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RESEARCH ARTICLE

Erudite Fish Swarm Optimization Based Routing Protocol to Maximize Wireless Sensor Network Lifetime

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Abstract – Wireless Sensor Networks (WSNs) are an influential network form that comprises remote nodes having sensing, processing, and communication capabilities. WSN is a unique ad-hoc network with a wireless telecommunications infrastructure that effectively supports, observes, and responds to natural and artificial events. It is impossible to employ the ad-hoc network routing methods in sensor networks since they are not scalable. WSN relies on the routing protocol to get data from sensors to their final destination in a timely way. If the routing protocol fails to work, then it is expected that a significant amount of time and effort will be spent finding the most efficient route, increasing the likelihood that the worst possible option will be selected. Because of this, WSN routing protocols must include the concept of "erudite" features, which refers to a high degree of sensing of the nodes around them to determine the optimum path. Fish swarm optimization is the basis of the new WSN routing protocol proposed in this paper, namely the Erudite Fish Swarm Optimization Based Routing Protocol (EFSORP). In EFSORP, nodes are treated as fishes. Nodes having prior knowledge about routes are selected at random. Foraging, following, swarming, and random movement is four of the most common behaviors of fishes while seeking food. These behaviors are mimicked to identify the best routes in WSN. EFSORP's performance is evaluated in NS3. A wide range of necessary computer network performance measures are used to assess EFSORP against existing routing protocols. EFSORP's results show that it outperforms the current routing protocols on all measures.

Index Terms – Routing, WSN, Energy, Delay, Fish, Optimization.

1. INTRODUCTION

Due to the sensor node's ability to be installed with no additional hardware and the network's tracking capabilities, wireless sensor networks (WSNs) have already found applications in various fields in recent years [1]. Several WSN experiments have focused chiefly on localization, coverage and navigation. Low-cost microsensors with wireless capabilities have the feature of minimum energy consumption for transmitting the data and resource constraints [2]. To extend the lifespan of WSNs which have limited resources, energy-saving measures must be used. WSN routing protocols have lately been the subject of a slew of studies, with the consensus being that schemes based on hierarchies and clusters hold the most promise for improving scalability and prolonging the lifespan of WSNs [3]. The low-energy adaptive clustering hierarchy (LEACH) [4] is a significant protocol in WSN. The energy consumption and scalability concerns are solved in LEACH through clustering. As a result, WSN apps frequently employ it. According to some scientists, heterogeneous WSNs might extend network life and make WSNs more suitable for applications [5], [6]. HWSNs can theoretically be classified into two categories: sensor nodes deployed with varying contact radii and sensor nodes deployed with varying energies, according to the theory. WSN routing methods often use a variety of different protocols [7].

An essential component of omnipresent/ubiquitous measurement is WSNs. The advancement in wireless technologies has led to many potential applications, including territory monitoring systems, lava control networks and industrial sensor networks [8]. The Heterogeneous Wireless Sensor Network (HWSN) comprises sensor nodes with various capabilities to achieve the target [9]. Different sensor devices have a diverse sensing range, thereby giving better versatility. To provide a variety of sensing services, we may construct a WSN with nodes that are equipped with various types of sensors. There are two types of sensor nodes: high-performance and long-distance sensor nodes, while low-performance and short-distance sensor nodes are less expensive and have a lesser processing and sensing capacity.

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WSN execution and cost balance can be achieved by using a hybrid implementation of these nodes. Heterogeneous routing protocols can meet the following requirements [10].

Routing is a critical component of WSNs, and it must be appropriately managed. A routing strategy is needed to establish communication between base stations and sensor nodes [11]. The difficulty with routing causes a loss in network life and increased energy use. As a result, various routing strategies are being proposed to decrease the utilization of energy and increase the lifespan of the entire network. The network topology and the quantity of participating nodes can be used to classify all routing protocols. Roaming networks face several issues ranging from low battery life and insufficient coverage to high energy usage and poor nodes [12]. Optimization plays a significant role in routing to minimize the routing overhead [13]–[22].

Sensor nodes use a short-range radio frequency (RF) transmission and receiving unit to communicate with one other. The volume of communication and the distance it travels affect the amount of energy used to transmit information. It is possible to save a large amount of energy by processing data locally to decrease travel. It is essential to reduce the quantity of data sent between sensors and reduce the distances between sensors to save energy. Multi-hop routing with low distances between each hop may save electricity by orders of magnitude over single-hop routing with a broad travel range for the same destination.

Similarly, to shorten signal transmission distance, multi-hop communication and clustering-based hierarchies have been developed to forward data in the network. If the application situation requires a certain direction to take precedence, then trade-offs must be negotiated. For example, removing redundant sensing might minimize data transmission; communication energy usage is lowered. However, this demands more sophisticated control systems, supported by more complex processing, and may result in increased energy usage for calculation.

Sensing and transmitting data are the essential functions of a sensor network. The nodes first create routing pathways, and only then may data be sent or received along those routes. In an energy-constrained sensor network, routing is critical for determining the best route and transferring data. The poor routing protocol in WSN fails to select the most efficient route if more than one best route is available to the destination. There are multiple chances for failing the best route in WSN for various reasons. Hence, there exists a need for deep sensing the nodes before finding the route to the destination. When sensor nodes are running low on energy, some network portions may not transmit data to the destination from sensor nodes. It is a critical challenge in WSNs to optimize the use of nodes' energy and extend the network's lifespan.

The main intention of this research work is to propose an "Erudite Fish Swarm Optimization-based Routing Protocol (EFSORP)", which is inspired by the natural foraging characteristics of fishes. EFSORP aims to minimize WSN nodes energy while determining the optimum path and sending data on the identified route to the destination. The main intention of EFSORP is to increase the WSN lifetime by minimizing the consumption of energy at each node. In a nutshell, the primary goal of EFSORP is to identify and use better nodes in the routes to the destination.

A brief introduction to WSN and its routing is provided in this section with a statement of the problem and research objectives. The relevant works of literature for this research are reviewed in Section 2. Section 3 proposes the routing protocol, namely EFSORP, to enhance the WSN lifetime. Section 4 provides the details of the settings used for conducting the simulation. Section 5 discusses the metrics used to analyze the performance of proposed and existing routing protocols. The findings of the simulation are discussed in Section 6. Conclusion with future enhancement is discussed in Section 7.

2. LITERATURE REVIEW

The current section discusses the current WSN routing protocols that have the drawback of more energy consumption leading to reduced network lifetime.

"Multi-Pole based Field Persistent Routing" [23] is proposed to examine the security-related issues in Electrostatic field-based routing, i.e., routing through multiple paths based on electrostatic routing. Secured Multi-Pole Field Persistent Routing is incorporated for better routing data in the network. Load balancing is enhanced and is safeguarded against different types of attacks. Four different technologies for security are analyzed to route, and protocols are classified into three various implementations in "Dynamic Routing Protocol" [24]. It has surveyed discovering routes and their maintenance, which may lead to the disclosure of information and interruption of communication. Forwarding data in the network is provided for safeguarding the broadband services in the satellite network. "Secure Clustering-based Energy Routing" [24] is proposed to improve the network's lifetime. Routing and networking were ensembled to transmit packets efficiently, and stability metrics were measured to increase energy efficiency for the cluster. The clustering model is used to balance the network's efficiency and integrity. "Path Stability Routing" [25] is proposed for securing the routing based upon route modifications. Gao-Rexford structure is used for diagnosing the strategies of routing and is deployed with different deployment mechanisms. The topology features were analyzed, and a derived pattern-based dispute chain was innovated to examine the issue. "Secure Deduplication Schemes" [26] are suggested for three different setups: semi-distributed, fully distributed, and centralized.

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Data retrieval, storage, deduplication, and sharing are all protected by the system's safeguards. Adapting to edge computing is used to safeguard data storage against conventional threats.

"Agent-Based Self-Protective Method" [27] is suggested for UAV networks based on the human immunological system. A multi-agent system employs an Artificial Immune System and a Route Request Packet towards the destination out of its source to identify the existing routes to detect the assaults. Safe routes are carefully selected by utilizing a protection mechanism at the point of origin. For identifying and isolating the network's malicious node. The trust-based assessment technique suggests "Energy Optimization-based Secure Routing" [28] for WSN. Each node's energy and trust levels are considered while designing an EOSR protocol. As a consequence, the trust nodes' energy consumption is allocated equitably. The proactive routing technique "Novel Proactive Routing Strategy" [29] is developed to safeguard MANETS from assaults to secure the network. Network activity monitoring ensures that specific nodes in the network are protected against node assaults. Multi-Point Relay (MPR) is used to enhance the security of the packets by selecting a new node for the transmission of data packets. "Ethereum Platform" [30] is a proposed platform for blockchain to analyze various factor analyses in networks. Blockchain-based drone system for data delivery and authenticating the warehouses and products using drones. Machine Learning-based intrusion system enhances communication using drones for controlling and commanding the network with security and robustness. "Event-Driven Routing Protocol" [31] is proposed for the robust system in Wireless networks. An energy-efficient network is presented to improve the medical sensor node's energy. A denial-of-Service attack is carried out based on the quality of Service parameters and compared with FCFU and LEACH algorithms for performance evaluation.

Security and prevention of intrusion can be achieved by designing the Software-Defined Network according to the SMPM paradigm. Ensembled multipath was employed to detect the intermediate attacks. To improve mutation efficiency, "Random Route Mutation" [30] is proposed to alter and redirect the course of events. According to RPM-algorithms Pathfinder for assessing security, QoS, and Overlap, it generates all possible routes from a source to a destination. Packets in the path can limit sniffer attacks.

"Energy-Efficient Secured Multi-Path Protocol" [32] is proposed to provide an optimized route to enhance communication among two different nodes and make the network lifetime efficient. Directed Diffusion Protocol is compared to show its better efficiency. A particular type of attack encompassing pulling traffic was detected, and the malicious nodes were removed. "Trust Management Scheme" [33] is proposed for the Mobile Internet of Things to communicate securely by ensuring efficiency, availability and reliability. Trust is integrated for delivering content inside Information-Centric Networks. Two devices were detected for identifying Man-in-The-Middle, Distributed Denial of Service and Denial of Service. The routing paths were identified using real-time feature parameters while transferring data to the destination from the source node. "Bee Colony based Secured Routing" [34] is proposed for routing data from a group of mobile nodes in MANET. EBeeAdhoc, an architecture, is developed based on fuzzy set theory for which digital signatures are integrated. TRUTIME, a toolbox in MATLAB, is used to simulate results. The security-based threats were examined for the study.

"Fuzzy Inference System-based Reverse Glowworm Swarm Optimization (FIS-RGSO)" [35] is a suggested method for reducing WSN energy usage by identifying the most efficient path to the destination. FIS-sensors RGSOs are designed to move as efficiently as possible to use the least energy potential while also extending their lifespan. In terms of lifespan and energy efficiency, FIS-RGSO increases the longevity and efficiency of green WSNs by restricting and organizing sensor motions based on decisions made by the Fuzzy-Inference-System, resulting in minimal energy consumption and reduced distance traversal. A proposed approach for reducing energy consumption in WSN data transmission is "Neighborhood Field Optimization (NFO)" [36]. NFO highlights the need for a well-defined neighborhood. The local search can be aided by the help of the neighborhood's nearest neighbors. Because of its population-based structure, NFO has a high exploratory ability at the beginning of its evolution. Neighbor-to-neighbor differences can estimate gradient information after the algorithm has reached a limited area. The programme may be able to use the situation to its fullest extent.

From the above discussed WSN current routing protocols, it was identified that there is a need for an erudite routing protocol that will save the energy at each node towards enhancing the WSN lifetime.

3. FISH SWARM OPTIMIZATION

An algorithm that uses decentralized, self-organized systems to solve problems is a "swarm". It has been widely employed to address various issues in various contexts. Swarm intelligence programmed concepts simulate individual fish behaviour, and the information exchanges inside a fish swarm are called a fish swarm optimization algorithm (FSOA). When searching for food or friends, artificial fish (AF) use four different behaviors: (i) preying, (ii) random movements, (iii) travelling in swarms, and (iv) following other fish. There are four distinct ways in which an algorithm might achieve global convergence: by preying on different strategies, forming swarms, accelerating their convergence, and

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randomly wandering around inside another strategy's convergence zone. Self-information, such as the vision field, movement step length, and maximum attempt number of each artificial fish, determines the fish's future action. An AF uses its sense of sight to learn about its surroundings, in which the $Visual$ denotes the AF's visual range and $Step$ which is the maximum moving step length. Current location is P_s, $Visual$ position is P_w, and an artificial fish's position is P_{next}, with P_{next} denoting the next position. To go to the P_{next} from P_s, the AF will head toward P_w if the food content found is higher than in P_s; otherwise, it will continue to explore the region within its field of vision.

Iterative food foraging is depicted in the basic $FSOA$ are as follows:

Step 1: To begin, several essential parameters are set, including the visual range $Visual$, the stepping length $step$, the cropping divisor θ, and the maximum number of tries F_t.

Step 2: Stochastic initialization of an AF swarm.

Step 3: Calculate the ideal concentration of food for each fish at the present location (objective function value) and note it on the bulletin board.

Step 4: There is a separate AF for each.

(a) It investigates and implements optimal following and SB to determine its fitness value.

(b) Assembling a new bulletin board in the new location and comparing the food concentration to the previous value ensures the current value is maintained.

Step 5: Once the halting requirement has been reached, repeat Step 4.

4. ERUDITE FISH SWARM OPTIMIZATION BASED ROUTING PROTOCOL (EFSORP)

This research work has developed an EFSORP model to identify essential routes incorporating fishes' natural characteristics. Four biological activities are included in the process of identifying essential routing information, including the use of an AF as a routing information set which are (i) foraging behavior (FrB), (ii) random behavior (RB), (iii) following behavior (FoB) and (iv) swarming behavior (SB). Candidate nodes have a major role in identifying the routes.

4.1. Initialization

T number of AFs are created by randomly picking a portion of previously-identified essential routing information, and each one has c such previously-identified routing information fragments. $Fish_s = (EP_{s1}, EP_{s2\ldots,}EP_{sc})$ $(where\ s = 1,2,\ldots,T)$ Encodes the location of fish $s$as c-dimensional integer set and represents a well-known essential routing information set.

4.2. Predatory Behavior

Studies have shown that essential routing information is more likely to be clustered together than independently. Hence, it is reasonable to assume that routing information near known necessary routing information is more likely to be crucial. With this in mind, it's essential to understand how a WSN network's topology affects the reliability of contact between two interacting routing information. Node interaction weights must first be determined before a neighbor's essentiality can be estimations. The weight of routing information pairings is calculated by $EFSORP$ using the Edge Clustering Coefficient (ECC). Edge's ECC may be described as $ECC(o,r)$ in Eq.(1).

$$ECC(o,r) = \frac{|T_o \cap T_r| + 1}{min\{y_o, y_r\}} \quad (1)$$

T_o and T_r are the neighbour sets of routing information o and routing information r, respectively, while y_o and y_r are the degree of routing information o and routing information r, respectively. Measures of node-to-node co-expression are based on the Pearson Correlation Coefficient (PCC). PCC may be defined as $PCC(o,r)$ in Eq.(2).

$$PCC(o,r) = \frac{\sum_{s=1}^{t}(o_s - \vartheta(o))(r_s - \vartheta(r))}{\sqrt{\sum_{s=1}^{t}(o_s - \vartheta(o))^2 \times \sqrt{\sum_{s=1}^{t}(r_s - \vartheta(r))^2}}} \quad (2)$$

There is a total of t gene expression time points for each routing information, o_s and r_s are the expression levels of each routing information, o and, at the time point s, respectively. Routing information is expressed in two ways: by the $\vartheta(o)$ and $\vartheta(r)$. The similarity of the two routing information o and v functions is also measured by the number of route ontology (RO) annotations they share. The more RO annotations a pair of routing information have, the more likely they will interact. Edge's CGO (o,r) are defined in Eq.(3).

$$CGO(o,r) = \begin{cases} \frac{|JK_o \cap JK_r|^2}{|JK_o| \times |JK_r|}, |JK_o| > 0\ amd\ |JK_r| > 0 \\ 0, \quad otherwise \end{cases} \quad (3)$$

Annotations for routing information o and v are represented by the RO terms JK_o and JK_r; the standard RO annotations between those two sets are represented by $JK_o \cap JK_r$. Moreover, for routing information to carry out their intended activities, specific subcellular compartments must be where they are housed.

For routing information to interact with another routing information, it must be inside a particular location in a cell. CSL (Common Subcellular Localizations) between routing information is defined as the CSL of edge (o,r), which is expressed in Eq.(4).

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$$CSL(o,r)=\begin{cases}\frac{|EZ_o \cap EZ_r|^2}{|EZ_o|\times|EZ_r|}, & |EZ_o|>0\, and |EZ_r|>0\\ 0, & otherwise\end{cases} \quad (4)$$

Subcellular localization sets EZ_o and EZ_r, respectively, define the subcellular localization of two routing information o and v the set of common subcellular locations between them, and it is denoted by $EZ_o \cap EZ_r$. Once this two-routing information has been determined, the weight of their interaction, o and v calculated using Eq.(5).

$$W(o,r)=\frac{ECC(o,r)}{(PCC(o,r)+CGO(o,r)+CSL(o,r))} * CGO(o,r) \quad (5)$$

To determine how closely related a routing information r in T_s is to route information in $Fish_s$. Let's consider T_s to be the collection of all routing information neighbors, and it is expressed in Eq.(6).

$$Close(r, Fish_s) = \sum_{o\omega Fish_s} W\,(o,r) \quad (6)$$

Once a neighbor routing information is added to $Fish_s$, then every AF$Fish_s$ goes on a foraging spree to locate its closest neighbor, which means finding the routing information in the T_s set with the highest possible proximity score and adding it to $Fish_s$. This is followed by an update to the collection of neighbors corresponding to $Fish_s$. Consider all fish should have a separate set of neighbors introduced to them. Until the number of fish neighbors grows to Ft, the FrB is repeated. If there are many neighbors with the same most excellent proximity score in the T_s set, then randomly select one among them by employing RB.

4.3. Observing and Reacting

The index is maintained in $EFSORP$ for determining which routing information are essential to identify the best candidates in route to reaching the destination. It is possible to compute the total weight of routing information o by adding up the weights of all the edges that are directly related to it, as Eq.(7).

$$weight(o) = \sum_{r\omega T_o} N\,(o,r) \quad (7)$$

Routing information, i.e., o has a set of neighbors called T_o and the weight between o and r is called $N(o,r)$. $EFSORP$ proposes an index to evaluate the total essentiality of Ft routing information introduced to each initial Ft of AF, which is described using Eq.(8).

$$essentially(s) = \sum_{o\omega Add(s)} Weight\,(o) \quad (8)$$

The routing information added to the first AF $Fish_s$ are called $Add(s)$. The more necessary a routing information set is, the higher its $essentiality(s)$ value becomes $Add(s)$. A fish with the greatest essentiality value is chosen as the best AF. In the Candidate set's routing information, recently identified routing information is added to the ideal one, and it can be considered a $Candidate$'s essential routing information.

4.4. Assembled Groups

The Algorithm $EFSORP$ depicts the general framework for identifying essential routing information, which is depicted in Algorithm 1. Except for the ideal fish, the remaining putative necessary routing information comes from the Add sets corresponding to the other AF's, which appears as Algorithm 1. The routing information in these Add sets is sorted by weight in descending order. $Candidate$ will have a total of Ft candidate essential routing information where the number of candidate essential routing information needed to be predicted is Ut. Then, the top $(Ut - Ft)$ of ranking routing information are picked and added to the $Candidate$ collection. The connection between Ft and Ut in this research meets Eq (9). As a result, the list of candidates' necessary routing information is divided into two parts: one routing information is added to the ideal fish, and another routing information is added to the other fish at the top of the ranking list in the search and mathematically denoted using Eq.(9).

$$Ft = 1.1 \times \frac{Ut}{T} \quad (9)$$

where T indicates the total number of AF.

4.5. Time-Complexity for Route Selection

EFSORP's time complexity is examined to evaluate the protocol's performance in identifying the best route. Best routes are not good at all times in WSN. For instance, if the best route (i.e., the quality of the route is good) consumes more time to deliver the data to the destination, it is not considered the best route. T is the initial population size of the AF, c is the amount of available essential routing information in each fish, Ft is the number of routing information given to each initial AF, and Ut is the number of essential routing information of candidates, all of which is shown in Algorithm 1. The following chart illustrates the degree of time complexity.

1) The initialization of AF's takes $K(T^*c)$ time.
2) $K(Ft^*T^*c)$ indicates the temporal complexity for adding routing information to AF's by FrB or RB.
3) Finding a portion of potential routing information using the FoB has a temporal complexity of $K((T+1)^*Ft)$.
4) It takes $K\big((T-1)^*Ft + (Ut - Ft)\big)$ to locate the rest of the putative essential routing information using SB.

Input:

(i) WSN network $J = (R, H)$

(ii) Data related to (i) RO,

(iii) Localization of Subcellular

(iv) identified set of essential routing information,

(v) essential routing information count of candidate U_t

(vi) neighbor routing information count included in every fish F_t.

Output:

(i) List of essential routing information that have been identified $Candidate$

Procedure:

1: T number of AF should be created at the beginning

2: Each fish includes m known necessary routing information, hence $Fish_s = (HM_{s1}, HM_{s2}, \ldots . HM_{sc})(s = 1,2, \ldots . T)$

3: Foreach $s = 1$ to F_t

4: Foreach AF $Fish_s$

5: Perform FrB to find the nearest neighbor via applying Eq.(6)

6: Update every individual AF

7: End Foreach

8: End Foreach

9: Follow the below steps to discover the best AF via applying Eq.(8)

10: Update the routing information equivalent to $Candidate$ set;

11: By utilizing Eq.(7), perform SB to discover the remaining routing information that are fully potential

12: $Candidate$ Output

Algorithm 1 Pseudocode of EFSORP

5. SIMULATION SETTING AND PERFORMANCE METRICS

Table 1 Simulation Settings

Bandwidth	100Hz
Initial energy level at nodes	10J
MAC Protocol Version	CW-MAC802.11DCF
Node density	350
Network Boundary Limit	1.5kmx1.5kmx1.5km
Packet size	74bytes
Runtime	300s
Rate of data transmission	10kbps
Sink density	4
Size of packet header	10bytes
Sensor nodes transmission range	≈350m
Transmission power	20W

WSN's protocol simulation and implementation features have long been a mystery to researchers, particularly the network's overall performance. WSN routing protocol analysis can be done using a variety of simulation settings. With NS3 simulations, an analysis of $EFSORP$ is carried out against the existing routing protocols. The NS3 was used to evaluate $EFSORP$ against the current routing protocols. $EFSORP$ and existing routing protocols are analyzed to understand the merits and demerits of the design. According to this research, the NS3 simulator works best with the C++ programming language. Table 1 summarizes the simulation setting used to assess the $EFSORP$ against the existing routing protocols.

5.1. Performance Metrics

- Delay is the time difference between packets received at the destination node and packets transmitted by the source node.
- Packet Delivery Ratio can be defined as the ratio of data packets received at the receiver-end to those transmitted by the sender end.
- Packet Loss Ratio is the ratio of packets that have not reached the destination against the total packets sent by the source node.
- Throughput represents the amount of data that can be delivered from a source to a destination in a particular amount of time.
- Energy Consumption is the entire amount of energy used by a packet to travel destination from the source.

6. RESULTS AND DISCUSSION

6.1. Delay Analysis

The X-axis and Y-axis of Figure 1 are indicated with node density and delay measured in milliseconds. Figure 1 shows that the proposed routing protocol $EFSORP$ has the lowest $delay$ than NFO and $FIS-RGSO$. EFSORP uses optimization strategies to identify the best route among the different available routes in WSN, leading to face minimum $delay$. ECC in $EFOSRP$ assist in meeting minimum $delay$. NFO and $FIS-RGSO$ aim to find the route to the destination in the shortest time. They ignore the quality of the route, which leads them to use a lousy route that causes the route to

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fail and need retransmission. Table 2a summarizes the data values of Figure 1 to aid comprehension, and Table 2b provides the average of *delay* faced by routing protocols.

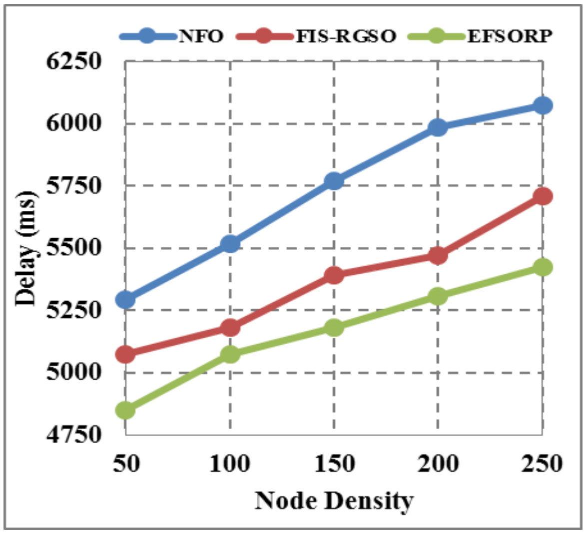

Figure 1 EFSORP vs Delay

Table 2a Delay - Result Values

Node Density	NFO (ms)	FIS-RGSO (ms)	EFSORP (ms)
50	5295	5072	4852
100	5516	5181	5076
150	5772	5394	5181
200	5987	5473	5306
250	6073	5709	5425

Table 2b Average Delay

Routing Protocols	Average Delay (%)
NFO	5728.6
FIS-RGSO	5365.8
EFSORP	5168.0

6.2. Packet Delivery Ratio Analysis

X-axis and Y-axis of Figure 2 are indicated with node density and *Packet Delivery Ratio* measured in percentage. Figure 2 shows that the proposed routing protocol *EFSORP* has better *Packet Delivery Ratio* when compared with *NFO* and *FIS − RGSO*. Route sharing strategy assists *EFSORP* to attain better *Packet Delivery Ratio*. Methods of sharing the identified routes with neighbor nodes are not present in *NFO* and *FIS − RGSO*, which makes them deliver a low number of packets to the destination than *EFSORP*. In short, the greedy mode is utilized for sending the packet to the destination without checking its quality, and it ends with route failure and leads the packets to fail. Table 3a summarizes the data values of Figure 2 to aid comprehension, and Table 3b provides an average of *Packet Delivery Ratio* provided by routing protocols.

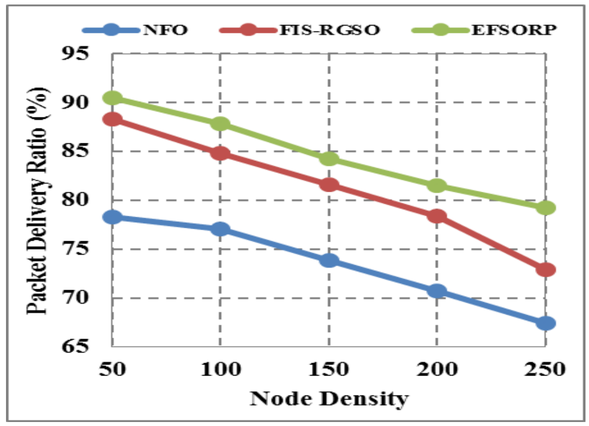

Figure 2 EFSORP vs Packet Delivery Ratio

Table 3a Packet Delivery Ratio - Result Values

Node Density	NFO (%)	FIS-RGSO (%)	EFSORP (%)
50	78.266	88.324	90.504
100	77.102	84.844	87.832
150	73.848	81.568	84.239
200	70.737	78.413	81.504
250	67.396	72.879	79.230

Table 3b Average Packet Delivery Ratio

Routing Protocols	Average Packet Delivery Ratio (%)
NFO	73.470
FIS-RGSO	81.206
EFSORP	84.662

6.3. Packet Loss Ratio Analysis

The X-axis and Y-axis of Figure 3 are shown with node density and $Packet\ Loss\ Ratio$ percentages on each axis. Figure 3 demonstrates that the proposed routing protocol $EFSORP$ outperforms NFO and $FIS-RGSO$ in terms of $Packet\ Loss\ Ratio$. Whenever a packet to the destination faces minimum delay, there is a deficient packet loss level. When the delay increases, then the $Packet\ Loss\ Ratio$ increases automatically. $EFSORP$ identifies the route only based on optimization because it faces minimum delay and low packet loss. Due to sending the packet in low-quality routes, NFO and $FIS-RGSO$ multiple route failure end in high packet loss. For ease of understanding, the data values of Figure 3 have been condensed in Table 4a, and Table 4b provides an average of $Packet\ Loss\ Ratio$ provided by routing protocols.

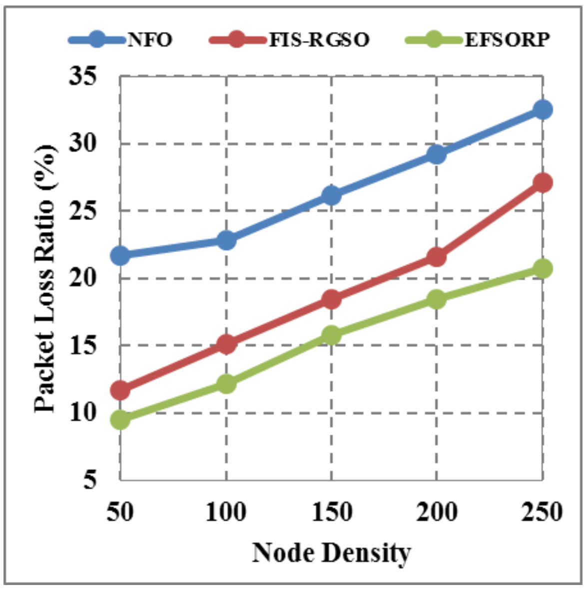

Figure 3 EFSORP vs PLR

Table 4a Packet Loss Ratio - Result Values

Node Density	NFO (%)	FIS-RGSO (%)	EFSORP (%)
50	21.734	11.676	9.496
100	22.898	15.156	12.168
150	26.152	18.432	15.761
200	29.263	21.587	18.496
250	32.604	27.121	20.770

Table 4b Average Packet Loss Ratio

Routing Protocols	Average Packet Loss Ratio (%)
NFO	26.530
FIS-RGSO	18.794
EFSORP	15.338

6.4. Throughput Analysis

Figure 4's X and Y axes are shown with node density and $Throughput$ measured in kbps, respectively. A comparison of $EFSORP$, NFO, and $FIS-RGSO$ demonstrates that $EFSORP$ has the best TP. EFSORP's optimization design adopts maximum node density and identifies the best route to the destination. Optimization in $EFSORP$ assists in attaining better $Throughput$. During the node density increase, like other routing protocols $EFOSRP$ also decreased $Throughput$, but not like other routing protocols, severe decrement in $Throughput$. NFO and $FIS-RGSO$ are designed to perform network operations (i.e., routing) with minimum node density, resulting in minimum $Throughput$ than $EFSORP$, during the increase of node density, NFO and $FIS-RGSO$ face the issue of identifying the best route, which results in maximum delay and minimum $Throughput$. Figure 4's data values are summarized in Table 5a to make it easier to understand, and Table 5b provides the average throughput of routing protocols.

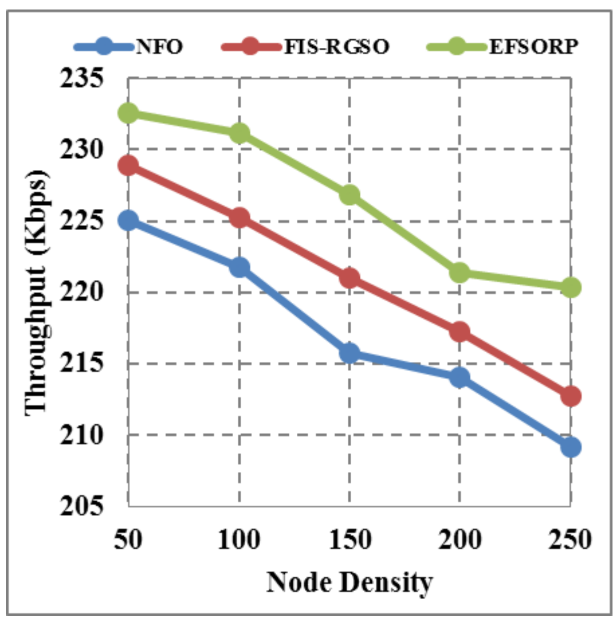

Figure 4 EFSORP vs Throughput

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Table 5a Throughput - Result Values

Node Density	NFO (Kbps)	FIS-RGSO(Kbps)	EFSORP (Kbps)
50	225.097	228.878	232.596
100	221.818	225.214	231.127
150	215.745	221.048	226.830
200	214.039	217.268	221.413
250	209.132	212.782	220.340

Table 5b Average Throughput

Routing Protocols	Average Throughput (Kbps)
NFO	217.166
FIS-RGSO	221.038
EFSORP	226.461

6.5. Energy Consumption Analysis

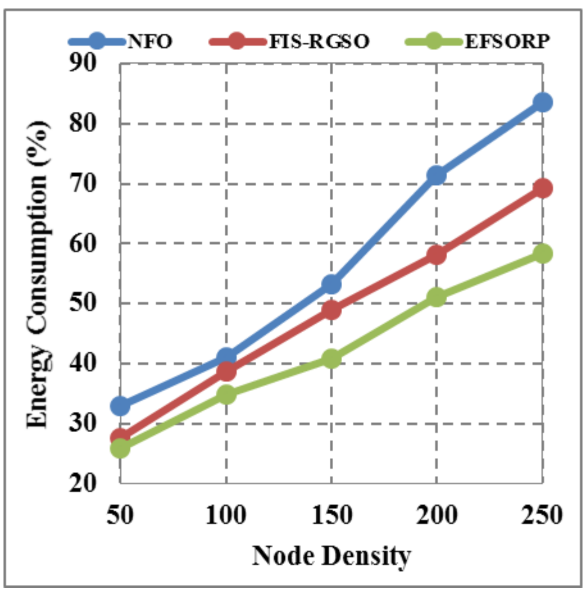

Figure 5 EFSORP vs EC

As seen in Figure 5, the node density and $Energy\ Consumption$ are shown on the X-axis and Y-axis, respectively. It is shown in Figure 5 that $EFSORP$ proposed routing protocol has less $Energy\ Consumption$ than NFO and $FIS-RGSO$. Route and node selection in $EFSORP$ are made using observing and reacting phases. $EFSORP$ utilizes the index to evaluate the total essentiality of the route identified. It makes $EFSORP$ determine the route has a deficient level of congestion leading to delivering the packet in a short duration and saving the maximum energy spent on it. NFO and $FIS-RGSO$ don't concentrate on selecting better nodes in the route. Due to this route failure, multiple retransmission arises in the network at unexpected times, leading to more $Energy\ Consumption$. Table 6a provides an overview of the data in Figure 5 to make it easier to understand, and Table 6b provides the average energy consumed by routing protocols.

Table 6a EC - Result Values

Node Density	NFO (%)	FIS-RGSO (%)	EFSORP (%)
50	32.956	27.569	25.868
100	41.007	38.609	34.924
150	53.240	48.908	40.745
200	71.447	58.245	50.990
250	83.620	69.345	58.340

Table 6b Average Energy Consumption

Routing Protocols	Average Energy Consumption (%)
NFO	56.454
FIS-RGSO	48.535
EFSORP	42.173

7. CONCLUSION

$WSNs$ are a fast-growing area of research and commercialization. $WSNs$ are used in various fields, including scientific, environmental and military. To keep track of changes in the environment, WSN is utilized. Nodes in $WSNs$ collect data about the local circumstances dispersed over a broad region and are set up to connect with the server, gateway and centralized hub. Data received from wireless sensor nodes are shared with other sophisticated platforms for further processing where delay and energy consumption are preferred. A new approach called $EFSORP$ is proposed in this paper to find the essential WSN routes. First, $EFSORP$ randomly selects a portion of known critical pathways as initial artificial fishes of the Poisson process. The nearest neighbor for each fish is then found iteratively by conducting foraging behavior or random activity, and the neighbor is then added to the fish. Finally, following and swarming behavior are applied to identify potential vital pathways. To illustrate the effectiveness of $EFSORP$, this research conducted a series of simulations. Comparing $EFSORP$ to other routing protocols, the findings show that it performs well and it has consumed 42.173% of energy, whereas NFO and FIS-RGSO have consumed 56.454% and 48.535%, respectively. WSN networks will need to include more significant biological information and other sophisticated optimization methods in the future to pinpoint critical routes reliably.

REFERENCES

[1] Pathak and M. G. Bhatt, “Synergetic manufacturing systems anchored by cloud computing: A classified review of trends and perspective,” Mater. Today Proc., 2020, doi: https://doi.org/10.1016/j.matpr.2020.07.435.

[2] T. A. Alghamdi, “Enhanced QoS routing protocol using maximum flow technique,” Comput. Electr. Eng., vol. 89, p. 106950, 2021, doi: https://doi.org/10.1016/j.compeleceng.2020.106950.

[3] T. M. Behera, S. K. Mohapatra, P. Mukjerjee, and H. K. Sahoo, “Work-In-Progress: DEEC-VD: A Hybrid Energy Utilization Cluster-Based Routing Protocol for WSN for Application in IoT,” in 2017 International Conference on Information Technology (ICIT), 2017, pp. 97–100, doi: 10.1109/ICIT.2017.42.

[4] B. Chakraborty and P. Mukherjee, “WAL: An Energy Efficient Hybrid Routing Protocol in Co-operative Communication,” in 2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA), 2018, pp. 1317–1322, doi: 10.1109/ICECA.2018.8474708.

[5] A. Mathur, T. Newe, W. Elgenaidi, M. Rao, G. Dooly, and D. Toal, “A secure end-to-end IoT solution,” Sensors Actuators A Phys., vol. 263, pp. 291–299, 2017, doi: https://doi.org/10.1016/j.sna.2017.06.019.

[6] M. Elappila, S. Chinara, and D. R. Parhi, “Survivable Path Routing in WSN for IoT applications,” Pervasive Mob. Comput., vol. 43, pp. 49–63, Jan. 2018, doi: 10.1016/j.pmcj.2017.11.004.

[7] J. John, G. S. Kasbekar, and M. S. Baghini, “Maximum lifetime convergecast tree in wireless sensor networks,” Ad Hoc Networks, vol. 120, p. 102564, 2021, doi: https://doi.org/10.1016/j.adhoc.2021.102564.

[8] M. C. Domingo and R. Prior, “Energy analysis of routing protocols for underwater wireless sensor networks,” Comput. Commun., vol. 31, no. 6, pp. 1227–1238, 2008, doi: https://doi.org/10.1016/j.comcom.2007.11.005.

[9] T. N. Sugumar and N. R. Ramasamy, “mDesk: a scalable and reliable hypervisor framework for effective provisioning of resource and downtime reduction,” J. Supercomput., vol. 76, no. 2, pp. 1277–1292, Feb. 2020, doi: 10.1007/s11227-018-2662-5.

[10] G. D. O’Mahony, K. G. McCarthy, P. J. Harris, and C. C. Murphy, “Developing novel low complexity models using received in-phase and quadrature-phase samples for interference detection and classification in Wireless Sensor Network and GPS edge devices,” Ad Hoc Networks, vol. 120, p. 102562, 2021, doi: https://doi.org/10.1016/j.adhoc.2021.102562.

[11] A. Arena, P. Perazzo, C. Vallati, G. Dini, and G. Anastasi, “Evaluating and improving the scalability of RPL security in the Internet of Things,” Comput. Commun., vol. 151, pp. 119–132, 2020, doi: https://doi.org/10.1016/j.comcom.2019.12.062.

[12] D. Gopika and R. Panjanathan, “Energy efficient routing protocols for WSN based IoT applications: A review,” Mater. Today Proc., 2020, doi: https://doi.org/10.1016/j.matpr.2020.10.137.

[13] J. Ramkumar and R. Vadivel, “Performance Modeling of Bio-Inspired Routing Protocols in Cognitive Radio Ad Hoc Network to Reduce End-to-End Delay,” Int. J. Intell. Eng. Syst., vol. 12, no. 1, pp. 221–231, 2019, doi: 10.22266/ijies2019.0228.22.

[14] J. Ramkumar and R. Vadivel, “Meticulous elephant herding optimization based protocol for detecting intrusions in cognitive radio ad hoc networks,” Int. J. Emerg. Trends Eng. Res., vol. 8, no. 8, pp. 4549–4554, 2020, doi: 10.30534/ijeter/2020/82882020.

[15] J. Ramkumar and R. Vadivel, “CSIP—cuckoo search inspired protocol for routing in cognitive radio ad hoc networks,” in Advances in Intelligent Systems and Computing, 2017, vol. 556, pp. 145–153, doi: 10.1007/978-981-10-3874-7_14.

[16] J. Ramkumar and R. Vadivel, “Multi-Adaptive Routing Protocol for Internet of Things based Ad-hoc Networks,” Wirel. Pers. Commun., pp. 1–23, Apr. 2021, doi: 10.1007/s11277-021-08495-z.

[17] J. Ramkumar and R. Vadivel, “Bee inspired secured protocol for routing in cognitive radio ad hoc networks,” INDIAN J. Sci. Technol., vol. 13, no. 30, pp. 3059–3069, 2020, doi: 10.17485/IJST/v13i30.1152.

[18] J. Ramkumar and R. Vadivel, “FLIP: Frog Leap Inspired Protocol for Routing in Cognitive Radio Ad Hoc Networks,” in International Conference on Recent Trends in Engineering and Material Sciences (ICEMS - 2016), 2016, p. 248.

[19] J. Ramkumar and R. Vadivel, “Intelligent Fish Swarm Inspired Protocol (IFSIP) For Dynamic Ideal Routing in Cognitive Radio Ad-Hoc Networks,” Int. J. Comput. Digit. Syst., vol. 10, no. 1, pp. 1063–1074, 2020, doi: http://dx.doi.org/10.12785/ijcds/100196.

[20] J. Ramkumar and R. Vadivel, “Improved frog leap inspired protocol (IFLIP) – for routing in cognitive radio ad hoc networks (CRAHN),” World J. Eng., vol. 15, no. 2, pp. 306–311, 2018, doi: 10.1108/WJE-08-2017-0260.

[21] J. Ramkumar, C. Kumuthini, B. Narasimhan, and S. Boopalan, “Energy Consumption Minimization in Cognitive Radio Mobile Ad-Hoc Networks using Enriched Ad-hoc On-demand Distance Vector Protocol,” 2022 Int. Conf. Adv. Comput. Technol. Appl., pp. 1–6, Mar. 2022, doi: 10.1109/ICACTA54488.2022.9752899.

[22] P. Menakadevi and J. Ramkumar, “Robust Optimization Based Extreme Learning Machine for Sentiment Analysis in Big Data,” 2022 Int. Conf. Adv. Comput. Technol. Appl., pp. 1–5, Mar. 2022, doi: 10.1109/ICACTA54488.2022.9753203.

[23] O. C. Ghica, C. Nita-Rotaru, G. Trajcevski, and P. Scheuermann, “Security of electrostatic field persistent routing: Attacks and defense mechanisms,” Ad Hoc Networks, vol. 36, pp. 270–295, 2016, doi: https://doi.org/10.1016/j.adhoc.2015.07.016.

[24] S. Gopinath, K. Vinoth Kumar, P. Elayaraja, A. Parameswari, S. Balakrishnan, and M. Thiruppathi, “SCEER: Secure cluster based efficient energy routing scheme for wireless sensor networks,” Mater. Today Proc., vol. 45, pp. 3579–3584, 2021, doi: https://doi.org/10.1016/j.matpr.2020.12.1096.

[25] Y. Yang, X. Shi, Q. Ma, Y. Li, X. Yin, and Z. Wang, “Path stability in partially deployed secure BGP routing,” Comput. Networks, vol. 206, p. 108762, 2022, doi: https://doi.org/10.1016/j.comnet.2022.108762.

[26] Y. Lin, Y. Mao, Y. Zhang, and S. Zhong, “Secure deduplication schemes for content delivery in mobile edge computing,” Comput. Secur., vol. 114, p. 102602, 2022, doi: https://doi.org/10.1016/j.cose.2022.102602.

[27] R. Fotohi, E. Nazemi, and F. Shams Aliee, “An agent-based self-protective method to secure communication between UAVs in unmanned aerial vehicle networks,” Veh. Commun., vol. 26, p. 100267, 2020, doi: https://doi.org/10.1016/j.vehcom.2020.100267.

[28] T. Yang, X. Xiangyang, L. Peng, L. Tonghui, and P. Leina, “A secure routing of wireless sensor networks based on trust evaluation model,” Procedia Comput. Sci., vol. 131, pp. 1156–1163, Jan. 2018, doi: 10.1016/J.PROCS.2018.04.289.

[29] G. A. E. Satish Kumar and P. Rama Devi, “A novel proactive routing strategy to defend node isolation attack in MANETS,” Mater. Today

RESEARCH ARTICLE

Proc., 2021, doi: https://doi.org/10.1016/j.matpr.2020.11.361.

[30] M. A. Cheema et al., "Blockchain-based secure delivery of medical supplies using drones," Comput. Networks, vol. 204, p. 108706, 2022, doi: https://doi.org/10.1016/j.comnet.2021.108706.

[31] M. P. Lokhande and D. D. Patil, "Secured energy efficient machine -to-machine communication for telerobotic system," Informatics Med. Unlocked, vol. 26, p. 100731, 2021, doi: https://doi.org/10.1016/j.imu.2021.100731.

[32] N. Nasser and Y. Chen, "SEEM: Secure and energy-efficient multipath routing protocol for wireless sensor networks," Comput. Commun., vol. 30, no. 11, pp. 2401–2412, 2007, doi: https://doi.org/10.1016/j.comcom.2007.04.014.

[33] G. Rathee, A. Sharma, R. Kumar, F. Ahmad, and R. Iqbal, "A trust management scheme to secure mobile information centric networks," Comput. Commun., vol. 151, pp. 66–75, 2020, doi: https://doi.org/10.1016/j.comcom.2019.12.024.

[34] M. Kuchaki Rafsanjani and H. Fatemidokht, "FBeeAdHoc: A secure routing protocol for BeeAdHoc based on fuzzy logic in MANETs," AEU - Int. J. Electron. Commun., vol. 69, no. 11, pp. 1613–1621, 2015, doi: https://doi.org/10.1016/j.aeue.2015.07.013.

[35] A. Chowdhury and D. De, "FIS-RGSO: Dynamic Fuzzy Inference System Based Reverse Glowworm Swarm Optimization of energy and coverage in green mobile wireless sensor networks," Comput. Commun., vol. 163, pp. 12–34, 2020, doi: https://doi.org/10.1016/j.comcom.2020.09.002.

[36] X. Zhang, X. Lu, and X. Zhang, "Mobile wireless sensor network lifetime maximization by using evolutionary computing methods," Ad Hoc Networks, vol. 101, p. 102094, 2020, doi: https://doi.org/10.1016/j.adhoc.2020.102094.

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