



The Evaluation Of Lorawan Performance With Uav Support Using The Meta-Heuristic Optimization Algorithm

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Abstract: A system based on unmanned aerial vehicles (UAV) and LoRa technology has been designed that enables data transfer from sensors to a central system. Even though there is a great distance between aircraft and ground sensors, the UAV–LoRaWAN network guarantees direct visibility between them, enabling data interchange. In order to identify the best performance in the field, this research thoroughly analyzed and compared four different meta-heuristic techniques for UAV-Assisted LoRaWAN. Network throughput and energy efficiency were also included in the investigation. After this examination, we need to decide which method is more effective and appropriate for data exchange that is error-free. NS2 software was used to implement all four models.

Index Terms - LoRaWAN, Unmanned Aerial Vehicle (UAV), Data collection, Seagull Optimization Algorithm, American Zebra Optimization Algorithm, low-density parity-check.

I. INTRODUCTION

People commonly refer to a UAV (Unmanned Aerial Vehicle) as a drone. A drone is an aircraft that functions without a pilot present, either through remote control or autonomous flight. People use UAVs for a wide range of purposes, such as military applications, commercial and civilian uses, entertainment and photography, search and rescue, and environmental monitoring. UAVs come in various sizes, from small consumer drones that are the size of a bird to large military or commercial models that are the size of a small aircraft. Depending on their intended use, they can carry a variety of sensors, cameras, GPS systems [1-2], and other payloads.

A new wireless communication technology known as Low Rate Wide Area Network (LoRAWAN) has recently emerged, which supports communication over long distances. To extend sensor networks over large areas, in recent years, there has been a growing interest in the application of unmanned aerial vehicles (UAVs) [3].

The combination of UAVs and LoRaWAN can provide significant benefits in scenarios where traditional infrastructure may be insufficient or impractical. But UAVs can act as temporary LoRaWAN gateways or repeaters, flying over an area to provide connectivity for IoT devices located in areas where ground-based gateways might not be available or feasible. UAVs can communicate with remote IoT sensors and relay data to a central server or cloud-based application. LoRaWAN operates over long distances with low power consumption, making it ideal for remote sensor networks [4].

IoT is being used by industrial sectors to enable defect-free manufacturing, quality control, and predictive maintenance [4]. IoT is also being used by the medical industry to enhance its capabilities in disease diagnosis and treatment. By flying at higher altitudes, drones can provide line-of-sight communication, avoiding obstructions like buildings or trees that might interfere with ground-based LoRaWAN signals. The UAV

collects data from multiple devices across the area, relays it back to a central system, and can even analyze or process data in real-time on board. This is sample paper format only please use this format and follow this structure as per your requirement

II. LITERATURE REVIEW

In order to globally optimize UAV pathways while satisfying security and speed constraints, in [5] author presented a path planning algorithm based on A* and DWA. The authors address the limitations of DWA by adaptively adjusting the evaluation function in accordance with UAV safety thresholds and environmental factors. Meanwhile, they improve the A* algorithm based on information about the UAV flight environment and motion constraints, resulting in the creation of a global optimal path evaluation subfunction.

In [6], the authors developed the 3Dimensional Improvised Clustering Algorithm (3DICA), a revolutionary cluster routing protocol, to address the node uncertainty issue in cluster head selection. The author creates the cluster head and cluster members, then computes the energy usage through transmission. The results of the simulation show that building 3D clusters with the recommended method produces more data in less time.

In [7], the authors introduce a dependable and safe architecture for UAV network services that combines deep learning and blockchain to give UAVs safer and more effective network services. To improve the security of UAV communication data transfer, we suggest a UAV cluster identity management module that combines blockchain, encryption techniques, and digital signatures.

In [8], the authors, proposed a multi-event data collection architecture for smart agriculture using unmanned aerial vehicles and the internet of things that is time-limited. The authors first illustrate the construction of the agricultural IoT framework, utilizing UAV assistance for data collection. Secondly, they show how the system functions and processes based on the event priority. Lastly, they offer a flight path planning method that takes into account the priority of the event.

III. METHODOLOGY

3.1 Proposed REDC-AZOA

A Reliable and Efficient Data Collection in UAV based IoT networks using AZOA (REDC-AZOA) was proposed. The main objective of this technique was to design an UAV-assisted data collection technique which will maximize the energy efficiency and reliability of data collection. Reliability of data collection depends on finite path planning. A fitness function is derived in terms of reliability and energy efficiency. Then the optimal stopping points and hovering time of UAV which maximizes the fitness function are determined, by applying AZOA.

The following equation 1 could be used to determine how much energy an IoT device uses to send M_x data to the y th UAV stop point:

$$E_{xy} = \frac{P_x M_x}{R_{xy}} \quad (1)$$

The amount of energy used by any IoT device is represented in equation 2,

$$E_{iot} = \sum_{x=1}^n \sum_{y=1}^{\theta} b_{xy} E_{xy} \quad (2)$$

The following equation 3 defines the total amount of energy consumed during data collection

$$E_{tot} = E_u + E_{iot} + E_F \quad (3)$$

Equation 4 refer the Total number of data transmission attempt (Txatt)

$$R = \frac{Tx_{succ}}{Tx_{att}} \quad (4)$$

A fitness function is derived in terms of reliability and energy efficiency are represented as equation 5,

$$Fit() = w_1 \cdot R + w_2 \cdot EE \quad (5)$$

Where w_1 and w_2 are weight values in the range of (0,1).

3.2 American Zebra Optimization Algorithm (AZOA)

AZOA is inspired by the behavior of zebras in the wild, particularly their migration and social interactions. The core idea is to model how zebras cooperate to find the best possible location, which can be translated to finding optimal solutions in problems like UAV path optimization or task scheduling.

Main Features of AZOA:

1. **Zebra Grouping:** Zebras form groups with different behaviors (explorers and followers). In AZOA, this can be mapped to the exploration (finding new areas or solutions) and exploitation (refining existing solutions) phases of the optimization process.
2. **Migration:** Zebras migrate to more optimal locations. This is similar to how optimization algorithms search for the global optimum in the solution space.
3. **Social Interactions:** Zebras have a social structure where the group leader has a greater influence on the group's direction. This interaction among agents (e.g., UAVs) can be mimicked in swarm-based algorithms.
4. **Leader and Follower Strategy:** Some zebras lead the group toward better locations, while others follow. This can be used in multi-agent systems like UAVs, where one UAV can lead others in a coordinated manner.

This section proposes the AZOA algorithm by mathematically simulating the social behaviour of American zebras. American Zebras' life activities are divided into five main stages, which are as follows:

Phase 1: Random zebra group formation

The stallion that serves as the group leader causes the zebras to dwell in several groups in the wild, seemingly dividing the entire population into these groups.

$$Z_{x,y} = Z_{min} + (Z_{max} - Z_{min})rand. \quad (6)$$

In this case, Z_{max} and Z_{min} determine the search area's upper and lower extreme points, respectively. A random value between [0, 1] is indicated by the symbol "rand."

Phase 2: American zebras' feeding activity.

As herbivores, zebras primarily eat different types of grass and green leaves. As a result, zebras constantly circulate about the family leader stallion and graze together. The following equations (7 & 8) are suggested as a way to quantitatively simulate American zebra feeding behaviour.

$$\bar{Z}_x^y = \begin{cases} 2R_u \sin(2\pi R_a) * (Z_s^y - Z_x^y) + Z_s^y, & \text{if } R_b < 0.5 \\ 2R_u \cos(2\pi R_a) * (Z_s^y - Z_x^y) + Z_s^y, & \text{otherwise} \end{cases} \quad \forall x \in y \quad (7)$$

$$Z_x^y = \begin{cases} \bar{Z}_x^y, & \bar{F}_x^y < F_x^y \\ Z_x^y, & \text{otherwise} \end{cases} \quad (8)$$

where N_y is the number of individuals in the y th group, and Z_s^y and Z_x^y stand for the location of the stallion and x^{th} zebra, respectively. R_a represents the adaptive parameter, R_b indicates a random value that lies in [0, 1], and R_u indicates a uniform random value between [-2, 2] that causes the zebra to feed at multiple angles.

$$R_a = 1 - t * \left(\frac{1}{T}\right) \quad (9)$$

In equation (9), the maximum iteration is indicated by T , while the current iteration is shown by t .

Phase 3: American zebras' breeding activity.

In order to breed, the young zebras depart from their families before reaching adulthood and join another zebra family. The following equations (10) have been created in order to simulate the zebras' breeding behaviour.

$$Z_k^q = \text{Crossover}(Z_x^a, Z_k^c) \text{ if } d \geq pc, x \neq k \quad \forall x, y, k \in N \quad (10)$$

where Z_y^b is the location of zebra b from the y th group, (Z_x^a, Z_k^c) is the position of zebra c from the k^{th} group, and Z_y^q and Z_k^q are the position of zebra q in the y th and k th groups, respectively, d is the distance between them.

Phase 4: Group leadership

Zebras place a high value on the family leader. In addition to giving his family wholesome food and drink, the leader frequently engages in combat with competing zebras. It can then be exploited by other people. The following equations (11) are used to model this strategy.

$$\bar{Z}_S^y = Z_S^y = \begin{cases} \bar{Z}_S^y, \bar{F}_S^y < F_S^y \\ Z_S^y, \text{ otherwise} \end{cases} \quad (11)$$

where G stands for water reserves, R_f for adaptive parameter, and R_g for uniform random number lies in $[0, 1]$. Re is a uniform random number that lies in $[-2, 2]$. F_S^y is the stallion's fitness value in the y th group, Z_S^y is the stallion's present position as the y th group leader, and $\bar{F}_S^y$ is the stallion's next position, refer equation (12).

$$f = 1 - t * \left(\frac{1}{T}\right) \quad (12)$$

Phase 5: Leadership transition

For the group to properly maintain discipline and organise food sources, it is imperative that they have a strong leader. The group's leader must be replaced if, under any circumstances, they start to show signs of weakness. To choose a new leader, the leadership transition step is modelled using the following equation (13).

$$Z_S^y = \{Z_x^y \text{ if } F(Z_x^y) < F(Z_S^y), \forall x \in N_y\} \quad (13)$$

where $F(Z_S^y)$ is the leader stallion's fitness value and Z_S^y is the stallion's current position in the y th group.

3.3 CF CDC-SLA (Collision-free and consistent data collection using SOA based LDPC Approach)

Data accuracy and consistency are of paramount importance in UAV-assisted IoT networks. Accurate data is crucial for making reliable decisions and Consistent data ensures optimal performance of the network. To ensure consistent data collection, error detection and correction methods are applied. However, considering the current transmission policy of LoRaWAN MAC layer, a huge number of collisions may happen. To tackle this problem, the propose collision free scheduling algorithm to allow transmissions at selective slots. Figure 1 shows the Proposed CF CDC-SLA Model.

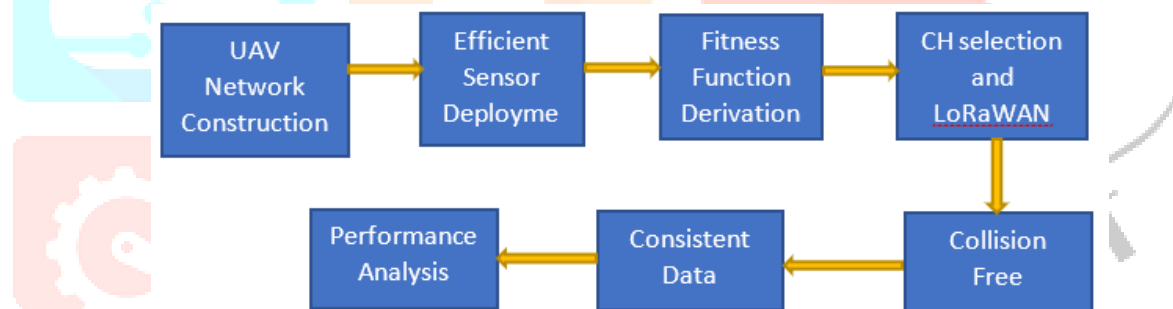


Figure 1- Proposed CF CDC-SLA Model

Seagull Optimization Algorithm (SOA) based Dynamic Clustering Approach employs the SOA to choose the cluster and routing leader. This section will elucidate numerous applications of SOA. Seagulls belong to the Laridae family, which spans a broad variety of parts of the biosphere. Even though there are many kinds of seabirds, seagulls are particularly appealing since they are tenacious and have a powerful desire to hunt their prey. As a result, seagulls are intelligent birds since they exhibit migrating and hunting behaviours.

Step 1: We initially construct the UAV network.

Step 2: After that, the sensor nodes and the multi-tiered clustering model are developed. Next, we use the proposed SOA to determine the fitness function.

Step 4: Next, based on SOA, the CH selection process takes place, advancing the routing over IoT networks helped by UAVs.

Step 5: After the clustering and routing procedures, we examine the sent data to determine if it is collision-free.

Step 6: Once it is known that there are no collisions in the transmission, the LDPC method is used on LORAWAN to make sure that data collection is always the same by finding and fixing errors.

CF CDC-SLA includes a collision-avoidance characteristic by design, it is mostly useful for producing congestion-aware routing with reliable data collection. The proper fitness function can be determined to

determine the correct fitness value. Several features, including network coverage, communication cost, residual energy, and node degree, were considered.

To find the network coverage, the below equation (14) was applied.

$$\text{Min } f1 = \frac{1}{nT} \sum_{i=1}^n Nc(ni) \quad (14)$$

To find the communication/ transmission cost to the neighbour hub/host, the below equation (15) was described,

$$\text{Min } f2 = \frac{1}{nT} \sum_{i=1}^n Np(ni) \quad (15)$$

IV Results

All the four approaches were implemented using NS2 simulation tool. And comparison has been made with network throughput and energy efficiency. The simulation settings are shown in Table 1.

Table 1 Simulation settings

Number of Nodes	10,20,30,40,50,60,70,80,90,100
Topology size	150 m * 150 m
MAC protocol	LoRaWAN
Source of Traffic	CBR
Traffic Flows	6
Traffic Rate	50 KB/s
Input Energy	25 Joules
Transmitting power	0.8 Watts
Receiving power	0.3 Watts
Speed of UAV	20-60 m/s

a) Energy Efficiency:

Energy efficiency entails using a smaller amount of energy to achieve the same output or result. This is the optimization of processes, equipment, and systems to reduce energy consumption while maintaining performance levels. In Fig. 2 the Energy Efficiency of CFDCD-SLA with REDC-AZOA, ESRD-PDCA, and EEDP-UAV is shown. Figure 2 shows that CFDCD-SLA outperformed REDC-AZOA, ESRD-PDCA, and EEDP-UAV by 12%, 16.84% and 10.27% respectively in case of energy efficiency.

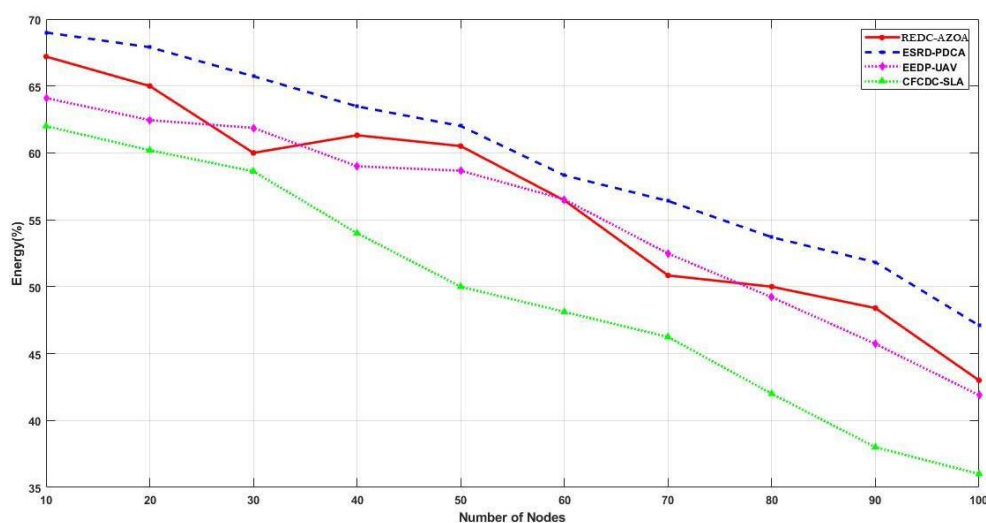


Figure 2. Effect of Node Density on Energy Efficiency in CFDCD-SLA with REDC-AZOA, ESRD-PDCA, and EEDP-UAV Algorithms

b) Network Throughput:

The metric known as throughput measures the speed at which data moves between various locations on a network. We typically quantify it in terms of bits per second or data packets per second. In Fig. 3 the Network Throughput of CFCDC-SLA with REDC-AZOA, ESRD-PDCA, and EEDP-UAV is shown. Figure 3 shows that CFCDC-SLA outperformed REDC-AZOA, ESRD-PDCA, and EEDP-UAV by 2.95%, 2.73% and 0.52% respectively in case of network throughput.

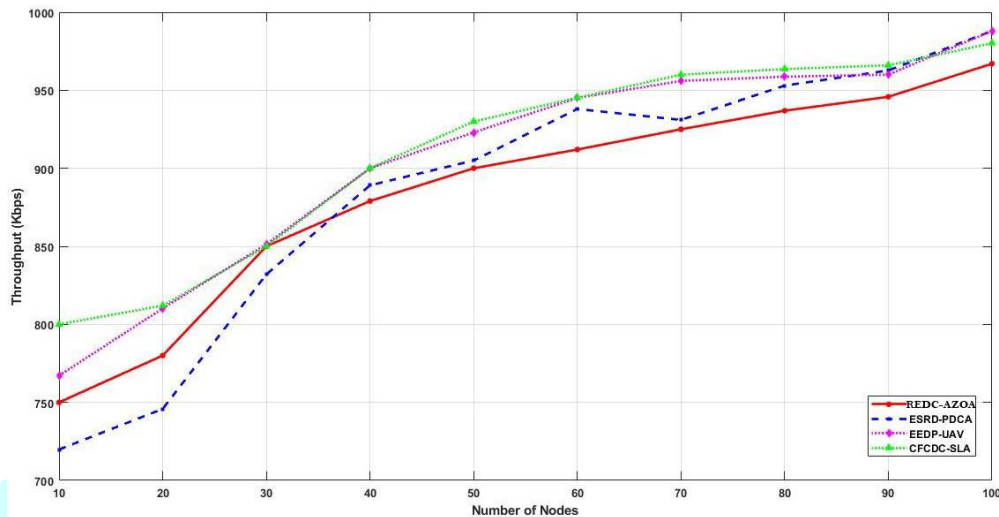


Figure 3: Effect of Node Density on Network Throughput in CFCDC-SLA with REDC-AZOA, ESRD-PDCA, and EEDP-UAV Algorithm

V Conclusion

We conducted a comprehensive analysis of four distinct meta-heuristic techniques implemented using UAV-Assisted LoRaWAN in this research to compare their performance in terms of area coverage, energy efficiency, and network throughput. Using NS2, we put CFCDC-SLA, REDC-AZOA, ESRD-PDCA, and EEDP-UAV into action. We compared CFCDC-SLA's energy efficiency to that of REDC-AZOA, ESRD-PDCA, and EEDP-UAV, and discovered that CFCDC-SLA was substantially more efficient (12.2%, 16.84%, and 10.27% better, respectively). The simulation results showed that CFCDC-SLA achieved a network throughput that was 2.95% higher than REDC-AZOA, 2.73% higher than ESRD-PDCA, and 0.52% higher than EEDP-UAV. Results from simulations show that CFCDC-SLA increases network throughput at the expense of energy efficiency.

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