Routing flying Ad Hoc network using salp swarm algorithm

Alaa Ibrahim Mahmood1, Omar Ibrahim Alsaif2, Ibrahim Ahmed Saleh3

1Department of computer Science, Directorate of Education in Nineveh, Mosul, Iraq
2Department of Computers system, Mosul Technical Institute, Northern Technical Univerit, Mosul, Iraq
3Department of Software, College of Computer and Mathematics, Mosul University, Mosul, Iraq

ABSTRACT
An Ad-hoc network is collection of mobile nodes without the necessity of existing any centralized access points. In this paper introduce novel protocol that used to improveAdHoc protocol with salp swarm algorithm to routed flying Ad Hoc Network (FANET) by method of simulation. FANET predicated unmanned aerial vehicles (UAV), it designed wireless network has nodes with high mobility, actively changing topology and movement in 3D space. The main problem for FANET manner of routing packets among managed nodes. The new protocol based on salp swarm algorithm called “SalpAdHoc” protocol to solve routing problem and less the conjunction, thesimulation results of an experimental study confirming the feasibility of using salp swarm algorithms for routing in FANET are presented.

Keywords: FANET, Routing, Salp swarm optimization, Self-organizing network, Unmanned aerial vehicles

1. INTRODUCTION
Flying Ad Hoc network (FANET) is a group of unmanned air vehicle (UAVs) communicating by analogy with mobile Ad Hoc network (MANET) and automobile peer-to-peer networks vehicular Ad Hoc network (VANET), represents private type of self-organizing network based on UAVs. These networks provide a vast range of commercial and civil usages. The organization of this type of communication is vital not only to implement tasks to ensure monitoring and observation but also effective coordination the movement of vehicles, improving safety (for example, as a means of preventing collisions) [1].

A classic ad hoc network type of a dynamic mobile network without an infrastructure. It automatically generated as a result of the connections between mobile nodes. The set of mobile nodes are collected in certain area randomly by the fact that no central control node. Each node of an ad-hoc network can function as a router, organizing and supporting the routing process both to other nodes on the same network, and to devices that are transmitters or receivers [2].

The features of ad-hoc networks include changing topologies; limited energy resources, change their location and changed signal propagation conditions. Moreover, bandwidth and visibility range varied from the radio signal. The purposes for ad-hoc networks can be very diverse. It is known that ad-hoc networks can be used in transport systems, and unmanned aerial vehicles (UAVs), often in those situations when you need to deploy a network for some time to transfer data. Currently, there are a large number of simulation systems for the design and analysis of computer networks. These modeling systems can be divided into specialized for example (COMNET [3], OMNet, OPNET, and NS-2 [4]) and general purpose modeling systems (ANYLOGIC [4]). The present in the article the instrumental tools of computer-aided design and simulation modeling of TriadNS [5]. One of the features ofNS-2 is a way to present a simulation model in three layers:

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- Layer of structures (computing nodes and computer network lines).
- Layer of routines (describes the behavior of computing nodes).
- Message layer (description of messages and data of a complex structure, it is assumed computing nodes exchange messages) [6].

In this paper used salp swarm optimization (SSA) based on the behavior for find foods. SSA is based on the self-organization that allows achieving the common goals thanks to low-level interaction. The SAA makes use of two-level strategy "exploration and exploitation" in first level exploration focuses on discovery best solution by seeking a search space suitably, while exploitation focuses on exploit data in local area.

The paper considers algorithms based on Salp swarm optimization, which implemented routing problem is solving in self-organizing wireless networks MANET or VANET. Experimental studies were conducted to determine the possibility of using the salp swarm optimization in the FANET [7].

The rest of paper, section 2 is illustratesalp swarms algorithm, section 3 is concerted for self-organizing unmanned, section 4 routing methods algorithms, section 5 routing in a self-organizing network based on salp swarm optimization, while section 6 is simulation the protocol, finally section 7 is conclusion.

2. SALP SWARM ALGORITHM (SSA)

SSA is developed in 2017, it simulates the behavior of salp swarms and them interaction socially [6]. They are living in deep of oceans and seas. They moving in regulated swarm called "salpchains" water forces to detect their food, it has leader which has optimal ruling for leadership a swarm in preparate environment, stayed for long time at heading of chain. However, but different other swarms, the leader no longer directly affects the movement of the whole group, but affects directly to move of second salp next to him, the second salp directly affects the third salp, and so on, as shown in Figure 1.

![Figure 1. Salp chain](image)

To represent salp chain mathematically that divided into two sets: “leader” is headsalp and others are called “followers”. It has been done to reinforce their movement in searching for food. The SSA algorithm has following properties:
- The position of salps is defined search space d-dimensional, where d is number of variables of a given problem.
- The source of food $F$ is swarm’s target. $F = [F_1, F_2, \ldots, F_D]^T$. The upper and lower boundsof search space are $ub = [ub_1, ub_2, \ldots, ub_D]$ and $lb = [lb_1, lb_2, \ldots, lb_D]$. Then initialize the position of salps $x_{ij}$ in a random manner, $i = 1, 2, \ldots, N, j = 1, 2, \ldots, D$.

$$x_{ij} = rand(N, D) * (ub(j) + lb(j))$$ (1)

- In equation 2 illustrate updated the position of leader,

$$x_{ij}^* = \{ F_j + c_1((ub_j - lb_j)c_2 + lb_j)i_j \geq 0 \ F_j - c_1((ub_j - lb_j)c_2 + lb_j)i_j < 0$$ (2)

Where $x_{ij}^*$ is the position of leader in $j$-th dimension, $ub_j$ is upper boundary, $lb_j$ is the lower boundary; $F_j$ is food source position [6].
- The coefficient $c_j$ is balances between the exploration and exploitation.
- Exploration focuses to find better solution from search space of exploring suitably, while exploitation focuses on exploiting data from local area. $c_1$ is decreased over iterations.
- $c_2$ and $c_3$ are important parameters random numbers produced within the interval $[0,1]$.
- $c_3$ is indicating whether next position of current leader salp should to be toward +$\infty$ or - $\infty$.
- The followers update their position according to Newton’s law of motion using (3).

$$c_1 = 2 \exp \exp - \left( \frac{4t}{L} \right)^2$$

The variables numbers $c_2$ and $c_3$ are randomly generated within interval $[0,1]$. $C_1$ is accountable for indicating whether next position of current leader should be toward +$\infty$ or - $\infty$. The followers update their position according to Newton’s law of motion using (4).

$$x_j^i = \frac{1}{2} a t^2 + v_0 t$$

Where $i \geq 2$ represent position of the i-th follows in the j-th dimension, $t$ is the time $v_0$ is the initial speed, and $a = \frac{v_{\text{final}}}{v_0}$ where $v_0 = (x-x_0)/t$
Since the time is considered as iterations and $v_0 = 0$, equation 5 can be reformulated as in (5) [6].

$$x_j^i = \frac{1}{2} \left( x_j^i + x_j^{i-1} \right)$$

Therefore, updating of follower position illustrate in (6).

$$x_j^i = x_j^i + R = \frac{1}{2} \left( x_j^i + x_j^{i-1} \right)$$

The pseudo code of SSA are shown in Figure 2:

```
begin
    Set algorithm parameters: The population size is $N$, the dimension of the problem is $D$, the maximum number of iterations is $Max\_Iteration$.
    Randomly initialize the population according to Equation (1). The fitness value of each salp individual is calculated, and the optimal individual is selected as the food source location.
    while ($t < Max\_Iteration$) do
        for $i = 1$ to $N$ do
            if ($i < \frac{N}{2}$) do
                Update the position of leader according to Equation (2).
            else
                Update the position of follower according to Equation (6).
            end if
        end for
        Calculate the fitness value of individual population and the food source location is updated.
        $l = l + 1$.
    end while
end
```

Figure 2. Pseudo code of SSA

3. SELF-ORGANIZING UNMANNED AERIAL VEHICLES
Recently, FANET networks have become very popular instead of VANET (peer-to-peer self-organizing), the main nodes of which are unmanned aerial vehicles (UAVs). In this type of networks used UAVs as a foundation for organization of network infrastructure is an attractive approach in terms of increasing telecommunications capabilities of network. The network based on the UAV is characterized by versatility, flexibility and low operating costs [7]. Such a network can be applied in the most diverse branches shown in Figure 3.
4. ROUTING METHODS ALGORITHMS IN FANET

The technologies for organizing self-organizing FANET networks are currently under development; new methods for routing algorithms are emerging [8]. The choice of routing protocol is determined by the requirements: number of nodes, their mobility, support for quality of service (QoS), and types of transmitted traffic. The basis algorithm for any routing protocol is found distance nodes. At the same time, routing methods must meet the following requirements [9]:

- Take into account the features of FANET that ensure fast convergence and creating a route without absence of looping routes.
- Ensure reliable delivery of packages for support multiple routes of information delivery to destination.
- FANET must have mechanisms to detect inaccessible routes and their removal/restoration to ensure the construction of routes in accordance with the requirements (QoS and jitter).
- Ensure minimal network load with service information.
- Have security mechanisms for routing and transferring data.
- Ensure minimization of energy consumption of network nodes [10].

5. ROUTING IN A SELF-ORGANIZING NETWORK BASED ON SALP SWARM OPTIMIZATION

Salp algorithms developed for telecommunication networks differ from most traditional algorithms. It has features that enable to solve routing problems in wireless self-organizing networks:

- Salps organize an effective and highly organized system.
- Demonstrate adaptability to changing environmental conditions;
- Possess fault tolerance and able to quickly restore their numbers after the loss of individuals. There is high populations scalability in this algorithm. Consider Salp Ad Hoc salp algorithm (see Figure 4) is routing process in a self-organizing network [11]. The first stage “intelligence” consists of direct and reverse intelligence. Direct intelligence officers search for a destination site on the network. When is detect a node of destination, the followers’ reverse returns to the source node. The followers contain following information: the followers identification (ID), the ID of the source node, the minimum residual energy (initial value equal to infinity) and number of hops (initial value equal zero). Leader is sent to all followers of source node. Each intermediate node increments the hop counts by one [12].

- The energy efficiency of the transmitted data depends on the value of this counter. When a destination node is detected, reverse returns to source node. On intermediate nodes, the algorithm monitors changes in characteristics. Intelligence officers and, guided by the information received, decides on the effectiveness of the route [13].

In this way, there are established multiple channels between source and destination node. After completion of exploration and establishment of the route, they determined require search through explosion, and then comes the stage of exploiting resources. Salp transmits data by analogy with lower bounds of the search space. The data is transferred from source node to destination, all decisions are initiated by the source node. In order to return, and salps must continuous to exploration accordance with the ID-routes. During the return, the quality of routes is limited, while energy-inactive are removed from routing tables [14].
6. SCENARIO FOR SIMULATION

Comparison of routing protocols in self-organizing networks FANET is difficult due to the influence of a large number of factors that are random in nature and for this reason poorly amenable to rigorous mathematical analysis [15]. To study the work of Ad Hoc network applied simulation tools. The emergence of simulation software has made it possible to carry out the necessary research and experiments, including improving existing and developing new routing protocols without actually deploying the network [16], [17]. For carrying out simulation modeling, a wide range of software is offered. The most well-known and popular are the following simulation tools “NS-3, OPNET/Riverbed SteelCentral, OMNET”.

In this paper, the salpAdHoc routing protocol was studied by NS-2 (network simulator) with install salpAdHoc protocol installed. The comparison was carried out with the protocols implemented in the simulator: AODV, DSDV, and DSR [18], [19].

In the simulated network, are defined in the following restrictions:
- Version of the network simulator - NS-2.34.
- Visualize the movement of the UAV using the utility NetAnim.
- The study of routing protocols was made for groups consisting of 10, 20, 30, 40, 50 UAVs.
- The parameters which used for simulation were chosen based on the analysis of various publications like [20], [21].

As a result, it was concluded that all researchers use approximately the same parameters in Table 1, which vary depending on the objectives of the study. The simulation experiment scenario consists of nodes simulating the behavior of UAVs moving randomly in accordance with the mobility model based on random route points random waypoint mobility (RWM) in the area of 1800x1800 m² (Figure 5) each node moves to selected position randomly with a randomly chosen speed between a predefined minimum and maximum speed [22], [23]. At the application level, a generator with a fixed packet delivery rate is used as a source of useful traffic. Simulation of traffic transmission at the transport level is performed using UDP datagrams at a speed of 512 Kbps [24], [25].

Apart from scenarios in which the number of nodes in the network and the speed of movement changed, the rest of conditions were same [26], [27]. The following metrics are used to evaluate the performance of routing protocols [28]:
- End-to-End delay: sum of delays from moment first transmitted byte until the last byte reached to receivers. It comprises transmission delay, propagation delay, and process queue delay.
- Throughput: features maximum possible rate of successful submission of packets over a connection channel.
- Routing Overhead: include the router’s operations such as choose routes of packets and designing routing table [29]-[32].

<table>
<thead>
<tr>
<th>Table 1. Parameters of simulation</th>
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<tbody>
<tr>
<td><strong>Parameter</strong></td>
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<tr>
<td>Area Size</td>
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<tr>
<td>Model of Mobility</td>
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<tr>
<td>Number of UAV</td>
</tr>
<tr>
<td>Iteration period</td>
</tr>
<tr>
<td>Speed of Knot</td>
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<tr>
<td>Traffic generator</td>
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<tr>
<td>Level of MAC</td>
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<tr>
<td>Signal publishing Model</td>
</tr>
<tr>
<td>Type of Antenna</td>
</tr>
<tr>
<td>Coverage Antenna Area</td>
</tr>
<tr>
<td>Level of Transport</td>
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<tr>
<td>Package size</td>
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</table>
7. SIMULATION RESULTS

In this paper suggested that an increase in the number of nodes, the salpAdHoc protocol will demonstrate better performance than Ad-hoc on-demand distance vector (AODV), dynamic source routing (DSR) protocols and destination-sequenced distance-vector routing (DSDV). It was expected increased routing overhead and end-to-end delay, whereas throughput would remain without significant changes. For experiment applied in this paper, used a varying number of nodes in range of values from 20 to 100. the expression result shown in Tables 2 and 3.

As shown in Table 2 that with an increase in the number of nodes, the throughput of the SalpAdHoc, DSR, AODV protocols increases, while DSDV throughput decreases in proportion to the increase in the number of nodes and also shown the SalpAdHoc is protocol in number 50 best from DSR protocol. Also see ratio of traffic shows that with an increase in the number of nodes there is an increase in “routing overhead” for all protocols consideration. At the same time, DSDV and DSR dispalybest performance, and salpAdHoc is on average superior to AODV.

According to Table 2 and Table 3 shows the behavior of algorithms relative to end-to-end delay for number of nodes. SalpAdHoc is slightly inferior with AODV and DSR protocols. DSDV has best performance since is a proactive/tabular protocol and routes to all nodes are stored in its routing table. Algorithms exhibit different behaviors in this regard; DSDV is marked by volatile behavior. SalpAdHoc is most adaptive algorithm in relation to topology changes; in public, change in speed has a negligible effect on its throughput. With increasing speed, the salpAdHoc and AODV algorithms quickly adapt inchanges and have better throughput performance.

From Table 3 that DSDV and DSR do not have a large load in terms of the routing overhead with increasing node mobility, simultaneously, salp AdHoc is increased stress. AODV has exactly the opposite behavior to salpAdHoc due to the fact that AODV uses the routing table to save multiple paths to destination, and alternative paths can be found without having to start the route discovery process. SalpAdHoc has large costs compared to protocols due to the need to find a new route to the destination node, which, in turn, gives an advantage over other protocols in terms of bandwidth.

Based on the results obtained during the experimental study, we can draw the following conclusion, the salpAdHoc algorithm provides a higher throughput compared to DSDV and DSR, but is inferior to them in delay. On average, salpAdHoc performance is similar with considered protocols DSDV, DSR and AODV. SalpAdHoc can be used to route packets on a FANET network.

Table 2. Compare ratio of bandwidth to speed of nodes movement

<table>
<thead>
<tr>
<th>nodes</th>
<th>Band width</th>
<th>Service traffic</th>
<th>End –to-end delay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salp AdHoc</td>
<td>AODV DSDV DSR</td>
<td>Salp AdHoc AODV DSR</td>
</tr>
<tr>
<td>20</td>
<td>16 16 16</td>
<td>16 10 10 8</td>
<td>0 0 0.016 0</td>
</tr>
<tr>
<td>40</td>
<td>52 38 54</td>
<td>54 10 15 15</td>
<td>0.012 0.008 0.014 0.013</td>
</tr>
<tr>
<td>60</td>
<td>76 34 80</td>
<td>76 15 30 30</td>
<td>0.035 0.02 0.01 0.035</td>
</tr>
<tr>
<td>80</td>
<td>78 20 82</td>
<td>80 225 45 50</td>
<td>0.048 0.018 0.006 0.049</td>
</tr>
<tr>
<td>100</td>
<td>79 0 100</td>
<td>62 290 50 50</td>
<td>0.052 0.042 0 0.054</td>
</tr>
</tbody>
</table>
8. CONCLUSION
To date, there is no routing algorithm that meets all the requirements for FANET, and provides high rates of network efficiency in various conditions. Using the salpAdHoc protocol as an example, an experimental analysis was conducted, the results of which confirm the feasibility of using salp swarm optimization for routing in FANET compared to other algorithms. The direction for further research is to study the behavior of the salpAdHoc algorithm when used in various scenarios. When conducting experimental studies, it is planned to emulate not only different types of traffic (voice/video), but also to change the size of the data packets being sent. In addition, it is advisable to conduct research related to the development of a unified methodology for testing routing protocols in FANET.

REFERENCES
BIOGRAPHIES OF AUTHORS

Alaa Ibrahim Mahmood was born in Mosul-Iraq. She holds a M.Sc degree in information Technology from university Utara Malaysia (UUM), B.Sc degree in computer science from college computer science and mathematic, University of Mosul, Iraq. She is a lecturer in secondary school (AL-Zuhur) in Mosul, Iraq. He can be contacted at email: alaaimahm2@gmail.com.

Omar Ibrahim Alsaif received his B.Sc. in electrical engineering from University of Mosul, Mosul, Iraq, in 1992. He received his M.Sc. and Ph. D degrees in electrical and microelectronic engineering from Mosul University, in 2005 and 2018 respectively. He is currently a lecturer in the Mosul Technical Institute/Northern Technical University in Mosul, Iraq. His research interests in clude microelectronic solid-state systems and renewable energy. He can be contacted at email: omar.alsai@ntu.edu.iq.

Ibrahim Ahmed Saleh was born in Mosul-Iraq in 1963. He received his MSc. degree in signal and image processing) from the University of Mosul, Iraq in 2003 and in 2013 he received his PhD in artificial techniques and computer networking from Mosul University. He became professor in 2021. From 1997 to 2005, he worked at computer center in Mosul University/Iraq. Currently he is lecturer at the Dept. of Software Engineering, College of Computer Sciences and Math, and University of Mosul, Iraq. He can be contacted at email: i.hadedi@uomosul.edu.iq.