbour degree, etc.

The EEMCS mechanism is based on two models, expressed as the Network Development Model and the Radio Energy Model, which route their data to the base station. These two models increase the network lifetime and energy level of sensor nodes, and also overcome the unnecessary formation of sensor nodes as cluster heads by re-clustering the basic process after a fixed interval of time. By comparing the EEMCS mechanism with other protocols, it yields better results and a more balanced network and energy consumption. The researcher in [42] Trong-Thua Huynh et al., proposed the research work in "energy-efficient clustering, based on multi-hop routing by using delay-constrained method in wireless sensor networks". It minimises energy consumption within sensor nodes and helps overcome the problem of end-to-end (E2E) delay in WSNs. Multihop routing in inter-clustering is used to sense data packets from the selected cluster head. It is responsible for transmitting the data packets to its base station, thereby minimising the high amount of energy in the system. When this inter-clustering process is established among the nodes, data transmission occurs from the source to its destination. All collected data is fused into a single packet, which is then sent to the base station. The selection of the cluster head can be done by adjusting the value of the trade-off for energy and delay (TED) about both the consumption of energy and the E2E delay. The method minimises the cost of energy consumed by sensor nodes. It satisfies their end-to-end delay constraints by optimally adjusting the parameter values of the trade-off for a specific network size. In [43], the researcher Khalid Haseeb et al., has implemented the Awareness of Energy and Security of Multi-hop Routing (ESMR) protocol which uses a secret encryption/decryption key sharing scheme, also increases the efficiency of energy and secure the system network by using multi-hop method for securing data privacy. Ensuring data security and integrity against malicious actions is a challenging task in the field of wireless sensor networks. In such cases, some constraints depend on the sink distance and the number of sensor nodes. To rectify this problem, the protocol above has been implemented to maintain the confidentiality of the data. By using this protocol, the network is divided into inner and outer zones, each with its segments, which operate according to the selection of the sensor node. The data transfer from selected cluster heads to their sink node is secured using an encryption/decryption secret key sharing scheme. Then the data is evaluated to minimise routing disturbances. These aspects provide data security by routing it using a multi-hop method, which sends a secret key to each cluster head. This secret key is used for encrypting and decrypting data packets at the base station. In [44], Energy minimization is a common issue in designing the wireless sensor network and data transmission becomes more complex in multi-hop approach. To overcome this issue, Indra Kumar Shah et al. have introduced the Intra-Cluster and Inter-Cluster (ICIC) energy minimisation approach for multi-hop wireless sensor networks (WSNs). In the intra-cluster mechanism, packet transmission to the cluster head (CH) node is based on a dynamic duty cycle or distance from child nodes. In the inter-cluster mechanism, the nearest route is chosen for packet transmission to the Base Station (BS) to minimise energy consumption. Multi-hop networks typically identify the shortest path using TDMA scheduling and link each node to activate it one at a time. The proposed mechanism improves the probability of transmission outage and energy efficiency, while utilising more network energy. In [45], New approach for increasing the network lifetime is a primary goal of researcher which is using Energy Efficient Hierarchical Clustering (EEHC) approach based on random clustering distribution algorithm for Residential WSN introduced by Jie Chen et al. A node itself declares about being selected as cluster head by calculating weights of sensor nodes. When the cluster head is replaced, neighbour nodes randomly select a new cluster head for a particular interval of time, and information is transmitted to the nearest sink node using a multihop communication technique. Residential energy management by RWSN involves a clustering algorithm, data transmission using a multihop method, and addressing the energy hole problem. In RWSNs, the data aggregation for multi-hop transmission depletes the energy, which tends to create the energy hole problem and creates a gap in the area around the BS. The proposed method effectively conserves network energy, thereby maximising the network lifetime and improving network performance. The researcher Antonino Masaracchia et al in [46] has mentioned that, in a natural disaster area, the communication between network infrastructure and device-to-device (D2D) based framework for disaster relief network is developed for making the network more energy efficient in WSNs, as they are based on the position of sensor nodes and the battery level of the device. To maximise the energy efficiency of the network in an affected area, multiple paths for communication are created within the infected area, thereby minimising the delay at both ends during communication. The use of relay nodes over selected coverage area is provided by sink node and function of this node is; the selection of sufficient number of gateways is being carried out to cover all the affected area by cluster creation, provide transmission power to each gateway and construction of multi-hop path for delivering the data at end-to-end delay. The proposed method statically allocates the power and creates a routing path which improves the network lifetime.

In [47], Mohammed Zaki Hasan et al. have proposed multipath routing for real-time applications in wireless multimedia networks to achieve high Quality of Service (QoS). The wireless multimedia application prioritises multipath routing, which supports multimedia data in various environments. The challenges in designing this multimedia network are dependent on the flow of data traffic and the end-to-end delay in data. The process of multipath routing is used to achieve high Quality of Service (QoS) by selecting a reliable path that avoids node or link-disjoint paths. Multimedia data can store a large amount of data and deliver it to the system network, so that routing protocols in "Wireless Multimedia Sensor Networks" (WMSNs) enhance energy efficiency, but energy drains quickly when sending data to the network.

In [48], by Yang Liu et al., researchers have developed an

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

improved method for getting the Efficient Energy- LEACH (IEE-LEACH) protocol for minimising energy consumption within the system network. In that cluster, a hierarchical routing protocol has been implemented based on the cluster to minimise energy consumption by the network. The proposed method, IEE-LEACH, optimally selects a cluster head and restricts other sensor nodes from becoming cluster heads. The selection of the cluster head in the IEE-LEACH protocol has the advantage that it cannot guarantee the formation of a CH according to the residual energy of its sensor node. Four energy parameters have been considered when selecting the threshold value: energy at the initial stage of the node, residual energy, total network energy, and the average energy of all nodes. This protocol can be applied to any type of hop routing and is primarily used for hybrid communications during data transmission. This protocol enhances the network lifetime and makes the network more energy-efficient.

In [49], Mohammad Hossein Anisi et al. propose a routing protocol to select a set of sensor nodes and ensure the timely delivery of data in a wireless sensor network. The commonly used routing schemes are Data Centre Routing, Clustering-based routing and Location-based routing. The Proposed Efficient Data Routing (EDR) algorithm, which employs a data-centric approach, is used. This algorithm mitigates the address routing issue in wireless sensor networks and provides Quality of Service (QoS) by broadcasting data from every sensor node to its neighbours. The routing of data is always acknowledged to the sensor node according to the best path. The Efficient Data Routing (EDR) algorithm consists of three main stages: initialisation, data forwarding, and route maintenance. The application can perform as an event-driven and query-driven system. The proposed method can increase network lifetime, ensuring the timely delivery of data to a base station. In [50], Yanjun Yao et al. have described a data collection protocol that utilises EDAL, i.e., energy-efficient delay-aware lifetime, to balance the collected data, thereby solving the open vehicle routing (OVR) problem. To reduce computational overhead, a centralised heuristic approach is employed. The EDAL protocol is used for OVR operation to find the shortest route for delivering data with time deadlines in a heterogeneous network, and the problem is known to be NP-hard in operational research. The purpose of EDAL is to route the path with minimal packet loss and balance the load constraints in a network. The network lifetime is also balanced by assigning nodes with remaining power. During the simulation, the researcher observed that the network increases with minimal data packet loss, and network lifetime gains can be achieved to a great extent. Researchers Yanshan Tian et al. in [51] implemented a clustering-based multihop routing protocol that relies on a fuzzy inference system with a multi-path tree-shaped structure to determine the next hop. The sensor node battery is limited, especially when placed in a large field, and the energy consumption at each node is a challenging task. By utilising a tree-type structure, wireless sensor nodes are grouped into clusters using a routing method, and the optimal path of the network is determined through a fuzzy inference method that considers the remaining energy within the sensor nodes and their traffic load. The combination of proposed algorithms enables better throughput. The proposed algorithm is considered in conjunction with the Low-Energy Adaptive Clustering based Hierarchically Enhanced (LEACHEN) method, which involves sending messages through multi-hop paths from CHs to the sink node during the stable system phase. This proposed method not only stabilises the sensor network but also reduces energy consumption in sensor nodes, balances the load, and hence increases the overall network lifetime. In [52], Jin Wang et al. utilise the Hop-based Energy Aware Routing (HEAR) algorithm to enhance energy efficiency and prolong the network lifetime by considering protocol design in wireless sensor networks. The proposed scheme is relatively based on the relationship between hop number and energy efficiency in a real network environment. In this paper, the researcher has not considered the data aggregation or routing overhead method. When nodes are deployed randomly, they obtain information based on GPS devices or received signal strength. The source node then sends a message with the shortest route path to the destination, i.e., the base station, and the best path is chosen for sending data. The HEAR algorithm achieves a 125% increase in network lifetime and a 50% reduction in energy consumption. In [53], Nhat-Tien Nguyen et al. have highlighted the network lifetime and energy efficiency issues in Underwater Wireless Sensor Networks (UWSNs). Researchers have proposed clustering in a multi-hop routing protocol for WSN to increase the efficiency of energy in a network. It operates based on the selection of cluster heads according to node depth and residual energy of sensor nodes. The nodes are deployed in rivers and oceans to monitor underwater conditions, and sensed data is forwarded to the base station at the onshore gateway according to the residual energy of each node. The underwater sensor calculates the weight of sensor nodes based on node depth and residual energy. Increased data transmission at the nodes results in high energy consumption. Simulation results show that EECMR considers only the residual energy of nodes that are elected as cluster heads, which is effective in improving the network lifetime and energy consumption of nodes. The researchers Shiva Rowshanrad et al. [54] have introduced a multi-hop balanced clustering (MBC) protocol based on the k-means clustering algorithm, utilising a genetic algorithm (GA). The deployment of sensors in a wide area and operated them with the batteries has become a problem in WSN because replacement of batteries is hard for researchers and to overcome this issue, MBC is used which is a centralized protocol that uses the genetic algorithm for multi-hop communication among cluster heads and effective selection of CHs leads to better performance which provides efficient energy by prolonging network lifetime. A genetic algorithm, also known as a probabilistic search algorithm, provides an optimal solution by creating a population of individuals and manipulating the data to form a next-generation population. In the MBC protocol, clustering is performed using k-means clustering, which is based on the Euclidean distance. The selection of CH is determined by a weighted function of sensor nodes and their residual energy.

Multi-hop route discovery is based on a genetic algorithm, and data scheduling and transmission to the base

Retrieval Number: 100.1/ijrte.F74550311623
DOI: 10.35940/ijrte.F7455.0311623
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

station are also implemented.

By using this process, the network is balanced and its lifetime is increased by 97%.

In [55] by Yisheng Miao et al, a process of clustering which is based on non-uniform routing of wheat farmland has been implemented by the researcher to collect the real time data in the field of agriculture. Wheat farmland WSN consist of a large area in which sensor nodes are deployed randomly, and there is an insufficient supply of energy for such a vast area. The use of this protocol enables more efficient energy utilisation in WSN by monitoring and selecting the appropriate path for data transmission. A non-uniform clustering approach based on adequate energy consumption (UCEEC) has been implemented in conjunction with the concept of image segmentation. The selection of a cluster head using a multihop path with two hops can be designed to calculate the energy consumption within nodes and balance the overall network. The non-uniform multi-path fading effect improves the cluster nodes according to their data and channel. The UCEEC method enhances the overall network lifetime cycle during the simulation process by effectively collecting data in the complex environmental conditions of a wheat field.

"Energy Efficient Compressive Sensing-based routing protocol" has been implemented in [56] by Quan Wang et al., for reducing energy consumption within networks. In this, researchers have developed a clustering process using a Compressed Sensor-based (CS-based) technique. The nodes are deployed beyond the reach of humans, and those closer to the base station (BS) are energy-depleted at a very high rate, creating the "Hot Spot Problem". The compressive sensing method recovers the data at a sampling rate whose characteristics are dependent on the signal's rate, rather than its bandwidth. The Energy Efficiency in Compressed Sensor-based Clustering Routing (EECSR) protocol comprises three phases, which are described as follows: cluster formation, spanning tree construction, and data acquisition. The results show that the researcher has confirmed that the backup and rotation mechanism of cluster heads (CHs) shortens the energy depletion, thereby increasing network lifetime and providing better throughput.

A mode of cluster gateway which is based on "multihop routing protocol for mobile ad hoc networks" has been introduced by R.K. Ghosh et al. in [57], for reducing workload of cluster heads (CHs) in a network. This type of network is better suited for efficient routing management within the network, as data is transferred through multiple cluster gateways. Routing tables are used to maintain a record of gateways, and a random approach has been implemented over the dense cluster gateway (DCG). A heuristic approach using k-tree cluster-based routing for the core backbone has been proposed to distribute the routing load on the cluster gateway, without maintaining information about dense cluster gateways. The researchers have demonstrated in their results that the randomised distribution of loads over cluster gateways provides a balanced load on gateway edges, and the rotation mechanism manages the load on a gateway node without incurring overhead for the actual load information. The sub-clustering process increases the chance of sensor nodes becoming cluster heads at the local level, rather than at the global level, in the k-tree core.

III. NETWORK REPRESENTATION

The paper presents a sensor network being considered, which consists of uniformly and randomly deployed N wireless sensors in a large field area for continuous monitoring of the field's environmental conditions. Some assumptions have been made about sensor nodes, and by this, we make the network model:

- All Sensor Nodes (SNs) are distributed randomly and uniformly.
- The network system has placed a Base Station (BS) at the centre and is stationary.
- Deployment of wireless sensor nodes with minimal energy. Every sensor node has a unique identity.
- Sensor nodes can wirelessly sense data and transmit it to the base station.
- The sensor is heterogeneous, as it prolongs the network lifetime and enhances energy efficiency.
- There are three different kinds of sensor nodes used, namely Normal, Intermediate, and Advanced, which have the capability of operating in active mode as they are responsible for sensing, communicating, and processing data.
- The formation of clusters to become cluster heads (CH) is used for data aggregation before sending it to the base station (BS).

A. Data Aggregation and Network Model of Energy Dissipation

The Data Aggregation and Energy Dissipation Network with RF model has been proposed in this research work. The process of aggregating data collected from cluster heads (CHs) removes redundant transmissions of data packets and provides aggregated data packets to the base station. This demonstrates an effective procedure for saving energy in WSNs. Many researchers widely use the cluster-based data aggregation process in WSNs to manage energy, thereby prolonging network lifetime. This model can be used for either "free space (d2 power loss)" or "multipath fading (d4 power loss)" by calculating their values based on the distance between sensor nodes and the base station.

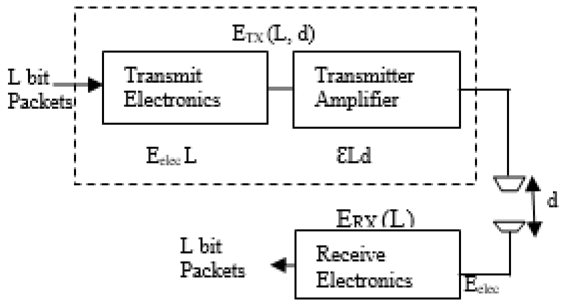

Fig. 2. Model of Energy dissipation

If the distance 'd is less than the confidence threshold value, then communication between sensor nodes and the base station will use the free space channel model; otherwise, the multipath model will be used.

The data aggregation process is incorporated from the cluster head.
(CH) formation to the base station (BS).

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

According to the figure that has been shown in the energy dissipation model, L is called a packet of length to distance d, and the expression for transmitting the energy in free space or multipath channel modelling can be calculated as:

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

Energy consumption at the base station or receiver side is;

$$E_{RX} = L.E_{elec} \quad (2)$$

By calculating the expression (1) considering d = d0, then

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$$

When the transmitting distance (d) is less than the threshold distance (d0), a model-free space channel is used; otherwise, multipath fading channels are preferred.

In our model, we assumed that perfect data aggregation of data packets is achieved, and a single packet is transmitted to the Base Station (BS). Energy consumption for data transmission is significantly reduced by considering the minimum distance from the Cluster Head (CH) to the Base Station (BS).

IV. PROPOSED METHOD

The primary objective of our proposed method is to utilise a routing protocol with a multipath sub-clustering technique to enhance energy efficiency and stabilise the network system. Here, we present three levels of energy heterogeneity, namely Normal energy nodes, Intermediate energy nodes, and Advanced energy nodes, according to their increasing energy levels. The network system consists of a random distribution of sensor nodes on a 100 x 100 meter field, with symmetric communication among sensor nodes and the cluster head. The cluster head (CH) collects all information from sensor nodes and transmits the aggregated data to the base station (BS). If the sensor node value is less than or equal to the threshold value, then the cluster head is selected for the current round.

Normal nodes' primary energy is considered as Eo, and the population count of this node is given by n $(1-x-x_o)$. The intermediate and advanced node populations are nx and nx_0. So, the calculation of energy for all three energy levels is mentioned below:

Calculation of energy for a normal node,

$$E_{normal} = nE_0(1-x-x_o) \quad (4)$$

Energy calculation by the Intermediate node is,

$$E_{int} = nE_0(1+y)\ x \quad (5)$$

Energy calculation by the advanced node is,

$$EAdv = nE0\ (1+y0)\ xo \quad (6)$$

Total initial energy in the proposed method for heterogeneous WSNs is calculated as:

$$ETot = Enormal + Eint + EAdv \quad (7)$$

$$E_{Tot} = nE_0 - nxE_0 - nx_oE_0 + nxE_0 + nxE_0y + nx_oE_0 + nx_oE_0y_0 \quad (8)$$

$$E_{Tot} = nE_0 + nxE_0y + nx_oE_0y_0 = nE_0\ (1+xy+x_oy_0) \quad (9)$$

The proposed method, which incorporates three energy levels of heterogeneity, contains more energy compared to a homogeneous network. Cluster head selection based on a probabilistic approach, supporting parameters can be calculated as:

$$R = \frac{E_{Tot}}{E_{Round}} \quad (10)$$

Where R is the number of rounds supported by the number of networks, E_{Tot} is the total energy of all three level nodes, and E_{Round} is the dissipation of energy after completing one round by the network, and E_{Round} is described as,

$$E_{Round} = K\ (2nE_{elec} + nE_{DA} + LE_{mp}\ d^4_{\text{to BS}} + nE_{fs}\ d^2_{\text{to CH}}) \quad (11)$$

Where K is the optimal cluster, EDA is data aggregation and d ' is the distance between the Cluster Head (CH) and the Base Station (BS).

'd' $_{\text{to BS}}$ and 'd' $_{\text{to CH}}$ calculated as,

$$\text{'d'}_{\text{to CH}} = M/(2piK)^{1/2}$$

$$\text{'d'}_{\text{to BS}} = 0.765 * M/2 \quad (12)$$

By taking the derivative of E_{Round} concerning 'k' and setting it to zero, it will give the optimum selection of the cluster head. K_{opt} can be calculated as,

$$K_{opt} = \sqrt{n}/\sqrt{2\pi}\ x\ \sqrt{Efs}/\sqrt{Emp}\ x\ M/\ d^2_{\text{to BS}} \quad (13)$$

$$P_{opt} = K_{opt}\ /\ n \quad (14)$$

Where $P_{opt} = 0.1$, i.e., optimal probability for selection of clusters [58].

After deploying sensor nodes in the field, EEMMSCR initiates the setup phase. Cluster head (CH) selection is based on the probability of being elected as cluster head. If the value of EMMSCR is not more than the threshold value, then the cluster head will be selected for one complete round.

The threshold value of the newly selected cluster head is given by;

$$Th(n_z) = \begin{cases} \dfrac{P}{1 - P_z\left(r * \text{modulas}\left(\frac{1}{P}\right)\right)} * [S(i).E] & \text{if } n \in G^Z \\ 0 & \text{otherwise} \end{cases} \quad (15)$$

Where P_z is the probability to become a cluster head for normal nodes, r is the maximum number of current rounds and [S(i). E] called as the current residual energy of sensor nodes, 'G' called as the cluster head, which has not been selected for the current round. Hence, the probabilities of Normal (P_{nrm}), Intermediate (P_{int}) and Advanced sensor nodes (P_{adv}) are given by:

$$P_{nrm} = \frac{P_{opt}}{1+\alpha.n+x.\beta} \quad (16)$$

$$P_{int} = \frac{P_{opt}(1+\beta)}{1+\alpha.n+x.\beta} \quad (17)$$

$$P_{adv} = \frac{P_{opt}(1+\alpha)}{1+\alpha.n+x.\beta} \quad (18)$$

Where α and β are called residual energy parameters for Advanced and Intermediate sensor nodes. P_{opt} is the optimal probability [59].

Every cluster head sends data to the base station using multiple hopped paths under inter-cluster communication, as it utilises various paths for routing data from the cluster head. The proposed method balances the load across the network, with the cluster head closer to the base station having a higher load.

A. Selection of Cluster Head

Deployment of sensor nodes, randomly distributed in a large field they is known to the location. We assumed that every sensor node is alive at the primary stage, having some initial energy.

A sensor node contains three. types at different energy levels, which can be described as Normal, Intermediate, and Advanced sensor nodes. After

Retrieval Number: 100.1/ijrte.F74550311623
DOI: 10.35940/ijrte.F7455.0311623
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

selecting the node type, the setup phase initialises for all three levels of sensor nodes in a heterogeneous environment, and their energy level is calculated at the initial stage.

The generation of random numbers for the selected sensor node is used with high initial energy, and every sensor node selects its number according to its ID number and the value of the threshold energy level. If the threshold value is not more than all energy levels, then the chance of being elected as Cluster Head (CH) with a higher residual energy of the sensor nodes is increased. If $d(i) < d\_TH$, the cluster head is capable of sending packets directly to the base station and will use the free space model. If $d(i) \geq dTH$, the selected cluster head will search for a nearby cluster head and obtain information from the base station, which further forwards packets to the cluster head that is closer to being elected as the cluster head and the base station. The selected cluster head will forward its packets to the next cluster head, which will be referred to as the Intermediate cluster head or next-hop cluster head. This process will continue until the packets reach the base station. At this phase, the cluster head, along with the remaining energy being calculated or analysed, will select the node with the highest residual energy as the new cluster head, which will continuously transmit packets to the base station. The process continues for the maximum number of rounds until the last alive sensor node is eliminated.

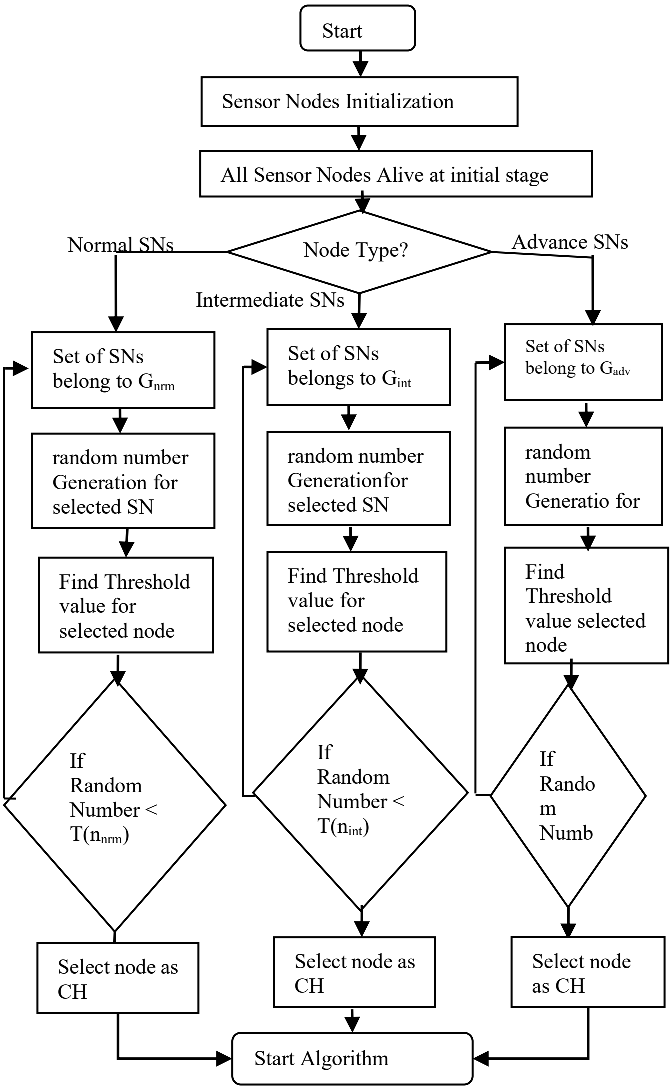

Fig. 3. Flowchart for Selection of CH

B. Protocol Explanation

Cluster head selection is based on the optimal election or the probability of sensor nodes being elected as cluster heads. After the selection of the cluster head, the current status is displayed, and for each round, it will always show its status. Then, data transmission takes place at the base station. During the clustering phase, the cluster head is selected and sends its data using intra-cluster TDMA scheduling in the setup phase. Data transfer from sensor nodes to the cluster head and from the cluster head to the base station occurs via multihop path communication.

Every cluster head generates a message containing a cluster head ID (CH-ID) along with the Carrier Sense Multiple Access (CSMA) MAC protocol. The selected cluster head broadcasts its ID and sends the acknowledgement for choosing the node as the first cluster head for round 1. The unselected cluster head starts sending its "JOIN REQUEST" message (join-REQ) to other cluster heads using the CSMA MAC protocol. "JOIN REQUEST "message (join-REQ) containing Cluster Head-ID, Cluster Member-ID and residual energy of the cluster head.

When the system model becomes aware of the cluster formation, the selected cluster head (CH) creates a TDMA scheduling within its cluster and sends its data along with the assigned time slot. There is a provision to add a time slot to the respective TDMA frame length, allowing it to transmit its aggregated data packet at the base station (BS).

Cluster setup phase: waking up the non-selected cluster head to exchange messages by displaying cluster head advertising messages, join request messages, and TDMA scheduling time frame messages using the CSMA MAC protocol. In clusters, the number of time slots is dependent upon the member nodes of the clusters. Inter-clustering communication occurs through a multihop path, where control messages and data packet availability messages are sent using the CSMA technique. When the cluster head set-up phase starts, sensor nodes that have not made decisions or participated at the time of selection will immediately exit the running process. The time interval length for intra- and inter-clustering communication depends on cluster size, as each cluster holds a cluster member for a time slot in TDMA. The extreme size of a cluster can be predicted with the help of the node density in a network.

There might be a possibility that some nodes, which have not become part of any cluster formation structure due to their deployment being far away from the cluster head, may not be included. In such cases, we have developed a sub-clustering method to enable sensor nodes to join and become cluster heads, as they may provide essential information at times. Hence, it is obvious that we need to collect data from those nodes that are far away in the field. In each sub-cluster, a formation of sub-cluster heads comes under the intermediate nodes. Inside each cluster and sub-cluster, all sensor nodes will forward data packets to the newly elected cluster head, and at this time, the sub-cluster will transmit data to the main cluster head. Forwarding data in both conditions, i.e., in the cluster and sub-cluster processes within the allotted TDMA frame.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The collected data will be aggregated using a sub-clustering process. A cluster member of the sensor node closest to the main cluster head sends the aggregated packet to the base station.

After completing the first round, we need to check whether the cluster head has residual remaining energy to become the cluster head for the next round or should get another cluster head. If the remaining energy is higher than that of the sensor nodes, it will continuously pretend to be the cluster head for the next round; otherwise, a new cluster head will be selected.

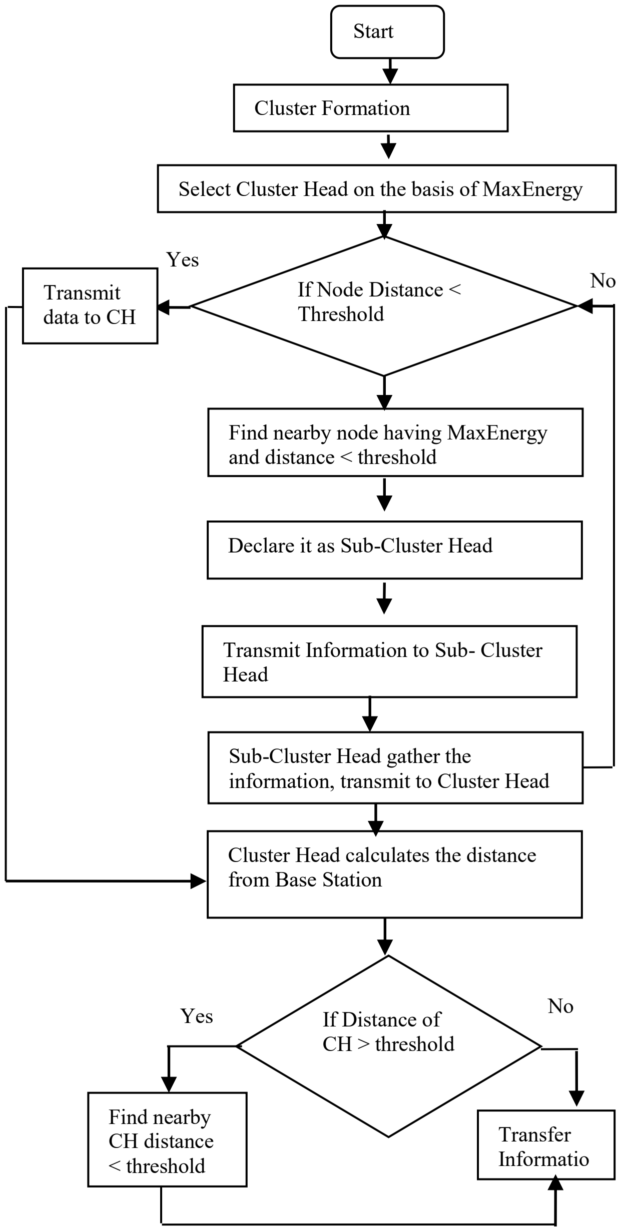

Fig. 4 EEMMSCR protocol Flowchart

V. SIMULATION PARAMETERS

This section explains a set of performance parameters used for validating results and simulating with other protocols. The metrics chosen were Stability Period, Lifetime of the Network, Packets transmitted to the base station (BS), and Number of Cluster Heads (CHs) per round. Additionally, the metrics included the Number of Packets transmitted to Cluster Heads (CHs) and Dead Nodes (DNs) for each round. Some of the parameters are explained as below [60]:

- **System stability period**: The period for operating the network before the expiration of the first sensor node among all available sensor nodes can be calculated by,

$T_{stability} = t_{FND} - tstart$ (19)

Where, $t_{FND} = 20 \times FND$.

- **Network Lifetime**: The period for operating the network until the last alive sensor node dies within the network for each round, which can be calculated by,

$T_{lifetime} = t_{LDN} - tstart$ (20)

Where, $t_{LND} = 20 \times LND$.

- **Data Transmission/Throughput**: Total data packets sent over clusters per round, in addition to sensor nodes or cluster heads to base station (including CHs and other nodes), can be calculated by

$data = data_{\ (CH\ to\ BS)} + data\ (_{N\ to\ BS})$ (21)

VI. RESULT VALIDATION AND DISCUSSION

This section focuses on the performance of the EMMSCR protocol, specifically its implementation strategy. Results were obtained using MATLAB 2022b as a simulation support environment. A computer with an Intel i3 processor, clocked at 2.4 GHz, is used for this experimental setup. The results have been compared with popularly known protocols, such as LEACH, O-LEACH, EEE-LEACH, and Z-SEP, as well as the proposed EEMMSCR protocol.

We have randomly deployed the sensor nodes in a wireless network field, which is a 100m x 100m area, and 100 sensor nodes are placed in the field. Advance sensor nodes (m=0.1) with 1-time additional energy (a=1) and normal sensor nodes (n=1) with 0.5-time additional energy (b=0.5).

Table I: Network Parameters for Simulations

N/W Parameters	Meaning	Values
x * y	Area Sizes	(100 x 100) meters
N	Total SNs	100
E_{elec}	Electrical energy	50 nJ/bit
EDA	Energy Data Aggregation	5 nJ/bit/message
E_0	Primary energy of SNs	0.5 J
k	Packet Size	4000 bits
P_{opt}	Optimal Probability	0.1
ε_{fs}	Free space	10 pJ / bit / m2
ε_{mp}	Friss multi-path	0.0013 pJ / bit / m4
a	Advance Energy level of nodes	1
b	Normal Energy level of nodes	0.5
m, n	% of advanced and normal nodes	0.1,1
BS	Base Station size	(50,50)
Rmax	Max no. of Rounds	5000

As we have already studied the LEACH protocol, it improves the network lifetime by providing an equivalent chance for sensor nodes to become cluster heads (CHs). However, it does not have a provision for residual energy within cluster heads (CHs), which are responsible for delivering packets to the base station (BS).

Fig. 5 shows the network lifetime performance of the proposed method in comparison with LEACH, O-LEACH, Z-SEP, and EEE-LEACH methods, and the plot is based on alive nodes versus rounds. The First Node Dead (FND) for the LEACH, O-LEACH, Z-SEP, and EEE-LEACH methods occurs at 513, 991, 1440, and 862, respectively.

However, the FND of our proposed method, i.e., the

Retrieval Number: 100.1/ijrte.F74550311623
DOI: 10.35940/ijrte.F7455.0311623
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

EEMMSCR protocol, dies at 2316, indicating that it has a greater and more stable network lifetime, thereby improving the overall system performance. The proposed system's performance is significantly better than that of other mentioned protocols, as it demonstrates that a cluster head with a high amount of remaining energy is selected, which is responsible for transferring data to the Base Station (BS). Half Sensor Node Dead (HND) of LEACH, O LEACH, Z-SEP, and EEE LEACH methods dies at 1175, 1544, 2281 and 1601. However, the HND of our proposed method, i.e., the EEMMSCR protocol, dies at 3173. The last sensor node dead (LND) of LEACH, O-LEACH, Z-SEP, and EEE-LEACH methods dies at 2506, 3145, 3664, and 2569, respectively. However, the LND of our proposed method, i.e., the EEMMSCR protocol, dies at 4306.

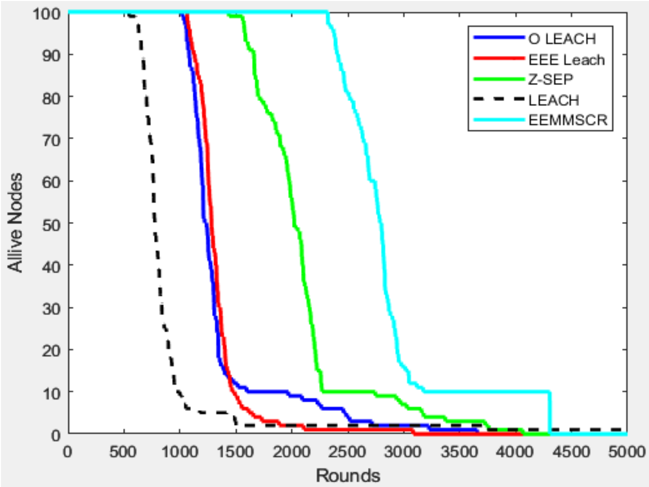

Fig. 5. Comparing the proposed method with LEACH, O-LEACH, EEE-LEACH and Z-SEP

Table II shows the value comparison between (FND), (HND) and (LND) for LEACH, OLEACH, EEE LEACH, Z-SEP and the proposed EEMMSCR protocol, along with their energy efficiency (in %).

Table II: Comparison Between FND, HND and LND

Protocols	FND	HND	LND	Energy Efficiency (%)
LEACH	513	1175	2506	58
Z-SEP	1440	2281	3664	85
EEE LEACH	862	1601	2569	60
O LEACH	991	1544	3145	73
EMMSCR	2316	3173	4306	100

Fig. 6 shows data packets being transmitted to the base station (BS) per round (r =5000) for O LEACH, EEE LEACH, Z-SEP, LEACH and EEMMSCR protocols.

To understand the excellence of any protocol, the rate of successfully transmitting data to the base station must be an essential parameter in wireless sensor networks. If the base station can receive a large amount of data from cluster heads, then it automatically proves that the protocol is functioning correctly. It can be observed that the proposed EEMMSCR protocol continuously transmits data from source to destination and has the highest successful data rate compared to other well-known protocols mentioned in the graph, over many rounds. Additionally, the proposed EEMMSCR has the highest number of cluster heads, up to 2.5 × 10^5. Consequently, the proposed multi-hop multi-path sub-clustering routing protocol sends a large number of packets per round at the Base Station (BS).

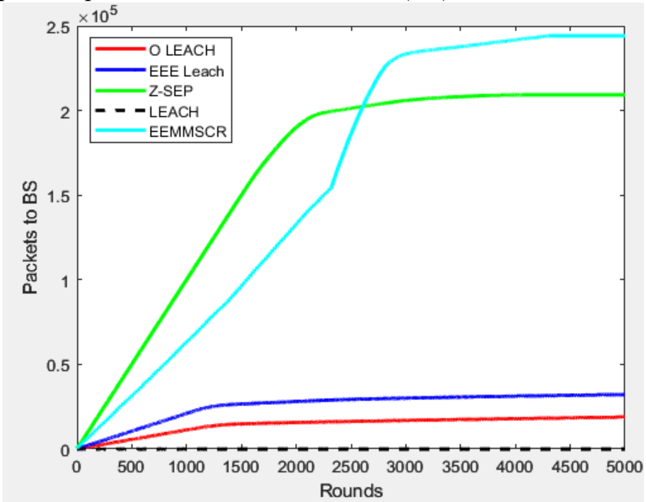

Fig. 6. Transmission of packets to BS, Vs per round for other protocols, along with the EEMMSCR protocol

Here, in Fig. 7, the dead nodes at each round (total rounds, r = 5000) for the O-LEACH, EEE-LEACH, Z-SEP, LEACH, and EEMMSCR protocols are depicted. When the number of dead nodes at each round increases, the number of rounds for the network also increases.

It is being observed from the plot, the network lifetime is just identical to alive node graph but dead node is showing results in reverse direction which states that the proposed EEMMSCR protocol has a smaller number of sensor nodes to die at 2322 as compared to the protocols LEACH, O LEACH, EEE LEACH and Z-SEP. In the proposed multi-hop protocol, approximately 60 sensor nodes die at round 2322. Whereas in LEACH, O-LEACH, EEE-LEACH, and Z-SEP protocols, sensor nodes die early as the number of rounds increases, and hence, they exhibit instability in the network system. However, in the case of the proposed method, the EEMMSCR protocol, the rate of dead sensor nodes is significantly lower compared to the other mentioned protocols, and instability in our network begins at a later stage.

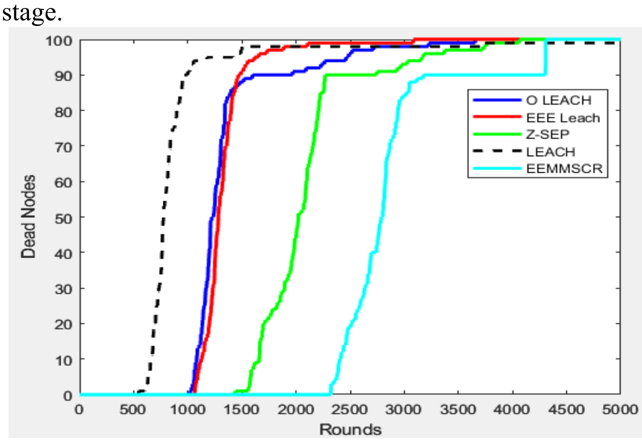

Fig. 7. Dead Nodes vs other protocols with proposed EEMMSCR protocol

Fig. 8 shows that the network energy dissipates per round when the number of rounds increases, and the network becomes unstable as it discharges energy, causing sensor nodes to become weak. It has been observed from the graph plot

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

that the network lifetime is increased by about 80% compared to other well-known protocols.

Therefore, the EEMMSCR algorithm performs well in cases where the field network size is large. As shown in the graph plot, our method achieves a great network lifetime by reducing energy consumption, which we have compared in our research work for the desired network field. The cluster head can remain the cluster head until the end of the process or until it dies at a later stage, leaving no residual energy. This protocol holds significant importance in the WSN area, as it offers diverse practical applications across various research fields.

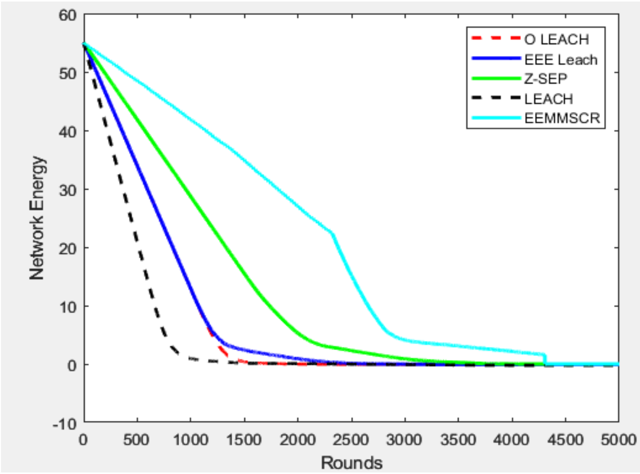

Fig. 8. Network energy per round for O LEACH, EEE LEACH, Z-SEP, LEACH and EEMMSCR

VII. CONCLUSION AND FUTURE WORK

This paper introduces the "Energy Efficient Multi-Hop Multipath Sub-Clustering Routing" (EEMMSCR) protocol, which combines sub-cluster-based routing protocols and multi-hop communication approaches, including intra-clustering and inter-clustering communication. It transmits data using multiple paths, thereby stabilising the network and improving its lifetime. A sub-cluster technique-based routing protocol balances energy by using a multipath method for effective communication. It gives every node an equal chance to become a CH. Cluster Head (CH) is selected based on the threshold value and the remaining energy within the sensor node. The routing method used in this paper identifies the primary factors that consume energy and prolong network lifetime. Also, the coverage range of the overall network includes nodes that are distributed farther away from the base station. Left-out sensor nodes, which are not participating in becoming cluster heads, are allowed to become cluster heads by introducing the sub-clustering concept. This approach demonstrates improvement in terms of network connectivity and reliability. The proposed method increases network lifetime and throughput, delivers a substantial number of data packets to the base station, and reduces packet delay and energy consumption. The results show that our EEMMSCR protocol method significantly enhances the network's energy efficiency compared to other research work. In future, the possible areas which can be analyzed which includes, the development of fuzzy logic approach by using optimization position of cluster head which could have increase the network lifetime, cross layer multipath routing protocol using MAC layer to achieve the path quality estimation, finally the development of multi-constrained QoS multipath routing protocol to guarantee the QoS for the applications in an open area. The same concept of the proposed algorithm can be applied to other algorithms, such as TEEN, APTEEN, and PEGASIS, to integrate different multipath routing methods efficiently. This integration further increases network robustness.

DECLARATION

Funding/ Grants/ Financial Support	No, I did not receive.
Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is not subject to interpretation.
Availability of Data and Material/ Data Access Statement	If applicable: Yes, it is relevant. (ieeexplore.ieee.org) and (scholar.google.com)
Authors Contributions	I (Kirti Bazar) have completed this paperwork under the guidance of Dr. Kanika Sharma, Assistant Professor at NITTTR, Chandigarh.

REFERENCES

1. Hoon Kim and Sang-wook Han, "An Efficient Sensor Deployment Scheme for Large-Scale Wireless Sensor Networks", IEEE Communications Letters, Vol. 19, No. 1, pp. 98- 101, 2015. [CrossRef]
2. Ravi Yadav and A.K. Daniel, "Fuzzy Based Smart Farming Using Wireless Sensor Network", 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), 2018. [CrossRef]
3. Md. Ahsan Habib, Sajeeb Saha, Fernaz Narin Nur, Md. Abdur Razzaque, Md. Mamun-Or-Rashid, "An Efficient Mobile-Sink Trajectory to Maximise Network Lifetime in Wireless Sensor Network", International Conference on Innovation in Engineering and Technology (ICIET), pp.27-29, 2018.
4. Omar Banimelhem, Muhammad Naserllah, and Alaa Abu-Hantash, "An Efficient Coverage in Wireless Sensor Networks Using Fuzzy Logic-Based Control for the Mobile Node Movement", Advances in Wireless and Optical Communication, pp.239-244, 2017. [CrossRef]
5. Young Sang Yun, Ye Xia, Behnam Behdani, and J. Cole Smith, "Distributed Algorithm for Lifetime Maximisation in a Delay-Tolerant Wireless Sensor Network with a Mobile Sink", IEEE Transactions on Mobile Computing, Vol. 12, No. 10, pp. 1920-1930, 2013. [CrossRef]
6. Sreevidya B. and Rajesh M., "Enhanced Energy Optimized Cluster Based on Demand Routing Protocol for Wireless Sensor Networks", IEEE International Conference on Advances in Computing, Communications, and Informatics (ICACCI), 2017. [CrossRef]
7. Raghunandan, G.H., Dr.A.Shobha Rani, Nanditha, S.Y., Swathi, G., "Hierarchical Agglomerative Clustering Based Routing Algorithm for Overall Efficiency of Wireless Sensor Network", International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), pp.1290-1293, 2017. [CrossRef]
8. Hamza Fahim, Nadeem Javaid, Zahoor Ali Khan, Umar Qasim, Shumaila Javed, Danish Mahmood, XafarIqbal, "Multilevel Routing Protocol for Energy Optimization in Wireless Sensor Networks", 9th International Conference on Innovative Mobile and Internet Services in Ubiquitious Computing, pp.86-93, 2015. [CrossRef]
9. Roxanne Hawi, "Wireless Sensor Networks – Sensor Node Architecture and Design Challenges", International Journal of Advanced Research in Computer Science, ISSN No. 0976-5697, Volume 5, No. 1, 2014.
10. R. Ramya1, G. Saravanakumar and S. Ravi, "MAC Protocols for Wireless Sensor Networks", Indian Journal of Science and Technology, Vol 8 (34), 2015. [CrossRef]

11. Rekha Prabha, Maneesha V Ramesh and Venkata Prasanna Rangan, "Building Optimal Topologies for Real-Time Wireless Sensor Networks", International Conference on Wireless Communications Signal Processing and Networking, pp. 1-6, 2018. [CrossRef]
12. Haining Shu, Qilian Liang and Jean Gao, "Wireless Sensor Network Lifetime Analysis Using Interval Type-2 Fuzzy Logic Systems", IEEE Transactions on Fuzzy Systems, Vol. 16, NO. 2, pp. 416–427, 2008. [CrossRef]
13. Ahmed Ahmed, Mathias Kleiner, and Lionel Roucoules, "Model-Based Interoperability IoT Hub for the Supervision of Smart Gas Distribution Networks", IEEE Systems Journal, pp. 1-8, 2018.
14. Pushpendu Kar, Arijit Roy, Sudip Misra, and Mohammad S. Obaidat, "On the Effects of Communication Range Shrinkage of Sensor Nodes in Mobile Wireless Sensor Networks Due to Adverse Environmental Conditions", IEEE Systems Journal, pp. 1-8, 2016. [CrossRef]
15. Rom´an Lara-Cueva, Rodolfo Gordillo, Liliana Valencia, and Diego S. Benıtez, "Determining the Main CSMA Parameters for Adequate Performance of WSN for Real-time Volcano Monitoring System Applications", IEEE Sensors Journal, Vol. XX, No. X, pp. 1-9, 2016.
16. Yu-Jia Chen, Li-Chun Wang, Feng-Yi Lin, and Bao-Shuh Paul Lin, "Deterministic Quality of Service Guarantee for Dynamic Service Chaining in Software Defined Networking", IEEE Transactions on Network and Service Management, Vol. 14, No. 4, pp. 991-1002, 2017. [CrossRef]
17. Asif Ali Laghari, Hui He, Asiya Khan, Neetesh Kumar, and Rupak Kharel, "Quality of Experience Framework for Cloud Computing (QoC)", IEEE Journals, pp. 2169-3536, 2018. [CrossRef]
18. Wei Feng, Zheng Yan, Hengrun Zhang, Kai Zeng, Yu Xiao, Y. Thomas Hou, "A Survey on Security, Privacy and Trust in Mobile Crowdsourcing", IEEE Internet of Things Journal, pp. 2327-4662, 2017.
19. Meirui Ren, Jianzhong Li, Longjiang Guo, Xiaokun Li, and Wenbin Fan, "Distributed Data Aggregation Scheduling in Multi-channel and Multi-power Wireless Sensor Networks", IEEE Access Journal, 2017.
20. Seung Hyun Cha, Minsu Shin, Jae-Hyun Ham and Min Young Chung, "Robust Mobility Management Scheme in Tactical Communication Networks", IEEE Transactions and Journal, Volume 4, 2016, pp. 2169-3536, 2018.
21. Hailin Feng and Jieyu Dong, "Reliability analysis for WSN based on a modular k-out-of-n system", Journal of Systems Engineering and Electronics, Vol. 28, No. 2, pp.407 – 412, 2017. [CrossRef]
22. Asmaa Mohamed, Walaa Saber, Ibrahim Elnahry, and Aboul Ella Hassanien, "Coyote Optimization Based on a Fuzzy Logic Algorithm for Energy-Efficiency in Wireless Sensor Networks", IEEE Open Access Journal, 2020. [CrossRef]
23. Kwang Y. Lee, Fellow, IEEE, and Jong-Bae Park, Member, IEEE, "Application of Particle Swarm Optimization to Economic Dispatch Problem: Advantages and Disadvantages", IEEE Access Journal, pp. 188-192, 2006.
24. Feng Zhao, Yilei Chen, Hanqiang Liu and Jiulun Fan, "Alternate PSO-based Adaptive Interval Type-2 Intuitionistic Fuzzy C-Means Clustering Algorithm for Colour Image Segmentation", IEEE Open Access Journal, 2019. [CrossRef]
25. Yuan Zhou, Ning Wang, and Wei Xiang, "Clustering Hierarchy Protocol in Wireless Sensor Networks Using an Improved PSO Algorithm", IEEE Access Journal, pp. 2169-3536 (c), 2016, [CrossRef]
26. Shantala Devi Patil and Vijayakumar B P, "Clustering in Mobile Wireless Sensor Networks: A Review", International Journal of Advanced Networking & Applications (IJANA) ISSN: 0975-0282, 2016.
27. Bo Chang and Xinrong Zhang, "An Energy-Efficient Routing Algorithm for Data Gathering in Wireless Sensor Networks", 2012 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference, 2012. [CrossRef]
28. Kun-Chan Lan and Ming Zhi Wei, "A Compressibility-Based Clustering Algorithm for Hierarchical Compressive Data Gathering", IEEE Sensors Journal, pp. 1530-437X, 2016.
29. Rahul Priyadarshi and Lucky Singh "A Novel HEED Protocol for Wireless Sensor Networks", 5th International Conference on Signal Processing and Integrated Networks (SPIN), pp. 296-300, 2018. [CrossRef]
30. Jyoti Bhola, Mohammad Shabaz, Gaurav Dhiman, S. Vimal, P. Subbulakshmi and Sunil Kumar Soni, "Performance Evaluation of Multilayer Clustering Network Using Distributed Energy Efficient Clustering with Enhanced Threshold Protocol", Wireless Personal Communications, 2022. [CrossRef]
31. Trupti Mayee Behera, Sushanta Kumar Mohapatra, Umesh Chandra Samal, Mohammad. S. Khan, Mahmoud Daneshmand, and Amir H. Gandomi, "I-SEP: An Improved Routing Protocol for Heterogeneous WSN for IoT-based Environmental Monitoring", IEEE Internet of Things Journal, 2019.
32. Sunil Kumar Soni and Gagandeep Kaur "Performance Analysis of Four Layer Clustering Network using Enhanced Deterministic Energy-Efficient Clustering Protocol in Wireless Sensor Network", Fifth International Conference on Advanced Computing & Communication Technologies, 2015. [CrossRef]
33. Salim EL KHEDIRI, Nejah NASRI, Anne WEI, Abdennaceur KACHOURI, "A New Approach for Clustering in Wireless Sensor Networks Based on LEACH", International Workshop on Wireless Networks and Energy Saving Techniques (WNTEST), Procedia Computer Science 32 pp. 1180 – 1185, 2014. [CrossRef]
34. Hamdy H. El-Sayed, "Performance comparison of LEACH, SEP and Z-SEP Protocols in WSN", International Journal of Computer Applications, pp. 0975 – 8887, Volume 180 – No.30, 2018. [CrossRef]
35. Meenakshi Sharma and Anil Kumar. Shaw, "Transmission Time and Throughput analysis of EEE LEACH, LEACH and Direct Transmission Protocol: A simulation-based approach", Advanced Computing: An International Journal (ACIJ), Vol . 3, No.6, pp. 75-82, 2012. [CrossRef]
36. Farzad Tashtarian, M.H. Yaghmaee Moghaddam, Khosrow Sohraby, and Sohrab Effati, "On Maximizing the Lifetime of Wireless Sensor Networks in Event-driven Applications with Mobile Sinks", IEEE Transactions on Vehicular Technology Journal, pp. 0018-9545, 2013. [CrossRef]
37. Kiran Maraiya, Kamal Kant and Nitin Gupta, "Efficient Cluster Head Selection Scheme for Data Aggregation in Wireless Sensor Network", International Journal of Computer Applications, Vol: 23, No: 9, pp. 0975-8887, 2011. [CrossRef]
38. Ahmed Al-Baz and Ayman El-Sayed, "A new algorithm for cluster head selection in LEACH protocol for wireless sensor networks", International Journal of Communication Systems, pp. 1-13, 2017. [CrossRef]
39. Bhawnesh Kumar and Vinit Kumar Sharma, "Distance-based Cluster Head Selection Algorithm for Wireless Sensor Network," International Journal of Communication Systems, pp. 0975-8887, Volume 57, No. 9, 2012.
40. Nadeem Javaid, Muhammad Babar Rasheed, Muhammad Imran, Mohsen Guizani, Zahoor Ali Khan, Turki Ali Alghamdi and Manzoor Ilahi, "An energy-efficient distributed clustering algorithm for heterogeneous WSNs", EURASIP Journal on Wireless Communications and Networking, 2015. [CrossRef]
41. Sehar Umbreen, Danish Shehzad, Numan Shafi, Bilal Khan, and Usman Habib, "An Energy-Efficient Mobility-Based Cluster Head Selection for Lifetime Enhancement of Wireless Sensor Networks", IEEE Access, Vol-8, 2020. [CrossRef]
42. Trong-Thua Huynh, Anh-Vu Dinh-Duc, and Cong-Hung Tran, "Delay-Constrained Energy-Efficient Cluster-based Multi-Hop Routing in Wireless Sensor Networks", Journal of Communications and Networks, Vol. 18, No. 4, 2016. [CrossRef]
43. Khalid Haseeb, Naveed Islam, Ahmad Almogren, Ikram Ud Din, Hisham N. Almajed and Nadra Guizani, "Secret Sharing-Based Energy-Aware and Multi-Hop Routing Protocol for IoT-Based WSNs", IEEE Open Access, 2019. [CrossRef]
44. Indra Kumar Shah, Tanmoy Maity, Yogendra Singh Dohare, Devvrat Tyagi, Deepak Rathore and Dharmendra Singh Yadav, "ICIC: A Dual Mode Intra-Cluster and Inter-Cluster Energy Minimization Approach for Multihop WSN", IEEE Access, Vol. 10, pp. 70581-70594, 2022. [CrossRef]
45. Jie Chen, Degan Zhang, Jie Zhang, Ting Zhang, Haoli Zhu and Jianning Qiu "New Approach of Energy-Efficient Hierarchical Clustering Based on Neighbour Rotation for RWSN", IEEE Access, Vol. 8, pp.123123 – 123134, 2020. [CrossRef]
46. Antonino Masaracchia, Long D. Nguyen, Trung Q. Duong and Minh-Nghia Nguyen, "An Energy-Efficient Clustering and Routing Framework for Disaster Relief Network", IEEE Access, Vol. 7, pp. 56520-56532, 2019. [CrossRef]
47. Mohammed Zaki Hasan, Hussain Al-Rizzo, and Fadi Al-Turjman, "A Survey on Multipath Routing Protocols for QoS Assurances in Real-Time Wireless Multimedia Sensor Networks", IEEE Communications Surveys & Tutorials Journals, pp. 1553-877X, 2016.
48. Yang Liu, Qiong Wu, Ting Zhao, Yong Tie, Fengshan Bai and Minglu Jin, "An Improved Energy-Efficient Routing Protocol for Wireless Sensor Networks", IEEE Sensors Journals, pp. 1-20, 2019.
49. Mohammad Hossein Anisi, Abdul Hanan Abdullah, Yahaya Coulibaly and Shukor Abd Razak, "EDR: efficient data routing in wireless sensor networks", International Journal of Ad Hoc and Ubiquitous Computing, Vol. 12, 2013. [CrossRef]
50. Yanjun Yao, Qing Cao, ACM, and Athanasios V. Vasilakos, "EDAL: An Energy-Efficient, Delay-Aware, and Lifetime-Balancing Data

Collection Protocol for Heterogeneous Wireless Sensor Networks", IEEE/ACM Transactions on Networking, Vol. 23, No. 3, pp. 1063-6692, 2015. [CrossRef]
51. Yanshan Tian, Qingguo Zhou, Fangqin Zhang and Jinjuan Li, "Multi-hop clustering routing algorithm based on fuzzy inference and multi-path tree", International Journal of Distributed Sensor Networks, Vol. 13(5), 2017. [CrossRef]
52. Jin Wang, Jinsung Cho and Sungyoung Lee, "A Hop-based Energy Aware Routing Algorithm for Wireless Sensor Networks".
53. Nhat-Tien Nguyen, Thien T. T. Le, Huy-Hung Nguyen and Miroslav Voznak, "Energy-Efficient Clustering Multi-Hop Routing Protocol in a UWSN", IEEE Sensors Journal, 2021.
54. Shiva Rowshanrad, Manijeh Keshtgary and Reza Javidan, "MBC: A Multi-hop Balanced Clustering Routing Protocol for Wireless Sensor Networks", International Journal of Artificial Intelligence and Mechatronics, 2014.
55. Yisheng Miao, Chunjiang Zhao, Huarui Wu, "Non-uniform clustering routing protocol of wheat farmland based on effective energy consumption", International Journal of Agricultural and Biological Engineering, Vol. 14, 2021. [CrossRef]
56. Quan Wang, Deyu Lin, Pengfei Yang, and Zhiqiang Zhang, "An Energy-Efficient Compressive Sensing-Based Clustering Routing Protocol for WSNs", IEEE Sensors Journals, pp. 3950-3960, 2019. [CrossRef]
57. R.K. Ghosh, Vijay Garg, M.S. Meitei, S. Raman, A. Kumar, N. Tewari, "Dense cluster gateway-based routing protocol for multi-hop mobile ad hoc networks", IEEE Ad Hoc Networks Journals, 2004.
58. Jun Yuea, Weiming Zhang, Weidong Xiao, Daquan Tang, Jiuyang Tang, "Energy Efficient and Balanced Cluster-Based Data Aggregation Algorithm for Wireless Sensor Networks", International Workshop on Information and Electronics Engineering (IWIEE), 2012. [CrossRef]
59. Guihai Chen, Chengfa Li, Mao Ye and Jie Wu, "An unequal cluster-based routing protocol in wireless sensor networks", Wireless Networks, 2009.
60. Santosh V. Purkar and R. S. Deshpande, "Energy Efficient Clustering Protocol to Enhance Performance of Heterogeneous Wireless Sensor Network: EECPEP-HWSN", Journal of Computer Networks and Communication, 2018. [CrossRef]

AUTHORS PROFILE

Kirti Bazar, ME scholar in Electronics and Communication Department at National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh, under the Punjab University. Graduate in Electronics and Communication Engineering from Punjab Technical University in 2013 and currently working as an Engineer in the Central Government Department, New Delhi, India. Her areas of interest include wireless sensor networks, embedded systems, and VLSI.

Dr. Kanika Sharma, Assistant Professor in Electronics and Communication Department at National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh. Ph.D from Punjab Technical University, Chandigarh, ME from PEC, Punjab University, Chandigarh, and B.E. from Maharishi Dayanand University, Rohtak. Her Publication Topics includes wireless sensor networks, telecommunication power management, routing protocols, energy conservation, pattern clustering, telecommunication scheduling, Internet of Things, copy protection, copyright, data integrity, data protection, decision making, digital rights management, discrete cosine transforms, embedded systems, image coding, image watermarking, intelligent sensors, low-power electronics, maximum likelihood estimation, message authentication, optimization, sensor placement, shift registers, smart power grids etc.

Retrieval Number: 100.1/ijrte.F74550311623
DOI: 10.35940/ijrte.F7455.0311623
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)