Hierarchical based Ad hoc Network Architecture of Micro Aerial Vehicles to Counter the Capturing of a Building by a Terrorist Group

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Abstract: Increased demand in battlefield operations to perform missions such as intelligence, surveillance, and reconnaissance has attracted various research agencies to develop the next generation of Unmanned Air Vehicles, called Autonomous Unmanned Micro Air Vehicles. Inspired by nature, the concept is to design intelligent micro flying robots resembling the shape and behavior of flying insects, such as flies, bees, and mosquitoes. Micro Air Vehicles are suitable for indoor surveillance and scouting as they can easily penetrate a building and dynamically establish an ad hoc network for communication. A suitable hierarchical approach is also desirable to address the network scalability issues. In this paper, we propose a hierarchical ad hoc architecture to watch the activities of terrorist during the capturing of a building by them.

***Index Terms* – Ad Hoc Network, Clustering, Surveillance, Micro Air Vehicles.**

I INTRODUCTION

Defense research organizations of various developing countries are competing to invent new technologies for future battlefield operations. This competition has led to the development of various Autonomous Unmanned Aerial Vehicles (UAVs) that can be operated without using remote controls and without a human being on-board [1]. Autonomous UAVs are suitable for use in hazardous environments such as forests, hilly areas, indoors, and other difficult terrains [2], [3]. Inspired by nature, scientists have recently designed intelligent Micro Aerial Vehicles (MAVs) known as biological MAVs, such that their size, shape and behavior resembles flying birds and insects [4]−[11]. The goal is to analyze and approximate the flight control of birds and insects in designing the flapping-wing MAVs [12]. In addition, the capability of a biologically inspired MAV to harvest energy from its flight, body movement and wing vibration will eliminate the concern of battery recharging or replacement in the future [13]. Biologically inspired bird-sized MAVs can fly at varying airspeeds and are capable of covering a larger area for border surveillance, monitoring and target tracking [14]. They can monitor Unmanned Ground Vehicles (UGVs) [15] as well as instruct the UGVs concerning danger and obstacles in their paths. They can also provide instructions concerning targets to the medium or heavy flying drones such as flying robot machine guns or robot helicopters to perform a strike on the ground, inside a building or in the air. Insect-sized MAVs are suitable for indoor surveillance as they can enter a building through small holes and other inlets and may remain undetected or ignored because of their resemblance to flying insects [16]. A research team at Cranfield University in England has a goal to develop a new generation of MAVs that could mimic the highly agile flight patterns of houseflies [17]. A common housefly has the ability to fly forward, backward, upward and downward with its body in one position; it can flip over to land on a ceiling; and it can crawl on the walls and ceiling of a room [17]. Approximating the flight of a common housefly in designing an MAV will lead to a new generation of surveillance drones.

II PROPOSED AD HOC NETWORK ARCHITECTURE TO COUNTER THE CAPTURING OF A BUILDING BY A TERRORIST GROUP

The characteristics of biologically inspired MAVs make them suitable to be deployed for dangerous missions such as capturing a building from a terrorist group or a mission across a border to leak a secret or eavesdrop on a strategic conversation between enemy army officials [18]. A swarm of MAVs must be deployed for these missions to work collectively, with an efficient communication scheme [19]. Ad hoc network technology is perfectly suitable for these missions because it is not dependent on infrastructure and has mobility, peer-to-peer communication over a wireless medium, self-configuration and rapid deployment [20], [21]. Housefly MAVs can establish an ad hoc network after landing upside down on the ceiling of a room and begin crawling in random directions and at random speeds. They can also randomly switch their states from mobile to stationary and vice versa or can fly from one location to another. In an ad hoc network of a large number of housefly MAVs, a suitable hierarchical approach is also desirable to resolve issues such as scalability and energy efficiency. This can be achieved by dividing an ad hoc network of housefly MAVs into interconnected virtual groups called clusters on the basis of rules to differentiate the nodes allocated to these clusters [22]. As shown in Fig. 1, each cluster is maintained by a coordinator housefly MAV called the cluster head MAV, which is responsible for controlling intra-cluster as well as inter-cluster communication and exchange of routing information [23]. Housefly MAVs within the proximity of two or more clusters are called gateway MAVs and are responsible for inter-cluster communication. Other housefly MAVs in the cluster without any inter-cluster link are called the member MAVs. Member MAVs in each cluster transmit their data to the cluster head MAV. The cluster head MAVs then aggregate the data and send it to the bird robots acting as flying or stationary sink nodes outside the building. In a remote location, two or more bird drones can be deployed to alternately gather the aggregated data from the MAV cluster heads, as only one bird drone in the group can act as a sink node at a time.

For example, in Fig. 2, a group of *N* bird drones is initially deployed to alternately act as the sink nodes. This group can be managed by initially assigning a unique sequence number (e.g., between 1 and *N*) to each bird drone in the group. The bird drone having the smallest sequence number (i.e., one in this case) is set to the *On* state and acts as the sink node; the other bird robots are set to the *Off* state. The bird in the *On* state gathers data for a specific period, based on its storage capacity. Once the memory capacity of this bird drone reaches its threshold level, it flies off to deliver its gathered data. Before leaving, it informs the other bird drones in its group and increments its sequence number by a factor *N*. This bird drone may later rejoin the group in an *Off* state after delivering its gathered data. After receipt of this signal, the bird robot in the *Off* state with the smallest sequence number switches to the On state and takes the control of the sink node. The above process is repeated until the completion of the mission. Fig. 3 depicts a flowchart representing the step-by-step functioning of the above scheme.

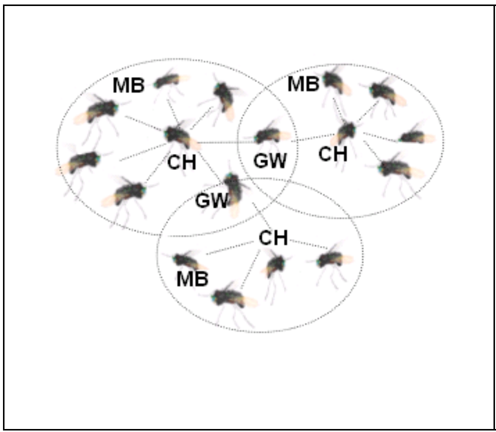

Fig. 1. MAVs forming clusters after establishing an ad hoc network on the ceiling of a room.

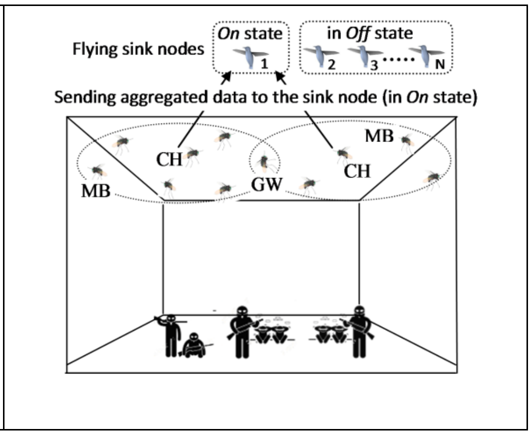

Fig. 2. Cluster heads relaying their aggregated information to the sink node (in an *On* state).

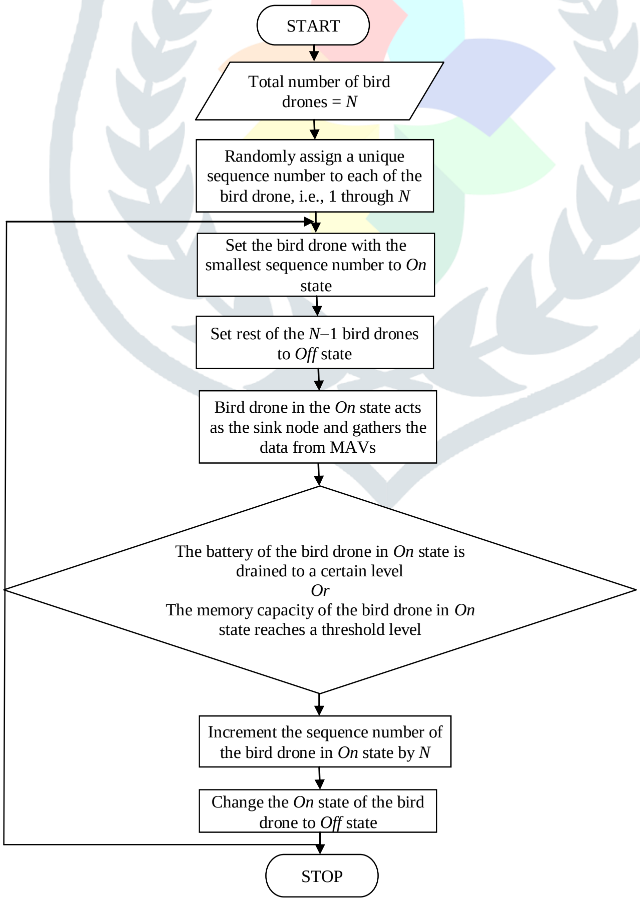

Fig. 3 Allocation of the sink nodes.

In the case of a multi-story building, where each story consists of a large number of rooms, the mission typically requires a very large number of housefly MAVs. In this case, a better approach is to deploy a separate ad hoc network for each floor with multiple groups of sink nodes, as shown in Fig. 4. In this multiple ad hoc network structure, the cluster heads in their respective networks relay the aggregated data to the nearest sink nodes. The bird drones assigned to each floor fly off with the collected information to their source location. The data from multiple bird drones are then further collected to assess the situation.

III Conclusion

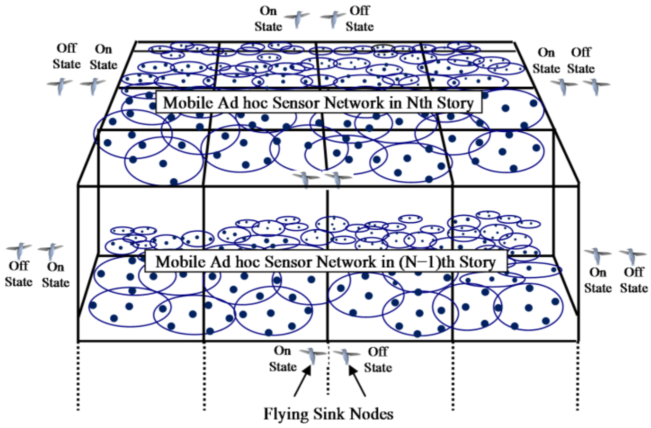

Fig. 4. MAVs establishing a separate ad hoc network on each floor of a multi-story building, each with multiple groups of sink nodes.

The biologically based features of MAV make it ideal for dangerous tasks, including seizing of a building by a terrorist group or trip across the frontier in order to spill secrets or to wake up the strategic communication between the officers of the enemy army. This requires the deployment of a swarm of MAVs to function together with an effective communication system. This can be achieved by setting up an ad hoc network of MAVs.

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