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Efficient routing mechanism for neighbour selection using fuzzy logic in wireless sensor network

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ABSTRACT

Numerous sensor nodes are getting utilized in the field of Wireless Sensor Network (WSN) for complex communication. In the recent scenario, there is a lack in the number of sensor node placement with less sensing and communication capabilities. There is less involvement with the characteristics of sensor nodes for direct communication with remote nodes. During the communication, sensor data are communicated to the sink with the help of sensor hubs. Therefore to improve the performance of QoS, routing in the integration of relay node selection plays an important role in WSN. In this paper, we propose Fuzzy based Relay Node Selection and Energy Efficient Routing (FRNSEER) make the routing more efficient by selecting the effective relay node while communicating with the sink node. For selecting the sink node, fuzzy rules are used where active relay nodes are selected as the outcome. The active relay node selection helps to determine the better energy and utility factor during the transmission process. To make better communication between the relay node and the sink node, sensor hubs are used with a lower energy expenditure schedule with expected functions of neighbor/working nodes. In the performance analysis, the proposed mechanism will perform better in terms of packet rate with low energy consumption compared to the existing algorithms such as Fuzzy-based Hyper Round Policy (FHRP) and Neural Network-based Localisation Scheme (NNBLS).

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1. Introduction

WSN comprises a group of dedicated sensor nodes that are mainly battery powered and deployed to monitor environmental conditions. The sensor collects the information and transmits it wirelessly to the central location called the base station. WSNs usually consist of loads of low-cost, less-power sensor nodes (homogeneous or heterogeneous), that can carry out activities like sensing, effortless computations, and short-series wireless communications [1]. As sensors in WSN have restricted battery limits; therefore, energy maintenance is such a critical aspect. Sensor nodes always are in any of the modes like off, idle, and active. If the node is active, then it would sense and transmit the data and energy consumed for the process; during idle mode, the sensor can wake up at any time if there is a need for any data processing till that energy can be saved and in of manner the node turned off eternally due to energy fall.

To boost up the lifetime and to improve network performance, it is important to improve energy utilization performance. By decreasing the count of active sensors in the network, energy consumption can be greatly reduced, thereby pushing others into sleep mode. Routing schemes in WSN can transport the sensed data from one node to another. The problems that arise during routing in the network are mainly due to coverage and connectivity issues among the sensor nodes [2, 3]. Generally, coverage issues can be classified into area coverage and target coverage problem. Area coverage is to cover a given area completely. Target coverage is performed towards maximizing network lifetime. Localisation of nodes plays a major role in WSN, and it can be done by measuring the distance between the nodes. By deploying fuzzy-based rules [4] the node localization is measured by their received signal strength indicator.

In this paper, the clustered coverage and connectivity issues in WSN is discussed. Here the sensors are deployed randomly and independently. The contribution of the work includes the desired coverage and connectivity maintenance for the clustered WSN. Optimal factors for identifying q-coverage efficiency and distance calculation for local route optimization are estimated to propose an energy-efficient clustered network.

This paper is organized as follows: Section 1 presents a detailed introduction on how routing is performed in wireless sensor networks and the novel approach. Section 2 details the related works available for efficient routing. Section 3, presents the detailed implementation of the proposed approach. Section 4 discusses the experimental result of the proposed and existing approaches. Section 5 presents the conclusion of the proposed work.

2. Related works

Various energy-efficient routing algorithms based on fuzzy model and coverage were discussed here, along with their techniques. Unnecessary data transmission and reception cause energy drop, and its lifetime gets affected as it comes with a limited battery. A fuzzy number based data aggregation scheme is presented in [5], which uses weighted average operators to reduce the rate of communication. Here the node maintains an estimated data aggregate value and decides whether the message needs to be propagated along with the network. Resource utilization and energy consumption need to be maintained for a longer network lifetime; therefore, Trust and Reputation Model (TRM) was proposed in heterogeneous WSN [6]. Pheromone value and path length factors are used to estimate TRM with the help of bio-inspired TRM and linguistic fuzzy trust and reputation. Integrated connectivity and coverage configuration in WSN for energy conservation was proposed [7]. Here the nodes are scheduled with sleep intervals so that the nodes stay active in a scheduled manner. The active nodes maintain the coverage and connectivity based on their configuration. Coverage Configuration Protocol (CCP) provides various degrees of coverage as per application needs. Probabilistic guaranteed coverage and connectivity in joining of CCP helps to improve the network's lifetime.

Distributed protocols for ensuring both connectivity and coverage was proposed [8] to prolong the network connectivity. The communication range should be twice the sensing range so that coverage can be maintained over connectivity. When the sensors are excessively placed over the network, it is mandated to adjust both connectivity and coverage levels. The excessively covered sensors and their transmission range can be switched to sleep mode for saving the transmission power. K-Coverage and Measures of Connectivity in 3D WSN was proposed to improve the connectivity [9]. Reuleaux tetrahedron model was designed to characterize the 3D field of k-coverage minimum sensor spatial density was measured. 3D k-covered WSNs can uphold a huge count of node failures by using the perception of conditional connectivity and prohibited defective sensor set. This 3D k-covered model proves that the sensor node has higher connectivity than their coverage degree k. However, k-coverage issues occurred due to a lack of connectivity. Centralized and Clustered k-Coverage Protocols for WSN [10] was proposed for efficient sensing range. Each monitoring field location is covered with k-active sensors and these active sensors are connected. Using k-active sensors, the k-coverage problem is modeled. Sensor spatial density with sufficient condition is derived along with k-coverage issues. The connectivity and sensing ranges can be maintained for both k-coverage of the monitoring area and connectivity among every dynamic sensor.

The most fundamental issues in WSN are coverage and connectivity problems. Considering this issue, coverage control based reNNBLSalgorithm [11] was analyzed in 3D WSN based on Energy Efficiency (EE). This method involves a fusion coverage managing algorithm based on EE in 3D WSN to analyze node deployment strategy. This hybrid control algorithm utilizes a non-natural immune algorithm for improving the ant colony algorithm function. This protective algorithm overcomes the shortcomings of the local optimum solution derived by ant colony function and improves the network quality. Full coverage and k-connectivity ($k<=6$) – optimal deployment patterns [12] were proposed. Here, various communications and sensing range of sensors are taken to achieve a better location for sensors' deployment. New patterns of 3-connectivity and 5-connectivity were proposed. The hexagon-based universally basic pattern is considered in that all finest patterns can be discovered. Therefore deployment-polygon-based methodology was applied, and the optimality of deployment patterns such as 3 to 5 connectivity proof can be achieved. R_C indicates the communication range, and R_S indicates the sensing range and their ratios can be taken as R_C/R_S. Adaptive Random Clustering (ARC), a novel control algorithm [13] was proposed to shape a group network with obligatory coverage and connectivity. This clustered network is created without location information. The coverage concentration and connectivity performance are relying upon node characteristics and their deployment location. ARC takes over an excellent EE from the formation of the cluster, and thereby this avoids the unnecessary collisions and overloading of redundant data. This ARC algorithm adaptively adjusts the number of active nodes for balancing the coverage area.

The coverage-Enhancing algorithm based on overlap-sense ratio [14] was proposed for Wireless Multimedia Sensor Networks (WMSNs). Here, the sensors' coverage area can be increased by adjusting the node's sensing direction with low computation complexity. The modified strategy is provided to switch off the redundant sensors, and hence the network's lifetime gets prolonged. Network coverage as well as connectivity is the major issues in mobile WSN. Minimizing Movement for Target Coverage and Network Connectivity [15] for MSN was proposed. The mobile sensor deployment problem is classified into two, such as Target coverage and Network Connectivity problem. The basic algorithm based on clique partition and the TV-Greedy algorithm based on Voronoi partition is the two heuristic algorithms proposed for reducing the deployment distance among the sensors. Steiner minimum tree with constrained edge length is considered as a solution for network connectivity. The sensors are scheduled by using a virtual hexagon partition composed of hexagonal cells. Based on the 3-symmetrical area method, the sensors are selected, so that the coverage efficiency can be improved by minimizing the overlapping of sensor coverage area.

The clustering approach involves extending network lifetime utilizing two methods, such as selecting the node as a cluster head using their residual energy and periodically rotating the cluster head. The fuzzy logic-based clustering approach was proposed with energy prediction [16]. This approach extends the network lifetime by distributing the workload evenly to all the cluster heads elected in the network. The protocol is extended with Fuzzy C-means Clustering (FCM) algorithm [17]. It describes the energy balancing behavior with a different number of nodes and various operating conditions.

Along with the FCM algorithm, a distributed k-means algorithm was proposed [18] using consensus theory for measuring the information exchange, where each node is equipped with sensors. This algorithm partitions the data that is observed by the nodes into measure-dependent groups. The initial centroids are found, and the degrees of membership values range from 0 to 1 for measure-dependent groups. The best cluster head is chosen among the presented CH's using probabilistic threshold value [19]. Only super CH can alone communicate over the mobile base station by choosing apt fuzzy phenomenal like remaining power level, base station mobility, and cluster centrality. The supercluster head is elected by applying the Fuzzy Inference System (FIS) of Mamdani's rule. Two-tier distributed fuzzy logic-based protocol (TTDFP) was proposed [20] to improve data aggregation operations over multi-hop sensor networks. TTDFP was developed to build the timeframe of multiple hops WSN by taking the power of agglomeration and routing phases collectively into consideration. It could be an appropriation of versatile conventions that run and scales gadget organize applications with effectiveness.

A Fuzzy-based Hyper Round Policy (FHRP) [21] was developed to schedule the clustering process. In FHRP, in its place of each round, the grouping is executed at the initiation of each Hyper Round (HR), which is gathered from various rounds. The HR length isn't fixed yet it is registered to utilize a FIS. The hub's suffering vitality and its separation from the sink are utilized to contribute to this fuzzy framework and the HR length is its yield. By applying a round-based policy, the network nodes are grouped for one round and re-grouped for the next round. Network load can be balanced slightly utilizing this policy. Stochastic Election of Appropriate Range Cluster Heads (SEARCH) algorithm was proposed to reduce the cost. NNBLS accomplishes a damaging objective on expanding the round of half dynamic hubs enduring (outstandingly stable period) just as dropping frail detecting period. During data transferring over a network, some extra energy will be used for path failures and recreation of alternate routes [22]. To avoid unnecessary energy consumption routing technique with Neural Network and SPEED routing protocol was proposed. Neural Network-based Localisation Scheme (NNBLS) [23] was proposed to make the trained network completely applicable to the correlated topology. This scheme helps to find node –distance estimation inaccurate. By calculating both node received signal strength and hop counts, inter-node distance can be estimated. Here the hidden layer takes a set of weighted inputs like signal strength hop counts and internodes distant from the input layer and process to produce a certain output through an activation function.

Invariant packet feature-based low rate attack detection [24], consider different features of the packet in the detection of low rate attack. Similarly, the same approach can be used in measuring the fitness of any route towards data transmission.

Region-based traffic impact measure based attack detection [25], discusses how the regional traffic can be used in detecting malicious transmission. In the same way, the regional bandwidth availability, traffic, and other features can be used to select a relay node for reliable transmission.

The automatic detection of bike riders [26], identifies the bike riders according to pattern matching techniques. Similarly, the same approach can be adapted to route selection, where the selection can be performed by considering different features of neighbor nodes.

The existing fuzzy-based data transmission protocol reduces the energy expenditure and partially balances the network load. However, the nodes and sink connectivity failed in the trained neural network when located in the largest distance with a lower remaining energy level. The active relay nodes are typically difficult to identify in each data transmission cycle. FRNSEER protocol is proposed to change the active relay nodes in each data transmission phase by applying a fuzzy rule-based algorithm with a local route optimization mechanism.

3. Proposed method

In WSN the nodes are placed at different locations (range-free localization) to collect sensitive information. Each sensor node in the network performs sensing and data forwarding. Initially, the source node starts data transmission by checking the routes' availability through broadcasting RREQ (Route Request) message. Once the RREQ message reaches the destination or sink, it reverts with RREP (Route Reply) message. The source node sends the collected information to the sink with active relay nodes to make the route more

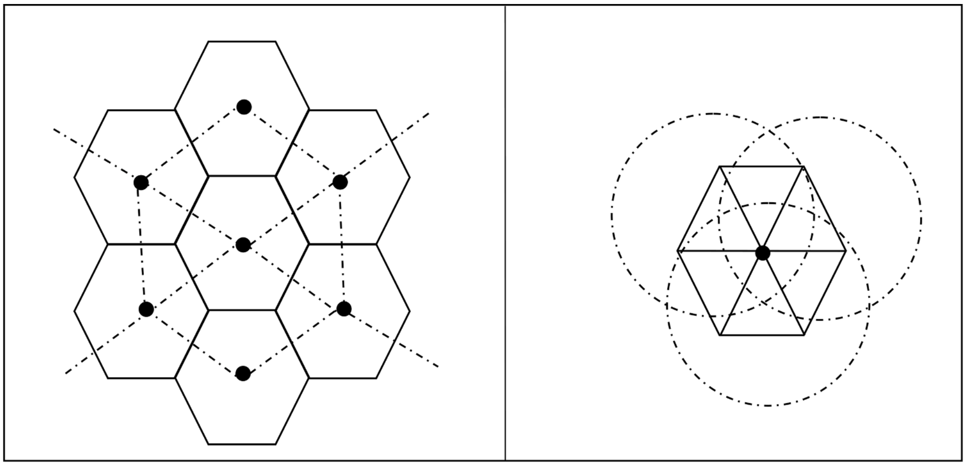

Fig. 1. Node Communication Range.

reliable. The active relay nodes are identified by applying the fuzzy logic method. A fuzzy Inference System with a rule-based mechanism is used for identifying the active relay nodes in the routing path. Fuzzy based active relay node selection approach includes energy and utility factor estimation; coverage distance estimation using Received Signal Strength (RSS). The fuzzy inference system selects the next relay node according to the coverage distance, energy, and utility factor, and bandwidth availability factors. As for each route, the method identifies nodes in the route and their features, as mentioned above. The same set of features is used to generate the fuzzy rules and use that only the method selects the relay node to perform data transmission.

3.1. Energy and utility factor

The active relay sensors can be selected by calculating their Energy and Utility (EU) factors. The sensor which has a high EU is selected as an active relay sensor in the path. If two or more sensors have equal EUf then the nearest node towards the sink is elected as an active, alive sensor.

An energy factor (E_f) and Utility factor (U_f) is measured by considering their energy level and marginal utility level of the individual sensor. The sensor's energy level depends upon its energy consumption E_c for processing i.e. usage level and higher leftover energy E_l sensors are more preferable. In the case of utility, a large number of connected sensors from their neighbors are more preferable.

$$E_f = E_c - E_l \tag{1}$$

$$U_f = \frac{n_{ai}}{n_i} \tag{2}$$

Both energy and utility factors are essential for determining active sensors in the routing path. Therefore the selection of dynamic sensors is based on energy and utility factor denoted by EU_f, which is given by

$$EU_f = E_f + U_f \tag{3}$$

3.2. Coverage distance estimation using RSS

Choosing progressively dependable neighbor nodes or hubs with high connection availability is one technique for better network execution. Connection estimation incorporates cost measurements like the distance between hubs and their RSS. The accessibility of the connection between the active relay hubs should be identified for efficient information routing. The accessibility of connection is found between every one of the hubs. The accessible distance between the hubs all around controls the connection availability and their quality. Based on the communication range, the coverage efficiency of the sensor nodes can be resolved.

Once the coverage efficiency is achieved, then the connectivity among the sensors is taken into consideration. For achieving energy-efficient clustered-connectivity local route optimizing protocol is used. Here relay nodes are placed between dynamic sensors for balancing energy levels among the sensors. The distance between the dynamic nodes 'D_O' is measured and is given by,

$$D_O = \sqrt{(x_a - x_b)^2 - (y_a - y_b)^2} \tag{4}$$

The sensors are located with the co-ordinates (x_a, y_a), whereas 'a' is the number of sensors {a=1, 2… n}. Thus every dynamic sensor should have connected atlas with one relay sensor. If the communication radius Rad_C is lesser than the Euclidean distance between the dynamic and relay nodes, $D_O = \sqrt{(x_a - x_b)^2 - (y_a - y_b)^2} \leq Rad_C$ then the sensors' connectivity is well-built. The complete coverage satisfaction is achieved by achieving maximum distance ($d_{O(max)}$) between the sensors regarding their sensing radius 'R_S'.

$$d_{O(\max)} = 2\sqrt{(R_s)^2 - (b/2)^2} \tag{5}$$

Here b represents the distance between the two significant nodes.

$$b = 2\sqrt{(x_c - x_o)^2 + (y_c - y_o)^2} \tag{6}$$

This significant node's distance 'b' is perpendicular to the maximum distance between them, '$d_{O(max)}$'. Here the coordinates (x_o, y_o) and (x_c, y_c) represents the cell center of significant nodes, respectively.

This algorithm is constructed based on the propagation range and communication range. The node's propagation range is the least range up to which the data can be transmitted over. The communication range is the range at which the current node and its next node can effectively communicate within the propagation range. An example scenario for node communication range is shown in Fig. 1. The transmission power of sensors is measured according to signal strength and distance. The communication range among the nodes is estimated by calculating the RSS. The average RSS (A_RSS) and maximum RSS (Mx_RSS) is measured with Eqs. (7) and (8), which are located within the transmission range.

$$A\_RSS = \frac{\sum_{i=1}^{n} RSS_i}{n} \tag{7}$$

The selection of reliable node in the transmission range is selected according to the RSS value and its average. If the RREQ packet's value is greater than the average value, then the node has been selected as a relaying node; otherwise, the RREQ is dropped.

$$A(Mx\_RSS) = \frac{\sum_{i=1}^{Mx(n)} RSS_i}{n} where RSS_i > A\_RSS \tag{8}$$

The node with a higher RSS value has been selected as the relaying node, and data transmission is performed through the node

The above Fig. 1, represents how the nodes are organized and show their transmission range. Each node has its communication range, which restricts them from communicating with other nodes.

The dynamic sensor's q-degree coverage is calculated by partitioning the sensor location in 6 equal symmetrical cells. The coverage efficiency is calculated by considering two consecutive coverage parameters, such as real coverage and required coverage. By determining the coverage efficiency, the degree of overlapping sensor coverage can be minimized. The affiliation between real coverage area and required coverage scale (q) is estimated using coverage efficiency (φ), which is given by

$$\varphi = \mu - q \tag{9}$$

The determined coverage efficiency 'λ' of the dynamic sensor may exist in three cases such as overlapping, exact efficiency, and incomplete coverage such as

$$\varphi = \begin{cases} \mu - q \succ 0; & overlapping \\ \mu - q \approx 0; & exact\,efficiency \\ \mu - q \prec 0; & incomplete \end{cases} \tag{10}$$

Thus the coverage proportion in each degree gets varied regarding the required coverage degree 'q'. The coverage fraction ratio is monitored, and it is given by,

$$\Lambda_\lambda = \frac{\cup_{\forall i}\left(\cap_{\forall i}^{\lambda} D_i\right)}{\partial} \tag{11}$$

where $\lambda \varepsilon\{-k, 1-k, \cdots, -2, -1, 0, 1, 2, \cdots, \mu - k\}$. In the case of $\lambda = -k$, it indicates that a certain area is not covered by any sensor. If $\lambda = 0$, this proportion indicates the sensor gives excellent coverage efficiency. Indeed, when $\lambda \geq 1$, indicates overlapping coverage degrees occurred.

3.3. Bandwidth availability estimation

Bandwidth accessibility estimation among every node is measured up for identifying the proficient data routing in the sink node's direction.

The bandwidth of the node β(n) can be calculated using the difference between the delivery rate and loss rate at the current time Tc.

$$\beta(n) = \frac{DR(n) - LR(n)}{T_C} \tag{12}$$

The bandwidth availability is straight proportional to the data path rate 'λ'. The data path rate is the rate at which the data can be sent and receive reliably; therefore the total bandwidth accessible rate 'ϕ(n)'is calculated as given in the equation,

$$\phi(n) = \lambda_{i,j} - \left(\frac{\sum_{n(i,j)}^{\rightleftarrows p} (\beta + \theta)}{\pi}\right) \text{inbps} \tag{13}$$

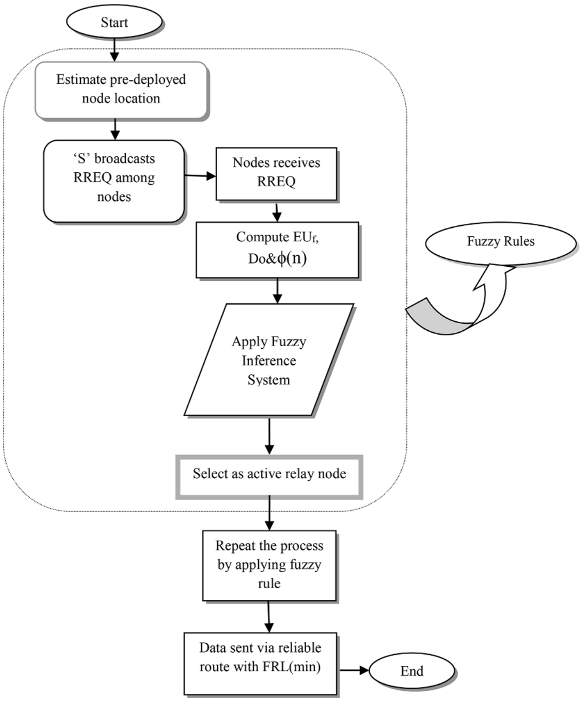

Fig. 2. Flowchart of FRNSEER.

The estimation of bandwidth access 'ϕ(n)' includes the node's data production rate 'β'. Re-transmission overhead which is referred to as 'θ' is included as well with the data production rate. 'π' indicates the time taken by the control packets for reaching its neighbor node. A bandwidth reference value is set by taking the average among the neighbors' bandwidth rate, and the highest bandwidth obtained node is given prior.

4. Algorithm - FRNSEER

Input:EU_f, A(Mx_RSS), Do
Output:$FRL_{(min)}$
Step 1: Begin
Step 2: SetSrc&Dest node;
Step 3: Broadcast RREq;
Step 4: Apply fuzzy rules → VE, VD& NB; //(value of energy, distance, bandwidth)
Step 5: Compute 'EU_f' 'Do' &'ϕ(n)'
Step 6: Measure E_fU_f→ EU_f
Step 7: Compute{Xo, Xi, Yo, Yi} {A(Mx_RSS)} {Eff 'φ'} → Do
Step 8: Measure bw(n) → ϕ(n)
Step 9: Process rule based FIS
Step 10: Estimate linguistic variables for VE, VD& NB;
Step 11: Check with reference values of VE, VD & NB;
Step 12: Compute crisp set
Step 13: Select Ni.FRL(min) ←towards Sink
Step 14: RevertRRep through ARN;
Step 15: Send data from Src to Dest
Step 16: Else process RReq to next hop
Step 17: Repeat step 4 to 15 till reaches to Dest
Step 18: End

Fig. 2, shows the overall functionality of the proposed FRNSEER (Fuzzy Relay Node Selection and Energy Efficient Routing) algorithm. The method finds the list of neighbors and their features using route request messages. Using the node features obtained, the method estimates different factors like energy, distance, bandwidth supports. Using them, the method identifies the most reliable route to perform data transmission.

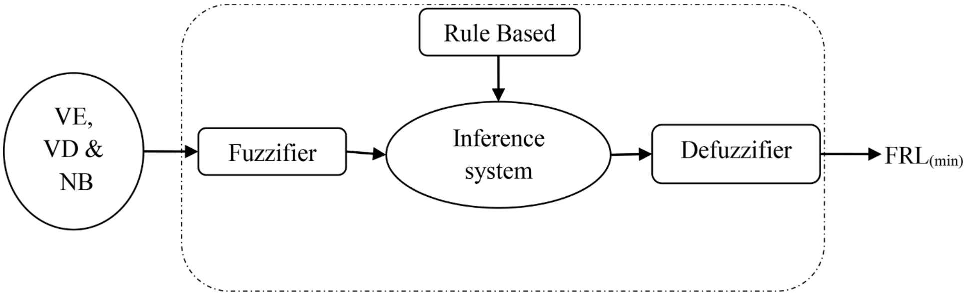

Fig. 3. Fuzzy Inference System.

5. Fuzzy approach for active relay node selection

Fuzzy logic in WSN allows combining and evaluating various parameters in an efficient way that increases network performance. The fuzzy approach applies FIS that utilizes energy and utility factor; link estimation with coverage distance using RSS. The fuzzy rule approach efficiently schedules the active, alive nodes for their coverage distance and leftover energy level. The fuzzy inference system involves rule-based in which EF-UF and coverage distance is considered as an input factor, and the minimal route factor derived using fuzzy-based routing length FRL(min) be the output factor.

The numbers of active, alive nodes present in the routes, their energy-utility factor, and the coverage distance among them are all considered for determining the route with minimum length. Each active, alive node calculates its routing length by using rule-based FIS. The fuzzy Inference System used for selecting active relay nodes is shown in Fig. 3.

The fuzzy inference system's overall functional architecture is presented in Fig. 3, which applies the fuzzifier rule to produce inference results.

The active relay nodes Ni in the routing path are identified by applying rule-based fuzzy logic. This considers the factors such as node residual energy, coverage distance, and node's maximum bandwidth through which the data can transfer. The node with a higher value of energy with the least distance is identified as minimum FRL. Sensor nodes are fixed over the network, and hence the lowest and highest distance from the sink to the deployed nodes is calculated as a preset factor. The node Ni can be calculated using inputs of FIS,

$$Ni.FRL \leftarrow \min(node(FRL_{\min} \times FIS(Ni.VE, Ni.VD, Ni.NB)), 1) \tag{14}$$

This equation limits the minimum value of FRL 0 to 1. The approximate distance for all the nodes to the sink is computed. This computation facilitates the appropriate power level to converse with the destination node. The node Ni represents the identity of the node. Consequently, any sensor node Ni can calculate Virtual Distance (VD) concerning the sink $d_o(Ni, sink)$, in adding up maximum (d_{max}) and minimum (d_{min}) distance of sensor nodes. The distance threshold level is set by evaluating nodes' maximum distance and minimal distance among the nodes. The distance threshold D_{Thresh} is approximate '250'.Each node computes Virtual Energy (VE) by taking the value of residual energy for its initial energy respectively,

$$VD = \frac{d_o(Ni, sink) - d_{\min}}{d_{\max} - d_{\min}} \tag{15}$$

$$VE = \frac{Ni, RE}{Ni, IE} \tag{16}$$

Energy threshold 'E_{Ref}' is set by considering the node's overall energy consumption that is present in the route. Therefore E_{Ref} can be evaluated by considering the average energy drain rate (17). Based on the values of energy remains i.e. energy level 'E_L' in the node that presents in the route is considered to calculate the reference value energy.

$$E_{Ref} = Avg \rightarrow (E_L / No.of\ nodes) \tag{17}$$

The reference bandwidth value 'B_{Ref}' is set by estimating the average packet size used to communicate by the node. The bandwidth reference is taken as 100 Mbps, and it is considered as a medium level of packet size through which data can be transmitted.

$$NB = \frac{\sum \beta(n)_{i,j}}{\pi} \tag{18}$$

$$B_{Ref} = Avg(B_w) \tag{19}$$

Therefore VE VD and NBare took as input variables for FIS, and the FRL is considered to be the output factor. The same route FRL cannot handle for maximum rounds of data transmission. Triangular membership functions are used mostly to avoid the computational cost to generate fuzzy sets. The linguistic variables such as high, medium, low are considered for VE in this membership function. In this fuzzy set, the variables such as near, adequate, and distant are the linguistic variables considered for VD. Very low, low, medium,

Table 1
Fuzzy Rules.

S.No	VE	VD	NB	FRL
1	High	Near	Very high	High
2	High	Adequate	High	Rather high
3	High	Distant	Medium	Medium
4	High	Near	Low	Rather low
5	High	Adequate	Very Low	Low
6	Medium	Distant	Very high	Rather high
7	Medium	Near	High	Low
8	Medium	Adequate	Medium	Medium
9	Medium	Distant	Low	Rather low
10	Medium	Near	Very low	Low
11	Low	Adequate	Very high	Rather low
12	Low	Distant	High	Low
13	Low	Near	Medium	Medium
14	Low	Adequate	Low	Rather low
15	Low	Distant	Very low	Low

Table 2
Linguistic membership variables and predefined values.

Variables	VE
High	7.5
Medium	5
Low	2.5
Variables	**VD**
Near	60
Adequate	125
Distant	250
Variables	**NB**
Very high	>100Mbps
High	100 Mbps
Medium	75Mbps
Low	50 Mbps
Very low	<50 Mbps

high, very high are the five linguistic variables taken for node bandwidth NB. The output variable chance for FRL has five linguistic variables: high, rather high, medium, rather low, and low for selecting the best route in the network.

In common, heuristic data is used to generate fuzzy rules that are shown in Table 1. The input values are converted into linguistic variables based on the membership function in FIS. The reference values are fixed by evaluating their average input values that are set during a simulation parameter design. Table 2 describes the linguistic variable membership parameters for VE, VD, and NB and their reference values. Based on the Mamdani model, if-then rules are developed to map the input variables to the appropriate fuzzy output variables. A crisp set of values is obtained through the de-fuzzification process. A fuzzy rule-based system is one of the de-fuzzification processes by evaluating if-then rules through fuzzification inference procedure. The node with high leftover energy, high bandwidth accessibility, and the shortest distance towards the sink generates reliable FRL.

The membership function of the fuzzy sets VE, VD, and NB are adjusted iteratively for the output results obtained. 'n' number of iterations occurs to detect the larger distant, low bandwidth and energy nodes. The maximum number of iteration that takes place is 3, to identify the active, alive nodes. Exemplary case: Assume nodes are numbered 1 ~ 8.

Iteration #**1**: the weight of nodes (1, 2, 3) against nodes (5, 6, 7), if weights of a node are same then either 4 or 8 is inactive, now another weight is required to identify the inactive one. If weights are different, suppose (1, 2, 3) < (5, 6, 7) (the other case can be identified in the same way).

Iteration #**2**: the weight of nodes (1, 4, 8) adjacent to (5, 2, 3) three cases:

Case 1: (1, 4, 8) == (5, 2, 3), then either 6 or 7 is inactive.

Case 2: (1, 4, 8) > (5, 2, 3), then either 2 or 3 is inactive.

Case 3: (1,4,8)<(5,2,3) then either 1 or 5 is bad.

Iteration #**3**: here, we assume 6 normal nodes and two inactive nodes. Simply compare a normal node with one inactive node; hence it is easy to identify the inactive one.

6. Results and discussions

The proposed real-time energy transition-based neighbor selection scheme is implemented using a network simulator (NS2), an open-source tool to simulate different network protocols written in C++. The method has been evaluated for its performance under

Table 3
Simulation parameters.

Parameter	Value
Type of channel	Wireless Channel
Time (Simulation)	100 ms
Number of hubs	50
MAC type	802.11
Type of traffic	CBR
Transmission range	250mts
Area of simulation	1200 × 800
Network Interfacing Type	WirelessPhy
Radio Propagation model	TwoRayGround

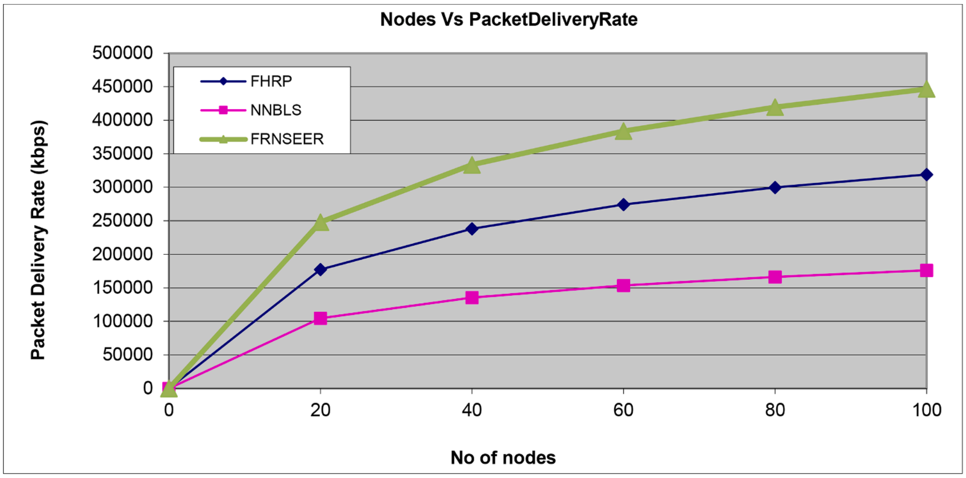

Fig. 4. Packet Delivery rate.

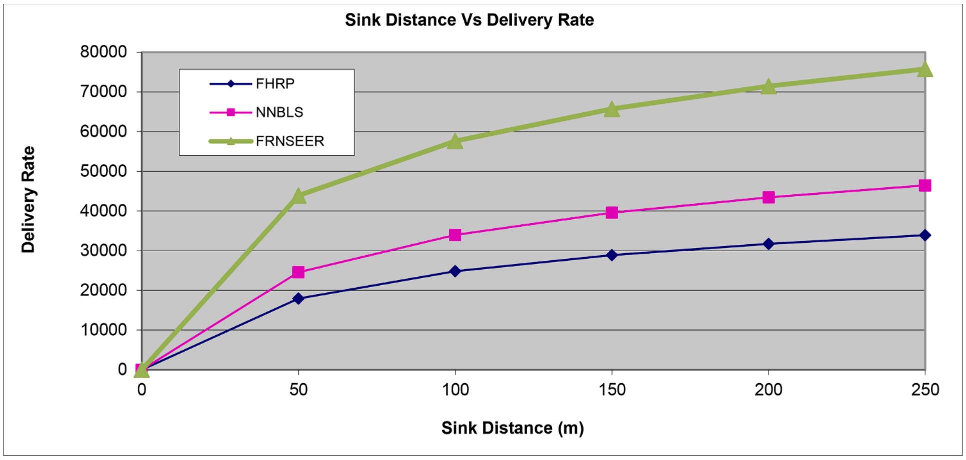

Fig. 5. Sink Distance vs Delivery rates.

different scenarios of the number of nodes, and the performance is measured on various parameters. The obtained results are presented in detail in this section. The parameters utilized for the simulation of the proposed plan are portrayed in Table 3.

Every single hub has an immediate connection with the hubs inside the range of 250 meters. The hubs are communicated with one another by utilizing the User Datagram Protocol (UDP). The proposed scheme's performance is analyzed by using the parameters Packet rate, Sink distance, Number of Alive nodes, Scheduling overheads, and Relative energy.

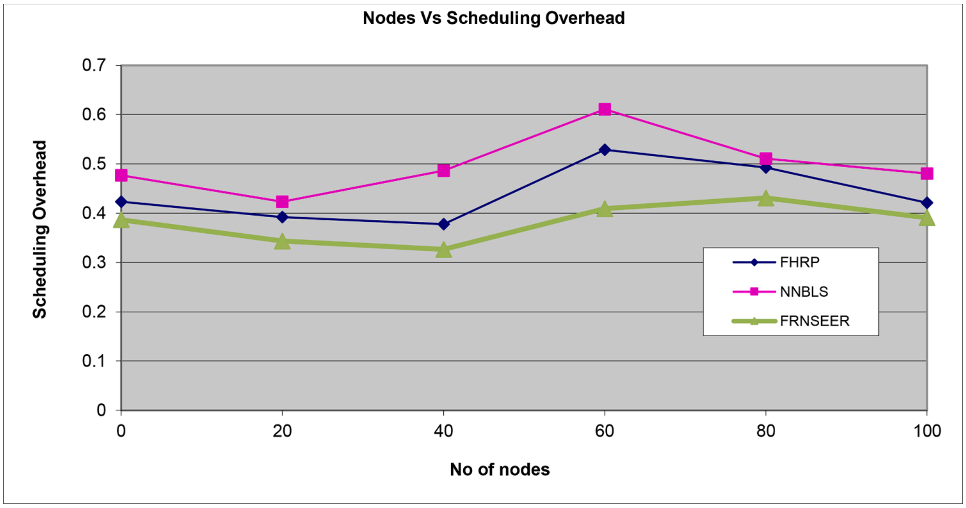

Fig. 6. Scheduling Overheads.

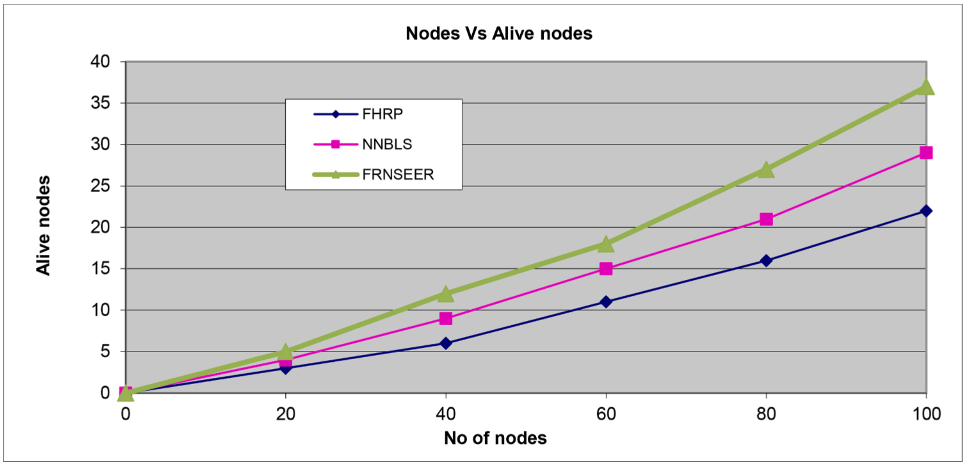

Fig. 7. Alive nodes Vs No of nodes.

6.1. Packet rate pertaining to nodes

The packet rate is the value measured according to the number of packets delivered to the destination or sink node for a fraction of time and the rate of a packet sent from the source. It is measured by using the equation

$$PDR = \frac{\sum_0^n Packets\ Received}{Time} \tag{20}$$

Here 'Pkts Received' is represented as the number of packets received by the destination or sink node for data transmission. Fig. 4 explains that the FRNSEER has produced a higher packet delivery rate than existing FHRP and NNBLS protocols. The increasing number of nodes in the network supports packet delivery ratio as the reliable route can be identified easily and more reliable routes can be identified.

6.2. Delivery rate related to sink distance

The delivery rate of packets concerning their sink distance for the proposed and conventional protocols is depicted in Fig. 5. The packet rate efficiency achieves better results for the proposed FRNSEER. Node to node communication range is considered for sink distance calculation. The single node can cover its communication range up to 250mts. The proposed protocol outperforms and achieves 35% efficiency compared to the conventional FHRP protocol.

The delivery rate introduced by different methods at different sink distances is measured and presented in Fig. 5. The proposed FRNSEER algorithm has produced higher delivery rates compared to other methods.

Table 4
Energy consumption Vs nodes.

No of nodes	FRNSEER	NNBLS	FHRP
0	1.159821	2.567046	3.863565
20	1.88073	2.44555	4.095827
40	2.434963	3.027426	5.185539
60	3.755487	4.194554	5.783327
80	4.683575	5.254189	6.403234
100	5.14568	6. 29345	7.19832

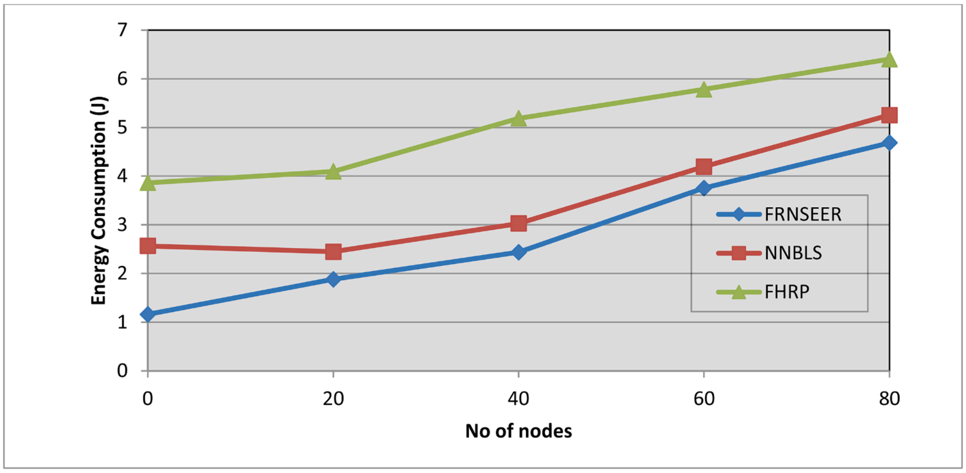

Fig. 8. Relative Energy Vs Nodes.

6.3. *Scheduling overhead*

Scheduling the routing nodes reduces the data transmission delay as well as energy cost metrics. By selecting minimum fuzzy-based routing length FRL(min), the scheduling procedure's overhead gets reduced. The scheduling costs of FRNSEER scheme are less than FHRP and NNBLS algorithms. Fig. 6 depicts scheduling overheads for all proposed and conventional protocols.

The scheduling overhead introduced by different methods is measured and presented in Fig. 6, where the proposed FRNSEER algorithm has produced less scheduling overhead than other methods.

6.4. *5.4 Active alive nodes*

The number of active nodes that present in the routing path is presented in Fig. 7. This illustrates the outperformance of FRNSEER over their conventional systems such as FHRP and NNBLS.

The number of alive nodes for the proposed method is higher after data transmission occurs in the routing path. For the mechanism of FRNSEER, more than 27 nodes are alive over a set of data transmission in the total routing length of 80 nodes in the network.

6.5. *Relative energy*

The relative energy is computed from the leftover energy of the nodes present in the routing length. The amount of energy consumed for processing the transmission is said to the node's energy consumption. Table 4 and Fig. 8 show the relative energy consumed for the proposed FRNSEER and the conventional schemes FHRP and NNBLS. The energy consumption level for the proposed scheme FRNSEER shows better results than the conventional protocols such as NNBLS and FHRP.

The performance in energy consumption is measured and presented in Table 4, where the proposed FRNSEER algorithm has produced a higher performance by introducing less energy consumption than other methods.

The relative energy consumed by the algorithm in data transmission is measured by varying the number of nodes in the network is presented in Fig. 8. When the numbers of nodes are increases, the ratio of energy consumption is less than other approaches. The FRNSEER algorithm has consumed less energy in all the cases considered.

7. Conclusion

Fuzzy based Relay Node Selection and Energy Efficient Routing protocol is proposed for efficient data transmission. The active relay nodes are selected towards the sink to make the routes more efficient and reliable. Fuzzy rules are applied in selecting relay nodes, and the outcome active relay nodes are elected for further transmission process. Energy-Utility factor and link estimation using RSS related to node distance are the metrics used to identify the active relay nodes. FIS's fuzzy rules are applied over route request messages to determine FRL(min) present in the path. As far as energy utilization, hubs with low power utilization are planned by a given extent of expected functions between the working nodes and the neighboring nodes, which adjusts the whole system's energy utilization and streamlines network resources. The proposed FRNSEER is 28% better in terms of packet rates delivered to the sink than the conventional schemes.

Declaration of Competing Interest

We authors not having any conflict of interest among ourselves to submit and publish our articles in **Computer and Electrical Engineering** journal.

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