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# Modified energy efficient multi-level and spectrum aware unequal clustering with primary user classification in cognitive radio sensor networks

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**Abstract:** The study has produced a cross-layered routing protocol, which was built as part of the research. This protocol uses an updated contention window technique and Particle Swarm Optimization (PSO) to construct consistent and energy-efficient network routing pathways. The protocol was established as a result of the study. The PSO algorithm takes into account a variety of metrics, including as the Traffic index, Average energy load, data success rate, and trust value, in order to successfully optimize routing patterns. These parameters are all calculated at the network layer. Contention windows at the MAC layer are constantly modified according to real-time measurements of contentions and average energy loads. This further improves the efficiency of communication by taking into account the data. The trustworthiness of a node is decided by taking into account not only the quality trust that is generated from the node's Quality of Service (QoS), but also the group trust that is offered by neighbouring nodes. As a consequence of this procedure, detailed trust ratings are bestowed onto individual nodes; these ratings serve as a guide for selecting relay nodes. In addition, the study presents a dual authentication system, which incorporates advanced dual authentication (EnDA) methodologies and key management processes to strengthen data security and guarantee data integrity. In addition, Elliptical Curve Cryptography (ECC) and Diffie-Hellman key exchanges using bilinear maps have been employed to further strengthen the security of communications. According to the findings of the tests, the suggested protocol has impressive performance in terms of successfully establishing a secure key agreement while data is being sent and maintaining acceptable levels of energy usage.

***Keywords:*** *CRSN, Cluster heads, Energy efficient, Multi-level Spectrum-aware unequal clustering algorithm, Network lifetime.*

## 1. Introduction

A composition of different sensor node types, whether they are of a homogeneous or heterogenous nature, works together to contribute to the accomplishment of common goals within a CRSN [1]. This is true whether or not the sensor nodes are of the same kind. These nodes are often outfitted with limited power supplies that are not capable of being recharged, and they are frequently subject to human supervision. The exact needs of the network's application-based requirements will ultimately determine

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how long the network will be able to remain operational [2]. When it comes to prolonging the life of the network, reducing the amount of energy that sensor nodes use on their own should be the top focus. These sensor nodes have intrinsic limitations, both in terms of their memory and their processing capabilities, which means that the regions that they can cover are necessarily restricted. As a consequence of this, the network requires the capability of sensor nodes to engage in self-organization and carry out operations independently in order to collect data and transmit it to the sink [3]. In a number of different sensor applications, individual sensor nodes are typically grouped together into clusters in order to improve the energy efficiency of the data gathering process. Each cluster is assigned a Cluster Head (CH), who is in charge of the data gathering, consolidation, and transmission [4]. In addition to this, clustering not only helps to enhance Quality-of-Service (QoS) qualities, but it also ensures the scalability of sensor applications [5].

The CH election process has been the subject of a great deal of study, the majority of which has been directed at developing methods that are more effective in terms of their use of energy. Many of these approaches focus entirely on evaluating the amount of energy that is used by a sensor node. This leads to inefficiencies since they overlook the base station's (BS) spatial placement, which causes problems with hotspots, especially in multi-hop settings [6]. Cluster Heads (CHs) that are located closer to the Base Station (BS) see a quicker depletion of their available energy sources in comparison to CHs that are located farther away from the BS. Recent research endeavors have resulted in the development of the idea of uneven clustering, which includes the production of clusters of varied sizes. [Clusters are] grouped according to their average size. In the context of this model, clusters that are situated at a shorter distance from the BS have dimensions that are more compact than clusters that are located at a higher physical distance from the BS. This design cuts down on the amount of intra-cluster relay operations that take place inside these clusters, which eventually leads to the establishment of an equilibrium that is able to accommodate the increased demands that are imposed by inter-cluster relays [7].

In recent years, clustering has gained attention as a typical method used in a variety of Wireless Sensor Networks (WSNs) to successfully control network topology. This is due to the fact that it is one of the most effective strategies for managing network topology. This strategy calls for the division of the whole network into a number of unique clusters, with some sensor nodes being designated as Cluster Heads (CHs), while the remainder nodes adopt duties as cluster members (CMs) inside their respective clusters [8]. It is the responsibility of the CH to transmit the aggregated data that has been gathered from its CMs to the next node along the routing route, with the end goal of arriving at the destination node, which is also often referred to as the sink node. When it comes to the planning of a WSN, improving the energy efficiency of the nodes that are going to be deployed should be of the utmost importance [9]. As a direct consequence of this, the vast majority of clustering approaches place a high priority on the evaluation of the residual energy levels of the nodes as a fundamental factor in the development of clusters. Furthermore, in the context of Cluster-Based Cognitive Radio Sensor Networks (CRSNs), cluster formation methods need to assure the construction of clusters with at least one common channel shared across CMs dwelling within a given cluster [10], which is an essential for CRSNs. This is because CRSNs rely heavily on communication between CMs resident inside the same cluster. The cluster architecture offers an effective structure for handling CR-based operations, such as channel sensing and routing, which makes it easier to coordinate all of these activities in a seamless manner. A Secondary User (SU) is able to take on numerous responsibilities inside the network when it is part of a clustered CRSN. These responsibilities may include those of the CH, CM, relay, and gateway. Communication between the CH and CMs takes place inside the cluster and makes use of a shared channel known as the operational channel, which is common to all SUs that are located within the borders of the cluster [11]. A CM that is part of a cluster also has the capacity to function as a relay SU, which enables it to transmit messages from the CH to other CMs in surrounding clusters that are placed outside of the CH's communication range. In addition, an SU that is located on the edge of the cluster's coverage area may play the part of a gateway node. This would make it possible for several clusters to connect with one another through a chain of hops [11].

The size of the different clusters in a network that is arranged into clusters has a major impact on the performance of the network. Smaller clusters, which are defined by a greater number of shared channels, improve connectivity among Secondary Users (SUs), while bigger clusters boost scalability and decrease the related cost in routing messages [12]. Smaller clusters also optimize connection among Primary Users (PUS), which is characterized by a lower number of shared channels. In addition, bigger clusters reduce the burden necessary for message routing, which contributes to an increase in the Cluster-Based Cognitive Radio Sensor Network's (CRSN) overall efficiency. The decrease in interference levels, congestion on shared channels, and total energy consumption contributes to an improvement in the overall performance of the network. It is very necessary for the process of cluster creation to take into consideration the availability of channels in order to guarantee the existence of common channels and decrease the complexity of the network. However, even a cluster that is well-structured may be affected by interruptions caused by events involving Primary Users (PUs), which may lead to frequent re-clustering and longer delays [13].

It has been suggested that standard Cognitive Radio (CR) and Wireless Sensor Network (WSN) deployments might benefit from a variety of different routing strategies. However, the direct application of these tactics to Cluster-Based Cognitive Radio Sensor Networks (CRSNs) is hindered by the divergence between CR, which does not take into account the amount of energy used, and WSN, which does not include dynamic spectrum access approaches. This is because CR does not take into consideration the amount of energy consumed. As a result, developing routing solutions for CRSNs is a difficult task due to the inherent unpredictability of spectrum availability and the ongoing search for the highest possible level of energy efficiency [14]. The goal of achieving the highest possible level of energy efficiency has given rise to this obstacle. In order to build routing protocols that are suited to CRSNs, it is necessary to carefully evaluate the characteristics that are unique to these networks.

In this inquiry, a technique known as Multi-level Spectrum-aware Unequal Clustering (MLSAC) is proposed as a solution customized for Cluster-Based Cognitive Radio Sensor Networks (CRSNs), successfully resolving the constraints that were stated before. MLSAC was developed as a solution adapted for Cluster-Based Cognitive Radio Sensor Networks. The MLSAC makes use of uneven clustering to facilitate the maintenance of energy balance across the network. Cluster Heads (CHs) are chosen based on a number of criteria, including residual energy, spectrum availability, channel conditions (which include the number of available channels and the number of common channels shared with upstream CHs), proximity to the sink, and closeness to their upstream CHs. The average amount of energy used by individual nodes is used to calculate the radii of each cluster. The careful selection of CHs and the frequent rotation of them serve as a means of mitigating the danger of an untimely depletion of energy reserves. MLSAC uses a hop-by-hop forwarding approach in order to provide energy-efficient data routing towards the sink node. This strategy is used during the event detection phase. This strategy incorporates the movement of data via CHs as well as main and secondary gateways. The suggested protocol not only improves fairness by assuring an equal allocation of leftover energy across sensor nodes, but it also adds to the extension of the network's lifetime by lowering the total amount of energy that is used. This allows for the network to function for a longer period of time. The following is a rundown of the most important contributions that were made by this study:

- In contrast to traditional clustering criteria, the MLSAC methodology that was introduced in this work takes into account residual energy, channel conditions (including the count of available channels and common channels shared with upstream CHs), proximity to the sink, and proximity to their upstream CHs.
- This algorithm provides an optimized clustering solution that can be adapted to a variety of application scenarios thanks to the utilization of a multi-level approach.
- In addition, the study presents a technique for the selection and rotation of CHs, which involves the strategic selection of CHs and the periodic rotation of those CHs in order to reach a state of energy equilibrium inside the cluster.

## 2. Related Work

An energy-conscious dual-path geographic routing protocol is described in Reference [15]. Its purpose is to solve the difficulty of routing holes, which are commonly found in standard geographic routing approaches. This innovative protocol's main purpose is to improve route recovery, especially in circumstances that include routing holes. An energy model that is specifically designed for use in heterogeneous Wireless Sensor Networks (WSNs) is originally presented in the cited study [16]. Following that, this model is put to use in expediting the creation of a routing system that takes into account both the patterns of traffic and the factors connected to energy consumption. It offers a basic structure that may be used in the building of a routing system like this one.

Secondary Users (SUs) provide main Users (PUs) with the capacity to collect Radio Frequency (RF) energy from them and relay PU signals to the access point (AP). In exchange for this service, Primary Users (PUs) provide Secondary Users (SUs) with a fraction of their available bandwidth on their main network. Notably, Primary Users (PUs) may only participate in RF energy gathering from Secondary Users (SUs) on the condition that Primary Users (PUs) are simultaneously engaged in RF energy harvesting. This is a prerequisite for RF energy harvesting from Secondary Users. It is essential to note that the operations of RF Wireless Energy Harvesting (RFWEH) and data decoding are independent from one another and are conducted by separate circuits inside the receiver. This introduces a trade-off between optimizing RFWEH and maximizing data transmission, which must be considered. RFWEH procedures are carried out during the beginning time fraction () of each time slot, while the remaining time is devoted to the transmission of data. Expanding on these efforts, Obaid and Fernando put up a hybrid RFWEH model in a recent work [17], expanding upon the foundations built by past research.

Within the confines of this model, chances to access the principal network are pursued and pursued by Secondary Users (SUs). In exchange for access to the main network, Secondary Users (SUs) are required to collaboratively transmit data belonging to main Users (PU) to the access points (APs) of the primary network. However, a certain amount of the bandwidth that is accessible has been set aside for the secondary network. The LEACH protocol, which is well-known for the energy-efficient Medium Access Control (MAC) characteristics it has, is used inside the system in order to improve energy management. Zhang et al. [18] provide an additional notion that is associated with energy-harvesting-assisted spectrum sensing. This concept is introduced within the context of heterogeneous cognitive wireless sensor networks.

TPE-FTED is an abbreviation that stands for the Trajectory Pattern Extraction-based Fault Tolerance Event Detection technique that Liu and colleagues [19] recommend for the implementation of. When a probabilistic model is in its active learning phase, each node performs an analysis of the distribution of sensed values across the many sensing phases that it has gone through. The word "trajectory" is used to refer to a certain collection of probabilistic models that are used to depict an event that had place in a particular way. Drawing on the implicit information produced from the predetermined trajectory, TPE-FTED recognizes patterns and analyses spatio-temporal situations in order to identify instances of node failures.

When thinking about the process of cluster formation, the author focused their attention on gaining an understanding of the dynamics of spectrum availability and the energy consumption that is associated with clustering. The purpose of this research was to get a more in-depth comprehension of the cluster formation dynamics. As a result of this, it led to the creation of a reliable cluster-based architecture with the goal of reducing the significant communication cost that is generally associated with frequent clustering. In order to accomplish this goal, it was necessary to cluster a smaller number of nodes together. An opportunistic form of data forwarding was used by SACR in order to provide the most effective data routing. This method chose a single cluster head for each instance based on a number of parameters, such as the total cluster size, the availability of channels, and the hop count to the gateway [20].

In order to determine whether or not the recently proposed distributed cluster-based data communication protocol (DEDC) is capable of achieving energy-efficient data transmission within Cognitive Radio Sensor Networks (CRSNs), comparative evaluations against previously established data transmission models were carried out. This procedure was kicked off by the DEDC protocol, which began by locating open channels that were acceptable for node communication. Subsequently, these channels were separated into licensed and unlicensed channels depending on their respective regulatory statuses. The protocol had a data aggregation routing mechanism that was designed specifically for circumstances in which free licensed channels were available. The protocol gave priority to the use of unlicensed communication channels in situations when licensed channels for the transmission of data were not available. This prioritization-based channel selection technique led to a significant decrease in the amount of energy that was used, in addition to a noticeable improvement in the amount of information that was sent [21].

The method that the author offered for picking Rfactor cluster heads took into consideration a variety of criteria, some of which were residual energy, residual data, and nodal speed. In addition, the protocol included a method for a backup cluster head, with the intention of reducing the amount of interruptions that may be generated inside the cluster as a result of mobile cluster heads. The findings of the simulations suggested that the RMAC-M protocol would be effective in ensuring the sustainability of the network across a broad range of node densities and transmission rates. Notably, RMAC-M outperformed other protocols, notably in regard to the longevity of the network, while having only a moderate effect on latency and ensuring compliance with acceptable delay criteria for the whole of the testing period. This accomplishment is especially noteworthy given that RMAC-M was able to do all of this while preserving compliance. By adding harvesting slots, it was able to efficiently handle node mobility concerns, all while maintaining a suitable balance between latency and energy efficiency inside the R-MAC architecture [22]. This accomplishment was completed without causing any degradation to the performance of the network.

## 3. System Model

### *3.1. Sensor Network Model*

In the situation that is described and represented in Figure 1, sensor nodes are dispersed at random across the region that has been defined as being of interest. These sensor nodes send the data that they have detected to the sink node in accordance with a timetable that has been specified or in response to the needs of a particular application. The sensor nodes in the sensor network have begun the process of clustering as part of an effort to reduce the amount of energy that is used by the network. There is one node that is denoted as the Cluster Head (CH) for each cluster, and the other nodes in the cluster are given the duty of performing the duties associated with cluster members (CM).

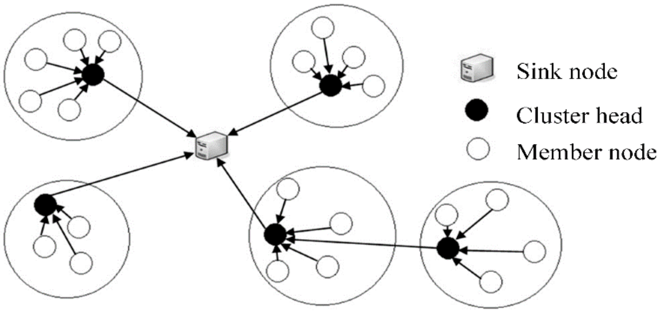

**Figure 1.**
Network model.

In addition, the procedure of transferring data from the source to the sink may be broken down into two independent stages that occur in sequential order. Data is independently transported from cluster members (CMs) to the Cluster Head (CH) via Time Division Multiple Access (TDMA) in the first phase, which is known as the intra-cluster data transmission phase. The succeeding phase is referred to as inter-cluster data transmission, and it is during this phase that the data acquired by the CH is sent to the next-hop forwarder based on particular relay selection criteria. These sensor nodes feature cognitive skills that provide them with access to licensed spectrum resources, which they are then able to exploit as required. Control signals are sent over a control channel that is shared by several devices.

### *3.2. Energy Model*

In the course of this research, a more straightforward energy model was used to carry out the task of data transfer. For the purpose of sending a $l$-bit message across a distance of $d$, the amount of energy required, denoted by the symbol $E_{tx}$ and expressed in joules, may be stated as follows:

$$E_{tx} = le_{ele} + \varepsilon_{amp} d^{\gamma} l$$

When referring to the amount of energy that is used by the circuitry of the sensor node, which includes components such as the transmitter and receiver, the word "$\boldsymbol{e_{ele}}$" is the abbreviation that is used. On the other hand, "$\boldsymbol{\varepsilon_{amp}}$" refers to the energy that is being lost due to the operation of the transmitter amplifier. It is very necessary to make certain that the channel path-loss exponent of the environment, represented by the $\boldsymbol{\gamma}$, complies with the given criterion of being somewhere between the numbers 2 and 4.

$E_r(j)$ is the symbol that is used to indicate the amount of energy that is necessary for the receiver to process a message that consists of $l$ bits.

$$E_r = le_{ele}$$

### *3.3. Proposed Method*

The MLSAC method was developed to divide a CRSN into clusters with the goals of establishing energy balance and retaining connection, which is particularly difficult in energy-constrained CRSNs. This was accomplished by dividing the CRSN into subnetworks. Within the network, the clustering framework consists of four distinct roles: Sensor Nodes (SNs), which are in charge of receiving data from Cluster Heads (CHs); Cluster Heads (CHs), which are tasked with collecting data; Cluster Members (CMs), which are in charge of reporting data; and Relay Nodes, which assist Cluster Heads in transmitting data to the sink node.

The MLSAC algorithm is used primarily for two different purposes. First, it determines the cluster radius for each individual node in the network. Nodes in a multi-hop network that are physically closer to the node that acts as the sink for data transfer use more energy than nodes that are farther away. As a result, MLSAC utilizes an uneven clustering strategy in order to maintain a consistent level of energy consumption across the network. Second, it deals with cluster creation, which is a process that has three separate stages that it goes through.

- The method for choosing Cluster Heads (CHs) is introduced into the first stage of the project when it is first being developed. Because CHs often use more energy than other nodes and are assigned with communication obligations involving Cluster Members (CMs) and other CHs, the selection of CHs spans all nodes within the network. This is due to the fact that CHs are tasked with communicating with other CHs. This selection procedure takes into account a variety of parameters, such as the amount of energy that is still accessible, the spectrum that is still available, the number of channels that are still open, and their closeness to either the sink node or their upstream CHs.
- After that, the subsequent phase will focus on establishing the Cluster Channel as its primary focus. It is of the utmost necessity to provide network connectivity, which includes both connections inside a cluster and links to other clusters. The number of CMs and Relay Nodes (RNs) that are included inside the cluster is taken into consideration by the MLSAC algorithm when determining which Cluster Channel to use.
- The last phase of the operation is where the process of cluster creation reaches its zenith and where the conclusion of the procedure happens.

Nodes that are farther away from the central node (SN) in a multi-hop network have a higher propensity to demonstrate lower levels of energy usage as compared to nodes that are located in closer proximity to the SN. Because of the discrepancy in energy usage, nodes that are close to the SN are at risk of experiencing a quick depletion of their energy stores. MLSAC uses an uneven clustering strategy to provide a fairer allocation of energy resources throughout a Cognitive Radio Sensor Network (CRSN) in order to lengthen the operational lifetime of a CRSN. This helps MLSAC accomplish its goal of extending the operational lifespan of a CRSN. This, in turn, contributes to the network's ability to remain active for longer periods of time.

Cluster Members (CMs) are tasked within each cluster with the duty of relaying data to the Cluster Head (CH), which acts as the major node within the cluster. It is the responsibility of the CH to collect all of these pieces of information and then send them on to the next hop, which may be a Sink node, an additional CH situated further upstream in the network (also known as an upstream CH), or a Relay Node (RN). The distance from the CH to the sink is taken into consideration while choosing the next step in the chain. In the event that this distance is more than Rt, one of the RNs will be chosen to complete the following hop. On the other hand, if the distance is smaller than $r\_0$, then nodes are able to transport data straight to the sink without the requirement for any intermediary nodes to be present. It is essential to keep in mind that the absolute highest level of energy consumption that is permitted is E_0.

### *3.4. Cluster Construction*

The partitioning of the network into a great number of distinct clusters is the primary purpose of the clustering procedure that is now being carried out. The first thing that must be done to accomplish this goal is to choose certain nodes to act as Cluster Heads (CHs), which is the function that they will play in the network. Next, an equal distribution of channels is applied throughout the clusters, which ultimately leads to the effective consummation of the process of cluster creation.

Selection of CHs: - In the context of clustering-based Cognitive Radio Sensor Networks (CRSN), the obstacles connected to energy that are often encountered in traditional Wireless Sensor Networks (WSN) as well as the channel-related concerns that are associated with Cognitive Radio Networks (CRN) may be efficiently handled. This is because CRSNs are based on the concept of cognitive radio sensor networks. This is because CRSNs are of the kind that are predicated on the concepts of cognitive radio sensor networks, which explains why this is the case. The selection of Cluster Heads (CHs) in MLSAC is determined by a number of factors, some of which include residual energy, the availability of spectrum, the accessibility of channels, closeness to the sink node, and proximity to upstream CHs. The optimum decision need to meticulously take all of these considerations into account.

- keep a greater number of accessible channels to facilitate connectivity with Cluster Members (CMs), other Cluster Heads (CHs), and Relay Nodes (RNs);
- exhibit shorter distances between CH and the sink, thereby minimizing energy consumption;
- maintain a greater number of accessible channels to facilitate connectivity with Cluster Members (CMs), other Cluster Heads (CHs), and Relay Nodes (RNs).

Defining node value (NOV): - It acts as an indication of the suitability of a node for data transmission by giving information about the node's energy, spectrum, available channel, and distance-related features. This is a significant consideration that must be taken into account throughout the CH selection process, and it may be officially expressed as follows:

$$nov_i = \omega_1 * f_1 + \omega_2 * f_2 + \omega_3 * f_3 + \omega_4 * f_4$$

$$f_1 = max\{residual_{energy}(n)\}, \qquad 1 \le n \le N,$$

$$where\ N = total\ number\ of\ nodes$$

$$f_2 = max\ \{spec\}$$

$$f_3 = max\{cc\}$$

$$f_4 = \ min\{dist\}$$

Where $\omega_1, \omega_2, \omega_3, \omega_4,$ is the weight coefficient for the fitness functions ranging between 0 and 1. $(0 < \omega < 1)$.

It is necessary for each node to broadcast its data to the sink. This data must include specifics such as the amount of remaining energy, the channels that are available, and the node's location. The sink is responsible for coordinating the CH selection operation, which results in a net decrease in the amount of

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energy that is used by individual nodes. The sink begins its search for CHs at the most central point of the network and works its way outward, selecting, at each stage, the nodes that have the greatest NOV (Node Overall Value).

Determining Cluster Channel: - After the CH has been selected, it proceeds to the subsequent phase, which involves the selection of the cluster channel and the initiation of the cluster formation process. In the context of MLSAC, the cluster channel holds great significance as it profoundly influences inter-cluster communication, the efficiency of clustering, and the interconnection between distinct clusters. The choice of which cluster channel to employ serves as a determining factor in the selection of CMs designated for the cluster. This decision hinges upon the total count of CMs and RNs to ensure comprehensive network connectivity encompassing both intra-cluster and inter-cluster connections, thereby optimizing the efficacy of clustering.

An optimal cluster channel is characterized by its ability to accommodate a larger number of CMs and facilitate seamless communication with its upstream cluster. This study introduces the concept of "Channel Value" and employs it as a criterion for the judicious selection of the cluster channel that best aligns with the prevailing circumstances.

The major criteria that is used in the cluster channel selection process is the channel's value, which is expressed as the channel's value. The following is an example of a mathematical definition that may apply to this value:

$$CHV_i = \begin{cases} |CM_i|, & if\ C_i == CC \\ |CM_i| \times |RN_i| & otherwise \end{cases}$$

When using MLSAC, the CHV, also known as the Cluster Head Value, is used to choose which cluster channel to use. When the cluster channel is marked as $c_i$, CHV is computed based on a number of different criteria, one of which is the count of relay nodes, which is written as $|RN_i|$. Another component is the number of cluster members, which is denoted as $|CM_i|$ . When everything is said and done, the cluster channel that has the greatest CHV value will be the one picked for implementation.

Cluster Establishment: - Following the completion of CH selection and cluster channel determination, the cluster formation process will commence. To be considered for membership in a cluster, nodes must meet the following criteria:

- They must not already belong to any other cluster under consideration. Each node in the network should be a member of only one cluster.
- An available channel must be present.
- The distance between the node and the CH must be less than or equal to the cluster's radius.

During the cluster formation process, the CH will broadcast a message containing its coordinates. Any node that receives this message and fulfills the specified criteria will become a cluster member.

Routing phase: - The TDMA method is employed for communication between clusters, while the CSMA scheme is utilized for inter-cluster communication. Both schemes find application in intra-cluster communication. Cluster Heads (CHs) are tasked with the responsibility of scheduling channels within specified time slots, and data transmission occurs during distinct transmission rounds. MLSPA operates in response to events, enabling the dynamic creation and storage of routes as necessitated by the prevailing circumstances.

Concerning the routing of packets from the event area to the sink, pivotal roles are assumed by CHs and gateways. Unlike the sharing of CM lists among CHs, each Secondary User (SU) possesses knowledge of its immediate neighbors. CHs make determinations regarding primary and secondary gateway selections based on information gleaned from their proximate neighbors.

Beacon signals emanate from the CHs and are met with responses from neighboring nodes, which relay information about their one-hop neighbors. To enhance data transmission across different clusters, potential primary and secondary gateway SUs are identified based on their geographical proximity. CHs oversee inter-cluster communication, while gateway SUs facilitate communication between clusters in close proximity to each other.

Inter-cluster data transmission can take one of two forms: the selection of a primary gateway SU from a candidate set of SUs or the utilization of a relay set of SUs to convey data to a secondary gateway

SU. This recursive process continues until the data packet reaches its ultimate destination, which is the sink node.

### *3.5. Algorithm*

```
For all the nodes n
    Calculate cluster radius '$c_r$'
Cluster construction
    CH selection
        For all the nodes n
        Estimate $NOV_n$
        If $(NOV_n > NOV_{n+1})$
            $CH \to n$
Cluster channel identification
        Estimate $CHV_n$
Cluster establishment
        Sink Broadcast JOIN message from Node $n$
        If $(n \notin c \ \&\& \ c_n \in s_i \ \&\& \ d_{sm,si} \leq r_m)$
        $Join\ (CH)$
        End CH selection
End for
Routing & relay selection
    $CH$ determines $G, SU$
    $CH$ broadcasts $beacons$
    Share $1 - hop\ neighbor\_list$
    Data transmission
End for
```

## 4. Result and Analysis

### *4.1. Simulation Results & Analysis*

In this part of the article, an overview of the simulation process will be offered, and it will be followed by a discussion of the results that were observed across a variety of different kinds of situations. The network space, which is 1000 meters on each side, has room for a total of 50 sensor nodes that are randomly dispersed around the area. Each data unit has a size of 1024 bytes, and all of the nodes start off with an initial energy endowment of 100 joules. This initial energy endowment is divided evenly among all of the nodes. In order to evaluate how robust, the suggested approach is, the dimensions of the network are gradually increased from fifty to two hundred and fifty nodes.

Multiple performance indicators, including as energy consumption, end-to-end latency, routing overhead, and packet delivery ratio, will be evaluated in order to determine how effective the strategy that has been suggested would be. In the interest of making it easier for you, an overview of the simulation parameters is provided in Table 1.

**Table 1.**

| Parameter | Value |
|---|---|
| Network field | 1000 m x 1000 m |
| Packet size | 1024 bytes |
| Number of sensor nodes | 50 to 500 |
| Traffic type | CBR |
| Transmission Protocol | UDP |
| Initial Energy | 100j |

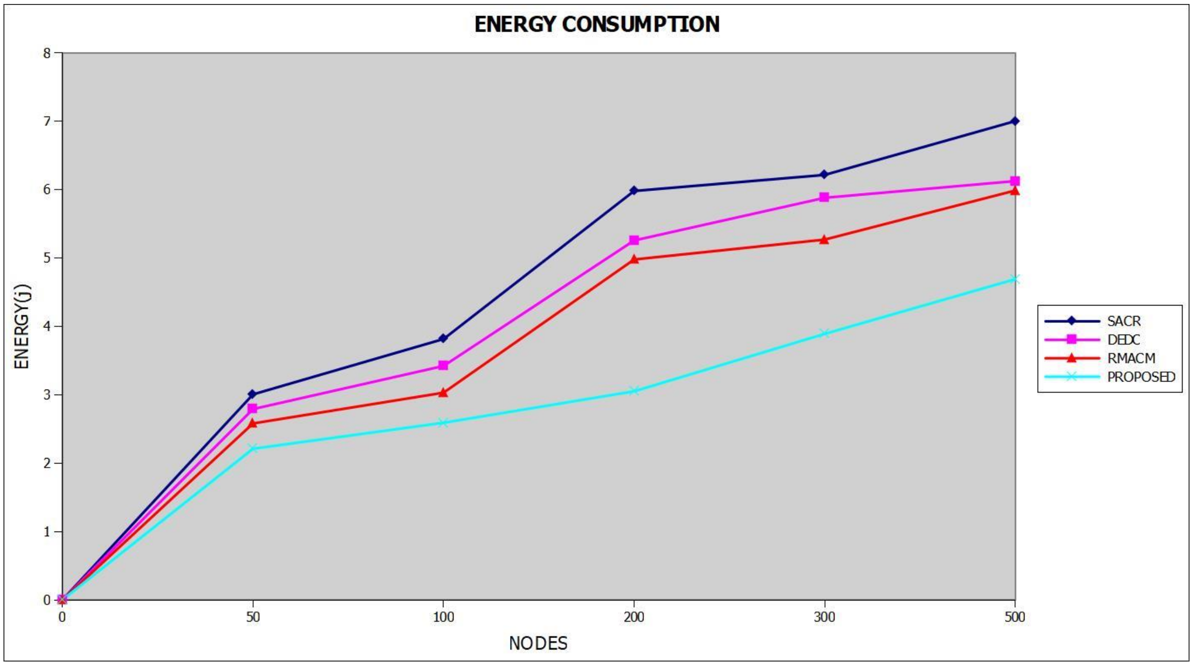

**Figure 2.**

Because energy is a necessary but limited resource in the world of sensor networks, optimizing the energy consumption of sensor nodes is of the utmost importance for attaining an increase in the network's overall energy efficiency. It has recently come to light that the selection of poor relays and ineffective data aggregation procedures frequently contributes significantly to the wasteful loss of energy that occurs. The technique that was developed, which relies on the identification of trustworthy Cluster Heads (CHs) and the careful selection of the most efficient relays, has been shown to be a very effective and efficient way of drastically decreasing energy usage. In real-world testing, this strategy showed an average energy consumption rate of 3.5 joules, which is far lower than the significantly high energy consumption levels associated with approaches that are presently being used. The results of the calculations used to determine the amount of energy used by networks of varied sizes are outlined in the table that is shown below for your convenience and consideration:

**Table 2.**

| Nodes | SACR | DEDC | RMACM | Proposed |
|---|---|---|---|---|
| 50 | 3.005 | 2.79 | 2.58 | 2.21 |
| 100 | 3.815 | 3.421 | 3.03 | 2.59 |
| 200 | 5.98 | 5.256 | 4.978 | 3.05 |
| 300 | 6.215 | 5.88 | 5.269 | 3.89 |
| 500 | 7.002 | 6.125 | 5.987 | 4.69 |

*DOI: 10.55214/25768484.v8i6.3245*

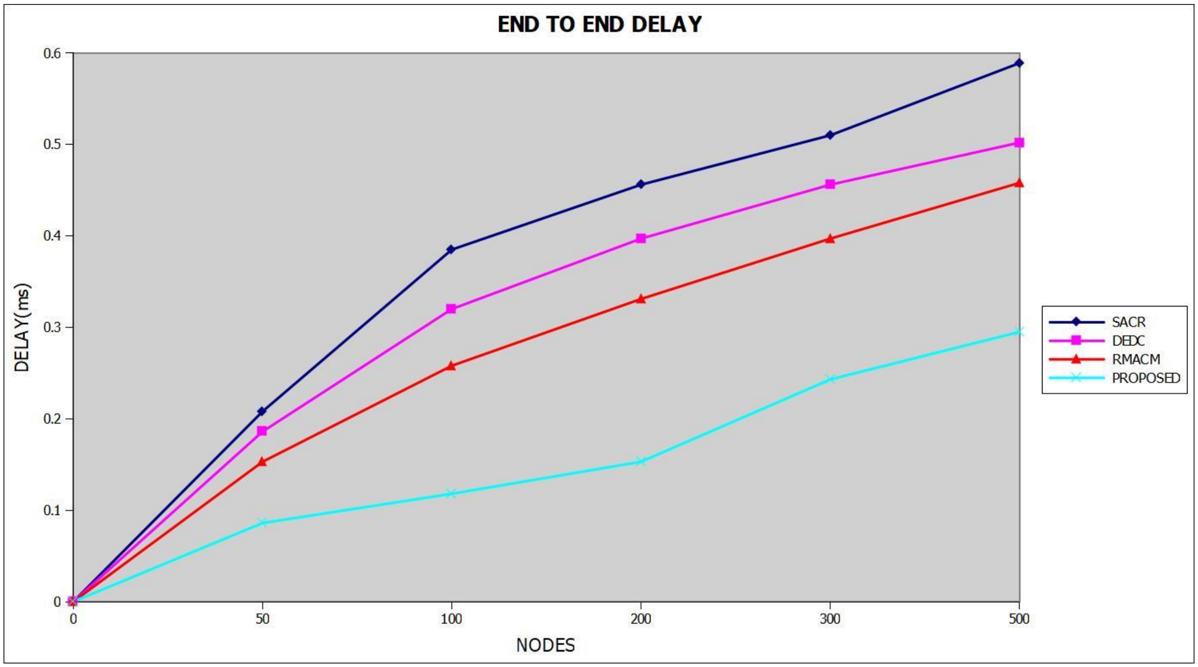

**Figure 3.**

When discussing wireless networks, the term "end-to-end delay" refers to the amount of time that elapses between the production of data packets and the arrival of those packets at the location to which they were sent. This parameter is of critical significance to the overall functioning of the network. The strategic selection of relay nodes is very important to the efficient control of end-to-end latency. In the scenarios that have been given, an important factor in reducing end-to-end latency is the efficient aggregation of data, which is made possible by relay nodes that are free from interference and have a plentiful supply of energy. According to the findings of the experiments, the suggested technique was successful in achieving a time delay of an average of 0.3 milliseconds. This represents a significant advancement in comparison to the conventional method, which had a maximum delay of 0.58 milliseconds. The following table, which offers a full breakdown of the experimental results, is provided for the purpose of comprehensive analysis:

**Table 3.**

| Nodes | SACR | DEDC | RMACM | Proposed |
|---|---|---|---|---|
| 50 | 0.208 | 0.186 | 0.153 | 0.086 |
| 100 | 0.385 | 0.32 | 0.258 | 0.118 |
| 200 | 0.456 | 0.397 | 0.331 | 0.153 |
| 300 | 0.51 | 0.456 | 0.397 | 0.243 |
| 500 | 0.589 | 0.502 | 0.458 | 0.295 |

*DOI: 10.55214/25768484.v8i6.3245*

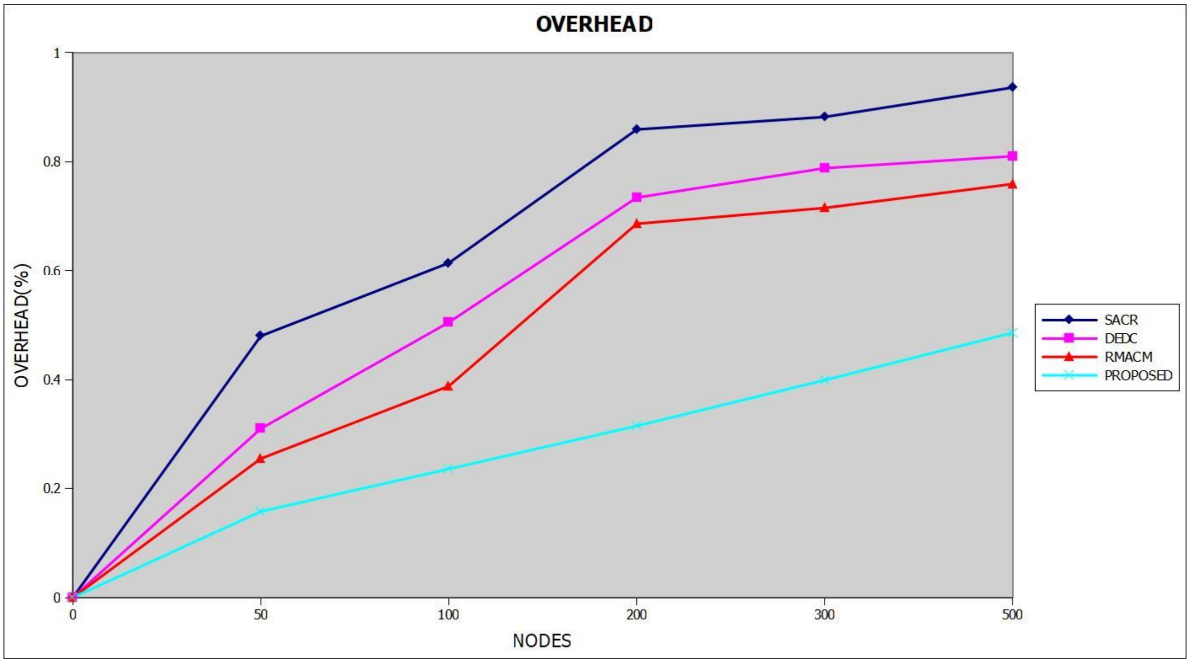

**Figure 4.**

The data that have been obtained so far in the simulation provide evidence of the overhead that is encountered by the network. The term "overhead" refers to the control packets that are sent out over the network in order to improve the efficiency of network operations. The suggested technique displayed an overhead rate of roughly 0.20% as the number of nodes in the network increased from 50 to 500. In contrast, the approaches that were examined recorded much greater levels of overhead. The fair selection of Cluster Heads (CHs) based on spectrum and channel availability helps to reduce the number of times that data has to be retransmitted. Optimal relay node selection is one factor that leads to a decrease in the number of route interruptions. As a consequence of this, the suggested technique keeps the amount of overhead to a minimum. The following is a comprehensive listing of the evaluation's findings for your reference:

**Table 4.**

| Nodes | SACR | DEDC | RMACM | Proposed |
|---|---|---|---|---|
| 50 | 0.48 | 0.31 | 0.255 | 0.158 |
| 100 | 0.614 | 0.505 | 0.388 | 0.236 |
| 200 | 0.859 | 0.734 | 0.686 | 0.315 |
| 300 | 0.882 | 0.788 | 0.715 | 0.399 |
| 500 | 0.936 | 0.81 | 0.759 | 0.486 |

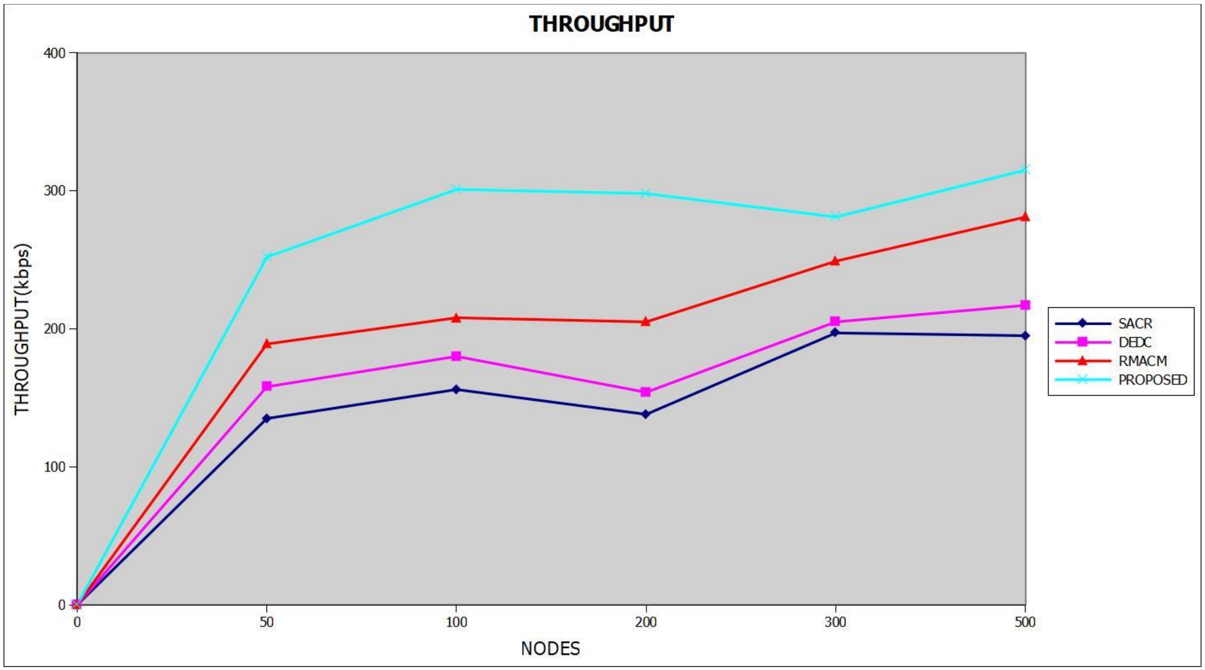

**Figure 5.**

The figure that came before this one showed the results of a simulation that looked at throughput for both the strategy that was offered and the approaches that were compared. The amount of data that can be sent from one sensor node to another is referred to as the throughput, and a greater throughput indicates a stronger capacity for transferring data. The data shown in the table below offers compelling evidence that the recommended strategy results in a much higher throughput rate in comparison to the ways that are presently being used in practice. The proposed method maintained a throughput rate of up to 270 kilobits per second (kbps) on average over the length of the testing, but the other alternatives consistently showed throughput rates that were lower than the one that was delivered. The following is a complete analysis of the outcomes of the experiment, which are presented in the subsequent section of this report:

**Table 5.**

| Nodes | SACR | DEDC | RMACM | Proposed |
|---|---|---|---|---|
| 50 | 135 | 158 | 189 | 252 |
| 100 | 156 | 180 | 208 | 301 |
| 200 | 138 | 154 | 205 | 298 |
| 300 | 197 | 205 | 249 | 281 |
| 500 | 195 | 217 | 281 | 315 |

## 5. Conclusion

Cognitive Radio Sensor Networks, also known as CRSNs, are networks that are made up of dispersed sensor nodes that have the mission of working across dynamic spectrum bands in order to identify event signals. When it comes to CRSNs, ensuring energy efficiency is mostly dependent on considerations like limiting energy usage and performing a variety of channel-related procedures. The currently available clustering methods, which were initially created for Wireless Sensor Networks (WSNs), are not able to appropriately meet the one-of-a-kind issues and features connected with Cognitive Radio (CR). In order to fill this need, the current research presents a new algorithm known as the Multi-level Spectrum-aware Unequal Clustering Algorithm (MLSAC). MLSAC is a method that has been customized particularly for CRSNs and makes use of uneven clusters in order to achieve energy balance.

The energy consumption of individual nodes is used to calculate cluster radii, while the selection of cluster heads (CHs) takes into consideration a variety of factors. These factors include residual energy, spectrum availability, channel conditions, and proximity to both the sink node and other CHs. The protocol that has been provided has as its major goal the improvement of fairness via the establishment of equilibrium in residual energy across sensor nodes. This will, in turn, contribute to a longer network lifetime through an overall decrease in the amount of energy that is used. The findings of the simulation give convincing evidence confirming the superiority of the proposed approach over current clustering strategies for CRSNs. This is notably the case with regard to important performance measures such as network lifetime, throughput, Packet Delivery Ratio (PDR), and end-to-end latency.

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