**Journal of Information Systems Engineering and Management**
2025, 10(20s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

**Research Article**

# Improving Network Quality of Service with Multipath Routing Protocol for Wireless Sensor Networks

Dr. R.G.Gokila[1], Dr. I. Kala[2], Dr. M. Rajesh Babu[3], Dr. S. Uma[4], Dr. T. Sivakumar[5], V.S. Arun Bharathi[6]

*[1]Assistant Professor, School of Computing,*
*SASTRA Deemed University,*
*Thanjavur, India*
*Email: rgokila1702@gmail.com*
*[2] Associate Professor, Department of CSE,*
*PSG Institute of Technology and Applied Research,*
*Coimbatore, India*
*Email: ootykala@gmail.com*
*[3]Professor & Associate Dean, School of Computing,*
*Rathinam Technical Campus,*
*Coimbatore, India*
*Email: drmrajeshbabu@gmail.com*
*[4]Professor, PG In charge, Department of CSE,*
*Hindusthan College of Engineering and Technology,*
*Coimbatore, India*
*Email: druma.cse@hicet.ac.in*
*[5]Professor, Department of CSE,*
*Sri Eshwar College of Engineering (Autonomous),*
*Coimbatore, India*
*Email: msg2sk2010@gmail.com*
*[6]PG Student, Department of CSE,*
*Hindusthan College of Engineering and Technology,*
*Coimbatore, India*
*Email: bharathiarun1@gmail.com*
*Corresponding author email id: rgokila1702@gmail.com*

**ARTICLE INFO**

Received: 21 Dec 2024

Revised: 27 Jan 2025

Accepted: 15 Feb 2025

**ABSTRACT**

Cognitive sensor networks (CSNs) are wireless sensor networks that utilize cognitive radio technology to provide adaptive responses to the environment and improve performance. However, CSNs face challenges such as dynamic spectrum circumstances, node mobility, and resource limitations. Multipath routing protocols have emerged as a potential solution to overcome these obstacles, improving the reliability and resiliency of communication between nodes. However, current multipath routing protocols have downsides such as increased overhead, inflexibility, and lack of reactivity to external conditions. There is a growing need for new multipath routing protocols specifically tailored for CSNs to solve these constraints. These protocols should decrease routing overhead, display flexibility, and consider environmental factors. They should be able to handle various traffic types, scale effectively, and improve security. This research proposes a Node Grade Factor (NGF)-centered node-disjoint multipath routing protocol, NGFMR, which aims to achieve energy-efficient node-disjoint route selection. This is made easier by introducing Quality of Service (QoS) measures into the path selection process, such as distance to SINK, availability of spectrum, communications cost, and node delay. The proposed disjoint routing protocol improves equal allocation of network burden over various routes, resulting in improvements to QoS. Simulations show that NGFMR is superior to other protocols in terms of throughput of network, packet delivery ratio, consumption of energy, and end-to-end latency.

**Keywords:** CSN, Multipath Routing Protocol, Node Grade Factor, QoS, Packet delivery ratio

## I. Introduction

The rise in the number of companies offering wireless services has resulted in a scenario known as spectrum congestion, which has culminated in the problem of spectrum scarcity. A technology solution dubbed cognitive radio (CR) has been created as a reaction to this problem, and it has emerged as a basic treatment [1–3]. The term cognitive radio refers to an intelligent wireless communications system that is endowed with a knowledge of its surrounding radio environment. This awareness makes it possible for the system to make opportunistic use of the spectrum segments that are accessible [4]. This intrinsic capability for opportunistic spectrum access is an excellent solution to the problem of scarce spectrum [5], and it simultaneously improves the efficiency with which spectrum is used. Utilizing the characteristics that are inherent to CR technology provides the ability to handle a significant percentage of the unique demands and challenges that are provided by wireless sensor networks (WSNs) [6]. WSNs, which are often dependent on pre allocated spectrum assignments, are subject to resource restrictions [7]. These limitations are most obviously seen in the communications and processing capacities of battery-powered sensor nodes [8]. As a result, equipping wireless sensor nodes with CR capabilities is beneficial [9], as it enables these nodes to intelligently use dynamic spectrum resources to improve data transmission goals. This, in turn, results in the development of cognitive radio sensor networks, also known by their acronym, CRSNs.

Wireless sensor nodes with cognitive radio capabilities make up most of the components of a Cognitive Radio Sensor Network (CRSN) [10]. The main goal, which is also one of its secondary goals, is to dynamically transfer the collected data throughout all accessible spectrum bands when certain events are detected [11]. When a sensor node detects an event, many nodes work together to establish the necessary channel to send the data to the central location [12]. This cooperative endeavor increases the likelihood of collisions, which in turn introduces problems such as packet loss and delay, ultimately leading to increase in power consumption [13]. On the other hand, sensor nodes that possess cognitive radio capabilities may dynamically access a myriad of different channels, which not only reduces the likelihood of collisions but also makes it easier to transmit collected data to the central destination.

A CRSN is a distributed network and is made up of wireless sensor nodes that have cognitive radio capabilities [14]. This concise explanation provides the most fundamental knowledge of CRSN and effectively conveys its core. This component's main purpose, which also happens to be one of its secondary goals, is to dynamically distribute the data that has been gathered among all accessible spectrum bands when certain events are detected [15]. To reduce the chance of collisions, for example, when a sensor node detects an event, many nodes work together to provide the required channel for prompt transmission to the central location. On the other hand, problems like packet loss and delay appear in collision-prone circumstances [16], which adds to the overall power consumption. Under these circumstances, sensor nodes that possess cognitive radio capabilities may dynamically access several channels, therefore decreasing the likelihood of collisions and expediting the transfer of gathered data to the central location [17].

### Multipath routing in resource-constrained environments

In situations when there is a limited availability of resources, multipath routing presents itself as a workable strategy for improving the efficiency and dependability of data transmission [18]. The use of multipath routing is one approach that shows promise for improving the efficiency of data transmission which also enhances its dependability. The traditional routing paradigm normally operates under the assumption that just one path between source and destination should be chosen as a default [19]. However, such an approach could not fit well with settings that have restricted resources, which can lead to an excessive consumption of network nodes and connections. Multipath routing, on the other hand, scatters data over numerous channels, which might result in possible advantages such as decreased energy usage, increased dependability, and decreased latency [20]. The more common practice of using a single routing route is one that may be replaced with multipath routing as an alternative. When it comes to the implementation of multipath routing, there is a wide variety of different ways that may be used. Load balancing is one of these strategies that stands out as a notable and extensively employed option [21]. In this method, the data is divided fairly into segments, and then each of those segments travels down a different route. If you choose this strategy, you can be certain that neither the individual nodes nor the connections will have to carry more weight than necessary. It is also possible to make use of path redundancy, which is an alternative method that falls under the umbrella of multipath routing [22]. In this hypothetical situation, numerous routes are chosen between the source and the destination to provide continuous data transmission over all accessible paths. This method has the effect of increasing system dependability, especially in situations in which one of the alternative pathways is compromised.

Multiple resource-restricted environments have been successfully routed through using multipath routing, as shown by the demonstrations. The use of several routing protocols increases the likelihood of accomplishing successful data delivery that is trustworthy via the reduction of the energy cost overhead associated with retransmissions caused by either link or node failures and via the facilitation of the construction of alternate paths, improved data delivery reliability may be achieved [23-24].

This study presents an energy-efficient node-disjoint route selection approach that is derived from an NGFMR-derived multipath routing protocol. This methodology was developed as part of this body of work. The authors of this work are credited with the development of this approach. By including Quality of Service (QoS) criteria such as distance to the SINK, spectrum availability, transmission cost, and node latency, the technique is planned to make it such that interference is never an issue. The discontinuous routing solutions that have been discussed allow for efficient load distribution, which in turn helps to improve the overall QoS levels that are present within the network.

**Contributions**

- The NGFMR protocol is used in its present suggested configuration to systematically pick all possible node-disjoint routes linking the provided source and destination pairs. This was stated as the goal of the configuration. This selection procedure considers several QoS indicators, which not only makes it easier to distribute data but also reduces the amount of time it takes for it to be sent.
- Additionally, the NGFMR protocol contributes to the equitable allocation of network traffic across the variety of available channels, which ultimately results in an improvement in the overall QoS across the network.
- The use of multipath routing significantly boosts the chance of successfully accomplishing trustworthy data transfer. Because of this, there has been a resultant decrease in the amount of energy consumption ascribed to data retransmissions resulting from link or node failures, as well as a lowered requirement for constructing alternate pathways.

## II. Related work

There have been significant leaps forward made in the performance of cognitive radio thanks to the use of approaches based on game theory. The capabilities of CRSNs in terms of spectrum usage and spectrum sensing have been improved because of the employment of these approaches. The challenges of energy management and privacy inside CRSNs were investigated in depth by Romero and colleagues in their research [25], which was intended to address these topics. In this scenario, they devised a plan to reinforce security against breaches in privacy by using a technique that included the production of artificial noise as a way of doing so. The choice to implement this strategy was carried out by making use of a competitive game model. This model also demonstrated resource-efficient energy consumption equilibrium, which helped to make the implementation of the strategy a success.

When it comes to WSNs, Wang and colleagues [26] confirmed the idea that clustering improves network lifetime by concentrating data under a cluster head inside a cluster. This was done to test the hypothesis. This method of clustering was used to arrive at this conclusion. Both clustering and the selection of cluster heads may be accomplished using traditional methods, but doing so requires a significant investment of communication resources. Because of this, the Q-Learning approach is used within the scope of this study to be included as an essential part of the cluster head selection process. Nodes are given the potential, by means of this Q-Learning method, to independently assess whether they are willing to take on the job of a cluster leader or not. Because of this, there is an achievement of a decrease in the amount of energy consumption related with the process of cluster head selection.

The Stability-Aware Cluster based Routing (SACR) protocol, introduced by the author in [27], integrates stability-aware clustering with opportunistic information forwarding. It has been demonstrated that SACR operates with decentralized pathways, eliminating the need for specific Cluster Coordination Centers (CCCs). The protocol considers energy levels and spectrums during both clustering and routing processes. In experimental evaluations, SACR outperformed CORPL and SCR protocols, exhibiting superior values in terms of PDR percentages, average delays, energy consumptions, and signaling overheads.

To improve the energy efficiency of data transmission in CRSNs, the distributed clustering protocol, or DEDC protocol, is examined in [28]. The protocol finds and assigns open network channels for communication, classifying them as approved or prohibited. The protocol uses data aggregation to find available licensed channels and uses them for communication during inactive times. The technology delivers higher transmission speeds and greatly lowers transmission energy usage by giving priority to certain channels. Furthermore, the suggested model improves the delay reduction efficacy.

The idea of choosing cluster heads according to the R factor was first presented by the authors in [29]. This method takes several things into account, such as residual data, nodal velocities, and energy levels left. The usage of reserve cluster heads (CHs) to lessen any cluster disruptions brought on by CH migration was also investigated in this work. The outcomes of the simulation showed that, even in the face of fluctuating node densities and speeds, the RMAC-M protocol successfully prevented network instability. RMAC-M was successful in meeting predetermined requirements, decreasing network latencies, and extending network lifespan. Despite node mobility, the protocol adeptly balanced energy concerns with latency, incorporating energy harvesting slots. Suggested directions for future research include optimizing RCH choices, utilizing machine learning based on R-factors to dynamically modify cluster formation weights, assessing mobility models through RMAC-M, and putting the protocol into hardware.

The assignment of slot lengths for sensor nodes was managed by a creative software solution known as the Energy Preservation and Network Critics based Channel Scheduling (EPNCS) algorithm, which is described in article [30]. To reduce power consumption, this objective was achieved by dynamically modifying the sleep periods of sensor nodes in response to environmental data flow. By computing scalable dynamic slots for every sensor node based on buffer space occupancy on average, the available channels were efficiently optimized.

A neighbor finding approach and two k-hop clustering techniques (k-SACB-EC and k-SACB-WEC) were presented by the author in the paper [31]. These algorithms were specially designed for Internet of Things (IoT) applications that need constant communication between and within clusters in Cognitive Radio Sensor Networks (CRSNs). This study's main goals were to create links on both channels and increase the network's longevity. The remaining energy levels of the nodes, spectrum awareness, the possibility of primary users (PUs) showing up on channels, channel quality, resistance to the presence of PUs, and the Euclidean distance between nodes were all taken into consideration throughout the clustering process. These variables had a direct impact on how hop counts were assessed and how common channels were distributed throughout the clusters.

One of the authors presented the Energy-aware Q-learning AODV (EAQ-AODV) routing method in [32]. An AODV-enabled routing protocol was leveraged by the EAQ-AODV that was suggested, and a Q-learning-based incentive mechanism was added into the design to pick cluster heads. The route was determined by this protocol using several different factors, some of which were Residual Energy, Common Channel, Number of Hops, Licensed Channel, Communication Range, and Trust Factor.

The author created a process in [33-35] to determine each node's Cluster Head Weight (CHW) and choose Cluster Heads (CHs) based on this measure. The suggested method combined fuzzy logic (FL) with an ideal relay selection system after the clustering and CH selection procedures to pick high-quality relay nodes for intra- and inter-cluster communications. The fuzzy system used channel quality, traffic index, and connection error rate as input parameters for relay selection. Simulation findings measuring routing overhead, end-to-end latency, network performance, lifetime, and residual energy revealed that the proposed strategy performed better than alternative clustering strategies in CRSN.

## III. System Model

### Assumptions

The following presumptions have been made to facilitate the completion of this inquiry:

The network is made up of 'n' different wireless sensor nodes, all of which are like one another and have been dispersed at random over the network space. In addition, there is only one sink node, and all the sensor nodes send the data that they have detected along a chain of intermediary hops to finally arrive at the sink node, which is the destination node for the information.

The network is modeled as an undirected graph and given the notation $G(V,E)$, where '$V$' stands for the set of nodes and '$E$' stands for the set of edges. This notation is used to describe the network. The edges are specified in such a way that $E \subset V \times V$, which indicates that the connection $(i,j)$is part of $E$ if the nodes $i$ and $j$ are capable of engaging in communication that may flow in both directions with each other. In addition, $N_i$is the collection of all nodes in the network that can be reached with a single hop when starting from node $i$ in the network.

Each sensor node in the network has its very own specific transmission range, which is represented by the letter '$R$' in this notation.

**Proposed method**

The Node Grade Factor based node-disjoint multipath routing (NGFMR) protocol, is presented as a new method in this investigation. This protocol determines the path that will provide the best results depending on the origin and destination of the data. To avoid interference between various channels, the process of route selection takes into account several QoS criteria. These parameters include the distance to the SINK, the availability of spectrum, the communication cost, and the node latency. The routing algorithms that were designed for non-continuous connections efficiently divide the load of the network among several channels, which ultimately results in an improvement to the network's overall QoS. This improvement is accomplished not via the method that has traditionally been used, but rather through computations that include the node grade function.

In a network, the concept of a "disjoint path" refers to the degree to which individual nodes contribute to the identification of numerous paths that may be taken from a source to a destination. Different types of disjoint paths have been proposed by several studies. These paths are typically divided into three categories:

1. Node-disjoint paths, also known as completely disjoint paths, are those in which each node participates in only one path.
2. Link-disjoint paths are those in which nodes may be part of multiple paths but not in a sequential manner, and
3. Non-disjoint paths are those in which nodes may participate in several paths sequentially. The following Figure 1 depicts the Node-disjoint multipath network:

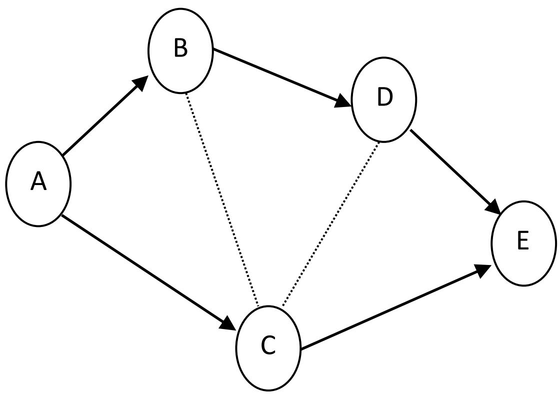


**Fig. 1. Node-disjoint multipath network**

The process that is used to estimate the likelihood of having $k$ node-disjoint pathways connecting the nodes:

i. A one-of-a-kind identification is given to each node in the network.
ii. Choose at random $k$ groups of nodes, with each of those groups containing $d_i$ nodes, and

iii. Check to see that the total number of nodes in all those groups, from i = 1 to $k$, is considerably less than $n$. Because of this selection procedure, each subset will only have a certain number of nodes to choose from.

Eq (1) is used to determine the probability, represented by the letter $p$, that each of these $k$ subsets is node-disjoint is given by:

$$p = \prod_{i=2}^{k} \frac{\left(n-2-\sum_{i=1}^{j} d_i\right)}{(n-2)} \quad \text{Eq (1)}$$

To carry out the computation, it is necessary to take into account a total of $(n-2)$ nodes, with the source and destination nodes being excluded from the consideration. Let us suppose for the sake of this discussion that there exist k node-disjoint pathways between a particular source node, which will be marked by the letter "S," and a sink node, which will be designated by the letter "D." It is essential to make it clear that the letter "S" stands for the source node, and the letter "D" stands for the sink node. The notation $i, j$ may be used to denote each node along the $i^{th}$ route, where $1 \leq i \leq k, 1 \leq j \leq d_i$. This allows for each node to be uniquely identified. It is very important to keep in mind that the source and sink nodes are the ones responsible for determining the endpoints of all k pathways.

The probability of a connection between nodes A and B in the $i^{th}$path route is represented by $\alpha 1$, while the probabilities of linkages $< B, C >, < B, F >$, and so on are represented by $\alpha 2, \alpha 3 \ldots . \alpha d_i$, correspondingly, up to $<d_i - 1, d_i>$ are$\alpha 2, \alpha 3 \ldots . \alpha d_i$. Then, we may define the probability β as follows: β= $\alpha 1, \alpha 2$, $\alpha 3 \ldots . \alpha d_i$. This indicates the presence of linkages from 'S' to 'D' in the sequence $< A, B, C \ldots . . d_i >$.This can be interpreted as:

$$\beta = \alpha^{d_i} + 1 \quad \text{Eq (2)}$$

The probability, indicated by the symbol $P_k$, that there are k different pathways leading from node S to node D may be written as:

$$P_k = \prod_{i=1}^{k} [1 - (1 - \beta)] \quad \text{Eq (3)}$$

Complete node-disjoint multipath routing distinguishes out from other techniques due to its better resilience when compared to other approaches, making it an ideal choice for assuring the dependable transmission of data. The identification of node-disjoint multipath routes, which are those that do not share any nodes in common with other multipath routes, is hence one of the most essential parts of multipath routing. Therefore, determining all the possible non-intersecting pathways between a source and a destination has the potential to considerably improve the operational efficiency of a great deal of protocols. An easy method is used by several on-demand multipath routing protocols for the purpose of multipath discovery. When using this technique, the source node will start the process of requesting a route anytime it wants to send data, and the destination node will reply to each route request it receives, regardless of whether it came from the same source as the first request. The process of establishing several paths for the source node may be made more straightforward by using this strategy. However, there are several different situations in which the multipath discovery process might fail, which will result in the identification of a smaller number of paths than are really accessible. These kinds of failures occur rather often.

A different method to multipath discovery is represented by the concept of source routing. This approach involves recording the addresses of routers in the route requests (RREQ) that are sent. This gives the destination node the ability to choose pathways based on the information provided and enables the detection of multipaths on demand. Although it would seem like an easy method for locating many pathways, using RREQ. It results, a considerable increase in both overhead and the amount of responsibility associated with routing. The inclusion of node addresses in packets causes an increase in the size of the packets with each iteration, which presents issues for mobile devices given the level of development they are now in. An efficient approach for picking multipaths based on a node grade factor path selection strategy is presented by the authors of this study as part of the research that they conducted.

**NGFMR protocol**

An overview of the NGFMR protocol is presented in this section. The NGFMR protocol utilizes a node disjoint path selection technique, in addition to its route selection and maintenance strategy. This topic is touched on lightly during the talk as well. The process of route selection comprises QoS variables such as Distance to SINK, spectrum availability, communication cost, and node latency, all are computed using the node grading function. This is done to minimize interference among the different pathways.

The NGFMR protocol's principal purpose is to ascertain the greatest number of possible paths that may be taken from a given source to a specified location to fulfill its responsibilities. Both the edges that are connected to the source node and the edges that are linked to the destination node have a significant role in determining the total number of multipaths that are accessible between the source and the destination. It is not possible to be a greater number of node-disjoint multipaths than edges in the network that are linked to both source and destination nodes.

**Route discovery**

During the phase known as "route discovery," the job of finding various node-disjoint pathways that are not bound by joint limits is one of the tasks that must be completed. To avoid interference between the nodes, the route selection procedure takes into account QoS criteria such as the distance to the SINK, the availability of spectrum, the cost of transmission, and the node latency.

**NGF algorithm**

The relay node selection is based on NGF – Node grade factor algorithm. Each node is assigned with a rank by estimating the selection parameters. The proposed NGF algorithm considers Distance to SINK, spectrum availability, communication cost, and node delay for efficient relay selection. The total functionality of Node grade factor with respective node level is given as:

$$NGF_n = \alpha_1 \times [Dist_{n2sink}] + \alpha_2 \times SPEC_{available} + \alpha_3 \times Com_{COST} + \alpha_4 \times ND \quad \text{Eq (4)}$$

Here, $Dist_{n2sink}$ denotes the distance to sink, $SPEC_{available}$ is the available spectrum, $Com_{COST}$ is the communication cost and $ND$ denotes delay of the node and $\alpha$ is the weight coefficient between 0 to 1.

The selection parameters are explained follows:

**Node distance to SINK ($Dist_{n2sink}$):** The factor of distance determines how much power a node has to expend while it is engaged in communication. A decrease in the distance between a node and the SINK leads to a reduction in the amount of energy that the node needs to consume. Therefore, routing techniques utilize this parameter to guarantee that the average distance between sensor nodes and the SINK is kept to a minimum as much as possible to maximize efficiency. One possible way to communicate this idea is given below:

$$D_{n2CH} = \sum_{i=1}^{N} \left( \frac{D_{(N-SINK)}}{D_{AVG(N-SINK)}} \right) \quad \text{Eq (5)}$$

Where $D_{(N-SINK)}$ is the notation used to indicate the Euclidean distance between the node and the SINK, and $D_{AVG(N-SINK)}$ is the notation used to represent the average distance between the node and the SINK.

**Spectrum availability $SPEC_{available}$:** Two of the criteria that influence the likelihood of a successful transmission are the amount of time that must be spent transmitting the data as well as the length of time that spectrum may be made available on the channel. One way to describe the spectrum that may be reached by moving from subunit i to its adjacent subunit j is given as:

$$SPEC_{available} = \frac{pkt_{size}}{v_k \times r_k} \quad \text{Eq (6)}$$

In this scenario, the packet size is indicated by the notation $pkt_{size}$, where $v_k$ is the transmission rate over channel $k$ and $r_k$ is the rate of channel k. The rate of channel k is expressed by the notation $r_k$.

**Communication cost $Com_{COST}$:** The expenditures spent by a node while engaging in communication with its neighbor or the charges necessary for the node to communicate with its peers are referred to as its "communication cost," and they are represented by the term "communication cost." This idea may be explained in more detail as follows Eq (7):

$$Com_{cost} = \frac{DIS_{avg}}{R} \quad \text{Eq (7)}$$

$R$ denotes the radius of the node, whereas $DIS_{avg}$ indicates the average distance between the node and its neighbors. This can be summarized for all the nodes as follows Eq (8):

$$TC = \frac{1}{M} * \sum_{i=1}^{N} Com_{cost} \quad \text{Eq (8)}$$

**Node delay ($ND$):** It is very necessary to measure the delay between the source node and the destination node in order to correctly calculate the route delay. This measurement takes into consideration a number of different delays, such as those caused by transmission, processing, queuing, and propagation.

$$NDELAY_{i,j} = \sum_{i,j}\left(\left(\frac{1}{\alpha 1 - \alpha 2}\right) + \frac{1}{BW_{link}} + \frac{D(i,j)}{Pro_{SPEED}}\right) \quad \text{Eq (9)}$$

The equation (9) contains the constants $\alpha 1 \& \alpha 2$, as well as the bandwidth of the connection ($BW_{link}$), the propagation speed ($Pro_{SPEED}$), and the distance between the nodes, which is given by the notation $D\ (i,j)$.

The NGF calculation is repeated for every node and the node which achieves the high value will be selected as relay nodes for communication. Figure 2 represent the disjoint path selection.

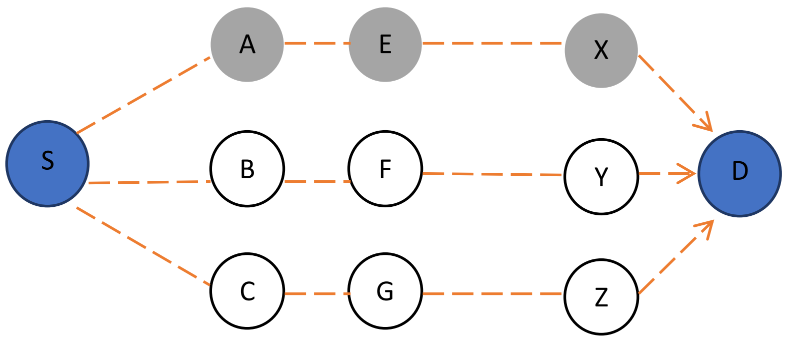


**Fig. 2. Disjoint path selection**

In Fig. 2, nodes S and D are source and destination nodes respectively. During route discovery phase, the NGF algorithm calculates the grade of all the nodes using NGF equation. Nodes A, E, ..., X have more grade value than the remaining nodes in the network. Which means, these nodes have more residual energy, easily accessible to the remaining nodes due to the less distance and better communication cost.

Once the grade value has been determined, the source node will start the process of route discovery by broadcasting a route discovery message. This will take place once the grade value has been determined. After the source node has finished its assessment of the grade value, this will take place. When these messages are received by the nodes that are directly adjacent to the source (also known as one-hop nodes), a subset of these nodes that are known as reference nodes (Ref_NODES), attach their addresses to the message. These reference nodes may be distinguished from other nodes by the prefix "Ref". After then, the role of these reference nodes, which are also referred to as Ref_NODES, changes to that of secondary source nodes. The intermediate nodes all make use of the message's source address in combination with a sequence number to differentiate between messages that are otherwise similar. This is done to prevent messages from being sent more than once. At the beginning of the procedure, the sequence number is allotted at the source node, and it is raised by one whenever the source node submits a route request.

After then, the destination node will proceed to send a broadcast of reply to messages to each and every one of the reference nodes. Each reply message creates a single route to each reference node, which the source node may then utilize to establish a variety of different paths by leveraging these routes. If there are more edges at the source node than there are at the destination node, then the number of multipaths will be equal to the number of edges at the destination node. If the opposite is true, then the number of multipaths will be equal to the number of edges at the source node. When intermediate nodes are presented with circumstances in which they are in receipt of a large number of replies to messages, these messages are just discarded.

**Data transmission phase**

Finding the path that has the greatest grade value among the many possible node-disjoint paths that go from the source to the destination is the key to establishing which of these routes should be considered the primary route. A comparison of grade values for each node that is part of the prospective routing paths must be done in order to determine which route will serve as the principal one. Each node along the road determines its own value by computing it based on a variety of parameters. These qualities might include things like the distance between them, the cost of transmission, the availability of spectrum, and the node's own delay. A higher node value is a signal that the node is well-equipped to handle data traffic, maybe because of having more residual energy and spectrum accessibility. This might be the case if the node has a higher node value. This conclusion may be drawn because of the high node value of the node.

Let's say that the $J^{th}$ node along the $P$ route has the greatest node cost of all the nodes along that route when compared to the other nodes along the same route. In such a scenario, the grade value that is allocated to route $P$ becomes equivalent with the grade value that is associated with the $J^{th}$ node. In a similar fashion, all grade values for $P = 1, 2, \ldots, k$are taken into consideration, and the main route is chosen based on having the highest-grade value possible. This major route, in its most fundamental form, functions as the way that can accommodate the most substantial data flow and stands out as the alternative that is the most dependable among the node-disjoint routes. The idea may be expressed in the following Eq (10):

$$Primaty_{PATH} = max\{NGF_i wherei \in P\} \text{ Eq (10)}$$

**Path maintenance**

After the route discovery phase has been successfully finished, the source node will go on to the next stage, which is starting the transmission of data traffic across the established network routes. This step will be taken after the route discovery phase has been properly completed. Over the course of time, it is possible that the energy reserves of the nodes may run out, or that there will be interruptions in the forwarding connections. Both outcomes are possible. Both possibilities are a real possibility. After all the energy reserves in a node have been used up, the node is referred to as a "dead node," and the route that it was linked to be severed. Because of this, any data traffic that was intended to go across this broken channel does not make it to the sink node, and the source node is not informed of this occurrence. As a direct result of this, the source node maintains its data transmission, which has a detrimental effect on the overall performance.

In these kinds of circumstances, a route alert packet is sent in the other way, in the direction of the node that was the source of the traffic in the first place. After then, as soon as the source node is aware that the warning packet has been received, it will continue to delete the whole route. After then, the data is redirected via a different active channel in accordance with the currently greatest grade value that is accessible. Figure 3 represents the flowchart of proposed method.

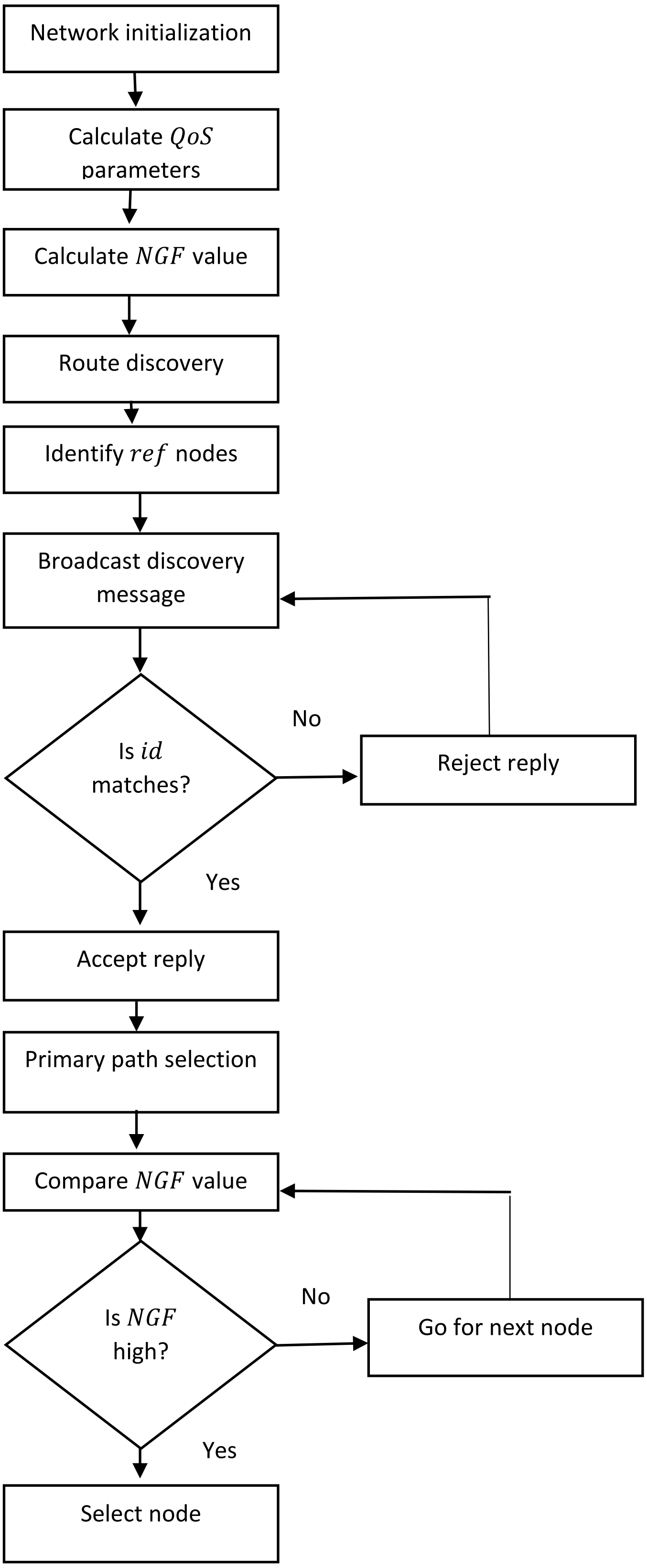


**Fig. 3. Flowchart of the proposed framework**

## IV. Simulation Results and Discussions

In this section, an analysis is conducted involving a simulation that encompasses 50 sensor nodes distributed across various network regions. Each of these nodes carries a data unit of size 1024 bytes, and the simulation is performed across multiple network regions. The three initial energy levels considered are 10 j, 50 j, and 100 j. The performance evaluation of the proposed method is based on the measurement outcomes of several metrics, which include energy consumption, end-to-end latency, routing overhead, and packet delivery ratio. The simulation's parameters are given in Table 1.

**Table 1. Simulation parameters**

| S. No. | Parameter | Value |
|---|---|---|
| 1. | Area of Network | 1000mx500m,1000mx1000m, 2000mx1000 m |
| 2. | Size of packet | 1024 bytes |
| 3. | Traffic Protocol | CBR |
| 4. | Data Transmission Protocol | UDP |
| 5. | Initial Energy of Node | 10j, 50j, 100j |

In the context of sensor networks, energy is a resource that is both essential and limited in its availability. Because of this, there is an urgent need to optimize the distribution of energy consumption among sensor nodes in order to improve total energy efficiency. The wasteful use of energy, which mostly results from incorrect data aggregation and relay selection, is the primary contributor to the unjustified depletion of this invaluable resource. The solution that has been suggested includes the implementation of a process for choosing relays that are both trustworthy and efficient, which results in a large decrease in the amount of energy that is used. The suggested method was put through rigorous testing and assessment across a variety of natural situations, which resulted in convincing findings that reveal a significant reduction in energy consumption in comparison to the ways that are presently being used. The suggested technique demonstrates the greatest energy consumption of 1.71 j across a variety of energy levels, which stands in striking contrast to the significantly raised energy consumption levels that are found in other methods that are currently in use. Figure 4represents the comparison of proposed method with existing methods by varying initial energy vs energy consumption. Figure 5 shows the comparison of network area vs energy consumption among proposed one with existing methods.

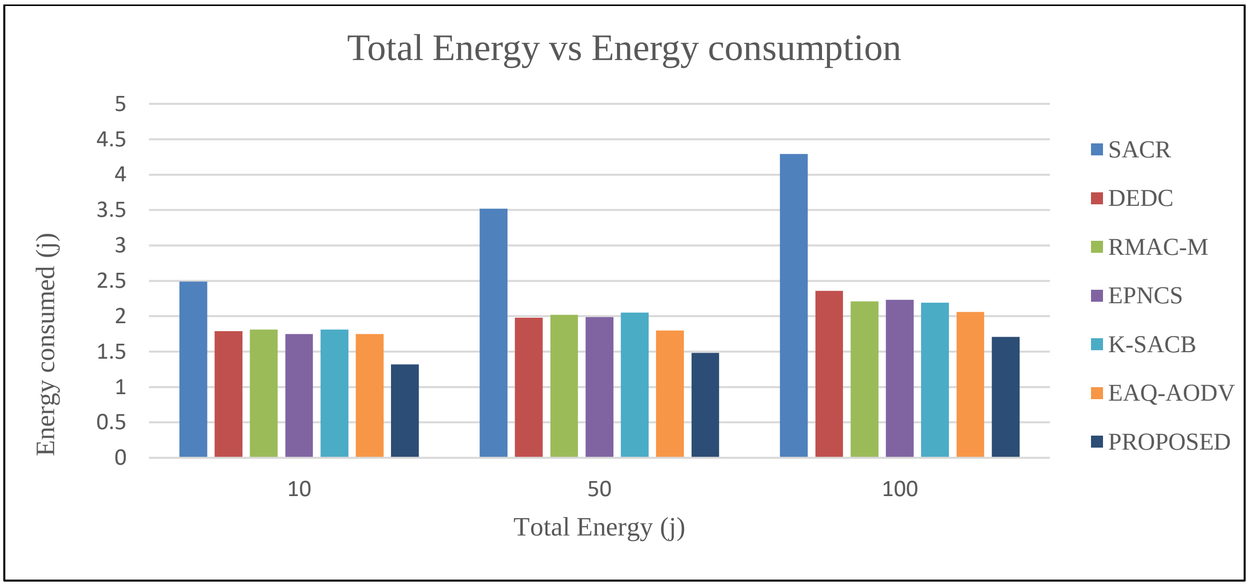


**Fig. 4. Initial Energy vs Energy consumption**

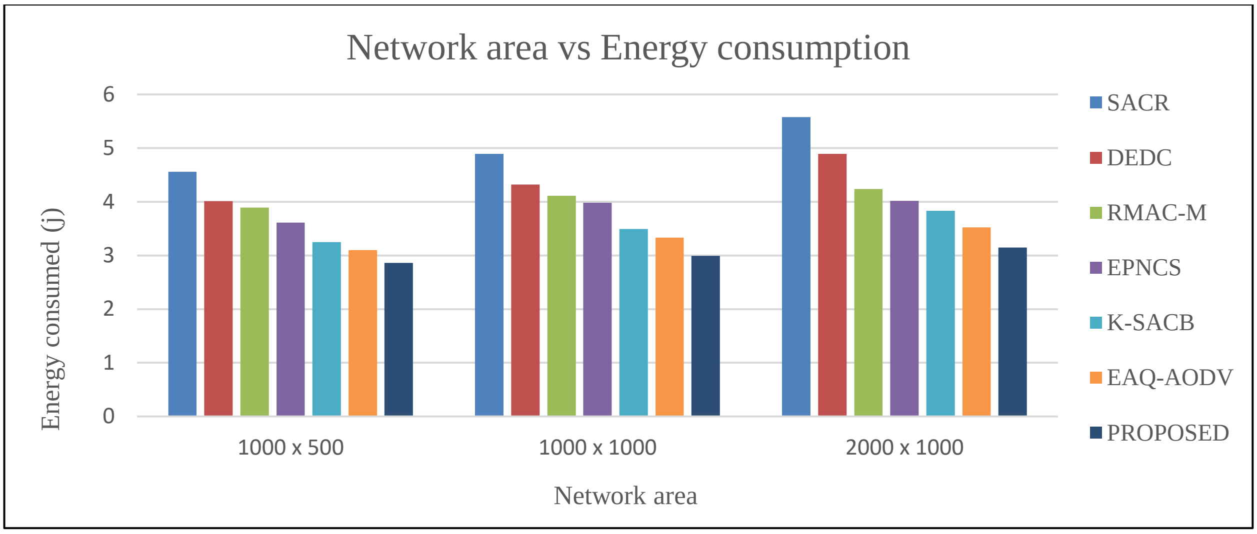


**Fig. 5. Network Area vs Energy consumption**

Tables2 and 3 presents the specific findings that apply to the consumption of energy, categorizing them according to the different network regions and beginning energy levels.

**Table 2. Initial Energy vs Energy Consumption**

| Initial Energy (Joules) | Energy Consumption(J) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SACR | DEDC | RMAC-M | EPNCS | K-SACB | EAQ-AODV | Proposed |
| 10 | 2.49 | 1.79 | 1.81 | 1.75 | 1.81 | 1.75 | 1.32 |
| 50 | 3.52 | 1.98 | 2.02 | 1.99 | 2.05 | 1.80 | 1.48 |
| 100 | 4.29 | 2.36 | 2.21 | 2.23 | 2.19 | 2.06 | 1.71 |

**Table 3. Network Area vs Energy consumption**

| Network Area(m²) | Energy Consumption(J) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SACR | DEDC | RMAC-M | EPNCS | K-SACB | EAQ-AODV | PROPOSED |
| 1000x500 | 4.56 | 4.01 | 3.89 | 3.61 | 3.25 | 3.10 | 2.86 |
| 1000x1000 | 4.89 | 4.32 | 4.11 | 3.98 | 3.49 | 3.33 | 2.99 |
| 2000x1000 | 5.58 | 4.89 | 4.24 | 4.02 | 3.83 | 3.52 | 3.15 |

The end-to-end delay is of critical significance in wireless networks because it denotes the amount of time that elapses between the production of a data packet and its arrival at the location specified in the packet's address. When it comes to the effective management of end-to-end latency, the choice of relay nodes emerges as a critical determining factor. In the situations that have been discussed, the efficient aggregation of data across numerous node-disjoint multipath relay nodes plays an essential part in substantially reducing end-to-end latency. The multiple node-disjoint multipath relay nodes are the ones responsible for playing this essential function. The results of the experiments indicated that the suggested technique resulted in a time delay of no more than 0.015*ms* on average across all the different energy levels that were evaluated. In sharp contrast to the longest delay of 0.58 milliseconds that was measured using the SACR technique, this data reveals an unexpectedly short latency. Figure 6 shows the initial energy vs delay performance evaluation while comparing proposed with existing methods. Figure 7 represent the network area vs delay performance.

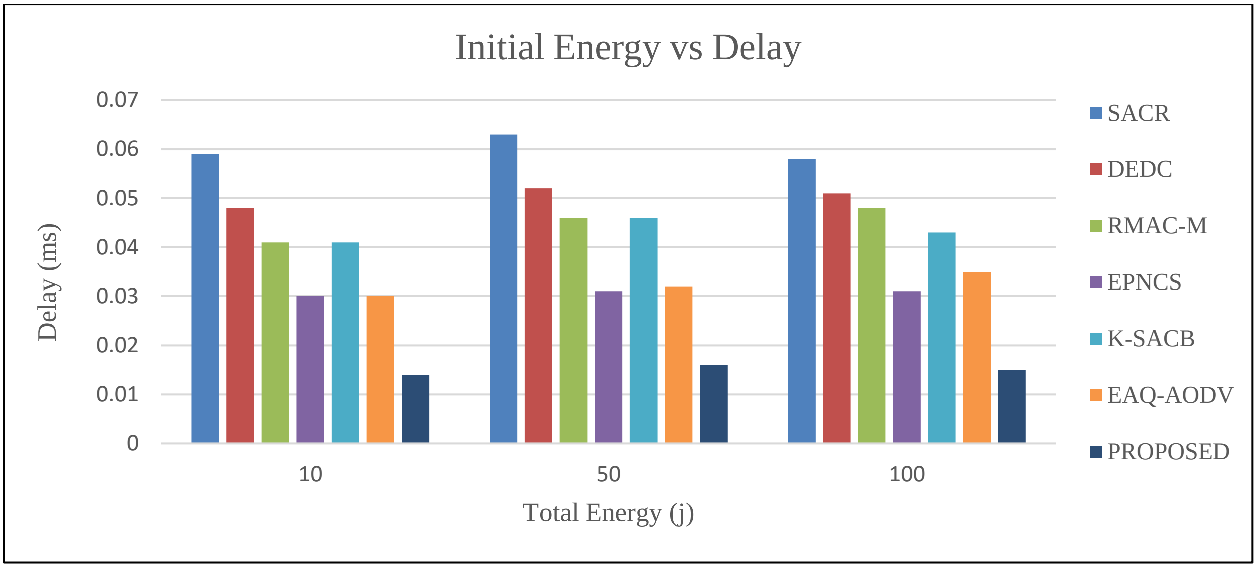


**Fig. 6. Initial Energy vs Delay**

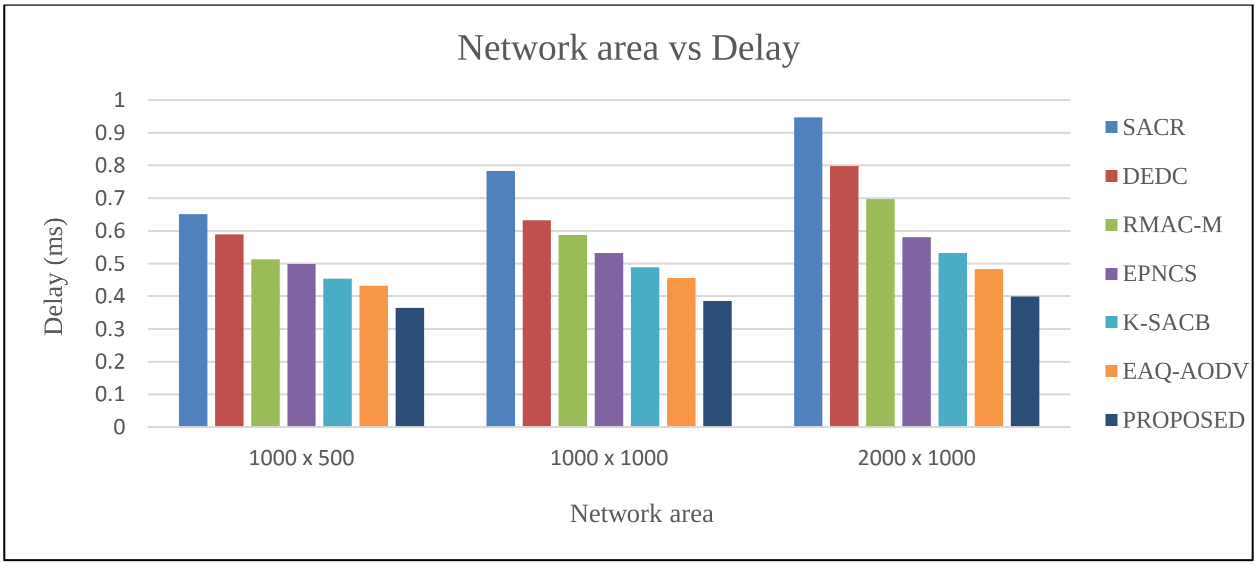


**Fig. 7. Network Area vs Delay**

Tables 4 and 5 offers a complete summary of the findings of the experiments.

**Table 4. Initial Energy vs Delay**

| Initial Energy (Joules) | End-to-End Delay(*ms*) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **SACR** | **DEDC** | **RMAC-M** | **EPNCS** | **K-SACB** | **EAQ-AODV** | **PROPOSED** |
| 10 | 0.059 | 0.048 | 0.041 | 0.030 | 0.041 | 0.030 | 0.014 |
| 50 | 0.063 | 0.052 | 0.046 | 0.031 | 0.046 | 0.032 | 0.016 |
| 100 | 0.058 | 0.051 | 0.048 | 0.031 | 0.043 | 0.035 | 0.015 |

**Table 5. Network Area vs Delay**

| Network Area($m^2$) | End-to-End Delay($ms$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SACR | DEDC | RMAC-M | EPNCS | K-SACB | EAQ-AODV | Proposed |
| 1000x500 | 0.651 | 0.589 | 0.513 | 0.498 | 0.454 | 0.433 | 0.365 |
| 1000x1000 | 0.784 | 0.632 | 0.588 | 0.532 | 0.488 | 0.456 | 0.386 |
| 2000x1000 | 0.947 | 0.798 | 0.697 | 0.580 | 0.532 | 0.483 | 0.399 |

The outcomes of the simulation of the network's overhead, which were covered in the section before this one, have now been shown. The term overhead refers to the number of control packets that are sent over the whole of the network to enable the operational activities of the network. The suggested technique revealed an estimated overhead rate of roughly 1.2% across a variety of network circumstances, while the methods that were examined had greater overhead rates across the board. The employment of appropriate node-disjoint relay nodes helps to a decrease in the number of route interruptions and lowers the possibility of the need for data to be retransmitted. As a direct consequence of this, the proposed technique can successfully keep overhead costs at a minimal level. Figure 8 shows the initial energy vs overhead and Figure 9 shows network vs overhead by comparing the proposed one with existing methods.

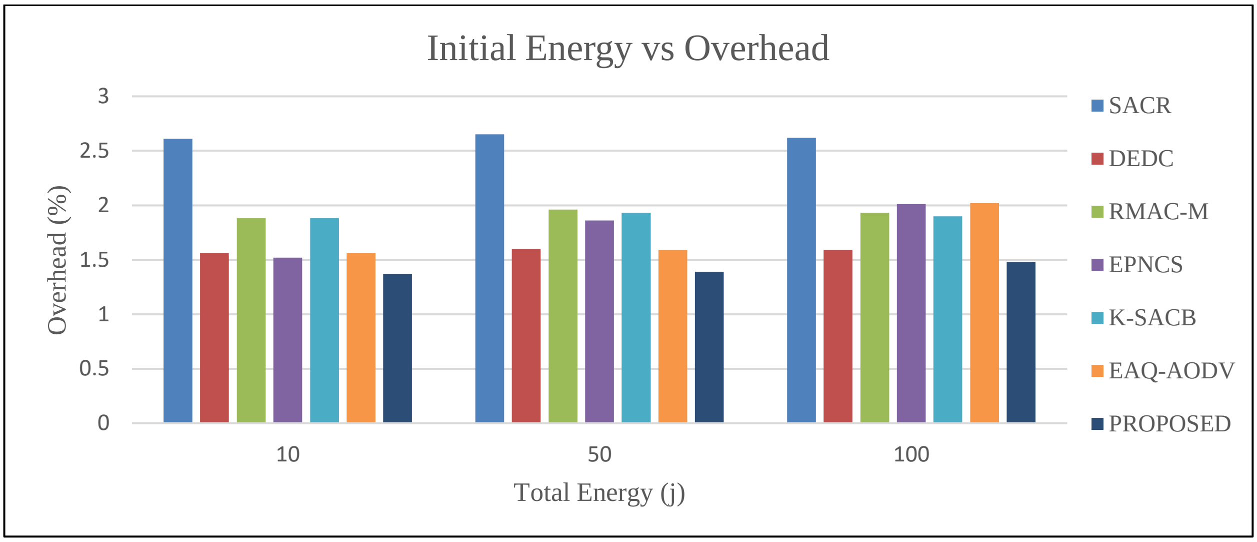


**Fig. 8. Initial Energy vs overhead**

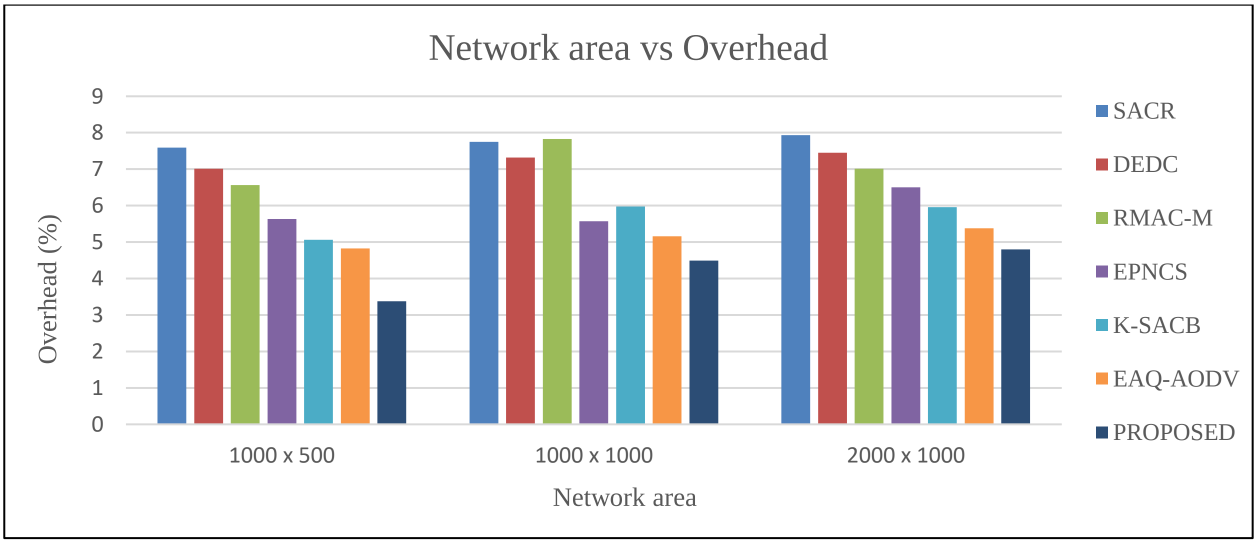


**Fig. 9. Network Area vs overhead**

Tables 6 and 7are shown for comparison of proposed work with existing methods by varying network area and initial energy vs overhead.

**Table 6. Initial Energy vs Overhead**

| Initial Energy (Joules) | Overhead (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SACR | DEDC | RMAC-M | EPNCS | K-SACB | EAQ-AODV | PROPOSED |
| 10 | 2.61 | 1.56 | 1.88 | 1.52 | 1.88 | 1.56 | 1.37 |
| 50 | 2.65 | 1.60 | 1.96 | 1.86 | 1.93 | 1.59 | 1.39 |
| 100 | 2.62 | 1.59 | 1.93 | 2.01 | 1.90 | 2.02 | 1.48 |

**Table 7. Network Area vs overhead**

| Network Area($m^2$) | Overhead (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SACR | DEDC | RMAC-M | EPNCS | K-SACB | EAQ-AODV | Proposed |
| 1000x500 | 7.59 | 7.014 | 6.56 | 5.63 | 5.06 | 4.83 | 3.38 |
| 1000x1000 | 7.75 | 7.32 | 7.83 | 5.57 | 5.98 | 5.16 | 4.49 |
| 2000x1000 | 7.93 | 7.45 | 7.01 | 6.50 | 5.96 | 5.38 | 4.80 |

The simulation results for throughput are displayed in the picture that has been supplied here. These findings compare the methodology that has been suggested to alternative ways. A crucial indicator for efficient data transmission is throughput, which refers to the volume of data that is transported from one sensor node to another. The data given in Table 8 provides conclusive proof that the suggested approach can achieve a much greater throughput rate when compared to methods that are already in use. Throughout all the studies, the suggested approach consistently maintained a throughput rate of up to 350 *kbps*, while the current methods demonstrated lower throughput rates regardless of the parameters of the network they were tested on. Figure 10 shows the initial energy vs throughput and Figure 11 shows network area vs throughput by comparing proposed one with existing methods.

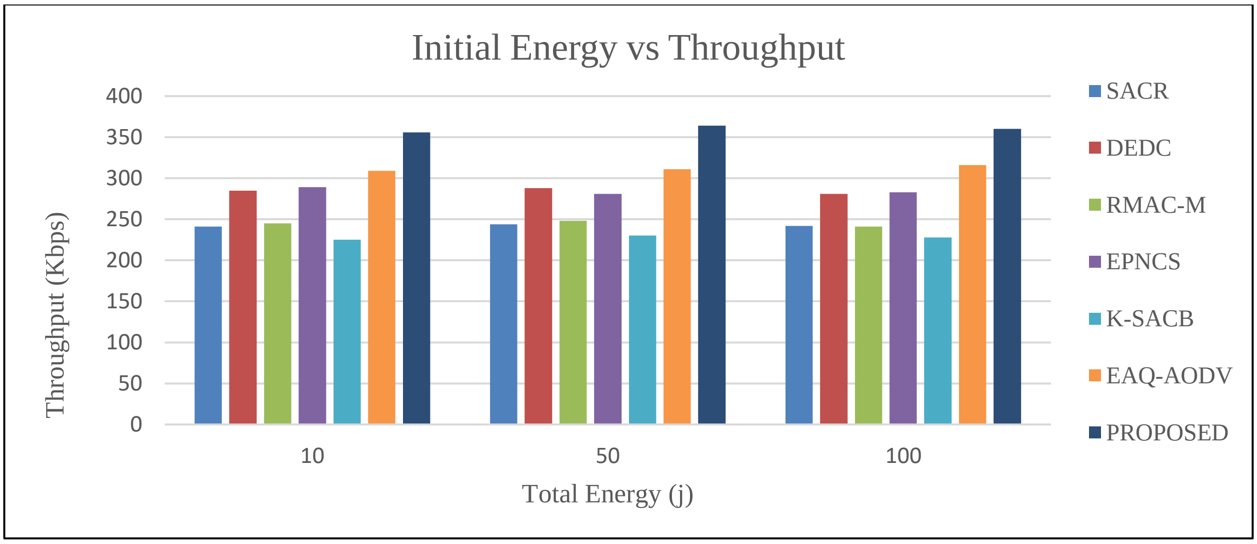


**Fig. 10. Initial Energy vs Throughput**

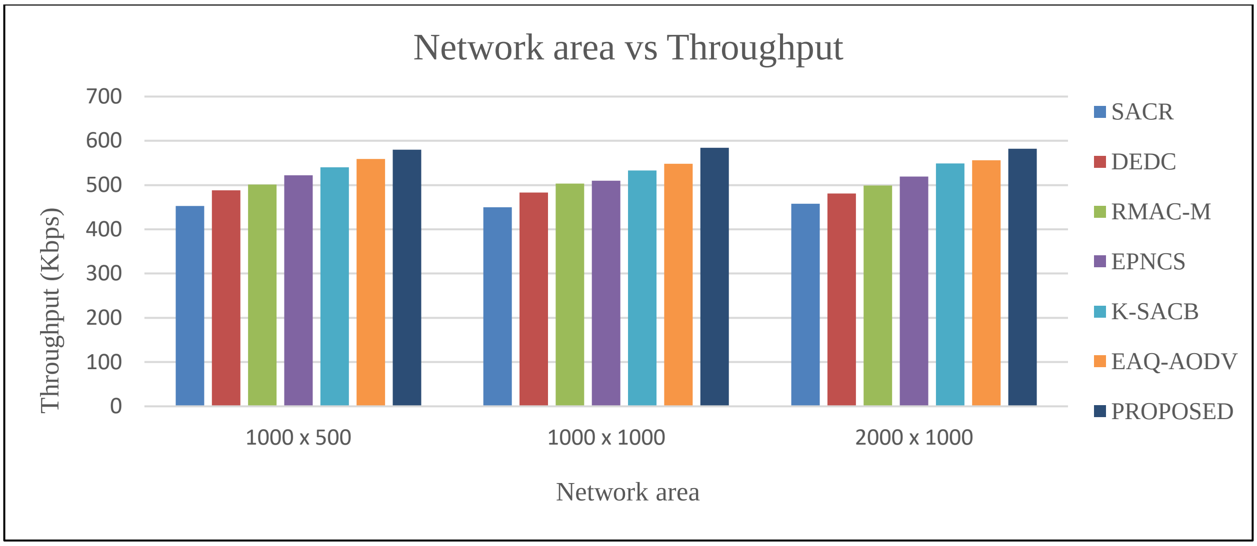


**Fig. 11. Network Area vs Throughput**

A comprehensive overview of the findings of the experiment can be found in Tables 8 and 9 by varying initial energy and network area with throughput.

**Table 8. Initial energy vs Throughput**

| Initial Energy (Joules) | Throughput (*kbps*) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SACR | DEDC | RMAC-M | EPNCS | K-SACB | EAQ-AODV | Proposed |
| 10 | 241 | 285 | 245 | 289 | 225 | 309 | 356 |
| 50 | 244 | 288 | 248 | 281 | 230 | 311 | 364 |
| 100 | 242 | 281 | 241 | 283 | 228 | 316 | 360 |

**Table 9. Network Area vs Throughput**

| Network Area($m^2$) | Throughput (*kbps*) | | | | | | |
|---|---|---|---|---|---|---|---|
| | SACR | DEDC | RMAC-M | EPNCS | K-SACB | EAQ-AODV | Proposed |
| 1000x500 | 453 | 488 | 501 | 522 | 540 | 559 | 580 |
| 1000x1000 | 450 | 483 | 503 | 510 | 533 | 548 | 584 |
| 2000x1000 | 458 | 481 | 499 | 519 | 549 | 556 | 582 |

## V. Conclusion

Current routing algorithms often lack resilience, energy efficiency, and high throughput because they prioritize one aspect while compromising others. This occurs because these algorithms focus on a single facet. For example, many routing protocols concentrate on selecting efficient routes to prolong the network's lifespan. However, this approach can lead to early node depletion due to excessive energy consumption. In contrast, multipath routing strategies distribute traffic across multiple routes instead of relying on a single optimal path. This can extend the longevity of wireless sensor networks or nodes.

This research article presents an energy-efficient multipath routing protocol that makes use of Node Grade Factor (NGF) to guarantee that nodes are routed in a manner that is distinct from one another. This research work served as the impetus for the development of the procedure. The suggested protocol considers a variety of QoS parameters in order to reduce the amount of route interference that occurs between nodes and to improve the network's overall quality of service. These metrics consider things like the distance to the sink, the availability of spectrum, the cost of connectivity, and the latency of the nodes. In addition, the protocol allows for load sharing to occur over many routes, which helps to further improve the QoS provided by the network. The findings of the simulations show that the NGFMR protocol, in the configuration that was recommended, outperforms traditional protocols in terms of network throughput, packet delivery ratio, energy efficiency, and end-to-end latency.

## References


[1]. Agrawal, S.K., Samant, A. and Yadav, S.K., 2022. Spectrum sensing in cognitive radio networks and metacognition for dynamic spectrum sharing between radar and communication system: A review. Physical Communication, 52, p.101673.

[2]. Manco, J., Dayoub, I., Nafkha, A., Alibakhshikenari, M. and Thameur, H.B., 2022. Spectrum Sensing Using Software Defined Radio for Cognitive Radio Networks: A Survey. IEEE Access, 10, pp.131887-131908.

[3]. Ahmed, R., Chen, Y., Hassan, B. and Du, L., 2021. CR-IoTNet: Machine learning based joint spectrum sensing and allocation for cognitive radio enabled IoT cellular networks. Ad Hoc Networks, 112, p.102390.

[4]. Umeonwuka, O.O., Adejumobi, B.S. and Shongwe, T., 2024. Deep Learning-Assisted Energy Prediction Modeling For Energy Harvesting in Wireless Cognitive Radio Devices. *IEEE Access*.

[5]. Edris, M., Ghasemi-Varnamkhasti, M., Kiani, S., Yazdanpanah, H. and Izadi, Z., 2024. Identifying the authenticity and geographical origin of rice by analyzing hyperspectral images using unsupervised clustering algorithms. *Journal of Food Composition and Analysis*, *125*, p.105737.

[6]. Ketshabetswe, L.K., Zungeru, A.M., Lebekwe, C.K. and Mtengi, B., 2024. Energy-efficient algorithms for lossless data compression schemes in wireless sensor networks. *Scientific African*, *23*, p.e02008.

[7]. Bataihah, K.M., Salameh, H.B., Al-Obiedollah, H., Al-Nairat, M. and Jararweh, Y., 2023. Improving Connectivity in Urban IoT-based Wireless Sensor Networks: A None-orthogonal Cognitive-based Power Allocation. *IEEE Sensors Journal*.

[8]. Gonzalez, M., Xu, P., Dekimpe, R., Schramme, M., Stupia, I., Pirson, T. and Bol, D., 2023. Technical and Ecological Limits of 2.45-GHz Wireless Power Transfer for Battery-Less Sensors. *IEEE Internet of Things Journal*.

[9]. Soundararajan, S., Kurangi, C., Basha, A., Uthayakumar, J., Kalaivani, K., Dhamodaran, M. and Shukla, N.K., 2023. Metaheuristic optimization based node localization and multihop routing scheme with mobile sink for wireless sensor networks. *Wireless Personal Communications*, *129*(4), pp.2583-2605.

[10]. Thareja, Y., Sharma, K.K. and Singh, P., 2023. Intelligent Smart Sensor for Cognitive Radio Networks: Comparison, Solution, and Analysis. In *Intelligent Sensor Node-Based Systems* (pp. 243-258). Apple Academic Press.

[11]. Gatate, V. and Agarkhed, J., 2021. Energy preservation and network critic based channel scheduling (EPNCS) in cognitive radio sensor networks. International Journal of Information Technology, 13(1), pp.69-81.

[12]. Mohan, D., Al-Hamid, D.Z., Chong, P.H.J., Sudheera, K.L.K., Gutierrez, J., Chan, H.C. and Li, H., 2024. Artificial Intelligence and IoT in Elderly Fall Prevention: A Review. *IEEE Sensors Journal*.

[13]. Ketshabetswe, L.K., Zungeru, A.M., Lebekwe, C.K. and Mtengi, B., 2024. Energy-efficient algorithms for lossless data compression schemes in wireless sensor networks. *Scientific African*, *23*, p.e02008.

[14]. Wang, J. and Ge, Y., 2022. A radio frequency energy harvesting-based multihop clustering routing protocol for cognitive radio sensor networks. *IEEE Sensors Journal*, *22*(7), pp.7142-7156.

[15]. Zheng, M., Wang, C., Song, M., Liang, W. and Yu, H., 2021. SACR: A stability-aware cluster-based routing protocol for cognitive radio sensor networks. IEEE Sensors Journal, 21(15), pp.17350-17359.

[16]. Guedes, B.T., Passos, D. and Passos, F.G., 2023. A spectral clustering algorithm for intelligent grouping in Dense Wireless Networks. *Computer Communications*, *198*, pp.117-127.

[17]. Wang, H. and Tan, L., 2023, April. An Event-Driven Spectrum-Aware Routing Protocol Based on Hungarian Algorithm in Cognitive Radio Sensor Networks. In 2023 IEEE 12th International Conference on Communication Systems and Network Technologies (CSNT) (pp. 767-773). IEEE.

[18]. Biswas, K., Muthukkumarasamy, V., Chowdhury, M.J.M., Wu, X.W. and Singh, K., 2023. A multipath routing protocol for secure energy efficient communication in Wireless Sensor Networks. Computer Networks, p.109842.

[19]. Jia, W.K. and Yu, C.M., 2023. WALS: A Lightweight Stateless Label Switching Framework Based on Prime Theorem for MANETs. *IEEE Internet of Things Journal*.
[20]. Balachander, T., Ramana, K., Mohana, R.M., Srivastava, G. and Gadekallu, T.R., 2023. Cooperative Spectrum Sensing Deployment for Cognitive Radio Networks for Internet of Things 5G Wireless Communication. *Tsinghua Science and Technology*, *29*(3), pp.698-720.
[21]. Hajipour, Z. and Barati, H., 2021. EELRP: energy efficient layered routing protocol in wireless sensor networks. Computing, 103(12), pp.2789-2809.
[22]. Saini, T.K. and Sharma, S.C., 2020. Recent advancements, review analysis, and extensions of the AODV with the illustration of the applied concept. *Ad Hoc Networks*, *103*, p.102148.
[23]. Abdulrab, H., Hussin, F.A., Abd Aziz, A., Awang, A., Ismail, I. and Devan, P.A.M., 2022. Reliable fault tolerant-based multipath routing model for industrial wireless control systems. Applied Sciences, 12(2), p.544.
[24]. L. V. R. C. Prasad, Y. Kamatham and D. Sunehra, "An Energy Efficient Node-Disjoint Path Selection Scheme for Cognitive Radio Sensor Networks," 2023 IEEE 5thInternational Conference on Cybernetics, Cognition and Machine Learning Applications (ICCCMLA), Hamburg, Germany, 2023, pp. 70-75, doi: 10.1109/ICCCMLA58983.2023.10346655.
[25]. Romero, E., Blesa, J., Araujo, A., 2019. An adaptive energy aware strategy based on game theory to add privacy in the physical layer for cognitive WSNs. Ad Hoc Netw. 92.
[26]. Wang, T., Guan, X., Wan, X., Shen, H., Zhu, X., 2019. A spectrum-aware clustering algorithm based on weighted clustering metric in cognitive radio sensor networks. IEEE Access 7, 109555–109565.
[27]. M. Zheng, C. Wang, M. Song, W. Liang and H. Yu, "SACR: A Stability-Aware Cluster-Based Routing Protocol for Cognitive Radio Sensor Networks," in IEEE Sensors Journal, vol. 21, no. 15, pp. 17350-17359, Aug, 2021, doi: 10.1109/JSEN.2021.3076995.
[28]. S, Gopikrishnan and Priakanth, P. & Srivastava, Gautam, "DEDC: Sustainable data communication for cognitive radio sensors in the Internet of Things", Sustainable Computing: Informatics and Systems, 29. 100471. 10.1016/j.suscom.2020.100471,2020.
[29]. Obaid, Arif and Fernando, Xavier &Jaseemuddin, Muhammad, "A mobility-aware cluster-based MAC protocol for radio-frequency energy harvesting cognitive wireless sensor networks",IET Wireless Sensor Systems, 11. 10.1049/wss2.12021,2021.
[30]. Gatate, V., Agarkhed, J. Energy preservation and network critic based channel scheduling (EPNCS) in cognitive radio sensor networks. Int. j. inf. tecnol. 13, 69–81 (2021). https://doi.org/10.1007/s41870-020-00523-8
[31]. R. Prajapat, R. N. Yadav and R. Misra, "Energy-Efficient k-Hop Clustering in Cognitive Radio Sensor Network for Internet of Things," in IEEE Internet of Things Journal, vol. 8, no. 17, pp. 13593-13607, 1 Sept.1, 2021, doi: 10.1109/JIOT.2021.3065691.
[32]. Joon, R. and Tomar, P., 2022. Energy aware Q-learning AODV (EAQ-AODV) routing for cognitive radio sensor networks. Journal of King Saud University-Computer and Information Sciences, 34(9), pp.6989-7000.
[33]. L. V. R. Chaitanya Prasad, Y. Kamatham and D. Sunehra, "An Energy Efficient Clustering and Relay Selection Scheme for Cognitive Radio Sensor Networks," 2022 International Conference on Innovations in Science and Technology for Sustainable Development (ICISTSD), Kollam, India, 2022, pp. 30-35, doi: 10.1109/ICISTSD55159.2022.10010509.
[34]. L. V. R. C. Prasad, Y. Kamatham and D. Sunehra, "An Energy Efficient Fuzzy Level Clustering for Stable Communications in Cognitive Sensor Networks," 2022 International Conference on Smart Generation Computing, Communication and Networking (SMART GENCON), Bangalore, India, 2022, pp. 1-6, doi: 10.1109/SMARTGENCON56628.2022.10083920.
[35]. Prasad, L.V.R.C., Kamatham, Y. & Sunehra, D. A modified energy efficient relay selection for cognitive radio sensor networks. *Wireless Netw* (2023). https://doi.org/10.1007/s11276-023-03466-7.