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PSO-Controlled WSN Environment to Mitigate Flooding and Improve Network Lifetime

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Abstract: - The Restricted Flooding-based Route Discovery (RFBRD) – Particle Swarm Optimization (PSO) routing scheme introduced for Wireless Sensor Networks (WSNs) in this article not only reduces the energy loss due to unwanted RREQ (Route Request) flooding but also improves the lifetime of the network. Excessive flooding depletes energy and affects the lifetime of the network. Nodes in scarce regions are allowed to forward first and subsequent RREQ packets freely in the network and are relocated using PSO to improve their neighborhood for better neighbor connectivity and coverage. Whereas, nodes in the populated region or dense region are governed by energy ratios and are allowed to forward first RREQ packets only when they satisfy the energy conditions. This scheme is efficient in maintaining a proper balance of QoS (Quality of Service) parameters works well for high-density networks for more than 50 nodes and can restructure network topology obtaining better connectivity. Experimental analysis showed that the performance of AODV is superior in the case of a low-density network (N=40 nodes) while RFBRD-PSO outperforms in all other configurations (60, 80, and 100 nodes). The Packet delivery ratio was increased by 0.08% and the throughput was higher by 11 kbps in the case of RFBRD-PSO. The routing overhead is low by approximately 40% and the average end-to-end delay is found low by 0.04 as compared to the AODV routing. The energy residue in the case of RFBRD-PSO is less than the value of AODV is the cost paid for a higher packet delivery ratio. The neighborhood connectivity is improved by approximately 32%.

Keywords: Restricted Flooding-based Route Discovery, Particle Swarm Optimization, Wireless Sensor Networks, scarce regions, dense region, Quality of Service, network topology, AODV, and neighborhood connectivity

I. INTRODUCTION

A wireless sensor network (WSN) with self-reliant sensors monitors bodily or environmental situations, inclusive of temperature, sound, pressure, and so forth. And also, cooperatively bypass their information via the community to the top place [1]. Wireless sensor networks are made up of individual sensor nodes that are dispersed around an area and work together to track various environmental and physical parameters like motion, temperature, pressure, vibration, sound, and pollution. In the beginning, military uses on battlefields were the primary factor in the development of wireless sensor networks, but today the application area has expanded to include other sectors including industrial monitoring, traffic control, and health monitoring. These days, the widespread deployment of sensor networks is extremely realistic [2]. Recently, wireless sensor networks (WSNs) have risen to the top of the list of essential technologies. WSN is known to self-arrange many energy-constrained tiny sensors and at a minimum of one sink base station (BS) [3-5].

The contemporary demands of various applications have spurred the advancement of wireless sensor technologies, giving rise to the Internet of Things (IoT) and introducing a new phase of widespread and smart IoT applications [4-6]. The next generation of wireless technologies is anticipated to support a large number of connections, create the fastest data rates, and have lower energy consumption and transmission latency [7–8]. Conversely, creating an effective communication and resourceful routing protocol for WSNs/IoT poses numerous challenges. These challenges encompass the unreliability inherent in low-power wireless networks and the limitations of resources, typically falling short in meeting Quality of Service (QoS) requirements. Therefore, these models were primarily interested in the fundamental needs for routing. Researchers therefore encounter many difficulties when creating routing protocols [9-11]. Alternative representations of the routing problem include tackling a multidimensional optimization problem aimed at maximizing throughput while minimizing latency, numerous evolutionary techniques inspired by biological processes, particularly those rooted in swarm intelligence, have garnered recent attention. Examples include Ant Colony Optimization (ACO) and PSO, which are used to find the best routes in

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WSN-based IoT applications [12–14].

The structure of a WSN is shown in Figure 1. This approach was selected for this paper because it is a good fit for the issue at hand. This is referred to as a population-based search technique that was motivated by social behavior in fish schools or flocks of birds. Using Network Simulator NS-2, the performance of the proposed solution was assessed by comparison with the Ad Hoc AODV protocol [15]. The structure of the research work is broken down as follows: In Section 2, we conduct a literature review exploring optimization methods that contribute to prolonging the network's lifespan and improving energy efficiency. Section 3 outlines the proposed strategy, followed by Section 4, where we evaluate the effectiveness of the suggested approach. The research's conclusion is then deliberated in Section 5.

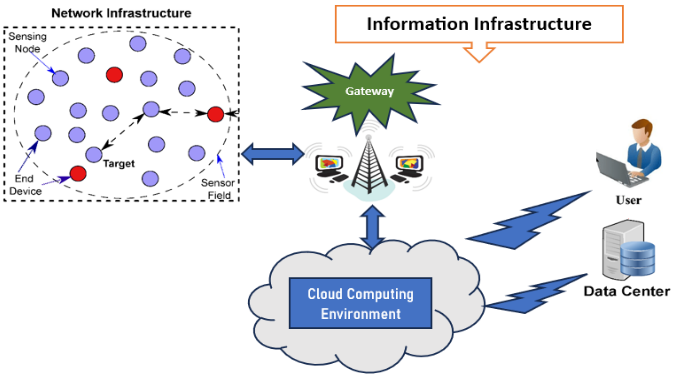

Figure.1: The structure of a WSN

II. RELATED WORKS

In wireless sensor networks, Position determination, temporal alignment, information consolidation, and safeguard measures, development of energy-efficient devices, extending the lifetime of WSNs, and implementing advanced algorithms for sensor-specific challenges are among the newly unveiled phenomena within the field of Wireless Sensor Networks (WSN). The network's nodes' data locations must be known by both static and dynamic nodes. Throughput, energy levels, and packet delivery ratio are the three main factors that affect how well the WSN performs [16-18]. The primary objective of the routing protocol structure is to minimize energy consumption by identifying the most energy-efficient routes between the source and the destination. As can be seen in [17], the researcher aimed to develop a routing protocol designed for energy efficiency with enhanced Quality of Service (QoS) attributes.

In WSN, a variety of routing techniques are usable for data transmission. They primarily focused on the widely used techniques such as AODV and Distance Source Routing (DSR) [18]. To evaluate performance through metrics such as throughput, PDR, and end-to-end delay, the researchers utilized a network simulator version 2 (NS2) for their software simulations. AODV exhibits significant superiority over DSR in terms of packet delivery ratio, whereas DSR outperforms AODV significantly in terms of throughput. The comparison of the AODV and DSDV protocols [19] in terms of throughput, end-to-end delay, routing overhead, and packet delivery ratio are explored. According to analysis, AODV has a higher packet delivery ratio, throughput, and routing overhead than DSDV. DSDV, as a proactive routing system, demonstrates an optimal end-to-end delay when compared to AODV. The early demise of WSNs characterized by extensive scale and high node density is prevented by the adoption of the energy-sensitive green cluster-based routing architecture [8]. According to estimates, the OLSR offers the least amount of latency in the network of 40 nodes when compared to AODV and DSR.

The WSN quality [4] is used as the basis for the routing algorithm's optimization. The authors conducted a comparison of networks utilizing various algorithms, which encompassed AODV, Genetic Algorithm (GA)-based AODV, Dijkstra algorithm, and GA-based Dijkstra algorithm. The authors of [20] introduce a multipath routing system that considers both wireless interference and energy conservation within the network. In [21], the authors put forth a PSO-based energy-efficient routing system, simplifying the PSO problem by incorporating energy and latency as two constraints. Their simulation results, along with a comparative study against Genetic Algorithms

(GA), revealed that PSO outperforms GA in terms of determining the most energy-efficient path.

Multipath routing has often been used in earlier studies to decrease data packet dropout rates and lengthen network lifetimes. After evaluating several background tactics used to address the problem of optimal path discovery in routing protocols, we found that further research is still needed in this area. For instance, WSN-based IoT applications find multipath to carry data from source to destination while using the least amount of energy possible.

The primary contributions of the paper include:

1. The drawbacks of RFBRD [5] had been eliminated in RFBRD-PSO based on finding optimized locations for the nodes in the scarce region using PSO. The routing scheme works during the route discovery phase on reception of the first RREQ packet.
2. The nodes in the scarce regions are positioned (moved) in the network space so that their neighborhood is increased without losing their initial neighbors to provide better coverage and connectivity.
3. The nodes in the populated regions are subjected to certain conditions based on energy ratios to save energy during the flooding of RREQ packets and the probability depends on a threshold that is determined concerning the energies of the node, neighborhood, and the network.
4. A greater balance between QoS parameters is obtained.

III. METHODOLOGY

The AODV routing is modified in the route discovery phase restricting the flooding in densely populated regions of the network and improving the coverage and connectivity in the scarcely populated region during the reception of the first RREQ by any node. The mechanism ensures the conservation of energy as well it also improves the density of the scarce region. The energy is conserved by allowing a node to forward RREQ with residual energy which exceeds the energy value in its neighborhood and the network energy. The node neighbor's density is improved by re-localization of the node using PSO. The PSO is used to find the optimum spatial coordinates for the node in its 20m radius where its neighbor's density is increased to improve connectivity and coverage. The radius of 20 m is selected to maintain the node's old neighbors and add new ones.

The following ratios are given by equations (1), (2) and (3) were calculated using the energies in the neighborhood and the network. The following ratios are:

$$v1 = Eg/AEg; \tag{1}$$

Where, Eg is node residual energy and AEg represents average energy in the node neighborhood.

$$v2 = AEg/nAEg; \tag{2}$$

And nAEg is the average energy in one step neighborhood of the node (Neighbour's neighbors)

$$v3 = Avg\_nbr/Avg\_nw; \tag{3}$$

Avg_nbr represents the average node density in the node neighbourhood and Avg_nw is the average node density of the network.

Assuming 'N' to be the total number of sensor nodes in the network, a threshold $T = (0.12 \times N)$ is used for determining the scarce region. It is set to ensure that a node should have at least 3 nodes in each of the 4 quadrants of a node placed at the origin or center. If the density of neighbors falls below the threshold T, the node is assumed to be in the scarce region while when the number of neighbors is above the threshold value, the node is considered to be in a populated region. Only the position of the nodes lying in the scarce region is optimized using PSO. That is the PSO finds a new location for the node in a radius of 20 m where it will have a higher number of neighbors than it initially has. The following Figure 2 explains how RREQ packets are restricted:

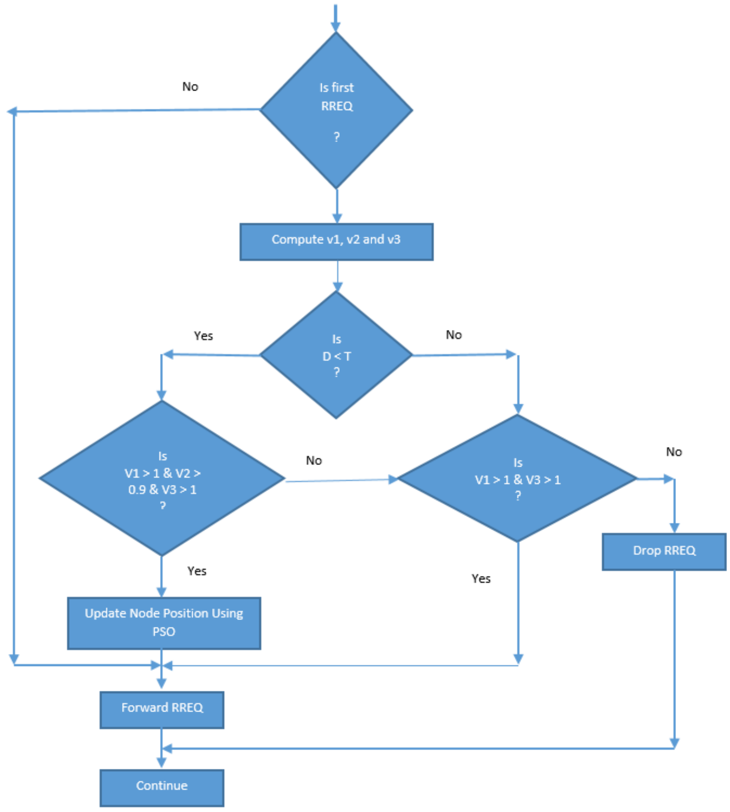

Figure 2 – The RFBRD-PSO strategy.

Figure 3 below shows how the neighbors in the scarce region are considered concerning a node at the center under consideration. The objective is to relocate the neighboring nodes of the center node (Receiving the first RREQ packet) in a 20m radius so that the neighborhood of the central node is improved providing better connectivity. When a node receives the first RREQ packet, it is subjected to the energy conditions as mentioned in Figure 2. That is, if the region density of the node acquiring the RREQ is less than the predefined threshold value, it is defined as the scarce region node. The next step is to improve its neighborhood relocating other neighboring nodes present in a 20m circular radius area. PSO is used to find the optimum location for each of the neighboring nodes lying in the 20m range to improve the neighborhood of the central node.

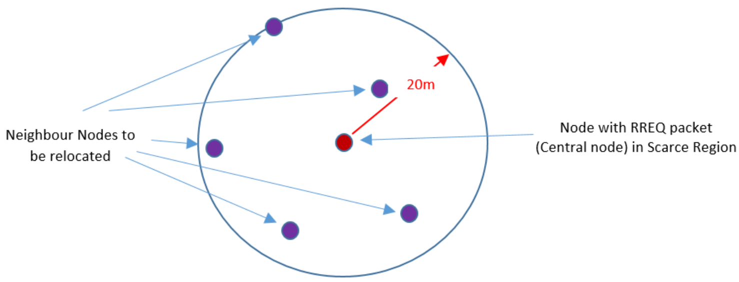

Figure 3 – The central node (First RREQ Receptor) and its initial neighborhood in a scarce region

The Optimized Location Using PSO

The initial parameters of PSO are initialized are listed in Table 1 and include the number of particles, the number of iterations, the minimum and maximum positions of the particles concerning their network space, the minimum and maximum velocities for the particles to accelerate, and the initial best position they should acquire. The following parameters are initialized:

Table 1 – PSO initial parameters

Parameters	Initial values
Number of particles (M)	20
Number of Iterations/Epoch (k)	10
Initial best positions - P_{best}	Same as the initial node location (For all M=20 particles)
Initial Global best position -G_{best}	0.0
Minimum and maximum velocities	vmin = 0.0 and vmax = 5.0
Minimum and maximum displacement for any particle	xmin = 0 and xmax = 20 (The initial position x and the displacement when added should not exceed the network space)
Constant c1 and c2	2.0
Inertial weight defining factor (t)	0.9 to 0.4 in steps of 0.5/epoch

The fitness function used for the PSO is to know whether the node position acquired by the particle improves its neighborhood or not. The fitness value (number of neighbors) should exceed the initial number of neighbors. The particle position that improves the neighborhood of the node better than other particles is considered to be the *Gbest* value. The process continues till the iterations are completed. The last *Gbest* value represents the number of nodes the node has in the neighborhood and the corresponding particle gives the new position for the node in the network space limited to a 20 m radius in its neighborhood. The value of radius = 20 m is set after experimentation. The lower the value, the lower the chances of improvising the neighborhood but better the retention of the initial neighborhood. If the value is set beyond 20 m, higher the probability of increasing the neighborhood but it also increases the chances of deserting its initial neighbors.

All the 20 particles P_x are initialized randomly in the 20 m circular range of the node lying in the scarce region. The initial best positions P_{best} for all the particles are set to the initial node position. The G_{best} value is set to 0.0. The performance of the PSO is governed by the neighborhood of the node under consideration. The PSO can find a new location for the node with improvised neighbors with a probability of 80%. Experiments were conducted on several particles and iterations, 20 particles with 10 iterations were enough to maintain a trade-off between computational complexity and failures. The particle velocities were limited to 5 m/s since the search region is limited to 20 m.

The following expressions from (4) to (8) are used to compute the inertial weight, new velocity of the particles, new position of the particles, and the local and global best solutions.

$P_{n,d}$ *- are particles in D-dimensional space, and the population is expressed as*

$$P_{n,D} = [X_{n,1}(t), X_{n,2}(t), X_{n,3}(t), X_{n,4}(t), X_{n,5}(t), \ldots\ldots\ldots X_{n,D}(t)]$$

MaxIterations – Maximum iterations for PSO and k – to represent the current iteration. w – is the inertial weight factor (self-adapting parameter) and is defined as,

$$w = w_{max} - \frac{w_{max} - w_{min}}{Max\ Iterations} * k \tag{4}$$

Where, w_{max}*=0.9 and* w_{min}*=0.4.* c_1 *and* c_2 *are acceleration constants and lie in the range* ($0 \le c_1, c_2 \le 2$)*,* r_1 *and* r_2 *are randomly generated values in [0 1].*

The velocity $V_{n,d}$ *and position* $X_{n,d}$ *in dimension D is updated using the following expressions,*

$$V_{n,d} = w * V_{n,d}\ (k\text{-}1) + c_1 * r_1 * \{P_{best} - X_{n,d}\ (k\text{-}1)\} + c_2 * r_2 * \{G_{best} - X_{n,d}\ (k\text{-}1)\} \tag{5}$$

$$X_{n,d}\ (k) = X_{n,d}\ (k\text{-}1) + V_{n,d} \tag{6}$$

For the minimization problem, the new value for P_{best} and G_{best} can be calculated as

$$P_{best} = \begin{cases} P_{curr}, & if\ \{fitness(P_{curr}) < fitness(P_{best})\} \\ P_{best}, & Otherwise \end{cases} \tag{7}$$

$$G_{best} = \begin{cases} P_{curr}, & if\ \{fitness(P_{curr}) < fitness(G_{best})\} \\ G_{best}, & Otherwise \end{cases} \tag{8}$$

The particles play the role of finding better solutions to the problem under constraints. The particles are limited to a specific search space and wander with different velocities limited to specific values in the search space. The fitness function is evaluated at each epoch to check whether the optimum solution is found concerning some predefined permissible error. The predefined error limit is the permissible error between the actual output and the desired output. If the PSO attains the permissible error or the iterations are exhausted, the algorithm stops. At any epoch, if the PSO is unable to meet the goal, particle velocities and positions are updated and the algorithm continues to iterate.

IV. RESULTS AND DISCUSSION

The following Tables 2 and 4 below show the performance of RFBRD-PSO routing for N = 40 and 80 nodes. The summarized performance of RFBRD-PSO routing for all the configurations including N = 40, 60, 80, and 100 is depicted in Table 5. It is seen that the average percentage increase in connectivity is approximately 38% for one round. That is, the source and the destination remain the same for one simulation time of 20 seconds. Almost 56% of average nodes belong to scarce regions of the network and remain in the populated region. The first column represents the node receiving the RREQ packet, while the second column indicates the node region (populated/scarce). The initial location and the new location for the PSO-optimized nodes are provided in the last two columns and a corresponding increase in the neighbor is provided in the fifth column. The percentage increase in connectivity is calculated by summing the initial and the new neighbor columns. The vacant entries of new neighbors are filled with initial neighbors while summing the new neighbors. The parameters governing Table 2 are listed in Table 3.

Table 2 – Node behaviour on reception of first RREQ packet and performance of RBFRD-PSO routing for 40 nodes

Node ID	Condition	Initial Neighbors	PSO Performed	New Neighbors	Initial Position	New Position
0	II	5				
3	II	4				
4	I	4	No		(146, 601)	-
2	I	2	Yes	4	(400, 787)	(415, 787.5)
5	II	3				
32	I	3	No		(124, 810)	
6	I	3	Yes	4	(550, 655)	(550.4, 673.4)
38	I	3	No		(610, 843)	
7	II	3				
10	II	1				
17	II	1				

8	I	1	Yes	4	(874, 737)	(879.4, 751.3)
34	I	3	No		(960, 730)	
9	II	2				
20	II	2				
11	I	1	Yes	3	(215, 189)	(224.7, 205.1)
39	I	2	No		(173, 108)	
29	I	2	Yes	4	(329, 84)	(339.8, 87.2)
18	I	2	Yes	4	(488, 122)	(496.5, 130.0)
13	II	2				
12	II	1				
19	I	3	No		(633, 53)	
14	II	1				
33	I	2	Yes	3	(1205, 841)	(1220.8, 853.9)
21	I	2	Yes	4	(1251, 625)	(1269.7, 632.9)
22	II	2				
23	II	2				
31	I	1	Yes	2	(1434, 805)	(1448.8, 813.1)
15	I	2	Yes	3	(1057, 369)	(1071.9, 383.0)
16	II	2				
30	I	1	Yes	2	(1580, 541)	(1594.2, 547.5)
24	I	2	Yes	5	(1211, 202)	(1212.5, 221.8)
27	I	1	Yes	2	(1658, 443)	(1668.6, 456.0)
37	I	3	No		(1130, 65)	
25	I	3	No		(998, 105)	
28	II	1				
26	I	1	Yes	4	(1699, 247)	(1710.0, 264.2)
35	II	2				

Table 3 – Performance parameters of RFBRD-PSO for 40 nodes

Total Nodes (including S and T)	40
RREQ Forwarding Nodes	38
Nodes satisfying the first condition (Scarce Region)	22
Nodes shifted to New Locations using PSO	14
PSO failed to find new location	8
Nodes satisfying the second condition (Populated Region)	16
Initial Neighborhood (Connectivity)	81

Neighborhood Improved by RFBRD-AODV	106

Table 4 - Node behaviour on reception of first RREQ packet and performance of RBFRD-PSO routing for 80 nodes

Node ID	Condition	Initial Neighbors	PSO Performed	New Neighbors	Initial Position	New Position
64	I	7	Yes	10	(122, 693)	(137.3, 698.5)
66	I	6	Yes	9	(250, 835)	(265.4, 835.5)
0	I	7	Yes	11	(246, 746)	(246.3, 750.0)
7	II	7				
2	II	7				
8	I	6	Yes	11	(146, 601)	(159.5, 601.3)
3	II	7				
4	I	8	Yes	11	(400, 787)	(401.6, 796.0)
7	II	10				
6	I	9	Yes	12	(381, 653)	(381.6, 660.8)
5	II	7				
9	II	7				
10	I	6	Yes	9	(265, 491)	(268.4, 499.7)
79	I	3	Yes	5	(64, 424)	(76.6, 442.9)
20	II	5				
11	II	7				
12	II	5				
13	I	5	Yes	8	(514, 766)	(514.2, 766.2)
76	I	4	Yes	5	(610, 843)	(619.0, 849.1)
14	II	4				
23	I	2	Yes	5	(99, 239)	(100.2, 239.1)
22	I	4	Yes	5	(215, 189)	(225.0, 189.1)
78	I	3	Yes	5	(173, 108)	(174.8, 112.3)
21	II	4				
15	I	4	Yes	9	(715, 667)	(721.1, 671.7)
58	I	5	Yes	7	(329, 84)	(347.0, 85.4)
77	I	5	Yes	8	(383, 147)	(386.3, 147.9)
25	I	3	Yes	6	(439, 251)	(450.3, 261.0)
36	II	6				
37	I	4	No		(531, 51)	
26	I	5	Yes	6	(566, 143)	(571.2, 143.9)

24	II	3				
19	I	5	No		(688, 518)	
18	II	5				
16	II	3				
35	II	3				
34	II	4				
39	I	5	No		(650, 195)	
38	I	4	No		(633, 53)	
27	I	1	Yes	3	(772, 167)	(777.2, 183.8)
51	I	1	Yes	4	(865, 80)	(872.4, 84.8)
50	II	3				
31	I	3	Yes	7	(958, 310)	(967.7, 318.5)
32	I	3	Yes	9	(1021, 237)	(1028.0, 242.2)
28	II	3				
30	I	5	Yes	8	(1057, 369)	(1075.0, 369.3)
33	I	4	Yes	8	(1141, 290)	(1156.6, 293.5)
29	II	4				
49	I	4	Yes	5	(1148, 145)	(1152.6, 146.4)
48	II	4				
74	I	5	Yes	6	(1130, 65)	(1138.2, 65.6)
47	I	4	Yes	7	(1237, 422)	(1244.1, 438.4)
43	II	4				
17	II	3				
46	II	3				
57	II	3				
42	II	4				
44	II	3				
68	I	3	Yes	6	(960, 730)	(960.9, 736.8)
41	I	4	Yes	5	(976, 834)	(993.6, 843.3)
40	I	4	Yes	6	(1070, 757)	(1084.9, 760.7)
67	I	2	Yes	5	(1205, 841)	(1208.4, 847.0)
45	II	3				
62	I	2	Yes	5	(1434, 805)	(1446.6, 807.2)
61	I	4	Yes	6	(!526, 694)	(1529.0, 700.1)
69	I	3	Yes	6	(1598, 781)	(1605.1, 785.4)

63	I	4	Yes	5	(1689, 661)	(1689.5, 661.3)
75	I	2	No		(1785, 754)	
60	II	3				
55	II	2				
56	II	2				
73	I	1	Yes	4	(1479, 56)	(1479.9, 56.13)
54	I	2	Yes	5	(1658, 443)	(1659.5, 449.7)
53	I	4	No		(1735, 376)	
52	I	3	Yes	8	(1699, 247)	(1712.0, 263.1)
70	I	4	No		(1724, 122)	
59	I	6	Yes	7	(1577, 163)	(1578.9, 167.3)
71	I	5	Yes	6	(1621, 91)	(1635.7, 100.6)

Table 5 – Overall performance of RFBRD-PSO for network configuration with 40, 60, 80 and 100 nodes

Sr. No.	No. of Nodes	Nodes in Populated Region	Nodes in Scarce Region	PSO Success	PSO Failure	Connected Nodes	Improved Connectivity	% Improvement
1	40	16	22	14	08	81	106	30.86
2	60	25	33	25	08	210	271	29.04
3	80	31	47	41	06	331	439	32.62
4	100	42	56	51	05	515	693	34.56
Average Improvement in connectivity								***31.77***

The static network considered for this novel research work provides mobility in terms of node re-localization using the RFBRD-PSO routing scheme during the route discovery phase. For one round of simulation, the proposed scheme improves connectivity by 31% which will be improved in subsequent rounds and a better topology can be obtained to provide better connectivity and coverage in the network conserving energy. The performance of AODV and the proposed RFBRD-PSO scheme is compared in terms of QoS parameters in Table 6.

Table 7 shows the average value of the QoS parameters over all the configurations which provides a clearer picture.

Table 6 – Comparative analysis between AODV and RFBRD-AODV for all configurations

QoS Parameters	**AODV**	**RFBR D-PSO**	**AOD V**	**RFBR D-PSO**	**AOD V**	**RFBR D-PSO**	**AOD V**	**RFBR D-PSO**
	40 nodes		**60 nodes**		**80 nodes**		**100 nodes**	
Total Packets Sent	177	77	138	140	83	173	114	203

Total Packets Received	155	67	114	127	65	159	93	190
Total Packets Forwarded	1364	631	1170	1306	697	1777	917	2339
Total Hello Packets Sent	1632	1640	2460	2456	3282	3301	4097	4104
Total Hello Packets Drop	304	133	613	521	836	1474	1700	3084
Packet Delivery Ratio	87.57	87.01	82.61	90.71	78.31	91.91	81.58	93.60
Throughput of the network (Kbps)	60.54	26.17	44.53	49.60	25.39	62.10	36.32	74.21
The total hop counts are	6552	3084	6548	7067	3930	10570	4667	15011
Average Hop Count (hops)	42	46	57	55	60	66	50	79
Routing Overhead	1619	909	2460	1338	2327	1770	3554	1619
Normalized Routing Load	10.44	13.56	21.57	10.53	35.8	11.13	38.21	10.44
Total Energy Residue	3618	3630	5433	5434	7260	7240	9066	3618
Average End to End Delay	0.22	0.34	0.238	0.25	0.38	0.27	0.40	0.22

Table 7 – Average values of QoS parameters over all configurations

QoS Parameters	AODV	RFBRD-AODV
Total Packets Sent	128	148.25
Total Packets Received	106.75	135.75
Total Packets Forwarded	1037	1513.25
Total Hello Packets Sent	2867.75	2875.25
Total Hello Packets Drop	863.25	1303
Packet Delivery Ratio	0.825175	0.908075
Throughput of the network(Kbps)	41.6992	53.027375
The total hop counts are	5424.25	8933
Average Hop Count	52.25	61.5
Routing Overhead	2490	1409
Normalized Routing Load	26.5098	11.419975
Total Energy Residue	6344.202185	4980.506301
Average End-to-End Delay	0.312582962	0.27474004

The graphical representation of the above comparison is shown in Figure 4. The performance of AODV is superior in the case of a low-density network (N=40 nodes) while RFBRD-PSO outperforms in all other configurations. The Packet delivery ratio and the throughput are better in the case of RFBRD-PSO. The overheads and end-to-end delay are less as compared to AODV. The energy residue in the case of RFBRD-PSO is less than the value of AODV is the cost paid for a higher packet delivery ratio. There is always a trade-off between various parameters in WSN. The proposed routing is successful in maintaining a proper balance between the QoS parameters.

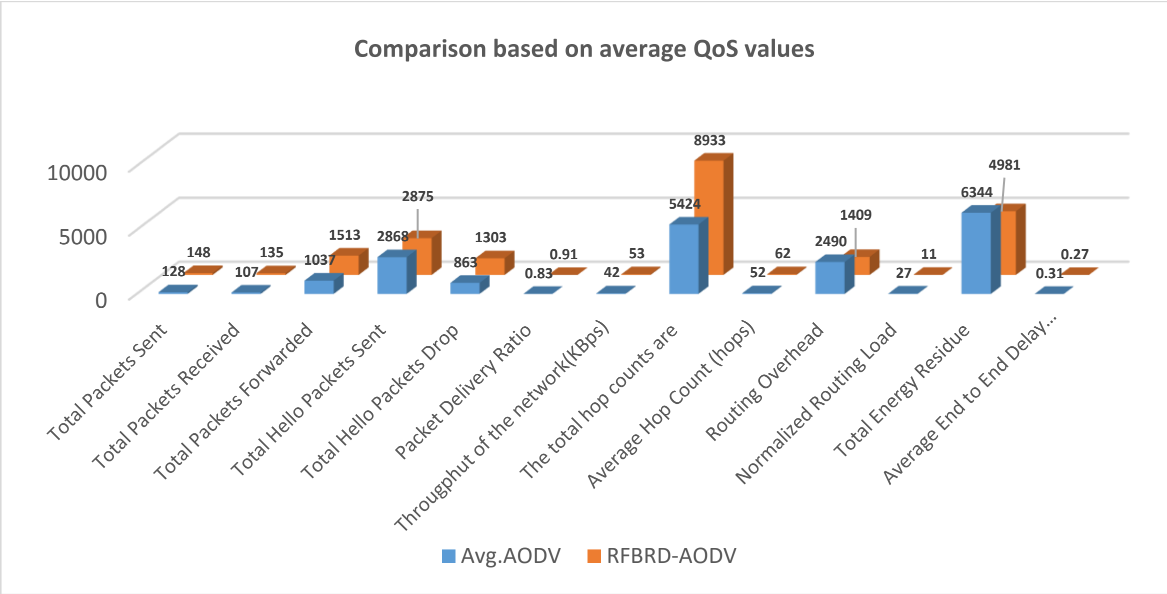

Figure 4 – Comparison of AODV and RFBRD-PSO for QoS parameters

V. CONCLUSION

The RFBRD-PSO routing scheme combines the features of RFBRD and node localization similar to the MECT-PSO scheme in a different framework. The proposed scheme computes different energy ratios in the node neighborhood receiving the first RREQ. It then determines the density of the node and allows the node to forward the RREQs only when the node lies in the scarce region. The density of such nodes is improved by relocating the neighbors such that the neighborhood is improved which in turn improves the connectivity and coverage. Nodes lying in the populated region are restricted from flooding the RREQ packet. The nodes in the populated region are only allowed to forward the RREQ packets when they satisfy energy conditions given by the expression (1) to (3). This saves a large amount of energy depletion due to flooding in the network and lengthens the network life.

The RFBRD-PSO helps to improve connectivity and coverage and lengthen the lifetime of the network conserving the node energies. This scheme is efficient in maintaining a proper balance of QoS parameters works well for high-density networks for more than 50 nodes and can restructure network topology obtaining better connectivity. As seen from the performance comparison of the proposed RFBRD-PSO routing scheme with AODV, AODV is superior in low-density networks while RFBRD-PSO outperforms when the network density is increased.

The Packet delivery ratio showed an improvement of 0.08% and the throughput exceeds 11 kbps in the case of RFBRD-PSO. The routing overhead dipped by 40% while the average end-to-end delay was found low by 0.04 as compared to AODV. The energy residue in the case of RFBRD-PSO is 4981 Joules lower than the value of 6344 Joules in the case of AODV. This is due to the cost paid for a higher packet delivery ratio. The overall neighborhood connectivity improved by 32%.

The nodes in the network are initially considered to be static and re-localized as per requirement. But real-time scenarios in most applications are different and nodes are permanently either static or dynamic and in other cases, they possess both characteristics. More sophisticated work is demanded in this area and a generalized routing scheme is required to handle dynamic networks.

REFERENCES

[1] Amar Adnan Rasheed, “A Dissertation Security schemes for wireless sensor network with mobile sinks”, Texas A&M University, May 2010.

[2] V. Kapoor, and D. Singh, “FBESSM: An Fuzzy Based Energy Efficient Sleep Scheduling Mechanism for Convergecast in Wireless Sensor Networks,” International Journal of Intelligent Systems and Applications in Engineering, vol. 11, no. 9s, pp. 767-781, 2023.

[3] A. Nandi, B. Sonowal, D. Rabha, and A. Vaibhav, “Centered sink LEACH protocol for enhanced performance of wireless sensor network,” in International Conference on Automation, Computational and Technology Management (ICACTM),

pp. 436–440, London, United Kingdom, 2019.

[4] M. Ouamri, G. Barb, D. Singh, A. Adam, M. S. A. Muthanna, and X. Li, "Nonlinear Energy-Harvesting for D2D Networks Underlaying UAV with SWIPT Using MADQN," IEEE Communications Letters, vol. 27, no. 7, pp. 1804-1808, 2023.

[5] P. T. Agarkar, M. D. Chawhan, R. N. Nawkhare, D. Singh, N. P. Giradkar, Prashant R. Patil, "An Efficient Restricted Flooding Based Route Discovery (RFBRD) Scheme for AODV Routing", International Journal of Computer Networks and Applications (IJCNA), vol. 10, no. 5, pp. 792-805, 2023.

[6] X. D. Zhang, "Design and implementation of embedded uninterruptible power supply system (EUPSS) for web-based mobile application," Enterprise Information Systems, vol. 6, no. 4, pp. 473– 489, 2012

[7] F. Jameel, W. U. Khan, N. Kumar, and R. Jantti, "Efficient power- splitting and resource allocation for cellular V2X communications," IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 6, pp. 3547–3556, 2021.

[8] O. M. Amine, D. Singh, M. Muthanna, A. Bounceur, and X. Li "Performance analysis of UAV multiple antenna-assisted small cell network with clustered users," Wireless Networks, vol. 29, no. 4, pp. 1859-1872, 2023.

[9] B. Prachin and S. Parul, "Communication technologies and security challenges for internet of things: a comprehensive review," AEU- International Journal of Electronics and Communications, vol. 99, no. 2, pp. 81–99, 2019

[10] S. Liu, "Adaptive repair algorithm for TORA routing protocol based on flood control strategy," Comput Commun, vol. 151, no. 1, pp. 437–448, 2020

[11] M. Radi, B. Dezfouli, K. A. Bakar, and M. Lee, "Multipath routing in wireless sensor networks: survey and research challenges," Sensors, vol. 12, no. 1, pp. 650–685, 2012.

[12] M. A. Ouamri, R. Alkanhel, D. Singh, E. M. El-Kenaway, and S. Ghoneim, "Double deep q-network method for energy efficiency and throughput in a uav-assisted terrestrial network," International Journal of Computer Systems Science & Engineering, vol. 46, no. 1, pp. 73-92, 2023.

[13] K. Vijayalakshmi and P. Anandan, "A multi objective Tabu particle swarm optimization for effective cluster head selection in WSN," Cluster Computing, vol. 22, no. S5, pp. 12275–12282, 2019.

[14] V. Kapoor, and D. Singh, "A Comparative Review on Channel Allocation and Data Aggregation Techniques for Convergecast in Multichannel Wireless Sensor Networks," In International Conference on Information Technology, pp. 321-331. Singapore: Springer Nature Singapore, 2023.

[15] M. Sharawi, I. A. Saroit, H. El-Mahdy, and E. Emary, "Routing wireless sensor networks based on soft computing paradigms: survey," International Journal on Soft Computing, Artificial Intelligence and Applications (IJSCAI), vol. 2, no. 4, pp. 21–36, 2013

[16] J. Wang, C. Ju, Y. Gao, A. K. Sangaiah, and G. J. Kim, "A PSO based energy efficient coverage control algorithm for wireless sensor networks," Computers, Materials & Continua, vol. 56, no. 3, pp. 433–446, 2018.

[17] D. Singh, M. A. Ouamri, M. S. Muthanna, A. Adam, A. Muthanna, A. Koucheryavy, and A. El-Latif, "A generalized approach on outage performance analysis of dual-hop decode and forward relaying for 5G and beyond scenarios," Sustainability, vol. 14, no. 19, 2022.

[18] A. A. M. Rahat, R. M. Everson, and J. E. Fieldsend, "Evolutionary multi-path routing for network lifetime and robustness in wireless sensor networks," Ad Hoc Networks, vol. 52, pp. 130– 145, 2016.

[19] O. M. Amine, G. Barb, D. Singh, and F. Alexa, "Load balancing optimization in software-defined wide area networking (SD-WAN) using deep reinforcement learning," In 2022 International Symposium on Electronics and Telecommunications (ISETC), pp. 1-6. IEEE, 2022.

[20] B. Guruprakash, C. Balasubramanian, and R. Sukumar, "An approach by adopting multi-objective clustering and data collection along with node sleep scheduling for energy-efficient and delay aware WSN," Peer-to-Peer Networking and Applications, vol. 13, no. 1, pp. 304– 319, 2020.

[21] K. Jaiswal and V. Anand, EOMR: an energy-efficient optimal multipath routing. Wireless Personal Communications, Springer Science+Business Media, LLC, part of Springer Nature, 2019.