Noname manuscript No.
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MCBRA (Multi-agents Communities Based Routing Algorithm): A routing protocol proposition for UAVs network

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Received: 30 Juin 2021 / Accepted: 22 October 2021

Abstract Group missions of autonomous aerial vehicles have attracted a big interest in the last years due to its vast coverage area and its capability of executing complex tasks in a short amount of time. To ensure a high QoS in this collaborative work, the designed routing protocol must overcome the constraints imposed by this type of wireless ad hoc network that are mainly driven by the rapid mobility of the UAVs. In this paper, we give a brief overview on flying ad hoc routing protocols, then, we theoretically present and argue about our bio-inspired routing protocol proposition that uses a smart multi-agent system communities followed with some adaptations of two existing routing protocols that we believe it can deliver a higher QoS.

Keywords FANET · UAVs network · Drone's fleet · routing protocol · multi-agent system

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1 Introduction

Developing an adequate routing protocol becomes a challenge for researchers and developers in sync with the raised possibility of using swarm robotics of unmanned aerial vehicles (UAVs) in various application areas after being exclusive for military use like borders supervising [22], autonomous tracking [12], and surveillance [21]. Now, UAVs swarm is witnessing other applications such as the scientific field like environment sensation(wind estimation [2]), and in managing urban traffic where the UAVs act like relies nodes in VANETs (Vehicular Ad Hoc Networks) [6]. FANET (Flying Ad Hoc Network) comes as a particularity of MANET (Mobile Ad Hoc Network) with an extension of a high speed of the mobile nodes that can up to 6 times faster than the common speed of MANETs' nodes. This high dynamicity causes more difficulties concerning data routing process by affecting the link stability, the topology variation frequency, and causing high network fragmentation.

Many routing protocol solutions have been proposed in literature attempting to overcome the presented difficulties in FANET, but no one agreed that it fully does [16]. The conflicting constraints and the numerous scenarios in FANET applications forced the researchers to go toward tradeoff solutions looking to satisfy the question that says: which routing protocol that suits more application scenarios, and delivers an overall better quality of service. However, we can say that FANET constraints like the shared bandwidth, the limited energy resource, and the high dynamicity make this research field alive for a long time.

It becomes obvious that implementing traditional MANET routing techniques is not a sufficient solution. Therefore, including novel strategies is crucial in this case. That was the reason that has pushed more innovations and interests toward in this field of application. Briefly, this work presents an overview on routing in FANET in parallel with a theoretical UAVs routing protocol proposition. The paper is organized as follows: First, we discuss some of the proposed FANET routing protocols in the second Section. In the third Section, we present and argue bout our solution proposal. Finally, we conclude our paper in the last Section.

2 Related works

In general, UAVs routing protocols have been classified by authors and reviewers into a set of protocols based on its used technique and tools. From the side of its appropriation for flying ad hoc network, in this section, we are going to present some of FANET routing protocols.

First, we are going to spot some topology-based routing protocols where each node has a routing table that contains paths that are based on the relaying nodes in the network. The metrics used here during the routing selection are the number of hops and the link state. This technique is perfect when dealing with static nodes, but using it alone in FANET where the topology changes rapidly costs a huge overhead and causes network congestion. For this reason, racing topology changes in FANET requires a set of adaptations that must be integrated. This category of protocols is divided into three main categories proactive, reactive, and hybrid routing protocols in which we are going to highlight some of these new propositions that are dedicated to FANET as follows.

A. I. Alshbatat and L. Dong proposed D-OLSR (Directional antenna OLSR) [1] as an extension of the OLSR [5]. D-OLSR uses Omni antennas for control packets exchange and directional antennas for data transfer to reduce signals interference among the nodes and to enhance the overall link state. The results showed that the network's overhead and latency were decreased. ML-OLSR (Mobile and Load-aware OLRS) [23] is proposed to improve the election of multi-points-relays. This protocol integrates the node's load and speed in the Hello message to avoid congested nodes in the decision making by adding a new metric named the stability degree and avoiding high relative speed nodes by adding a second metric named the reachability degree.

To be integrated in FANET, the authors in [13] proposed UE-DSR (UAV Energy Dynamic Source Routing). This reactive routing protocol includes ab energy balancing mechanism in the well-known routing algorithm the DSR [10] to prolongs the network lifetime. RE-DSR (restricted DSR) [14], this new DSR protocol can optimize the memory capacity of the node's and reduce the routing overhead by limiting the maximum hop count of the route request. For reducing packet collisions TS-AODV (time-slotted AODV) [8] uses a defined time to send data where one node can transmit its packets, the results show a high delivery ratio and low congestion average, but the risk of time synchronization deviation still be in real implementations.

ZRP (Zone Routing Protocol) [9] is a hybrid routing protocol. Unlike HWMP, ZRP doesn't switch from reactive to a proactive state. The developers useed both routing approaches by dividing the coverage areas into small zones where the nodes proactively broadcast its routing table. When a node decides to reach an out-zone node, it uses the reactive approach and floods RREQ in the whole network to continue the communication with the same strategy. SHARP (Sharp Hybrid A Routing Protocol) [17] exploits the same method used in ZRP and improves the path discovery process when a node establishes a communication outside of the inter-zone. The word "sharp" is used to describe the intersection between the source node RREQ during its discovery process with the zone that contains the destination node. Instead of going inside the container zone, it is sufficient to reach one of the zone member nodes, then the last one gives the scheme toward the target directly and continues the routing process.

The following routing protocols are categorized as position-based routing protocols, in which this category is not entirely independent of the topology-based technique. The routing protocols here use the position information for supporting the discovery process of the destination node. In some propositions, it has been used for path maintenance as well. However, it is essential when dealing with high dynamic networks like FANET where the topology rapidly changes over time. This technique is not complicated when the positions of the nodes are known, but for autonomous moving objects, this case requires frequent position broadcasting. Examples of position-based protocols are given as follows:

The authors in [19] proposed MUDOR (Multipath Doppler Routing). Based on its name, the multipath refers to the application of the technique used in the famous routing protocol DSR that provides multipath routing choices. The Doppler word referes to the doppler effect of the electromagnetic waves fadding. This latter indicates the stability of the links and the lifetime of the relaying nodes in the transmission range and the routing table. GLSR (Geographic Load Sharing Routing) [15] is an improved version of the GPSR dedicated to FANET. GLSR exploits the geographic position of the moving nodes as well as it's speed to estimate the link stability. Also, it includes the the node's buffer (queued packets) consumption and uses it as a metric when choosing the next-hop relay. GRG (Greedy Random Greedy) [7] switches to tow routing modes. The first one is the greedy mode in which GRG uses it during the regular situation when assuming that there are no disconnections between the nodes. If a disconnection appears, the last relay node tries to continue the process by randomly selecting another relay node using the RW algorithm. Reversely, RGR (Reactive Greedy Reactive) [20] uses the same strategy but differently. This efficient protocol is a combination of two routing modes. In the first phase, the AODV protocol is used to discover the destination node by flooding an RREQ in the network. Then, after having the destination response. In the case of a link failure, the second algorithm GGF (Geographic Greedy Forwarding) is activated to recover the broken links after having the address of the destination in the first phase (with the AODV), then it returns to the first mode.

3 Solution propostion

Based on what we mentioned earlier and our work in [4] that illusrates how a FANET routing protocol proposition should cover, we recommend the use of a nature-inspired routing protocol to improve the QoS in this type of networks. The reasons behind this choice are driven from the difficulties imposed by the environment modeling where there is a lack of a mathematical formula that can describe the swarm behavior in a way that makes it impossible to cover all the scenarios that can happen during the mission, or the data transfer process. In drone's fleets applications: (i)The incoming events are not identified where, when, and how it can happen, (ii) the drone has a limited perception of its environment, (iii) it needs the collaboration of others drones to transfer its gathered DATA, (iv) it must react intelligently to the unexpected events during the mission execution. All these facts stand directly with the use of multi-agents system techniques. This promising technique has been invented to particularly deal with this sort of problems. According to the mentioned parameters in the latter section, Its strong points are its simplicity (few simple rules), scalability (maintain performance in both small and large agents number), flexibility (agents behave instinctively in a known manner), and its low cost.

The search for the optimum path in a continuous way in this type of network necessarily requires a complexity of calculation and a high cost of communication and energy. In these kinds of problems, even if the obtained path is a global optimum, this solution is subject to failure due to instability and high mobility. So the approximation or the convergence towards the global optimum (Multi-path routing) is favored in this case rather than risking and wasting time finding a non-guaranteed optimal solution. For these reasons, we decided that our proposition must be a multi-path routing protocol in which it is going to be a combination of three routing protocols: MMSR (Mobile Multi Agent System for Routing in Adhoc Network) [18], POSANT (Position Based Ant Colony Routing Algorithm) [11], and BIODRA(Bio-inspired On-Demand Routing Protocol) [3].

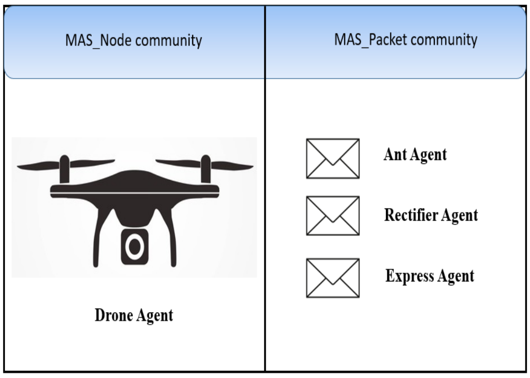

Fig. 1 MMSR agents communities.

MMSR is a multi-agent system routing protocol dedicated to MANET. It has two agents communities within, SMA-Node and SMA-Packet communities (see Figure 3). The first one represents a physical agent group that is the moving nodes (robots), and the second community is a set of abstract agents in the form of packets where the latter has three agent families the Ant-agents, the Rectifier agents, and the Express agents. Each agent type has its own assigned functions (these functions are well detailed in [18]) in a way that each group is dedicated to accomplishing a specific purpose. Node agents and Ant agents are working collaboratively to build paths, Rectifier agents are made to update the routing table when a topology change is detected, and Express agents are issued to reduce the end-to-end delay between the sender and the receiver.

POSANT is also a multi-path routing protocol targeted for MANET which is based on the well-known ACO algorithm to establish its paths. Generally, the point that makes this algorithm difference is its use of the position information to guide the ant agent to the destination node rapidly. The guidance process is based on creating a virtual zone within each node where the ant agent can put its pheromone trails on. The idea relays on the assumption that says that: The shortest path is more likely to form a position progression angel toward the destination node. Based on that and as Figure 4 shows, we see three built zones; the belongingness of each node to a specific zone depends on is the relative angle between the claimant node and its destination node in which node H (neighbor node) belongs to zone1 if θH $<= \pi/4$, zone2 if $\pi/4 < \theta$H $<= 3\pi/4$ zone3 if $3\pi/4 < \theta$H $<= \pi$. After putting the pheromone on the corresponding zone, the quantity of the pheromone is multiplied by factors. Each factor ν_i in attached with its zone i in which $\nu_1 \geq \nu_2 \geq \nu_3$ as a method to enhance the probability of reaching shortest paths faster.

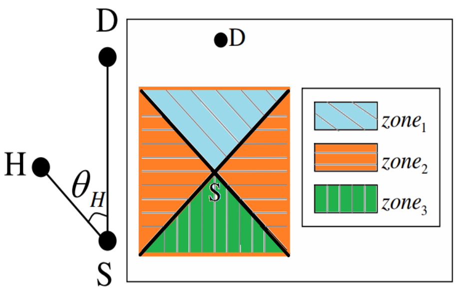

Fig. 2 POSANT virtual zones for pheramone trails.

Both propositions are trying to use the minimum control packets to avoid network overhead to provide a high QoS under the presence of MANET topology changes. Our proposed routing protocol is the integrity of these two algorithms with a new adaption to suit the requirement imposed in this high-speed network FANET. We maintain the same principal of MMSR, and we assign the virtual zones of the POSANT algorithm to the node agent where we keep the same fundamental number of the pheromone zones, and we divide zone number 2 into two zones with the same attributed coefficient ν_2. Finally, our

main contribution is we add a function to the evaporation process that controls the pheromone quantity withing the Node agent in the ax of time by using the position and the direction information in order to reduce the frequency of releasing the Ant agent in the network where we can increase the amount of the pheromone and decrease it without the visiting of the ant agent to the node itself as equation (3).
The former evaporation equation:

$$\psi_{\mathrm{it}} = (1-\alpha) * \psi_{\mathrm{i(t-1)}} \tag{1}$$

Our adaption:

$$\psi_{\mathrm{it}} = f(\overrightarrow{position_j}, \overrightarrow{velocity_j}) * \psi_{\mathrm{i(t-1)}} \tag{2}$$

$$\Delta\mathrm{q} = [\mathrm{C(i,j,d)}^{*}\mathrm{E_j} + \mathrm{q}] * v_i \tag{3}$$

$f(\overrightarrow{position_j}, \overrightarrow{velocity_j})$ works for adjusting the pheromone evaporation in the axis of time by using the position and the velocity vectors of the corresponding node, and Equation (4) express the integrity of POSANT zone coefficients to the quantity of the posed pheromone. The scenario comes as follows: Our proposed algorithm uses a small number of control packet in the proactive phase the same way as MMSR but in a lower amount. Here, we embrace the geographical information of the flying nodes within the virtual zones where each node releases just one ant agent (not 3 ant agents in POSANT case) from the zone that has been not received an ant-agent form it to increase the probability of visiting as possible as it can of nodes from different positions in the zone of interest. After this phase, we can say that the corresponding node has enough update information about its neighboring nodes. when information is about to be sent to a destination node, the same protocol as MMSR runs, also the pheromone quantity is multiplied by its attributed zone as mentioned in POSANT, as well as the node in the selected path start to align with each other using the algorithm that used in BIODRA (will be discussed in the next paragraph).

BIODRA is a reactive routing protocol proposed for FANET that uses the well-known AODV algorithm. The main idea of this protocol is when a connection starts between tow nodes the concerned nodes in the path and the neighborhood begin the align and get closer to each other as a flock using Craig Reynold flocking behaviors to maintain enough time for passing the message and reduce packet loss. From our point of view, we see this routing protocol as a cross-layer mobility model more than a routing protocol because the main contribution can be applied in all routing algorithms. However, we also integrate this technique into our proposed routing protocol due to its efficiency during high dynamic networks like our case.

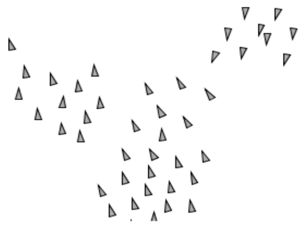

Fig. 3 Craig Reynold flocking boids.

4 Conclusion

In this paper, we briefly talked about FANET specifications and constraints. We reviewed a set of proposed solutions in the literature. We discussed some details mentioning a recent work of ours that refers to how a proposed routing protocol should be assessed in order to suit FANET applications. That was the structure that we used to introduce and argue about our routing protocol proposition that is based on a multi-agent system of multiple communities in which we believe that it is a promising solution that takes advantage of a large scale of used techniques and tools that can fit FANET requirements and balance its conflicting constraints.

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