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RESEARCH ARTICLE

Whale Optimization Routing Protocol for Minimizing Energy Consumption in Cognitive Radio Wireless Sensor Network

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Abstract – Cognitive Radio Wireless Sensor Networks (CR-WSN) works on nodes that are dependent on batteries. A critical problem with CR-WSN is a lack of energy, especially in situations such as warfare where rapid and aggressive action is needed. The battery level of nodes degrades CR-WSN performance. Researchers face significant difficulty developing a routing protocol for CR-WSN, and that obstacle is posed by energy consumption to deliver a packet. A substantial number of nodes reside in CR-WSN. Every node in CR-WSN is constrained by battery. To minimize network cost, it should be feasible to have the routing protocol used for CR-WSN to be energy efficient. This paper proposes an optimization-based routing protocol, namely Whale Optimization Routing Protocol (WORP), for identifying the best route in CR-WSN to minimize the delay and lead to network efficiency. WORP draws inspiration from the behaviors of whales as they forage, similar to their hunting activity. By prioritizing residual energy and the total energy of the nodes in the route, WORP encourages energy-aware route selection. WORP is examined via simulation with NS2 against current routing protocols. Benchmark performance metrics are used to assess the effectiveness of WORP. Results make an indication that WORP has superior performance than current routing protocols in CR-WSN.

Index Terms – WSN, CR-WSN, Routing, Optimization, Delay, Energy Consumption.

1. INTRODUCTION

QoS is a group of technologies that guarantee the dependability of a network so that it can reliably handle critical applications and traffic when network capacity is at a premium. This is handled through the use of differentiated QoS techniques, which assign handling and capacity to various traffic flows. Assigning the order in which packets are treated and allocating bandwidth to that traffic flow is possible with this feature and it is most expected in sensor network [1], [2].

1.1. Traditional Wireless Sensor Network

Wireless Sensor Network (WSN) communicates by use of events. Nodes of WSN produce a massive amount of data when an event gets occurs. Many WSN nodes attempt to access a channel as soon as an event happens in a dense network setting. Currently, a growing number of sensitive and critical actions have been surveilled and watched by WSNs. As the number of heterogeneous WSNs increases, the delay-sensitive data waits a long time. Usually, wireless sensors are placed in areas that are difficult to access [3]. Away from us, the WS nodes are a self-organizing entity, and the duration of their existence is crucial as well. WSNs use WS nodes positioned at random places throughout the sensor field, with a node-to-node distance typically set to only a few meters. A Sink Node (SN) or base station acts as the center point for the data acquisition process. SN transfers the data obtained to the user base over any communication medium such as the internet or by some other route. WSNs work inside the ISM (industrial, scientific, and medical) band, utilizing several other popular communication technologies. WSNs' overall performance is compromised by cohabitation in the ISM band [4], [5].

Radio-Frequency (RF) technologies that employ (i) high transmit power, (ii) extensive deployments, and (iii) vast coverage areas may adversely affect the overall performance of WSNs when utilized in contiguous frequency bands [6]. In the discussion of WPANs in an unauthorized frequency band, you may learn more about how they cohabit with some other wireless devices in the unlicensed frequency band. WPAN (i.e., Wireless personal area networks) operate in an unlicensed frequency spectrum alongside other wireless devices. A WSN device is also an interferer on occasion. The creative ways to minimize interdependencies include using several diversity channels, namely [7], [8]: (i) frequency, (ii) time, and (iii) location. Due to problems with unlicensed bands, the concept of coexistence has been the topic of much investigation.

1.2. Cognitive Radio WSN

Cognitive Radio WSN (CR-WSN) is a special ad-hoc network category and performs its actions in a distributed manner. Nodes (i.e., Sensor devices) in the network are enabled with cognitive radio features [9]. CR-WSN has certain things that vary from both general cognitive radio networks (CRN) and common WSN. Usually, CR-WSN is formed with a massive number of WSN nodes that are spatially distributed[10]. Nodes need cognitive capacity at a high level towards adaption and cooperation to complete a task. Nodes focus not only on data transmission but also on saving licensed users in accessing the network without any disturbances [11]. When an event occurs in the network, nodes sense the same and collaboratively communicate with neighbor nodes. The communications in CR-WSN are multi-hop and dynamic. With CR-WSN, it is possible to enhance the utilization of spectrum, which will result in achieving the primary objective of increasing the efficiency and lifetime of the network [12].

Identifying the best route in CR-WSN is entirely different and the strategies that are suitable and developed for other networks. In CR-WSN, routes are identified depending on the availability of spectrum where sensing plays a vital role in determining spectrum availability [13] and it acts as an extra challenge while comparing with traditional and ordinary WSN. To perform a routing process in CR-WSN, node coordination is mandatory till the entire data gets transmitted to the destination. Sensing the spectrum and transmitting the data cannot be done simultaneously by a node [9], [14]. Hence, the development of a protocol for routing in CR-WSN is always a challenge. Failing to detect the presence and absence of primary users provides a way for inadequate utilization of spectrum and too much interference [15], [16]. All the nodes in CR-WSN are limited to battery power and their tasks are [5], [17]: (i) sensing of the spectrum (ii) discovering of routes (iii) transmitting data packets. Hence, there arises a need for a protocol that effectively manages and utilizes the available power for finding the best route for data transmission.

1.3. Difference Between WSN and CR-WSN

Understanding the difference between WSN and CR-WSN assists the readers in understanding the importance of this research article and its contribution. Table 1 differentiates the WSN and CR-WSN.

CHARACTERISTICS	WSN	CR-WSN
Medium	ISM Bands	ISM or Licensed Bands
Availability	Immediate Available	Not available immediately
Deficiency of Bandwidth	Very few times	Most times
Suitability	Less-crowded ISM band	Over-crowded ISM band
Decision support system (DSS)	Self DSS	Cognitive DSS
Utilization of Whitespace	No	Yes
Rate of Route Failure	High	Less

Table 1 WSN Vs CR-WSN

1.4. Applications of CR-WSN

Among different applications, some of the CR-WSN applications are:

a) Public safety applications widely used by the military.

b) Indoor applications and home appliances for health care.

c) Applications that are highly bandwidth-intensive.

d) Live video surveillance systems.

e) Vehicular networks include road networks, trains, and subways.

f) Purpose-driven sensing.

1.5. Problem Statement

Today's CR-WSN applications are much more sophisticated and it ends with more consumption of energy. Data-intensive applications create vast volumes of data (i.e., Big Data). The reliability of data sharing depends on the use of wireless communication technologies. When choosing a wireless data transmission method, it is critical to ensure the dependability of data flow between nodes while also accounting for the energy required. In designing CR-WSN routing protocols, a complex set of properties are taken into consideration. There are numerous factors to consider when implementing routing protocols for CR-WSN, and many of them are pretty distinct.

1.6. Motivation

Nodes in CR-WSN are enabled with a battery, and they cannot be replaced. When the battery life and network functioning are impacted, nodes dead are inevitable where routing strategy alone assists in prolonging the battery life and conserving power. CR-WSN falls under the category of the multi-hop network in which data are transferred from sensor nodes that are positioned farther down the route. They are particularly susceptible to failure when connecting sensor nodes. Network reliability is jeopardized whenever there is a connection breakdown. This issue ignites our curiosity and also inspires us to develop robust routing protocols.

1.7. Objective

Both the latency and the network lifespan must be minimized to maximize network efficiency. The paper proposes a Whale Optimization Routing Protocol (WORP) for CR-WSN to improve route discovery and route selection strategy to deliver data packets successfully.

1.8. Organization of the Paper

The current section has briefed the introduction of WSN and CR-WSN, the difference between WSN and CR-WSN are discussed, problem statement, motivation and objective of the research are also discussed. State-of-the-art is discussed in section 2 with advantages and disadvantages. Whale Optimization Routing Protocol is proposed in section 3. Metrics used for measuring the performance and simulation settings are provided in section 4. Discussion of results is provided in section 5. The conclusion of the research and future scope are discussed in section 6.

2. LITERATURE REVIEW

“Geographic Multipath Routing (GMR)” [18] intends to find different node-disjoint routes in the network. It identifies a node to forward the data packet depending on the distance. The handshake strategy has been to send and receive data. It concentrates more on selecting stable routes. “Clustering Routing Algorithm (CRA)” [19] is proposed to enhance the packet delivery ratio in heterogeneous WSN. To perform clustering of nodes in network, a wolf optimization algorithm is applied. CRA transforms nodes into an integer to improve the logistics function value and it is used to find the route in heterogeneous WSN.

Dynamic clusters are created to enhance the routing. “Decision-Theoretic Framework (DTF)” [20] is proposed for large-scale WSN to monitor and track network events. It aims to provide trade-offs energy and privacy of source node location. DTF seeks to detain the configurations of different routing protocols for various network-specific applications.

“Cross-Layer Adaptive Multipath Routing (CLAMR)” [21] is proposed to identify a non-correlated route for the transmission of multimedia data. It is dependent on the MAC layer and the route that is selected. A Wake-up scheduling strategy is applied for efficient data transmission. Mathematical analysis has been conducted to check the effect of the wake-up schedule. “Wolf Prey Inspired Protocol (WPIP)” [22] is proposed to minimize the packet drop in cognitive radio networks. WPIP is developed by following the natural swarm behavior of wolves towards hunting for prey and it is applied in network to find the optimum route to destination but most energy is consumed by nodes to share the identified routes with each other. “Multi Adaptive Routing Protocol (MARP)” [23] aims to minimize the delay by optimally finding the best route during route failure. MARP adopts swarming nature of fishes to finding route in cognitive radio networks. It initially gathers nodes information regarding the available energy and location. Nodes location are synchronized periodically to ensure the reliability of routes.

“Dissimulation Routing Protocol (DRP)” [24] is a load balancing protocol designed for mobility-enabled WSN. It intends to decrease the energy level consumed for delivering the packet. It is designed to function only in the happening of a networking event. It performs mining on the history of mobility to identify stable routes. It attempts to exchange the control messages by minimizing the overhead. “Energy Efficient Clustering (EEC)” [25] is proposed to enhance nodes lifetime by reducing the energy spent for finding the best route. Hierarchical routing strategies are utilized for creating clusters at different parts of the network. Cluster heads are assigned based on node and energy level configuration, where its primary role is to identify the best route and share with its member nodes and share with other clusters. “Multisource Multipath Routing (MMR)” [26] used 2D Gaussian distribution for deploying the relay nodes in an optimum manner. It aimed to increase the routing performance two times by applying Gaussian distribution. Routes are selected based on the length and residual energy where multimedia data are transmitted. “Dynamic Directional Routing Protocol (DDRP)” [27] is proposed to adopt the mobility of sensor nodes and achieve an energy efficiency route. It aims to detain data flow in the network by optimizing the path to the sink node. Preferences are given to the node's residual energy to assist in identifying the suitable route.

“Fault-Tolerant Routing Algorithm (FTRA)” [28] is proposed to identify the route using particle swarm optimization. Before performing the optimization, it creates intra-clusters and inter-clusters. Along with residual energy and distance, ranges of communication are computed for identifying the best routes. Routes are reconstructed during the failure. “Grid-Cycle Routing Protocol (GCRP)” [29] aims to minimize the update overhead faced in the head node. It partitions the network into different grids and shares network-related information with all grids. Neighbor grids are updated using two different strategies, namely interior cycle and exterior cycle. “Neuro-Fuzzy based Routing Algorithm (NFRA)” [30] attempts to minimize the packet drop during link failure. It applies the neuro-fuzzy concept to enhance the network performance where the primary intention is to avoid the fast energy depletion in nodes. Machine learning algorithms are used to classify routes more accurately. “Efficient Routing Protocol (ERP)” [31] attempts to minimize the energy utilization at nodes while it transmits the data packet to the destination. It applies virtual multi-ring infrastructure by broadcasting the location of sink nodes. Sink nodes identify routes and it shares with nodes by avoiding network collisions. Optimization [23], [32]–[36] has also created an impact in multiple fields, including networking. Bio inspired optimization is utilized in networking to find a suitable route to the destination. Table 2 compares the advantages and disadvantages present in the previous methods discussed in this section.

Previous Methods	**Advantages**	**Disadvantages**
Geographic Multipath Routing (GMR) [18]	Improved network lifetime	More power consumption
Clustering Routing Algorithm (CRA) [19]	Finding a stable route to the destination	Reduced network lifetime
Decision-Theoretic Framework (DTF) [20]	Better trade-off between energy and privacy	Theoretical and cannot be applied in real-time or even in simulation
Cross-Layer Adaptive Multipath Routing (CLAMR) [21]	Detection of more number of routes	Reduced latency
Wolf Prey Inspired Protocol (WPIP) [22]	Minimized Packet Drop	Maximized energy consumption
Multi Adaptive Routing Protocol (MARP) [23]	Optimum route selection	Increased delay
Dissimulation Routing Protocol(DRP) [24]	Balanced load across the network	Unexpected failure of routes
Energy Efficient Clustering (EEC) [25]	Identification of alternate routes in short duration during failure	More consumption of energy
Multisource Multipath Routing (MMR) [26]	Ideal cum deterministic distribution of identified routes to neighbors.	Increased control packets
Dynamic Directional Routing Protocol (DDRP) [27]	Maintenance of minimum distance routes	Poor optimization of routes
Fault-Tolerant Routing Algorithm (FTRA) [28]	Reconstruction of routes on failure	Unbalanced load and unexpected failures of route
Grid-Cycle Routing Protocol (GCRP) [29]	Sharing of location update to neighbors	Pervasive approach
Neuro-Fuzzy based Routing Algorithm (NFRA) [30]	Better route classification	Low-level energy management at nodes
Efficient Routing Protocol (ERP) [31]	Enhanced network lifetime	Low-level good put

Table 2 Comparison of Previous Methods Advantages and Disadvantages

3. WHALE OPTIMIZATION ROUTING PROTOCOL

3.1. Natural Characteristics of Whale

Whale Optimization Algorithm (WOA) falls under the category of the meta-heuristic algorithm family. The natural characteristics of Humpback Whales (HW) are used in the design and development of WOA. When a humpback whale pursues its prey at sea, it makes bubbles in the form of a wheel (i.e., a circle).

A pilot study [37] found that humpback whales practiced bubble netting techniques to lure their prey 12 meters below the surface but then quickly burst their bubbles into spheres to float up to the surface.

3.2. Prey Encircling

WORP assumes that the response to the current objective (i.e., prey) must be good enough to achieve a plausible solution. HW initially observes the prey's location and it will encircle the same. Once after defining the hunting agent, the other members will synchronize their locations to the preeminent hunting agent. WORP incorporates the encircling mechanism, Eq.(1) and Eq.(2) are used for encircling the prey.

$$Q = \|P \cdot Y^*(u) - Y(u)\| \tag{1}$$

$$y(u+1) = Y^*(u) - F \cdot Q \tag{2}$$

where F and P represents the co-efficient vectors, u indicates the count of the current iteration, Y^*denotes the location of optimal solution identified in the so-far completed iterations and $Y(u)$ is the vector used to represent the position. $\|\cdot\|$ indicates the absolute integer value and $\cdot$ represents the constituent multiplication.

Eq.(2) is developed to update the location of the searching agent in the currently identified best solution which will assist more in encircling the prey. It is to be shown that Y^* need updation at the end of each iteration, only if a better solution is found. Co-efficient of F and P vectors are computing using Eq.(3) and Eq.(4):

$$F = (2 \times b \times rv) - b \tag{3}$$

$$P = 2 \times rv \tag{4}$$

Where b indicates encircling component, which is linearly reduced from 3 to 0 during the overall iterations, rv represents a random vector falls in$[0,1]$.

3.3. Strategy of Bubble-Net Attack

To mathematically express HW's behavior of bubble-net attack, two different methods are modeled: (i) encircling using shrinking method and (ii) location update using the logarithmic spiral method.

3.3.1. Encircling Using Shrinking Method

This method is attained by linearly minimizing the value of vector $b$from 3 to 0 using Eq.(3). It is noted that reducing the importance of vector b will result in the value of vector F. Alternatively, the same can be said as vector F is a random number that falls between $-b$ and $+b$, where b is minimized from 3 to 0 in all the iterations. Setting a random value for vector F that falls between -1 and $+1$ will characterize the new location of the searching agent from its unique site to its current preeminent location.

3.3.2. Location Update using Logarithmic Spiral Method

Initially, HW starts searching for their prey and performs distance calculation from its current location to the prey's location. Every HW needs to update its current location based on spiral flight route methodology and is mathematically expressed as Eq.(5) and Eq.(6).

$$Q' = \|Y^*(u) - Y(u)\| \tag{5}$$

$$Y^*(u+1) = Q' \cdot exp^{c \times m} \cdot Sin\left(\frac{2 \times m}{\pi}\right) + Y^*(u) \tag{6}$$

where Q' represents the distance between prey's location and so far found best solution location, m is a random value that falls in $[-1,1]$, $c$denotes a constant value that describes the shape of logarithmic spiral and $\cdot$ represents the constituent based multiplication.

It is to be noted that HW swims around a circle towards prey, but at the same time, its movement will be in a logarithmic spiral model. For easy understanding, it is assumed that the position of HW will be updated either by using Eq.(2) or Eq.(6) and it is expressed as Eq.(7)

$$Y^*(u+1) = \begin{cases} Y^*(u) - F \cdot Q & if\ z > 1/2 \\ Q' \cdot exp^{c \times m} \cdot Sin\left(\frac{2 \times m}{\pi}\right) + Y^*(u) & if\ z < 1/2 \end{cases} \tag{7}$$

Where z indicates the random value that falls between 0 and 1. Additionally, HW have added the behavior of seeking prey randomly and its mathematical model is discussed in Section 3.4.

3.4. Seeking for Prey

In reality, all HW will randomly seek prey when they intend to follow other's solutions. At this stage, WORP concentrates on search space and entice search agent to pursue in the faraway distance for a better solution. The vector F is utilized to explore a deep scan for prey to be higher than 1 or lesser than -1. In contrast to the exploitation era, the location of a search agent in the discovery period would update following a randomly chosen search agent other than the best agent identified so far. WORP utilizes the vector F that hasa value greater than 1 to attain solutions globally and avoid local optimum solutions where the same can be mathematically expressed in Eq.(8) and Eq.(9).

$$Q = \|P \cdot Y_{rv} - Y\| \tag{8}$$

$$Y(u+1) = Y_{rv} - F \cdot Q \tag{9}$$

Where Y_{rv} is selected from the currently identified random location vector.

3.5. Levy Flight

WORP utilizes Levy flight to diversify the search agents to explore better search space, which avoids local minima's accomplishment. This indicates achieving the enhanced trade-off between exploring and exploiting. In short, WORP utilizes a levy flight strategy to synchronize HW location after its update, where Eq.(10) expresses the same.

$$Y(u+1) = Y(u) + (\delta \cdot sign[rv - 0.5]) \otimes Levy \tag{10}$$

where $Y(u)$ represents jth whale or position of vector F at the iteration u, δ represents a randomly selected number that is uniformly distributed, $\otimes$ indicates N array circled times operator, rv is a random number value that falls in $[0,1]$. It is to be noted that $sign[rv - 0.5]$ has three values alone, which are $-1,0$ and 1. Eq.(10) follows the random walk strategy and it assists WORP in exploring search space efficiently because the distance present in each step will have maximum value. Eq.(11) expresses the levy flight in a random walk.

$$Levy \simeq v = \frac{1}{s^h}, \quad 1 \le h \le 3 \tag{11}$$

Eq.(12) is utilized to imitate $h$stably by random step generation with length w having similar behavior of levy flight.

$$w = \frac{\gamma}{|v|^{1 \div \alpha}} \tag{12}$$

Where w represents the length of step used in levy flight, $Levy(h)$ follows $h = 1 + \alpha$.

Algorithm 1 provides the detailed information regarding the functioning of the proposed routing protocol WORP.

```
Population Initialization $Y_p(p = 1,2,3,\dots,q)$
Compute search agent fitness
$Y^*$= preeminent searching agent
$\boldsymbol{while} t < maximum\_iteration)$
    $\boldsymbol{for}$ individual searching agent
        perform updation for b, F, P, m and z
        $\boldsymbol{if}$ (z < 0.5)
            $\boldsymbol{if}(\|F\| < 1)$
                update location of current searching agent using Eq.(2)
            $\boldsymbol{else\ if}(\|F\| > 1)$
                choose random searching agent $(Y_{rv})$
                update location of current searching agent using Eq.(9)
            $\boldsymbol{end\ if}$
        $\boldsymbol{else\ if}(z > 0.5)$
            update location of current searching agent using Eq.(6)
        $\boldsymbol{end\ if}$
    $\boldsymbol{end\ for}$
    $\boldsymbol{for}$every searching agent
        update location of current searching agent applying levy flight
    $\boldsymbol{end}$
    Verify whether any searching agent went outside the target searching area, and rectify it
    Compute every searching agent's fitness
    Perform update for $Y^*$ if any better solution is found
    u=u+1
$\boldsymbol{end\ while}$
return $Y^*$
```

Algorithm 1 WORP

4. PERFORMANCE METRICS AND SIMULATION SETTING

NS3 is used to simulate the proposed protocol WORP and the settings used are tabulated in Table 3. The proposed protocol WORP evaluated against current routing protocols, namely WPIP, CLAMR and MARP using standard metrics [38, 39] and it is defined below:

- ✓ **Throughput:** It denotes the data quantity transferred from the sender node to the receiver node in given time duration.
- ✓ **End-to-End Delay:** It represents the actual time the packet takes to travel to its destination. The delay will grow with the extra distance.
- ✓ **Packet Delivery Ratio:** It refers to the total number of packets delivered to the destination node versus the total number of packets sent by the sender node.

✓ **Energy Consumption:** It denotes the consumption of energy to deliver the packet from source to destination.

Parameter	Value	Unit
Count of runs	5	-
Count of nodes	100 to 500	Node
Speed of Nodes	25	Meter/second
Size of Queue	50	packet
Area of Simulation	2500 x 2500	Meter^2
Model of Mobility	Random Way Point	-
Size of Packet	512	Byte
Range of Transmission	256	Meter
Type of Traffic	CBR	-
Energy at Initial Level	15	Joules
Power Consumption for Receiving	0.025	Joules
Power Consumption for Sending	0.0015	Joules
Time of Simulation	100	seconds

Table 3 Simulation Settings

5. RESULTS AND DISCUSSION

5.1. Throughput

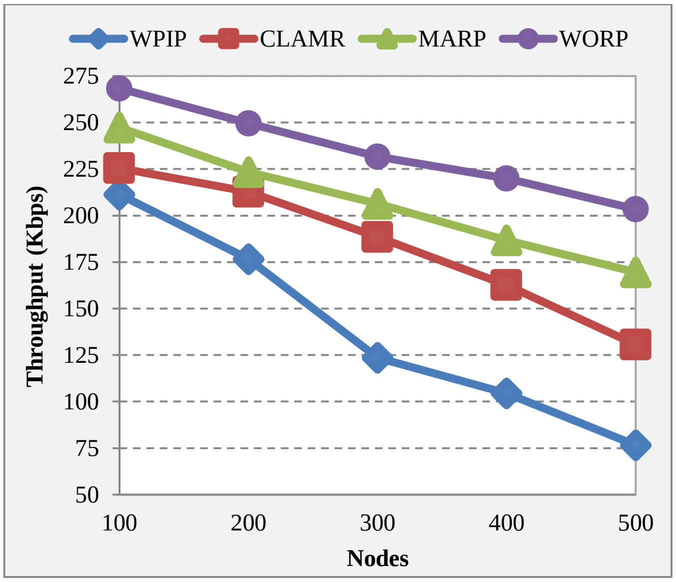

Figure 1 Throughput Vs WORP

In Figure 1, the x-axis is indicated with the count of nodes, and the y-axis is marked with throughput measured using kilobits per second. WORP in Figure 1 shows superior throughput compared to the current routing protocols, namely, WPIP, CLAMR, and MARP. Levy flight strategy in WORP leads a way to attain better throughput by finding a better route where the existing routing protocols have concentration only on finding route but not on its quality. Numerical result values of Figure 1 are provided in Table 4, and average throughput attained by proposed and existing routing protocols are provided in Table 5.

Protocols / Nodes	WPIP	CLAMR	MARP	WORP
100	211.407	225.444	247.411	268.366
200	176.605	212.805	223.396	249.501
300	123.516	188.397	206.416	231.726
400	104.394	162.57	186.673	219.917
500	76.6119	130.583	169.495	203.471

Table 4 Throughput Results

Protocols	Average Throughput
WPIP	138.507
CLAMR	183.96
MARP	206.678
WORP	234.596

Table 5 Average Throughput

5.2. Packet Delivery Ratio

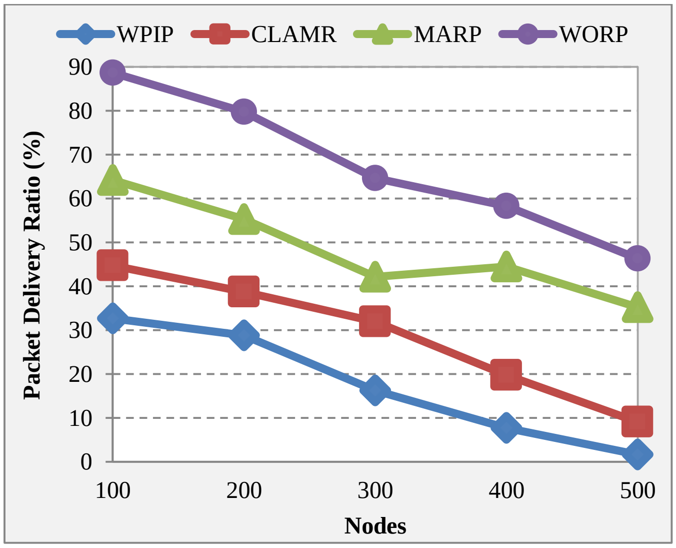

Figure 2 Packet Delivery Ratio Vs WORP

In Figure 2, the x-axis is indicated with the count of nodes, and the y-axis is marked with the packet delivery ratio measured in percentage. In Figure 2, the packet delivery ratio of WORP is better than that of the existing routing protocols, namely, WPIP, CLAMR, and MARP. Node location update strategy of WORP assist in handling the route failure that leads to increased delivery of packets. Existing routing protocols select the routes based on availability, i.e., without checking the updated location of intermediate nodes routes are chosen, which provides a way to increased packet drop. Numerical result values of Figure 2 are provided in Table 6, and the average packet delivery ratio attained by proposed and existing routing protocols are provided in Table 7.

Protocols Nodes	WPIP	CLAMR	MARP	WORP
100	32.661	44.692	54.221	58.670
200	28.789	38.723	49.277	55.750
300	16.239	22.919	34.195	47.682
400	7.659	19.734	25.513	36.313
500	1.621	9.100	12.195	28.331

Table 6 Packet Delivery Ratio Results

Protocols	Average Packet Delivery Ratio
WPIP	17.394
CLAMR	28.834
MARP	48.280
WORP	67.549

Table 7 Average Packet Delivery Ratio

5.3. Delay

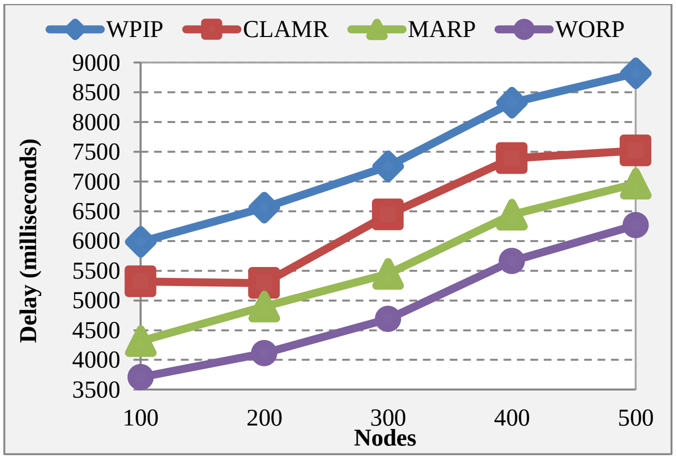

Figure 3 Delay Vs WORP

In Figure 3, the x-axis is indicated with the count of nodes, and the y-axis is marked with delay measured in milliseconds. In Figure 3, the delay of WORP is lower than that of the existing routing protocols, namely, WPIP, CLAMR, and MARP. Search agent concepts present in WORP randomly reform search for the best route and provide a convenient solution during the route error or route failure. Sequential search is a time-consuming process in any network and existing routing protocols follow it to face route failure, which leads to increased delay. Numerical result values of Figure 3 are provided in Table 8, and the average delay attained by proposed and existing routing protocols are provided in Table 9.

Protocols Nodes	WPIP	CLAMR	MARP	WORP
100	5988	5317	4318	3707
200	6564	5291	4896	4115
300	7255	6442	5450	4691
400	8328	7392	6441	5664
500	8821	7521	6964	6264

Table 8 Delay Results

Protocols	Average Delay
WPIP	7391.2
CLAMR	6392.6
MARP	5613.8
WORP	4888.2

Table 9 Average Delay

5.4. Energy Consumption

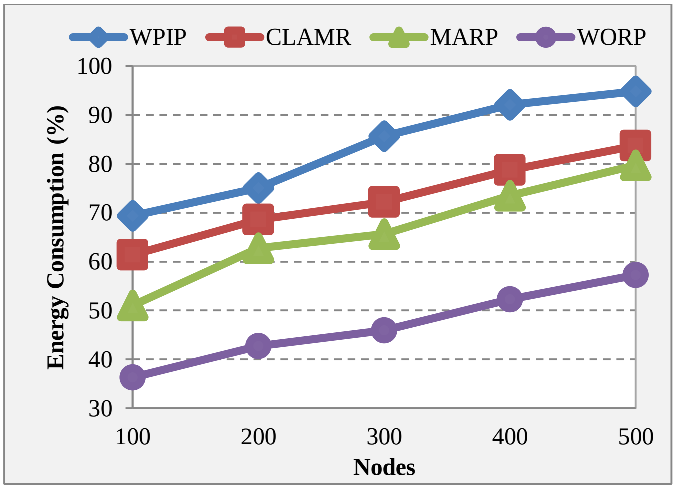

Figure 4 Energy Consumption Vs WORP

In Figure 4, the x-axis is indicated with the count of nodes, and the y-axis is marked with energy consumption measured in percentage. From Figure 4, it is easy to understand that WORP consumes minimum energy to deliver data packets to the destination. The shrinking method of WORP leads to minimizing energy consumption in discovering the new routes and selecting the best route that fits the data that is going to get transmitted. WORP ensures the fitness of the route before data transmission. In existing routing protocols, the fitness of the route is not analyzed before sending the data, which leads to multiple route errors and data transmission errors. Numerical result values of Figure 4 are provided in Table 10, and the average energy consumption of proposed and existing routing protocols are provided in Table 11.

Protocols Nodes	WPIP	CLAMR	MARP	WORP
100	69.393	61.359	51.049	36.338
200	75.102	68.602	62.736	42.736
300	85.703	72.207	65.665	45.927
400	92.103	78.732	73.512	52.271
500	94.808	83.703	79.700	57.292

Table 10 Energy Consumption Results

Protocols	Average Delay
WPIP	83.421
CLAMR	72.921
MARP	66.532
WORP	46.913

Table 11 Average Energy Consumption

6. CONCLUSION

Quality of Service represents collection of technologies and methodologies that work on any network to ensure its ability to consistently execute maximum priority enabled applications and congestion under restricted network capacity. This paper has proposed a QoS enabled routing protocol that is inspired by the foraging behavior of whales namely Whale Optimization Routing Protocol (WORP). The natural characteristic of whales is applied in CR-WSN to find the most appropriate route to the destination. Routes are selected based only on fitness which leads to decreased delay. WORP is evaluated in NS3 against existing routing protocols, namely WPIP, CLAMR and MARP. Results make a shred of evidence that WORP has better performance in CR-WSN than other routing protocols. The future scope of this routing protocol can be ensembled with machine learning techniques to attain even better performance.

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