



REVUE ALGERIENNE DES SCIENCES

Section -A-

Sciences de la Nature et de la Vie
Sciences techniques

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Selection of a cluster head for a real-time UAV application using artificial intelligence

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Informations	Abstract
Key words : Drones networks Routing protocol Artificial intelligence Cluster head protocol Correspondence : chemseddine.bemmoussat@gmail.com	In recent years, the search for new wireless communication mechanisms has been highly motivated, with strong growth due to new technologies or configurations in airborne technologies, surveillance of hard-to-reach areas or in case of disaster. Drone (UAV) networks is one of the solutions. In this project, we improved the hierarchical routing protocol using a new technique based on artificial intelligence for the selection of the cluster head in order to have an optimal choice. This technique consists in providing three input parameters to our integrated fuzzy system, which after applying the fuzzy rules and in conjunction with the inference engine will indicate the most appropriate decision to choose the cluster head In our scenario.

1- Introduction

In remote monitoring, FANETs (Flying ad hoc networks) are one of the most important parts. UAV ad hoc networks define a new form of MANET (mobile ad hoc network) where the nodes are UAVs that allow messages to be retransmitted to their destinations. Indeed, recently, research has been conducted to create collaborative multi-UAV systems as in [1], [2] or [3], where several UAVs cooperate with each other to accomplish a mission with better performance. These collaborative systems require the establishment of inter- UAV communications to ensure coordination between the different agents of the system such as the exchange of geographical positions for collision avoidance or for autonomous re-planning of tasks between the agents of a mission. UAV ad hoc networks can be applied to systems where several UAVs are used, a single UAV cannot create an ad hoc network.

2- Introduction to drones networks

Flying ad hoc networks are a sub-family of VANETs [1]. FANETs emerged in response to the need to interconnect multiple UAVs (Unmanned Aerial Vehicles) within a multi-UAV system.

A UAV is defined in [4] as an unmanned aircraft that navigate autonomously using an

on-board system or with the help of a remote control system. A UAV is typically equipped with sensors to determine its position and collect information about an area of interest. UAVs promise new military as well as civilian applications such as interconnection of terrestrial ad hoc networks, search and rescue operations after natural disasters, detection and tracking of military targets, forest fire surveillance, agricultural remote sensing, etc. In a multi-UAV system, ground or satellite base stations provide UAV-to-infrastructure communication. However, as the number of UAVs in the system increases, direct communication between UAVs is an attractive alternative to centralized communication via base stations.



Fig 1 :FANET applications

This can be achieved by establishing an ad hoc network between the UAVs. Indeed, the use of several UAVs in ad hoc mode has the following advantages [4]:

- Reduction of mission accomplishment time: reconnaissance, surveillance and rescue missions can be accomplished more quickly depending on the number of UAVs used.
- Reduction in total maintenance cost: instead of using one large expensive UAV, it is better to use several mini-UAVs with minimal maintenance cost for each.
- Scalability: the theatre of operations can be easily expanded by incorporating as many UAVs as necessary.
- Reduced detectability by radar: this is an important property for military applications. Due to their small size, mini-UAVs have low signatures.

3- Our Scenario

The aim of our scenario is to monitor a dense forest and to transmit the information in real time to the base station.

In order to cover this forest, we have to cooperate with other drones to have a wide coverage, because one drone will never be enough to cover a dense forest. In our scenario, we have opted for three fleets of drones that cooperate to exchange and relay information between them in order to monitor open and wild environments for life after a fire for example.



Fig 1 :Our scenario

- CH : Drone cluster head
- : Wireless communication between CH and members
- : Wireless communication between CH and CH or between CH and base station

The deployment of a fleet of collaborative drones with ad hoc routing mechanisms could be one of the possible solutions to implement such applications. However, this solution will face many challenges, including the high mobility of the drones, maintaining connectivity but most importantly the choice of drone to transmit the data to the base station. This will ensure that the drones have a maximum lifespan.

Our objective here is to remedy these problems. Since the problem is wide coverage and in addition to having real-time transmission and keeping the lifetime of the drones as long as possible, we have opted for clustering routing. The purpose of clustering is to divide the UAVs into groups, each group will be led by a cluster head (CH), which will be able to communicate at any time with its members (m) or with neighboring cluster heads and also with the base station (BS).

The choice of cluster is very important in clustering routing protocols

4- Related works

In order to route information between two distant UAVs, one or more intermediate nodes in the network cooperate with each other by forwarding the data to their destinations. Indeed, routing protocols are responsible for choosing the best route to the destination that minimizes collisions, interference, or delay. The highly mobile nature of UAVs eventually leads to frequent topology changes, which causes connectivity problems for efficient communication. This mobility therefore implies instability of the routes, which have to be recalculated more or less often depending on the dynamics of the network. In recent years, several researches have been proposed to solve routing problems in FANETs as in [5],[6],[7],[8] and [9].

The highly mobile nature of UAVs eventually leads to frequent changes in topology, resulting in connectivity problems for efficient communication. The answer to these problems is hierarchical routing known as clustering. Clustering breaks down the network into subclusters. A cluster usually consists of a cluster head (CH) and its corresponding members (m). The selection of the cluster head, which is an important phase of clustering algorithms [7], is done among all members and it is responsible for managing the whole cluster for inter- and intracluster communication.

In recent years, several researches have been proposed to solve routing problems using clustering in FANET.

In [6], the authors proposed a clustering scheme for a swarm of UAVs named MPCA that uses the combination of dictionary structure prediction and link expiration time (LET). The LET, between two drones, is calculated based on the location of the drones and their mobility information.

The CH is elected based on the highest weight of the neighbouring UAVs and the CH then broadcasts the CH announcement to the neighbouring UAVs. The drone that receives several messages consider the CH with a longer LET. Its main advantage is to reduce the instability of the clustering and thus improve the performance of the network.

In [8], the authors presented a proposal for multicluster FANETs for efficient network control, in which the submitted proposal notably reduces the value of communications, improves network performance and exploits a less complex, lowrate IEEE 802.15.4 (MAC) protocol for inter- and intra-cluster communications. They examined a mobility prototype, called Reference Point Group Mobility (RPGM). They analysed the network performance for two proactive prototypes (DSDV, OLSR) and one reactive protocol (AODV).

5- Our Contribution

The choice of cluster is very important in clustering routing protocols. Following our state of the art, we opted to integrate artificial intelligence (AI) for the choice of CH. The goal of AI is to have a maximum of parameters for the choice of our cluster head, because we have judged that a single parameter is still insufficient for the choice of CH. Artificial intelligence will allow us to make this choice based on the following parameters

- **Energy:** this is one of the most important parameters in FANETs as its directly related to the flight autonomy of drones.
- **Stability:** this parameter can affect the quality of the communication as it is directly related to the speed of the UAVs.
- **Connectivity:** is a very important parameter as it affects the quality of communication. If the connectivity is bad then the communication will be disastrous.

Moreover, in ad hoc networks of drones, each drone has the ability to move according to a preprogrammed flight plan. Each of the drones has certain main characteristics such as an average speed of movement, a battery level, a field of view and means of communication. In addition, the CH has information

on the environment (such as a map of the forest environment and the coordinates of the burnt area) and has the possibility to communicate, not only with the base but also with all other CHs. The CH will be solely responsible for the routing in its cluster.

5.1. Integration of fuzzy logic in the simulation for CH selection:

In recent years with the increasing application of unmanned aerial vehicles (UAVs), the network technology of UAVs has also raised concerns. In the context of a mission, it is necessary that the connection is maintained in order to avoid any undesirable effects. On the other hand, its need to guarantee QoS increases with time with the revolutions in FANETs, this is the reasons why we leaned towards integrating artificial intelligence to improve the performance of FANETs.

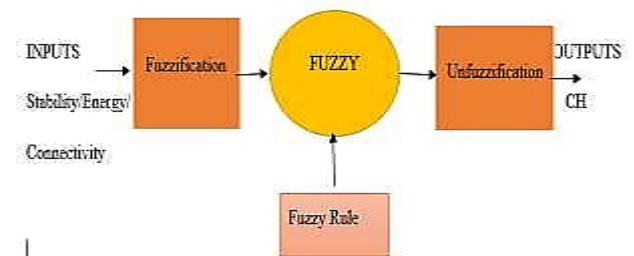


Fig 3 :Our fuzzification model

Precedent figure, illustrates the structure of the fuzzy inference process, which consists of four parts, namely fuzzification, fuzzy rule base, fuzzy inference engine and unfuzzification. The fuzzy inference process contains three input parameters (stability-energy-connectivity) and one output parameter, which is an approximate value:

- **Stability** is related to the speed metric, which is an important measure as it can affect the quality of communication/transmission. It is this metric that indicates the speed at which the drones move, thereby changing the network topology when approaching or leaving a particular area. For the variable, three language values have been defined: low speed (range 0-5 m/s), medium speed (range 4-13 m/s) and high speed (when the speed is greater than 11 m/s).
- Another important measure is **energy**, which is directly related to the battery capacity of the aircraft; it is related to the amount of time the UAV will be able to fly over and monitor a particular area.

The higher the battery capacity, the longer the flight range and therefore the more active the route and network topology will remain. This metric is divided into three language values that are low range (0-600

seconds), medium range (600-1200 seconds) and high range (more than 1200 seconds).

- The third and final metric used is **connectivity**. The higher the connectivity, the better the communication between the drones. Conversely, the smaller the connectivity, the worse the communication between drones. For the variable, three linguistic values have been defined: low range (0 to 10), medium range (10 to 20) and high range (more than 20).

The input variables are collected for the integrated fuzzy system, which based on a rule table and the inference machine, will indicate the optimal choice for the CH.

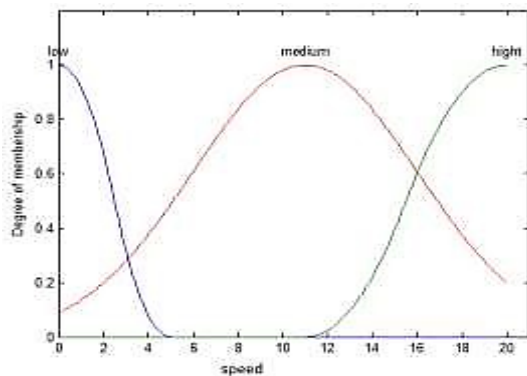


Fig 4 :membership function of stability

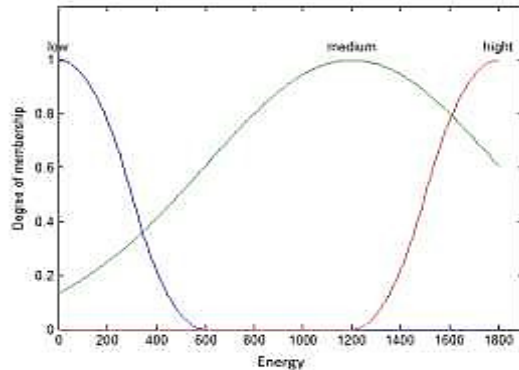


Fig 5 :membership function of the energy

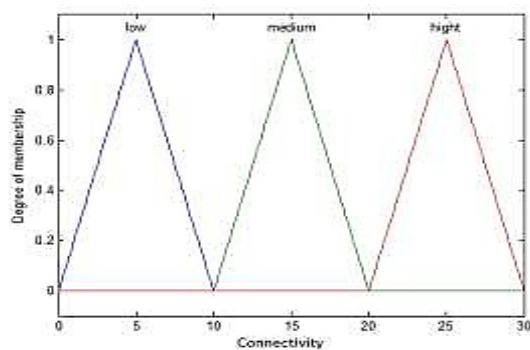


Fig 6 :membership function of the CH output

Figures 4, 5 and 6, shows respectively the membership degrees of the inputs and the CH

output, we note that each figure contains three membership functions. For the first two input parameters (stability and energy), we have chosen to present them by the Z-form for low levels, the Gaussian form for medium levels and the S-form for high levels. For the 3rd input parameter (connectivity), we chose the triangular shape to present them.

We could have chosen other shapes such as the gbel and trapezoidal shape but it all depends on the scenario we wanted to map.

a. Our Results

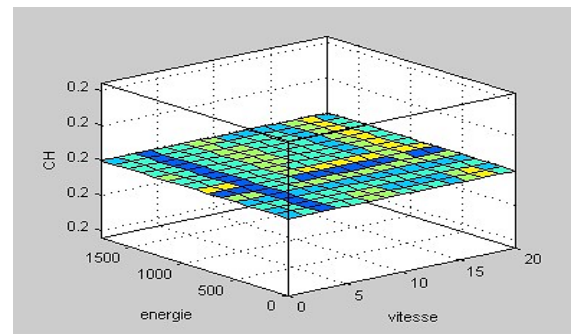


Fig 7 :The 3D representation of CH choice for low connectivity

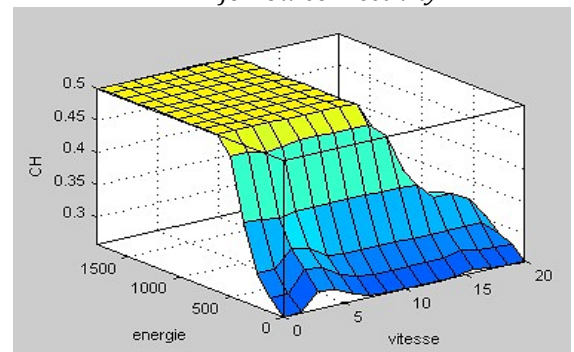


Fig 8 :The 3D representation of CH choice for average connectivity

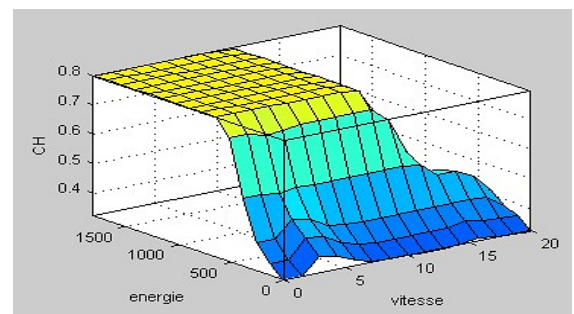


Fig 9 :3D representation of CH choice for high connectivity

Figures 7,8 and 9 illustrate the 3D representation of the cluster head selection. We notice that a UAV with low connectivity (0 to 10) within the cluster is not an optimal choice, regardless of its flight autonomy and speed.

This is due to the fact that the CH is responsible for all protocols within the cluster and as such it must have at least a good connectivity with its members. On the other hand, a drone with high connectivity (figure 8) is the most optimal choice as long as its speed is not too high and also its energy is not too low. This leads us to conclude that :

- The most optimal choice is a drone with low speed, high energy and high connectivity.
- A drone with low speed, high energy and medium connectivity can be considered a good choice.
- A drone with high speed or low connectivity or low energy will not be elected as a CH because it is a disastrous choice.

As already discussed in the state of the art the choice of the cluster head is the biggest problem in the hierarchical routing protocol. Several authors have tried to find an efficient solution for cluster head selection in FANETs as in [18],[17],[12].

However, if we take for example the paper of Park et al [6] they tried three approaches:

- First the selection was done randomly
- Then with energy
- And finally, they used a hybrid approach (notably through energy and distance to the base station).

They later proved that the latter approach is much more efficient compared to the two previous approaches.

Their result was acceptable as they had 70% efficiency in terms of drone lifetime.

After the analysis and interpretation of the results of our method we made a comparison between our model and the single parameter and then two parameter selection models for the choice of CH as shown in Figure 9 :

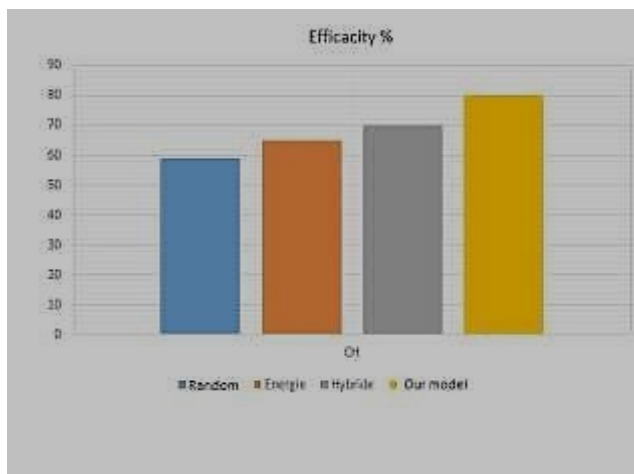


Fig 10 :Comparison between our model and stat of art

Figure 10, illustrate the comparison between our selection model and the selection models already performed (i.e. the selection models performed with one parameter and then with two parameters).

We notice that our model proposes 80% efficiency in terms of UAV lifetime while the other three models propose respectively 59%, 65%, and 70% efficiency.

This performance is achieved , to the integration of fuzzy logic but also and especially because the selection was made using the three parameters that we considered relevant, to maintain a good communication in the ad hoc network of drones.

By increasing the input parameters in our AI system, the efficiency of our model increases and the cluster head will be well selected to do such a mission.

6- Conclusion

We presented a detailed description of our scenario, which consists in monitoring a large region through a clustering protocol. Since the choice of the CH is a major problem in this type of routing, we used fuzzy logic, which allowed us to make a much more optimal choice.

We focused our discussions, simulations and interpretations on the usefulness of artificial intelligence in FANETs.

The results were compared to other results and we obtained a considerable improvement in terms of flight autonomy.

Finally, the integration of artificial intelligence in FANETs allowed us to make an optimal choice, to have more efficiency in terms of energy and lifetime of the UAVs and thus to improve the communication within the network.

This work opens the way to several works. The moment the cluster is formed, a communication protocol can be installed to complete a mission in real time

7. References :

- [1] I.Bekermeczi and al « Flying adhoc networks survey » ad hoc networks, vol 11, pp 1254-1270, 2013
- [2] F.Morbidi and all "Cooperative active target tracking for heterogeneous robots with application to gait monitoring ",in 2011 IEEE/RSJ International Conference on Intelligent Robots and Systems, 2011, pp. 3608-3613: IEEE.

- [3] B. Bethke, M. Valenti, and J. How, "Cooperative vision based estimation and tracking using multiple UAVs," in *Advances in cooperative control and optimization*: Springer, 2007, pp. 179-189.
- [4] O. K. Sahingoz, "Networking models in flying adhoc networks (FANETs): Concepts and challenges," *Journal of Intelligent & Robotic Systems*, vol. 74, no. 1-2, pp. 513-527, 2014.
- [5] N. E. H. Bahloul, S. Boudjit, M. Abdennebi, and D. E. Boubiche, "A flocking-based on demand routing protocol for unmanned aerial vehicles," *Journal of Computer Science and Technology*, vol. 33, no. 2, pp. 263-276, 2018.
- [6] C. Zang and S. Zang, "Mobility prediction clustering algorithm for UAV networking," in *2011 IEEE GLOBECOM Workshops (GC Wkshps)*, 2011, pp. 1158-1161: IEEE
- [7] J.-H. Park, S.-C. Choi, H. R. Hussen, and J. Kim, "Analysis of dynamic cluster head selection for mission-oriented flying ad hoc network," in *2017 Ninth International Conference on Ubiquitous and Future Networks (ICUFN)*, 2017, pp. 21-23: IEEE
- [8] W. Zafar and B. M. Khan, "A reliable, delay bounded and less complex communication protocol for multicluster FANETs," *Digital Communications and Networks*, vol. 3, no. 1, pp. 30-38, 2017.
- [9] X. Li, T. Zhang, and J. Li, "A particle swarm mobility model for flying ad hoc networks," in *GLOBECOM 2017-2017 IEEE Global Communications Conference*, 2017, pp. 1-6: IEEE