ISSN: 2229-6948(ONLINE)
DOI: 10.21917/ijct.2021.0365

ENHANCED LION SWARM OPTIMIZATION ALGORITHM WITH CENTRALIZED AUTHENTICATION APPROACH FOR SECURED DATA TRANSMISSION OVER WSN

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Abstract

Securing data accuracy in WSNs (Wireless Sensor Networks) is a major problem. Aggregation techniques for improving accuracy in data processing have been gaining attention of scholars, recently. Existing security systems using singular paths for transmission of data have delays in transmissions while being open to intrusions. Moreover, increased computational overheads and processing time increases the delay of data transmission in the given networks. To overcome these issues, this work proposes ELSOA-CA (Enhanced Lion Swarm Optimization Algorithm and Centralized Authentication) method. This method focuses on an optimal, faster and energy efficient data transmissions while ensuring accurate decisions on tomato crops. Multipath routing introduced in the proposed method ensures faster data transmissions by selecting optimal forwarder nodes which satisfy the constraints of delay and energy. Optimal forwarder node selection is done using ELOSA algorithm. Data transmissions are secured by centralized authentication involving third party nodes. Each and every node in a region gets registered with the authentication node where a node's genuineness is checked the node is allowed into the forwarder node list, used for data routing. CA (Centralized Authentication) enhances the security level of data transmissions over WSN multi path routing. ELSOA-CA framework's simulation results provide higher throughputs, reduced energy consumptions, improved network lifetimes PDRs (Packet Drop Ratios) and lesser delay times.

Keywords:

Wireless Sensor Networks, Enhanced Lion Swarm Optimization Algorithm, Centralized Authentication Approach, Secured Data Transmission, Multipath Routing

1. INTRODUCTION

WSNs are made of thousands of sensor nodes which communicate amongst themselves and are used in environment monitoring like humidity, temperature, air pollution and seismic event detections. WSN sensor nodes have processing, sensing and communication units. They transmit data using radio transceivers to a centralized collection point called Base Station (BS) [1] [2]. WSN nodes are powered by non-rechargeable batteries and their energy resources are limited. Though the distance between the sink and nodes is long, high node density and multi-hop models compensate this distance during communications. Each node passes collected information to neighboring nodes in the network.

Harvested energy is not-based on a time factor and varies thus predicting energy is a crucial task. The low energy levels of sensor nodes can cause serious impacts such as packet drop, data reliability and network lifetime. Many approaches have proposed management of node activities like node's sampling rate or energy harvests for effectively improving network lifetimes and performances [3]. WSN routings approaches-based on energy harvests have been widely proposed. For Example, an intelligent approach-based on harvested energy using maximum point tracking algorithm powered by solar power was proposed in [4], while the study in [5] presented Harvesting Aware Speed Selection (HASS) by implementing an iterative process with dynamic voltage scaling to maintain the network energy consumption levels and saving harvested energy. Similarly, geographical routing-based approaches have also been adopted widely in which 1-hop neighbor nodes are selected for data transmissions.

The study in [6], presented Easy-Go approach using geographical routing-based packet forwarding for energy management. Duty-cycle-based approaches have also been introduced to improve the network lifetime [7]. The aforementioned techniques are-based on the different type of forwarding schemes. Schemes-based on packet forwarding, sleep-awake scheduling etc. have been addressed using cross-layer-based communication [8]. Though these schemes provide better lifetime performances, maintaining energy consumptions and harvesting energy is important and hence development of harvested energy management is a crucial task

In general, the energy harvesting process is mainly categorized into two main categories as energy harvesting from natural resources such as wind, thermal and vibration and energy-rich sources using wireless energy transfer mechanism. As discussed before, WSNs adopted for various applications can use energy harvesting techniques for improving network lifetime as energy harvesting techniques provide a continuous supply of energy to the sensor nodes, keeping them alive [9].

This assumption culminated in [10] where energy harvesting was used for packet forwarding. The study's proposed scheme created gradient-based node's relative position. This clustering model chose cluster heads-based on a value computed using storage and relative distances. The model also proposed a distribution of energy where the cluster heads shared traffic loads amongst themselves. Their scheme reduced cluster head reformation frequencies by reducing overheads. The Fig.1 depicts the structure of a WSN.

Current WSNs use multi-path schemes to enhance network performances as they can be accomplished by efficient utilization of resources. These schemes have also been formulated in wired and WSNs for reliability/fault-tolerant data transmissions, QoS (Quality of Service) and congestion controls. Multi-path routing schemes need to consider several constraints like power limitations, minimized computational capability and low memory resources. Moreover, the limitations in short-range radio communications like fading effects and interferences add challenges to multi-path protocol designs [11]. Existing multi-path schemes of traditional WSNs like Ad hoc networks have issues directly-based on low energy resources.

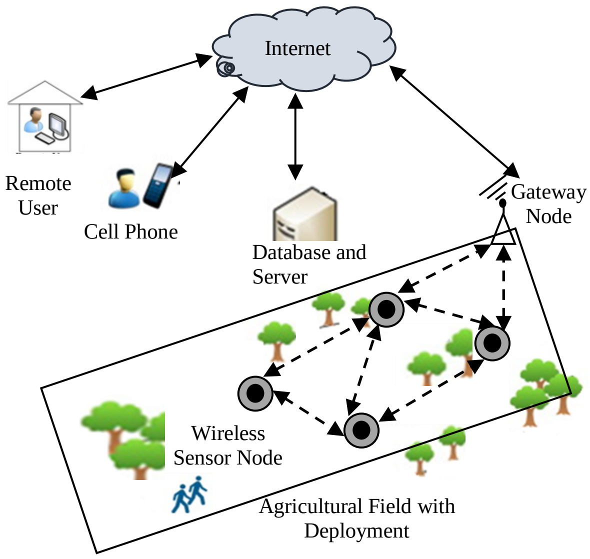

Fig.1 Structure of WSN

Due to the aforesaid reasons, the main aim of this work is optimizing the routing in WSNs with quick data transmissions. The next section is a review of related literature while section three discusses the proposed ELSOA-CA framework. Experimental results and the proposed scheme's performance are analyzed in section four. The paper concludes with section five.

2. RELATED WORK

Nguyen et al. [12] discussed the advantages of the WSN and the contribution of energy-harvesting schemes to improve the communication performance of the network. The authors focused on the advantages of energy harvesting schemes for IoT (Internet of Things)-based applications. The main advantage of the energy harvesting technique is that the energy source replacement issues can be resolved by providing the continuous power supply with the help of ambient sources of energy. Various types of approaches have been introduced recently to overcome the issue of energy harvesting such as the development of an efficient model for power generation and energy-aware routing protocols etc. The hardware implementation can cause a higher cost of implementation hence routing protocols are considered as a promising solution to address these issues. In this work, authors focused on the energy harvesting and developed energy-harvesting-aware- routing for heterogeneous IoT-based WSN applications.

Tang et al. [13] also focused on the IoT-based application scenario for energy-harvesting in WSN. In this work, a Trust-Based Secure Routing approach is developed which helps to improve the security and maximizes the available energy for energy-harvesting for sensor networks. According to this process, source and sink communicate using disjoint paths and hence the data can be verified separately to ensure the security. Furthermore, a traceback approach is also implemented which uses a probability-based approach to identify the malicious node. This probability-based approach helps to cop-up the issue of security and battery levels.

Fractional clustering was used by Sirdeshpande et al. [14] in their study. Their optimization algorithm called Fractional Lion (FLION) used clustering for finding energy efficient routing paths. Their proposed schema improved network's lifetime and energy in their rapid selection of Cluster Heads (CHs). Their proposed FLION clustering algorithm used a fitness function for computing intra/inter cluster distances, CH energy, delays and node's energy while formulating multi-paths for routing. Their fitness function quickly identified cluster centroids for efficiency in discovering routing paths. They evaluated their proposed FLION clustering with other clustering algorithms like Fractional LSDAR, Low Energy Adaptive Clustering Hierarchy (LEACH), Artificial Bee Colony (ABC) and Particle Swarm Optimization (PSO)-based clustering algorithms. Experimentations of FLION showed that the scheme maximized WSN's lifetime.

Conditions conducive to routing were specified by Arya et al. [15]. The study detailed on ideal conditions required for feasible bandwidth usage. Their bandwidth estimations were optimized for saving energy using Ant Colony Optimization (ACO). Their work showed the performances of energy aware routing protocols without optimizations to compute WSN energy utilizations with estimated bandwidths. ACO optimized energy consumptions and computed optimized bandwidths for routing paths. Network performance was analyzed using bit error rates. Their experimental results showed ACO optimizations provided feasible and efficient routing solutions that improved WSN's lifetime.

Lion Swarm Optimization (LSO) was used by Guo et al. [16] in their work which attempted to improve global exploration capabilities using multi-agent structures. Their scheme combined LSO and multi-agent system for improving efficiency and accuracy in searches and by using group/environment information in a recursive fashion for economic load distribution of power. Their experimentation results showed that their proposed system significantly improved efficiency and robustness of power distribution, proving its effectiveness.

The work by Chang et al. [17] used Elliptic Curve Cryptography (ECC) in WSNs for improving authentications for protocols. The proposal initialized systems, registered nodes and authenticated nodes. A multiplication operation and sensor ID hash value were used for authenticating nodes. Nodes also authenticated other nodes using the scheme to enhance WSN security.

ECC was also used by Shankar et al. [18] to implement data exchanges or secure distribution of keys which paralleled RSA security with a lesser key size. The scheme also proposed mutual authentications between sink nodes and base station servers. The sink's ID, a random registered and timestamp values were used for the bi-authentication mechanism. The proposed scheme could detect replay attacks and enhanced security in healthcare-based WSN devices.

3. PROPOSED METHODOLOGY

The proposed methodology is aimed at helping agriculture by proposing ELSOA-CA framework which ensures accuracy of decisions regarding tomato crops using WSN sensor data. The overall methodology of ELSOA-CA framework is depicted in Fig.2.

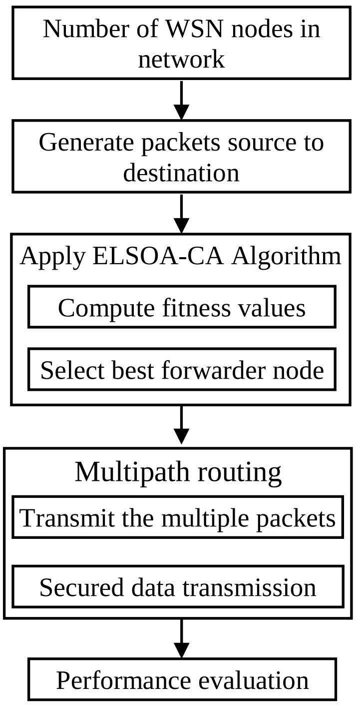

Fig.2. ELSOA-CA Framework - Block Diagram

3.1 SYSTEM MODEL

In this scenario, WSN is composed of N different sensor nodes, which can sense, observe and obtain data. Each node in the given network are immobile and power controlled [19]. All WSN nodes execute sensing tasks regularly with constant information transmissions to the BS which handles nodes within/outside its range. Nodes can be CHs or plain sensor nodes. The network formation is shown in Fig.3.

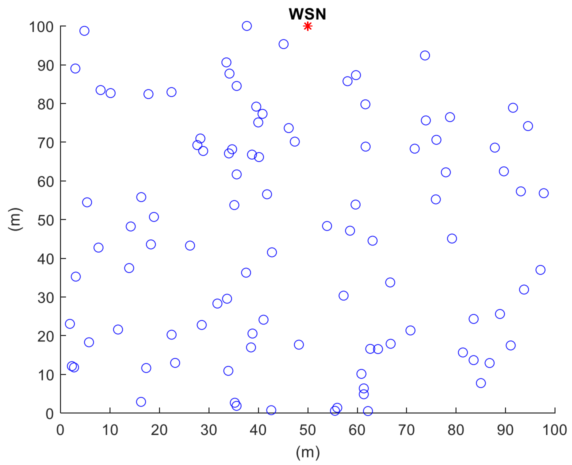

Fig.3. Network Formation

3.1.1 Energy Model:

The proposed framework analyzes energy of nodes. Assuming each node has an initial energy, E_i, then the energy gets depleted when a node i, replies or broadcasts to another node j. The power consumed in transmissions is P_T while P_R the power utilization of i while receiving data unit from j. Again, assuming that a sink node has unlimited energy and constantly moves till end of network lifetime (from the start till it is dead), then the objective of optimization narrows down to finding optimality in routing strategies and CH selections which can enhance network lifetime. Linear programming models can maximize network lifetimes. The Power consumed while transmitting L bits for distance D_t is shown in Eq.(1),

$$P_T = \begin{cases} P_{cons} * L * P_{amp} * D_t^2 & if\ D_t < D_0 \\ P_{cons} * L * P_{amp} * D_t^2 & if\ D_t \geq D_0 \end{cases} \quad (1)$$

$$P_R = P_{cons} * L \quad (2)$$

where

E_{amp} is power dissipated.

P_T is power consumption while transmission of packets

L is bits

P_{amp} is power amplification

D_t is distance among nodes

D_0 is threshold distance

P_R is power consumption while receiving the packets

The power consumption is reduced significantly in the node further while the data transmission and shortest routing path can be ensured effectively.

3.1.2 Mobility Model:

This model is for IoTs nodes in a system. The model is-based on device location, speed and connectedness. Let n_1 and n_2 be IoT nodes at locations (u_1,v_1) and (u_2,v_2), respectively. Assuming the nodes travel to a new position (u'_1,v'_1) and (u'_2,v'_2) for an association, then the Euclidean distance between them can be expressed as

$$d(0)=|u_1-u_2|^2+|v_1-v_2|^2 \quad (3)$$

WSN-based IoT node distances at time l and their positions can be computed as:

$$d(l)=|u'_1-u'_2|^2+|v'_1-v'_2|^2 \quad (3)$$

where (u'_1,v'_1) and (u'_2,v'_2) are new locations of n_1 and n_2.

3.1.3 Objective Model:

In this research, the objective model is considered such as energy, and delay on the given WSN network. In this research, ELSOA algorithm is introduced to select best forwarder node that develops the optimal solutions for scalable network. Then apply CA framework for multipath data transmission over the WSN network. The formula is defined for delay, hop count, energy and lifetime is given below:

$$delay(d) = \frac{\sum_{i=1}^{n}(t_{ri} - t_{si})}{n}$$

where, T_{ri} – i^{th} packet receipt time, T_{si} - i^{th} packet sending time and n - total packets count.

$$Energy(e)=[(2*pi-1)(e_t+e_r)]d \quad (6)$$

where, p_i - data packet, e_t - transmission energy of packet i, e_r - energy for receiving packet i and d - distance between source and destination node.

The objective model O_M can be derived as:

$$O_M=n(M_e*L_d) \quad (7)$$

where, N - nodes count with optimal energy, and delay values, M_e - Minimum energy consumption node and L_d - Less delay.

It is further used to select the multiple optimal forwarder node selection and multipath routing through the ELWOA_CA approach.

3.2 OPTIMAL FORWARDER NODE SELECTION USING ELSOA

The proposed ELSOA algorithm selects the best forwarder node for faster network transmissions. The selection of a forward node is a complex issue. Each source node exists with a group of neighbors. Forwarder node selections are-based on many parameters: their residual energy; physical distances and available link quality. Forwarded data packets stay for a specific period of time in forwarder nodes-based on transmission distance/range, speed of sound propagation, remaining energy, avoiding packet collisions and avoiding redundancy in transmissions. The node that holds packets for a minimal time-based on the above said factors is the best forwarding node. When a node finds overheard packets, the packets are dropped while other packets remain in the buffer until forwarded.

Metrics considered for forwarder node selection directly impact routing protocol's performance where residual energy metric helps in balancing node energies. Link quality is also an important metric that impacts node's energy consumptions and PDRs (Packet Delivery Ratio) [20]. Depth metric usage reduces energy consumptions as they compute local depths while physical distances are computed using sink's beacon messages. Thus, it becomes mandatory for a forwarder node selection algorithm to consider multiple metrics for energy efficiency and reliability of forwarder nodes.

Forwarder nodes chosen with selected metrics transmit packets while other nodes hold the data packets. These nodes also forward when their holding time is exhausted and do not overhear. Thus, shortest path selection is a basic issue that impacts transmissions and network's lifetime-based on energy [21]. It is common to select nodes which have lesser depth than the sender for reducing transmissions and forwarder node selections.

This work uses stochastic optimization in its proposed ELSOA for forwarder node selection. Lion Optimization Algorithm (LOA) is met heuristic and capable of generating multiple solutions in each of its iterations. Lions, the strongest of the mammals live in groups with females being resident. Their social living area or territory is guarded by Lions and cubs [22]. A wandering Lion is engaged in a fight by the territorial lion and the victor stays as the territorial lion and drives out the loser. If the wanderer is the victor then the territorial lion's cubs are also killed and female is forced to mate. Cubs reaching puberty also challenge the territorial lion for holding the territory.

Lion's social behavior can be that of residents or nomadic where these behaviors. LOA searches for optimality in solving problems-based on social behavior of lions which can be expressed as defense or takeover. The Fig.4 shows the nature of LOA

- *Territorial Defense*: Resident lions/cubs fight with nomadic males for controlling territory. LOA evaluates current solution (territorial) with a new solution (nomad). If the nomad is better it replaces the territorial lion or existing solution.
- *Territorial Takeover*: LOA, while exhibiting this behavior stores only the best male/female solutions while removing existing solutions.

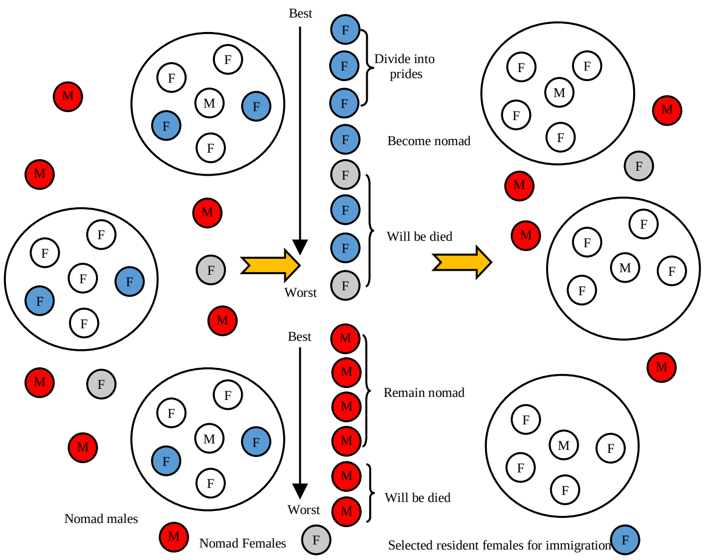

Fig.4. Nature of LOA

Initialization: LOA initialization starts with random generation of Lion population which is stored in a matrix form as the solution space where lions are solutions represented by:

$$Lion = [x_1, x_2, \ldots, x_{Nvar}] \tag{8}$$

where x_{Nvar} are the generic forwarder nodes selected. Randomly generated nomad lion ratio is denoted by %N while the rest are resident lions. The solution required for selecting the best forwarder node from inputs is executed using LOA which can search and identify hidden relationships between individual elements of a network.

Fitness Computations: An objective function evaluates the fitness values of lions in the sorted and saved matrix

$$f(Lion) = f(x_1, x_2, \ldots, x_{Nvar}) \tag{9}$$

Fitness values are-based on energy and delay or optimality of emergency message forwards effectively by the forwarder node. Most required parameters for this fitness function involve delay and reduced energy consumption given in:

$$Fitness = Min \frac{\sum_{i=1}^{N}\left(P^{i}_{energy\_consumption} + P^{i}_{delay}\right)}{2} \tag{10}$$

where, $P^{i}_{energy\_consumption}$ - node consumption energy while receiving packets and P^{i}_{delay} - delays of nodes for selection.

The mathematical formulation for delay and energy consumption is given in Eq.(5) and Eq.(6).

On computing fitness values, they are updated as solutions where hunting, mating, roaming, defense are the operations used. Female lions search for prey inside their territory, thus hold the optimal solution within the territory. This work's selection of forwarder nodes is based on the above described fitness function values and subsequent updates.

***Hunting Operation*:** There are three classes of hunters. Hunter with best fitness value is the center while the other two forms its left and right. Randomly chosen hunters attack dummy preys which escape when hunter's fitness improves and is updated to a new location.

***Movements Towards Safety*:** Only selected female lions hunt for prey while others stay in safe territory. The best positions for each territory are computed and saved. High victory count indicates that the lions have moved away from the optimum point. Lower values indicate lions are roaming for enhancement and hence assessment of competitions indicates achievements.

***Roaming of Lions*:** Roaming is a difficult operation and restricts searches of lions. LOA uses this to hunt in a search space and find an enhanced solution. Lions move by n units towards their preferred territory.

$$n \sim U(0, 2*d)$$

where n is a random number with uniform distributions and d is a male lion's distance from selected territory. Nomad lions also move randomly in the search space

***Mating*:** Mating is primary for lion survival and the process of creating new generations. On identifying suitable female and male lions, cubs are produced. This process produced new and best solutions from existing solutions using crossovers and mutations. Elimination of weak lions ensures best solutions are derived.

***Defense*:** This behavior is important to lions. Matured males engage other lions in a battle. Losers turn into nomads or get out of the territory. Nomadic lions winning a battle take control of the loser's territory. Thus, LOA operates defense in two modes namely defending lions against new matured resident males and nomadic males. Thus, the strongest lion in the group is found by LOA.

***Migration*:** This process is a relocation process where randomly chosen females turn into nomads and fitness values determine their rearrangement where the fittest females replace positions of females which turned nomads.

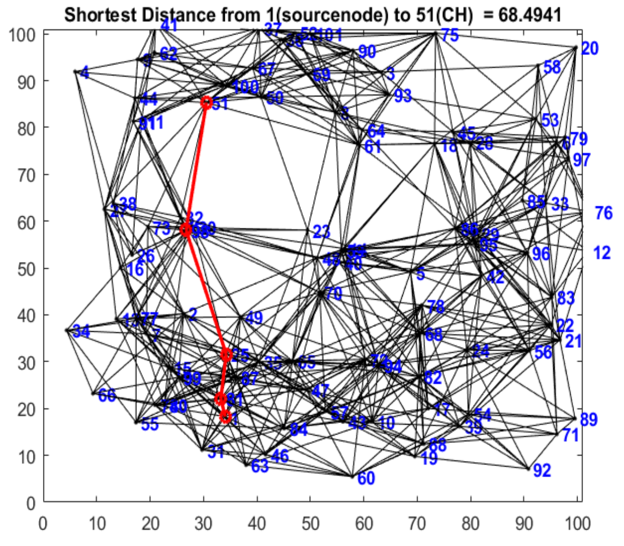

Fig.5. Shortest distance between nodes using ELSOA algorithm

***Population Equilibrium of Lions*:** Every iteration ends in an equilibrium point or position of stability in the lion's population where a count for maximum lions per gender in assessed. Lions with low fitness values are eliminated from the population. Fig.5 displays shorter distances between nodes. Found by ELSOA. the distances are lower for CHs near the BS while they increase as CHs get away from BS.

***Criteria for Termination*:** The proposed terminates when more iterations achieve best fitness values. The partition with highest fitness values is the best partition and is selected for broadcasting messages. The territorial takes over operation keeps replacing lions with lower fitness values by higher fitness lions. Thus, only the solutions including males and females are saved while other solutions are discarded.

In ELSOA, ant's position updates are-based on random walks around the ant-lions and selected by Roulette wheel where the best particle is preserved. Hence, ELSOA has advantages in terms of quick speed calculations, effective convergence and high efficiency [23]. Premature convergence and local optimum are issues for complex optimizations and improvements proposed for overcoming these issues for selection of forwarder nodes is presented below.

$$Ant=(R_A+R_E)/2 \tag{11}$$

where,

Ant - new position,

R_A - ant-lion's random walk as selected by Roulette wheel,

R_E - random walk around the elite. An ant's new position is modified if does not fit into the bounded area.

Algorithm 1: ELSOA

Input: Nodes from a network

Output: Best forwarding node

Step 1: Begin

Step 2: Random position initialization

Step 3: Initialization of normal and nomadic lion positions

Step 4: Assess the fitness value of each lion using Eq.(10)

Step 5: Select hunting females and move others to a safer position

Step 6: Select hunting nomadic females and move the rest to safety

Step 7: Remember the best solution

Step 8: For each lion do

Step 9: Try mating

Step 10: End for

Step 11: Update the position of pride and nomad lion (11)

Step 12: Merge new mature male and old male

Step 13: Sort all males according to their fitness

Step 14: Weakest male drives out and remained male become pride

Step 15: If terminating criteria fulfilled then

Step 16: Return the best forwarder node selection

Step 17: Else

Step 18: $t=t+1$

Step 19: Until t > Max_Iteration

Step 20: Return the best forwarder node selection

Step 21: Stop the algorithm

The algorithm 1 explains LOA and to summarize lions, strongest mammals exhibit a social behavior that can be residential or nomadic. Lions switch between these behaviours. Resident lions live in a territory where they mate to produce an offspring. Nomadic lion movements are sporadic and move alone or in pairs where outclassed males move in pairs.

3.3 SECURED DATA TRANSMISSION USING CA

In this work, secured data transmission is executed using CA with third party node for increasing the trust level. Each node within a region is registered with the authenticating node which checks genuineness of a node before allowing the node to be a part of forwarder node list. Authentications confirm a user's entry into a system-based on identity or is a control system for users to be on the system.

Any user logging onto a system is authenticated and in case of two logins, user is authenticated twice. This process grows in complexity as entries into multiple systems require multiple authentications. Users have to keep track of multiple usernames and passwords which complicate the matter for both systems and users. A centralized authenticating server-based credential helps in avoiding this complexity.

Further, these types of servers eliminate redundancy and hence this work uses CA. When a BS receives packets that are encrypted, it decrypts the packets. This ensures the wireless carriers transmit data safely while the use of CA releases the network from the burdens of authentications. Application without CA's grows in complexity with added contents [24].

The study [25] introduced a multipath routing protocol for energy-efficient communications by balancing network traffic in multiple paths. The study's significant metric was the energy of a route in the route discovery phase. The study failed to achieve much as it did not consider wireless interferences and assumed links were free from errors.

This work is interference aware where the multipath routing protocol has three stages namely initialization, route discovery/establishment and route maintenance. Each node obtains neighborhood information in the first stage which is then used by the second stage to discover routes. In route establishment, the best next-hop node towards the sink is found. The second stage is triggered on an event detection with the outcome of discovering multiple paths between the source and sink with minimized interferences for data transmissions.

WSN-based agricultural experiments enhance growth and quality of tomatoes [26]. Hence, this work combines WSNs with agriculture in assessing event-based experimentations using tomato crops. The crop's growth in a greenhouse does not cross 100 days for maturity or harvest.

4. SIMULATION RESULT

ELSOA-CA performances are reported and evaluated with other methods in this section. Methods considered for comparisons include Ant Colony Optimization (ACO), Light Weight Structure-based Data Aggregation Routing (LSDAR) and the proposed ELSOA which were simulated using NS-2 simulator. The metrics used for comparisons include end to end delays, throughput, energy consumptions, and network lifetimes. Simulation parameters used is listed in Table.1.

Table.1. Simulation Parameters

Parameter	Values
No. of Nodes	100
Area Size	1100×1100 m
Mac	802.11
Radio Range	250m
Simulation Time	60 sec
Packet Size	80 bytes

4.1 PERFORMANCE EVALUATION

- ***End-to-End Delay***: The average time taken by a packet to get transmitted from a source to a destination in a network.

$$\text{End-to-end delay} = \frac{\sum_{i=1}^{n}(t_{ri} - t_{si})}{n} \quad (12)$$

where t_{ri} – i^{th} packet receipt time, t_{si} – time the i^{th} packet was sent and n - total packets.

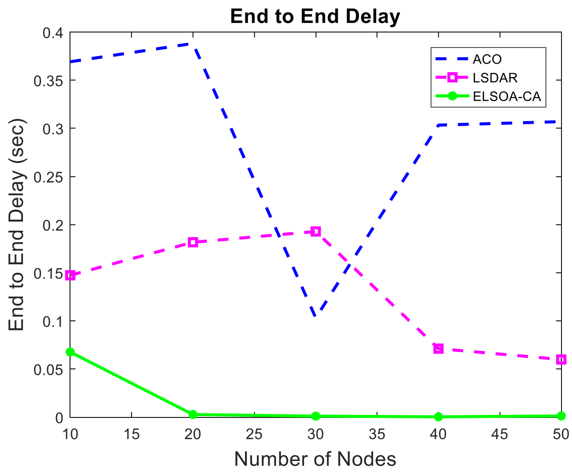

Fig.6. End-to-end delay comparison

The Fig.6 depicts evaluation comparisons in terms of end to end delay performance, where nodes are in x-axis and y-axis represents their end to end delay values. Methods compared are ACO, LSDAR and proposed ELSOA-CA algorithm which shows lesser end to end delays. Thus, the proposed ELSOA-CA system selects superior forwarder nodes-based on ELSOA fitness values.

- ***Throughput***: The rate in which the data packets are successfully transmitted over the network.

$$\textit{Throughput} = \textit{total number of packets sent / time} \quad (13)$$

The Fig.7 depicts evaluation comparisons in terms of throughput performance, where nodes are in x-axis and y-axis represents their throughput values. Methods compared are ACO, LSDAR and proposed ELSOA-CA algorithm which shows higher throughputs. Thus, the proposed ELSOA-CA system selects superior forwarder nodes-based on ELSOA fitness values.

- ***Energy Consumption*:** Energy consumption is the average energy necessary for transmission of a packet to a node in the network in a specific period of time.

$$Energy(e)=[(2*pi-1)(e_t+e_r)]d \quad (14)$$

where, p_i - data packet, e_t - packet i's transmission energy, e_r - energy required for receiving packet i and d - distance between transmission and destination nodes.

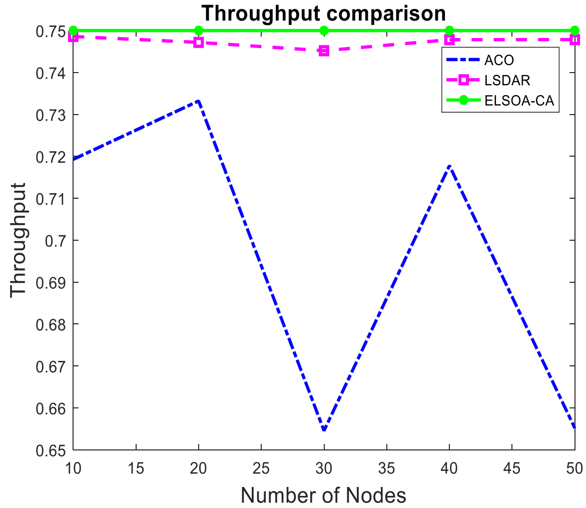

Fig.7. Throughput comparison

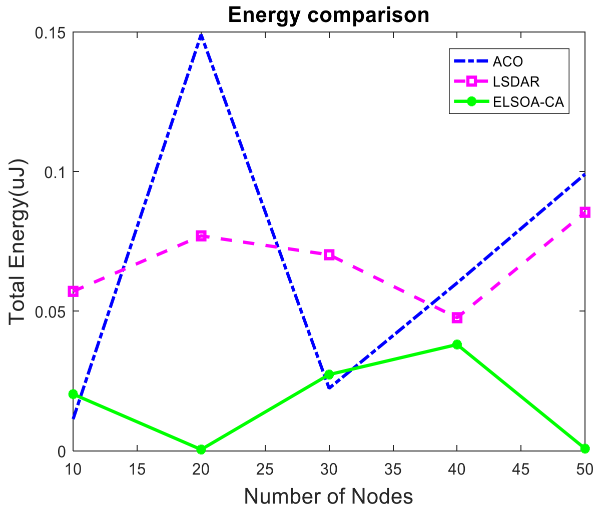

Fig.8. Energy consumption comparison

The Fig.8 depicts evaluation comparisons in terms of energy consumption performance, where nodes are in x-axis and y-axis represents their energy consumption values. Methods compared are ACO, LSDAR and proposed ELSOA-CA algorithm which shows lower energy consumptions. Thus, the proposed ELSOA-CA system selects superior forwarder nodes-based on ELSOA fitness values.

- ***Network Lifetime*:** The lifetime of a network.

$$Lifetime\ \mathbb{E}[L]=\frac{\varepsilon_0-\mathbb{E}[E_w]}{P+\lambda\mathbb{E}[E_r]} \quad (15)$$

where, P - constant power consumption of network and continuous, ε_0 - total non-rechargeable initial energy, λ - average sensor reporting rate, $\mathbb{E}[Ew]$ – anticipated wasted energy or unused energy till the network dies and $\mathbb{E}[E_r]$ – reported energy consumption of nodes.

The Fig.9 depicts evaluation comparisons in terms of network lifetime performance, where nodes are in x-axis and y-axis represents their network lifetime values. Methods compared are ACO, LSDAR and proposed ELSOA-CA algorithm which shows higher network lifetime. Thus, the proposed ELSOA-CA system selects superior forwarder nodes-based on ELSOA fitness values.

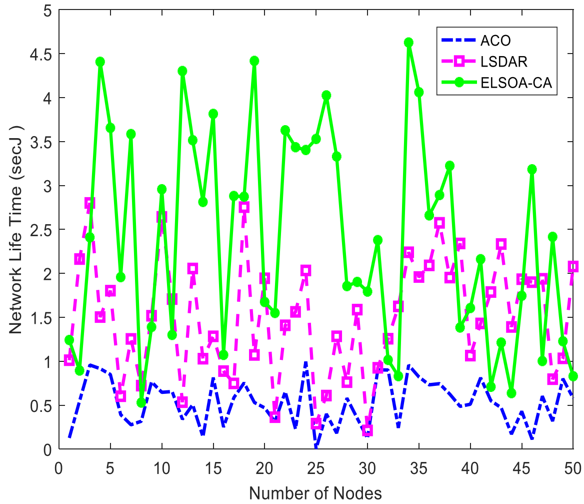

Fig.9. Network lifetime

- ***PDR*:** represents the ratio of the number of lost packets to the total number of sent packets

$$\text{Packet loss ratio} = \frac{N^{tx}-N^{rx}}{N^{tx}}\times 100\% \quad (16)$$

where, N^{tx} - transmitted packets, N_{rx} - received packets. This evaluation was done by extracting all real-time packet sizes that were transmitted and received.

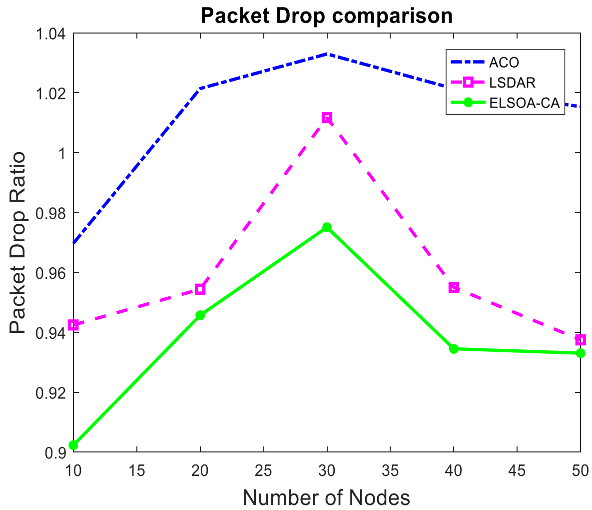

Fig.10. Packet drop ratio

The Fig.10 depicts evaluation comparisons in terms of PDR performance, where nodes are in x-axis and y-axis represents their PDR values. Methods compared are ACO, LSDAR and proposed ELSOA-CA algorithm which shows lower PDR. Thus, the proposed ELSOA-CA system selects superior forwarder nodes-based on ELSOA fitness values.

5. CONCLUSION

This work has proposed and demonstrated a new ELSOA-CA approach for optimizing selection of forwarder nodes in a WSN. The proposed ELSOA, selects the best forwarding node by reducing hops and choosing nodes with best fitness values. This work produces optimal solution for the forwarder node selection by considering residual energy and end to end delay which are computed using a fitness function. The CA is focused to improve the secured multipath data transmission using route discovery and route maintenance function for increasing the WSN performance. The result concludes that the proposed ELSOA-CA algorithm provides higher throughput, network lifetime, and lower end to end delay, packet drop ratio, energy consumption than the existing approaches. In future work, the hybrid LOA and novel encryption algorithm can be developed for dealing with computational complexity issues prominently.

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