Bio-Inspired Drones Recruiting Strategy for Precision Agriculture Domain

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***Abstract*—UAV stands for Unmanned Aerial Vehicle and it is a flying device characterized by the absence of the pilot on board. Its support in many situations and different applications is able to relieve the human operator thanks to its capacity of having a rapid deployment and quickly performing its action. In order to make its tasks, every UAV/Drone is equipped with a set of on-board sensors specific for each task. One of different applicative fields is the precision agriculture, where, thanks to the possibility of equipping the UAV with on-board cameras, it is able to perform detailed analysis of the health status of the plants intervening suddenly if it is needed. In this paper, coordination protocols applied to the problem of controlling a swarm of UAVs/Drones against parasites attacks to crops has been analysed, studying different approaches in order to measure their performance and costs. One of the problems with these devices concerns the limited quantities of fuel and pesticide. A possible approach to this issue is asking for help to other UAVs/Drones in order to destroy completely the parasites. The idea is to apply the concepts of bio-inspired approach to the recruitment protocols providing performance evaluation in order to give the goodness of the proposal.**

***Index Terms*—UAV, Drone, Precision Agriculture, Coordination Protocol, Bio-Inspired**

I. Introduction

Precision agriculture was born in the United States of America in the early nineties and the name comes from the English Precision Agriculture or Precision Farming or Site Specific Farming Management. Its birth and evolution have been favored and supported by the potential deriving from the widespread application of new technical solutions to the primary sector. This practice consists in applying technologies, principles and strategies for spatial and temporal management of the variability associated with aspects of agricultural production, in relation to the real needs of the plot [1].

The application of this innovative approach requires an in-depth knowledge of the physical, chemical and biological characteristics of the fields, their mapping and storage so that they can then be managed by computer control of the crop operations, placed on board the machines [2]. The environmental benefits derive from a more targeted use of chemicals, better efficiency or, in the case of pesticides, the reduction of the development of resistance to various active ingredients. All this has effects on water quality and the reduction of its consumption, on the quality of soil and air, on climate mitigation and on the energy issue.

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For that concern precision agriculture, these new flying devices allow to follow the plants growth intervening in cases of parasites infection. Also, they are able to fly at specific height in order to acquire images without interfere with satellites, [3]. [4].

The possibility of creating team of UAVs/Drones is a big advantage in this application domain. This because UAVs can collaborate together in order to reach the prefixed task considering that they are equipped with a limited amount of energy for battery life and limited amount of, for example, pesticide in that case in which farmers have to fight against parasites. Then, the cooperation between these devices represents an important aspect and, it is important to study the coordination techniques able to create group of UAVs that collaborate together, paying attention to energy saving [5] and energy harvesting [7], [8]. There are other important topics that are object of research in the scientific community about UAVs/Drones. A very studied topic regards the possibility of providing coverage in particular scenario (such as emergency situations) [6], and, then, the bandwidth management performing mobility prediction of the users and the opportune admission call [9], [10] preserving packet loss [11], [12] in the network. This type of devices can be utilized in cooperation with Satellite platforms [13], [14] in order to give a more ubiquitous connection or with VANET network in order to give support to networks of vehicles [15]. Also, different routing techniques are possible to use in these new networks based on new approaches such as opportunistic mechanism [16], [17]. In this paper, a comparison between two recruiting protocols are evaluated: a classical flooding mechanism and a bio-inspired approach. After explaining briefly the protocol functionality, the results obtained compared the two approaches in the Precision Agriculture domain are presented.

The paper is organized in the following way: in Section II related works are presented; an high level panoramic about protocols for coordination is shown in Section III; two different coordination strategies with comparison are detailed in Section IV; finally, conclusions are presented section V.

II. Related Work

In the following, some works that deal with coordination issues in UAVs platforms are shown.

In [18], authors deal with coordination movement of swarms of UAVs/Drones using mobile networks. In [19], authors propose a biologically-inspired mechanisms to coordinate

UAVs performing target search with imperfect sensors. In [20], author proposal is based on stigmergy approach that previews of depositing digital pheromone on those locations where UAVs sense potential target. In [21], authors propose a control strategy for a group of UAVs through the use of a bio-inspired approach for creating a robust control and coordination strategy. The paper [22] proposes a solution for the non-linear problem of the constraints optimization showing the UAV motion coordination in which a reference UAV can be seen as a leader in the group.

III. Routing Protocols for Coordination Techniques

The coordination techniques allow to organize UAVs in groups, forming a so called Flying Ad-hoc NETwork (FANET) [23], in order to perform together a specific task exploiting messages exchange between each other. In the following, a classification of the routing protocols is given in order to show the different approaches that it is possible to follow.

A. Routing Protocols Classification

Routing protocol can be classified in the following way:

Proactive: Devices exchange packets on periodical basis, updating the routing table of each node. This permits of having always updated routing information despite the large amount of messages in the network. Proactive protocols have the following characteristics:

- *Exchange of packets at fixed intervals*: Proactive protocols have the property of allowing the components of the network to have the most up-to-date routing information available. This mechanism is possible because the devices, without any necessary request, exchange information packets between them. The packets reveal both the routing information and the topological changes in the network.
- *Use of tables*: The use of one or more tables that store all information regarding the network topology is a peculiar characteristic of the Proactive class.
- *Updating of tables*: Updating routing tables is a fundamental quality of this class of protocols, which means that users who choose these protocols can have a large network available.

Reactive: Reactive protocols main feature is to make paths among nodes on-demand: an important feature for very dynamic networks such as FANET. Reactive protocols send a packet from a source to a destination in the following way:

- *Route discovery*: Used for discovering several paths between source and destination node;
- *Route maintenance*;
- *Route deletion*.

A generic reactive protocol behavior is shown in Fig. 1: a Route Request (RReq) message is sent by source node (S in the figure) to its neighbors to discover the best path towards destination. This message is forwarded by other nodes if they miss information to reach destination (C in the figure). A Route Replay (RRep) message is sent back towards the source when it arrives on a node that knows the destination. This behavior is depicted in the figure below (Fig.1) through the time epochs T1, T2, and T3.

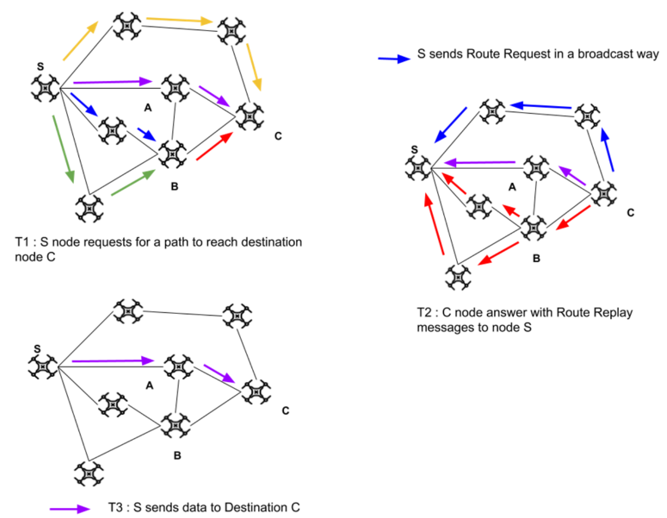

Fig. 1. Messages exchange in a reactive protocol

Hybrid: A protocols family able to join the proactive and reactive positive features is called "Hybrid". Examples are: Location-Aided Routing (LAR) and Zone Routing Protocol (ZRP) [24].

Hierarchical: This family is able to reduce overhead of proactive protocols by grouping nodes into classes inserted in the tables. In particular, the network is divided into clusters, in which a cluster leader is elected obtaining a centralized structure to implement more scalable protocols. Within the cluster, proactive techniques are used, while for inter-cluster communication, reactive techniques are used, so to allow of reaching the destination cluster.

Location based: Based on GPS information, another protocols family is able to perform routing according to the position of the searched node. Routing is optimized so that it occurs in a certain area (Routing Zone) that contains the Expected Zone, which is the area in which it is reasonable to think of finding the destination node.

Power-aware: In the last protocols family, the nodes are aware of the limitation of their energy resources and this information is used to decide when to be switched on or off, or to choose the least expensive path from a power point of view. A protocol example is: PARO (Power-Aware Routing Optimized) [25].

IV. Coordination Strategies

UAVs recruitment is used in many situations, such as in those cases where help is needed from other UAVs. This mechanism is performed by using different approaches. In this section, two different techniques are explained: flooding base and bio-inspired base recruitment.

A. Flooding base recruitment

When a UAV needs help, it sends a broadcast message starting a timeout and awaiting that a UAV in the Wi-Fi range receives this message and, if available, sends a reply. At the timeout expiration, the requesting UAV, considering the replies, chooses the UAV with the maximum pesticide level, or, for equal pesticide, with maximum energy level, or, for equal pesticide and energy, nearest UAV. In case of equal pesticide, energy and distance, the choice is for the first answering UAV. So, the UAV that needs help sends a recruiting message towards the chosen UAV returning to the recharging base. If the UAV does not receive response to its help request it stores its coordinates in order to come back after recharging.

B. Bio-inspired recruitment

The bio-inspired technique is based on an Ant Colony Optimization (ACO) approach for performing recruitment: each node, periodically, sends Forward ANT (Fant) messages. The probability of sending the FANT message from node i to node j is performed on the basis of this formula:

$$p_{i,j} = \frac{\pi_{i,j}^{\alpha} \cdot \epsilon_{i,j}^{\beta}}{\sum_{k \in K} \pi_{i,k}^{\alpha} \cdot \epsilon_{i,k}^{\beta}} \tag{1}$$

where π_{ij} is the pheromone of the entry node in the table in which the destination is the destination to be reached and the next hop is the node j, $\epsilon_{i,j}$ is the local heuristics on the connection between node i and node j represented by a random number, α is the incidence of the pheromone on the choice, β is the incidence of heuristics on the choice, K is the set of nodes, with distance equal to 1 hop from i, that are able to reach the destination. Once the FANT reaches the destination node, this last one sends a new message called Backward ANT (BANT) on the reverse path.

The reinforcement of the pheromone for a given destination takes place at the BANT packet crossing. In particular, at the BANT crossing the pheromone is strengthened in the entry of the routing table with destination equal to the node sending the packet and next hop equal to the node from which it is receiving the packet.

Evaporation of the pheromone occurs periodically as follows (to manage those paths no longer crossed by packets):

$$\pi_{i,j} = (1 - \rho) \cdot \pi_{i,j-1} \tag{2}$$

where $\pi_{i,j-1}$ is the pheromone present before evaporation in the routing table of node i towards a known destination passing through the next hop j, ρ is the evaporation coefficient of the pheromone and it is a value between 0 and 1.

C. Recruiting Protocol Comparison

Differently from previous work [27], where a comparative analysis between a reactive flooding versus a link state approach in a precision agriculture domain has been presented, in this contribution, a comparison between a classical flooding mechanism with a recruiting protocol based on bio-inspired approach has been evaluated considering consumed energy, killed parasites and protocols overhead metrics. In order to perform these comparative analysis, a UAV simulator designed for evaluating UAV performance in Precision Agriculture domain has been used [26].

In Fig.2, the number of killed parasites is shown. It is possible to view how the bio-inspired approach is able to find an higher number of parasites in respect to the reactive flooding mechanism. This is due to the capacity of bio-inspired approach of performing a better UAV recruitment thanks to FANT and BANT messages, differently from Reactive Flooding that floods messages towards the overall networks.

In Fig.3 it is possible to view the comparison between the two approaches in terms of number of recruiting requests. As mentioned previously, bio-inspired approach sends an higher number of UAVs recruiting requests. This means an higher number of UAVs recruiting and, then, a greater number of killed parasites in the considered area.

In Fig.4 it is possible to view the trend of the consumed energy in both approaches. The bio-inspired technique, as it is possible to observe in the figure, is more energy consuming in respect of the reactive flooding approach. The reactive flooding sends a lesser quantity of data in respect of the bio-inspired approach, then its energy consumption is lesser but it results in a lower number of killed parasites.

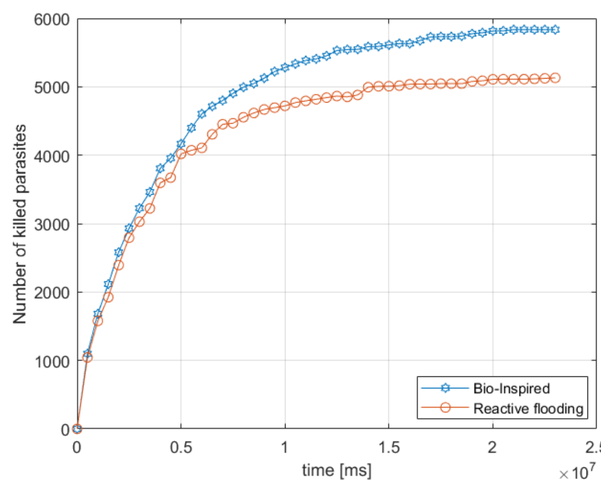

Fig. 2. Number of killed parasites comparison

V. CONCLUSION

This paper presents a comparative analysis between two different recruiting approaches for coordinating UAVs in a Precision Agriculture domain in the fight against parasites. It has been used a simulator specifically designed for this applicative context. The simulation results showed that the bio-inspired approach performs better than reactive flooding one being able to kill a great number of parasites and to exploit better the recruitment of other UAVs, even if it presents a drawback: a greater energy consumption.

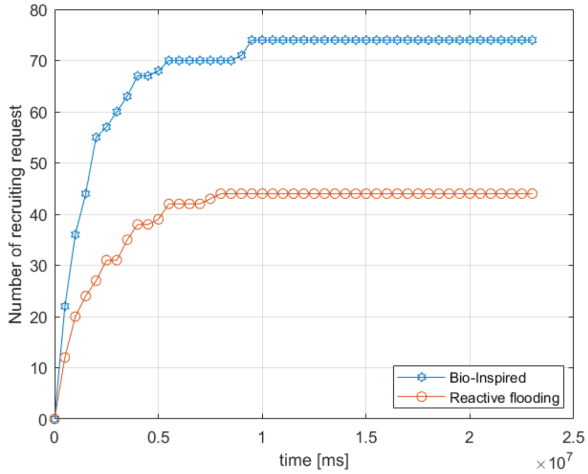

Fig. 3. Number of recruiting request comaprison

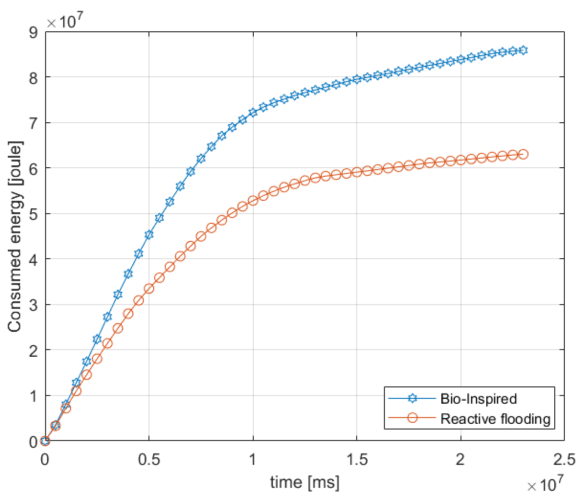

Fig. 4. Consumed energy comparison

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