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BES-OEERP: Bald Eagle Search Inspired Optimized Energy-Efficient Routing Protocol for IoT assisted WSNs

Soni Chaurasia*, Sheetal^, Prabhjot Kaur+, and Kamal Kumar#

Abstract – *WSN technology is widely used in IoT to gather data from several sensors and transmit it to a central server or BS for processing and analysis. IoT applications that demand real time data collecting from dispersed sources are made possible by WSN. Many wireless sensor devices in a WSN are built to run at low power, increasing battery life. Due to the need for extra processing power, connection, and potentially complex data analytics, integrating IoT capabilities might occasionally increase power usage. As a result, sensors may have shorter battery lives. To overcome the issue related to energy efficiency, the researched proposal on Bald Eagle Search inspired Optimized Energy-Efficient Routing Protocol for IoT-assisted WSNs (BES OEERP) is based on the Bald Eagle Search algorithm. It minimizes the information transmission by using an optimal route, sending optimal data to the BS, and comparing BES OEERP's effectiveness with the results of competing routing protocols on critical factors like average energy consumption and delay. The outcomes show that the BES-OEERP performs significantly more energy efficiently than its rivals.*

Keywords – Routing, Bald Eagle Search algorithm, and Energy Efficiency.

1. INTRODUCTION

WSNs are crucial because they give the end user an excel lent understanding of the environment. Numerous studies are being done on the fundamental issue of how much energy sensor networks use. As shown in Figure 1, the WSN is utilized to send and receive data over a wide area. The sensors communicate and handle data transmission [1]. A sensor is equipment that perceives physical attributes or changes in its environment and turns this information into a measurable electrical signal or data. Sensors typically consist of several vital components, such as Sensing Element, Transducer, Signal Conditioning Circuitry, Power Supply, and Processing. They are enhancing the lifetime of sensor nodes in WSN. Therefore, it's crucial to offer a means of overcoming the limitations of routing protocols while using less energy [3]. The forwarder node sends the data via opportunistic routing [4]. Information is stored and sent by the forwarder node. Furthermore, it performs better than a conventional routing system. This strategy keeps the message alive and distributed throughout the network till a more appropriate destination or node is identified if a suitable node cannot be located. Many studies have investigated meta-heuristic algorithms to solve the forwarder based routing problem.

*Department of CSE, Galgotias University, Gr. Noida, India.

^Department of CSE, SGT University, Gurugram, India.

+School of Computing, DIT University, Dehradun, India.

#Depratment of IT, IGDTUW, New Delhi, India.

Email: soni28sep@gmail.com; sheetalmahlan@gmail.com; info.prabh@gmail.com; kamalkumar@igdtuw.ac.in

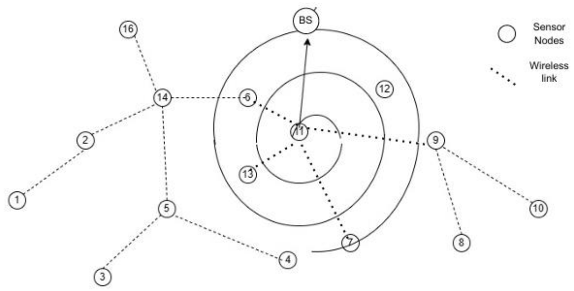

Fig. 1. Architecture of IoT assisted WSN

2. RELATED WORK

The most important research topics are increasing network longevity and boosting power efficiency in WSNs. To address the issues with routing, Implementing an energy-efficient solution is essential. Different routing protocols, including metaheuristic and meta-heuristic-based opportunistic routing, are processed by routers to build networks through which data is forwarded.

2.1 Metaheuristic Protocol

MOCRAW [5], based on an optimized CH selection meta-heuristic routing approach, is intended to reduce node energy use and speed up data transfer. By utilizing the Dragonfly Algorithm (DA), which bases its choices on both local and global search optimization, MOCRAW eliminates isolated nodes and provides loop-free routing. Previous research explored clustering and routing techniques to reduce network energy usage. The current work presents a novel EAFTC-RIS [6] approach based on this explanation. Select CHs uses a Moth Flame Optimization, and the routing method uses Social Spider Optimization. Cluster, routing, and fault-tolerance techniques increase network lifetime with different input parameters. ECRP-UCA [7] enhanced

ACO methods. The network is segmented using a batch-based clustering approach. It addresses problems with fault tolerance, optimum local solutions, and unequal load balancing. The heuristic function's foundation is the distance, next-hop node energy, and NPPRN. The NPPRN prevents the algorithm from quickly selecting the most suitable local optima and improves its ability to determine the most effective optimum solution. HMBCR [8] uses WWO-HC-based routing and BSO-LD to determine the best set of CHs. The hot spot problem in WSNs can be resolved using metaheuristic-based uneven clustering techniques. This work intends to provide an ACI GSO hybrid method [9] since the CHS is the main contributor. For the WSNs' energy efficiency, choose the optimal CH by the routing protocol. The glow worm's position is enhanced by randomly dispersing many glowworms around the search region. The ACO algorithm frequently focused on how ants gather food by emulating their behavior. Using a hybrid optimization method [10], which considers PSO and GA techniques, respectively, for each job, "CHS" and "BS" mobility-based packet transmission" are optimized. For optimize CH selection based on GA and sink mobility optimization path based on PSO. The moFIS-BFO model [11], based on the BFO and moFIS. The moFIS-BFO protocol determines each node's likelihood of turning into a CH chosen by using degree difference, residual energy, and distance between nodes & BS. The BFO chooses the appropriate CHs every round while considering the calculated node possibilities. A priority ranking approach is used to manage queues in cluster clusters to prevent congestion and wasteful packet usage. In MIFA [12], the nodes transfer the packet to the BS by applying the built-in ring structure. The radius of the ring is predetermined when it is established. If the ring node begins to die, the neighbor node is placed automatically. This automatic role switching is best based on the defined multi-objectives, such as the distance from network centers, energy, and the distance between the neighbors. In this HS-CSS [13] technique, the HS is used for local search, while the CSS is used for global search. CSS and HS were employed successfully to fix the routing issue. The CSS algorithm's initialization is the foundation of Level 1 of the HS-CSS algorithm, the ranking of charged particles (CP), and the formation of charged memory (CM). Level 2's foundations include searching, solution creation, CP position correction, CP ranking, CP exclusion, and CM updating. Criterion control is terminated at level three. Repeat the operation at the search level until the termination criterion is reached. CSO-UCRA [14], the CH node selection and routing method based on the CSO approach, CHs selection based on the resulting CH proficiency function. These steps are described in more depth below. The choice of CHs is the first step, followed by routing. First, the CH selection process initializes all particles with random sensor nodes as CHs. Each pair of randomly chosen particles has been pitted against one another in the second step. Then, based on the fitness value in CH selection, one of each pair is deemed the winner. Next, the winner is immediately moved on to the following step while the loser is updated. The modified looser was then transmitted with the updated particle to the upcoming generation. The value of m is estimated in this phase. In the event that it drops below m/2, raise m's value and go through each step again until the termination condition is satisfied. The routing algorithm follows the identical process flow after collecting the CHs to provide an effective routing path. Hybrid ACO-BOA [15] minimizes energy consumption and maximizes the network lifetime. The residual energy, neighbor distance, node degree, BS distance, and node significance are all crucial in deciding which CH to choose, which is done using the BOA. The ACO determines the best route between the CH and the BS, considering distance, residual energy, and node degree. In a hybrid HFAPSO [16], to identify the optimum CH option, an algorithm analyzes the residual energy and node distance. HFAPSO has been researched for instantaneous applications requiring dense sensor networks. CPMA [17] is divided into two parts and aims to maximize the lifetime of WSN. The first step is to choose an online cluster leader and coordinate communication. The HS algorithm and fitness function are used to pick the CH. The second step is to choose an offline parameter optimization using the ABC algorithm. FPU-DA [18] is a new clustering approach that considers four key factors—energy, latency, distance, and security—to identify the best cluster head. Additionally, position updates in Dragonfly were replaced by a new hybrid algorithm called Firefly to help choose the best CHs. This algorithm combines the ideas of dragonfly and firefly.

Table 1. Notation and their meaning.

Notation	Meaning
ACI-GSO	ACO integrated Glowworm Swarm Optimization
DA	Dragonfly algorithm
GSO	Glowworm Swarm Optimization
PSO	Particle Swarm Optimization
CH	Cluster head
ASFO	Adaptive sunflower optimization approach
ACO	Ant colony optimization
FA	Firefly algorithm
FPU-DA	FA- dragon fly algorithms
CHS	Cluster Head Selection
BS	Base station
ACO	Ant Colony Optimization
ACO-BOA	Butterfly Optimization Algorithm with ACO
MW-LEACH	Multiple Weight- LEACH
GA	Genetic algorithm
CSS	Charged System Search
HFAPSO	Hybrid FA with PSO
MOORP	Meta-heuristic-based Optimised Opportunistic Routing Protocol for WSNs

2.2 Meta-Heuristic Opportunistic Protocol

A meta-heuristic-based MOORP [19] is focused on the optimal forwarder selection using route optimization. The node's Euclidian distance and remaining energy are taken into consideration while selecting the forwarder node with the maximum efficiency. The Dragonfly algorithm determines the route between the forwarder and the destination. The CORP [20] is based on the VWAE-ASFO model. To reduce data error rates for ideal data collecting and path traversal. Initially detecting the data, the VWAE contains all the network data in the subsequent data-gathering phase. The ASFO, which aims to lessen data inaccuracy and model complexity, updates the weight of VWAE. It is suggested that EBAR [21] use an ant-based pragmatic forwarding method for determining routes and heuristic update matrices. WSNs are paying increasing attention to optimal forwarder selection, or OFS. The purpose of OFS is to use the best method to transfer redundant data to the sink while utilizing minimal electrical power. BMOOR[22] is a Bat algorithm-based opportunistic routing technique based on forwarding the packet through the multi-hop and achieving global optimization; with the help of this technique, it Enhances network lifetime.

2.3 Research Gap

The comprehensive analysis of prior literature has shown several study gaps, including:

• WSN network lifespan extension is a challenging issue that needs additional research.

• Dynamic CH selection and opportunistic routing have seldom been combined in experiments.

• There aren't many meta-heuristic-based methods for choosing the best forwarder.

• A hybrid meta-heuristic approach is used for both exploration and exploitation.

The paper's remaining portions are listed as follows: Section III explores the energy model and BES algorithm in more detail, along with how they relate to opportunistic routing. The simulation setup and metrics for the simulation parameter are discussed in Section IV, the results and analysis are presented in Section V. Section VI gives our work's originality and effectiveness as a conclusion.

3. METHODOLOGY

The aim of the suggested work is to choose a forwarder node and move data to the next node. Using opportunistic routing over a network, the BS receives data from the forwarder. The BES algorithm is employed based on exploration and exploitation for the decision-making method. WSN's primary concern is energy-efficient communication. For that reason, a workable solution was found by developing a WSN opportunistic routing protocol.

3.1 Energy Model

According to BES-OEERP, the total energy absorbed by the network and dispersed by each forwarder during a single round.

$$\xi_{round} = (\xi_{tx} + \xi_{rx}) \qquad (1)$$

The approach for calculating energy usage uses a complete transmission.

The amount of energy used in transmission $\xi_{tx(x,d)}$ and reception $\xi_{rx(x,d)}$ obtained using Equations (2) and (3) can be used to determine the required necessary energy for sending x-bits of the packet.

$$\xi_{tx}(x,d) = \begin{cases} \xi_{ele}*x+\xi_{amp}*d^2, d<d_0 \\ \xi_{ele}*x+\xi_{amp}*d^4, d\geq d_0 \end{cases} \qquad (2)$$

$$\xi_{rx}(x,d) = x * \xi_{ele} \qquad (3)$$

In this equation, ξ_{ele} stands for the energy used for each bit, ξ_{amp} for the transmit amplifier, and d_0 for the threshold distance that determines whether one state is present or absent.

$$d_0 = \sqrt{\xi_{ele}}/\sqrt{\xi_{amp}} \qquad (4)$$

3.2 Bald Eagle Search Approach

Inspired by nature, a meta-heuristic optimization algorithm imitates bald eagles' intelligent social behavior or hunting tactics while looking for fish. There are three phases of searching for BES:

• An eagle chooses the area with the highest concentration of prey during the first step of the process, known as "selecting a spot."

• The eagle's second step involves searching in space, inside the predefined region, for prey.

• After deciding on the best hunting spot, the eagle moves from the optimal position it selected in the second step to the third stage, which is known as swooping. The best place to begin swaying is where all subsequent movements should be focused.

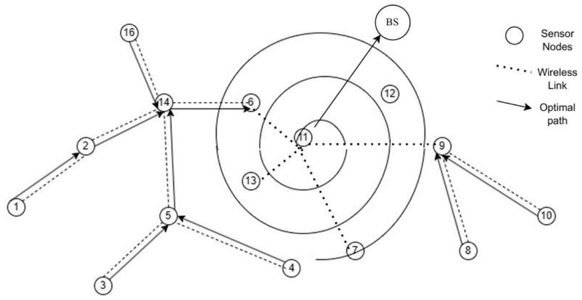

Fig. 2. Optimized Routing Protocol

3.3 BES-OEERP Protocol

Bald Eagle Search inspired Optimized Energy-Efficient Routing Protocol for IoT-assisted WSNs (BES-OEERP).

The symbol and its meaning are defined in Table II. The steps for utilizing the BES using opportunistic routing are as follows:

• Step-1: Arbitrary nodes are placed throughout a wireless network to gather environmental data.

• Step-2: The forwarder node sends Sense data to the next node. It focuses mainly on looking for food and locating where they can find prey by Equation (5).

$$M_{\text{new },i} = M_{\text{best }} + \alpha * r\left(M_{\text{mean }} - M_i\right) \quad (5)$$

• Step-3: Determining the residual energy using equations (2 and 3).

• Step- 4: The forwarder node uses the search stage strat egy to send the crucial message to the neighbor while reducing network overhead utilizing Equations (6), (7), and (8).

$$M_{i,\text{ new }} = M_i + y(i) * (M_i - M_{i+1}) + x(i) * (M_i - M_{\text{mean }}) \quad (6)$$

where

$$x(i) = \frac{xr(i)}{\max(|xr|)}, \quad y(i) = \frac{yr(i)}{\max(|yr|)} \quad (7)$$

$$xr(i) = r(i) * \sin(\theta(i)), \quad yr(i) = r(i) * \cos(\theta(i)) \quad (8)$$

$\theta(i) = a * \pi *$ rand(c),
$r(i) = \theta(i) + R *$ rand (d),
where a=[5,10] and R=[0.5, 2]

• Step-5: After choosing a forwarder node, utilize equation (11) to decide which forwarder node, based on the swooping stage, is the best.

$$M_{i,\text{ new }} = \text{rand } * M_{\text{best }} + X + Y \quad (9)$$

Where X=$x1(i) * (M_i - c1 * M_{\text{mean }})$, Y=$y1(i) * (M_i - c2 * M_{\text{best }})$

• Step-6: Determine the node's dynamic energy at every iteration or round.

As shown in Figure 2, sensor nodes 2,5,14,9, and 6 become forwarder nodes, and 11 becomes the best forwarder; optimal data is sent data to BS through opportunistic routing.

4. SIMULATION PARAMETER

4.1 Simulation Setup

The BES-OEERP protocol simulates by NS2 simulator. Table III represents the simulation parameters.

4.2 Simulation Metrics

The Bald Eagle Search inspired Optimized Energy-Efficient Routing Protocol for IoT-assisted WSNs (BES-OEERP) based on AEC and delay simulation metrics.

1) Average energy consumption (AEC): Calculating the AEC of nodes involves weighing the remaining power by the average operating period rate. Energy used for timers, transmission processing, and reception is all included. The communication node expends this much energy.

$$AEC = \sum(\xi_{N[i]} * \tau_{ss} - \xi_{ele} * \tau_{sb}) \quad (10)$$

2) Delay: A data packet's routing delay is the amount of time it takes to travel over a WSN from its source to its destination. Delay is calculated in Milliseconds (ms).

$$AD = \frac{\sum_{i=1}^{N}(T_r - T_s)}{N} * 1000 \quad (11)$$

Table 2. Symbol and their meaning.

Symbol	Meaning
α	Controlling parameter for changes in position range [1.5,2]
r	Random number [0,1]
M_{best}	Best forwarder
M_{mean}	All information from the previous points M_i
$\xi_{N[i]}$	Initial energy
τ_{ss}	The start time
τ_{sb}	The stop time for transmission
AD	Average delay
N	Number of delivered packets
T_r	Reception time
T_s	Send time

Table 3. Simulation parameter.

Parameter	Value
Node	10,30,50,70,100,120
Packet Size	1000Bytes
rxPower	0.78
txPower	0.58
Area	500m2
Propogation	Two way
Initial energy	The stop time for transmission
Queue	PriQueue
Node deploy	random
Sensor power	0.015
Mobility	Static

5. RESULT AND ANALYSIS

Given that the theoretical and simulation values are nearly equal, it implies. When a packet collides as simulation time increases, the average energy usage gradually falls until a certain threshold. It takes the most incredible energy to deliver each packet to the BS efficiently as more packets are lost due to collisions. As a result, BES-OEERP works better than previous systems since it reduces energy use and unnecessary transmissions. Due to packet loss, most current routing protocols are relatively energy-intensive; however, By sending data via the most efficient path, BES-OEERP optimizes data transmission, reduces packet collisions, and boosts energy efficiency

5.1 AEC

As seen in Figure 3, the LEACH method yielded worse outcomes even though it could provide higher-excellent energy dispersion while keeping the minimum energy usage. For residual energy, the MOCRAW algorithms performed better than LEACH simultaneously. Regarding energy consumption, the suggested BES-OEERP model fared better than the alternatives. As shown in Figure 3, the BES-OEERP is more energy efficient as compared to LEACH And MOCRAW, is 78%, and 2%.

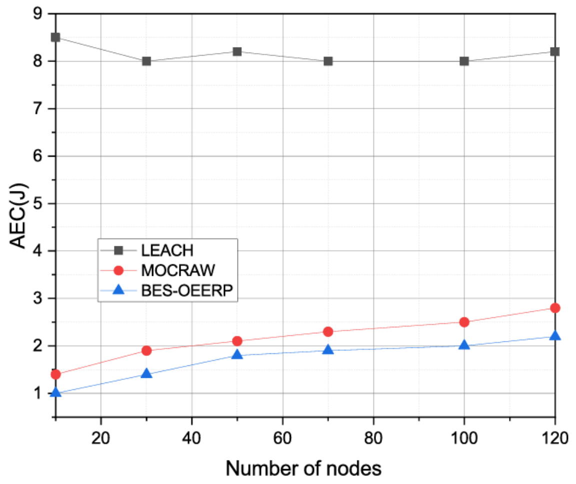

Fig. 3. AEC vs number of nodes.

5.2 Delay

The peer protocols have a higher delay as compared to BES-OEERP. The suggested protocol reduces time by determining the minimum & maximum distance and using the best forwarder in each node. using the chain implementation technique to save time requires using distance information. As shown in Figure 4, the BES-OEERP is more energy efficient than LEACH and MOCRAW, which is 32% and 4%.

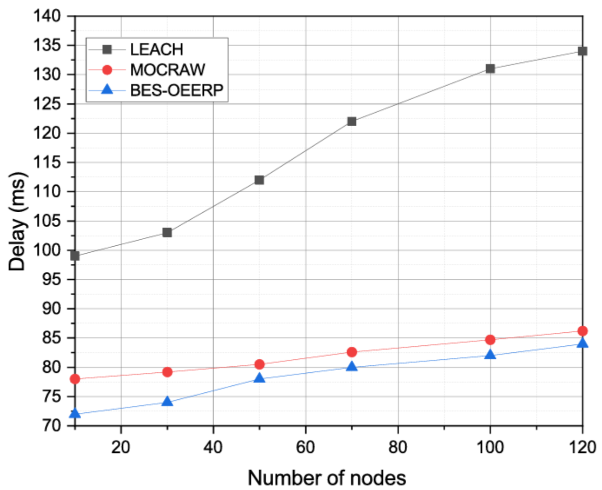

Fig.4. Delay vs number of nodes.

6. CONCLUSION

A power supply and other supporting components are paramount when constructing a sensor node. They may gather cumulative information, detect their surroundings, and broadcast it to adjacent nodes or BS. They are scattered throughout the entire area. Data and routing are optimized by the sensor node using a meta-heuristic method. The BES method enhances search optimization for NP-hard problems. To encompass both local and global best solutions. The outputs are uniform for ideal solutions, and the approximations are accurate. As a result, the sensor network's lifespan, coverage area, and energy efficiency are all boosted.

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