Adapting Ad-hoc Routing Protocol for Unmanned Aerial Vehicle Systems

Ahmed Refaat Ragab [a,1,*], Pablo Flores [a]

[a] Drone Hopper Company, Carlos III University, Avda. Gregorio Peces-Barba nº1, Madrid, 28919, Spain
[1] ahmed.refaat.csis@o6u.edu.eg
* **corresponding author**

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ABSTRACT

The field of the ad-hoc network and its routing protocols had attracted a lot of researchers for many years, due to the various usage of the ad-hoc networks in many fields and especially the field of Unmanned Aerial Vehicles (UAVs). Routing protocols in the ad-hoc network are the main focused problem, for their characteristics and role during the communication process of the ad-hoc networks, with its different types. In this paper, we are going to analyze and sheds the light on the performance of ad-hoc routing protocols, for both Flying ad-hoc network (FANET) and vehicle ad-hoc network (VANET) when applying three different ad-hoc routing protocols, respectively Reactive routing protocol, Proactive routing protocol, and Hybrid routing protocol, in order to shed light on the ambiguous misunderstanding of ad-hoc routing protocols functionality and to choose the best routing protocol to be used and adapted for UAVs.

1. Introduction

The famous aspect of ad-hoc networks is their character as a special network that attracts many researchers, due to their variety and wide usage in many applications such as military or civilian applications. Also, due to its power usage it engages with the field of the Internet of things (IoT), the term ad-hoc comes from an ancient Latin word, which means " For this ", or actually " For this purpose", but in the fact, it is really used for special purposes, so we can also call it " Network for special purposes ". The ad-hoc network can be also defined according to the infrastructure, as it is a network without an infrastructure because such a network works without the aid of access points, routers, etc [17].

So, it is cleared that ad-hoc networks perform all their activities without the aid of access points or any routers because the ad-hoc nodes themselves act as a router to forward, receive and collect information or data for its network. Due to all these aspects, we can recognize that an ad-hoc network is a special intelligent wireless network. Therefore, its routing protocols must be also unique, special, and intelligent, in order to be similar or equivalent to the types and purposes of the missions required from these networks. In this paper, a performance analysis of Ad-hoc routing protocols will be clarified briefly, to understand the behavior of these routing protocols.

This paper is organized into six sections as follow, section two gives a brief discussion for Ad-hoc networks, section three describes Ad-hoc Routing Protocols and their features, section four describe the implemented scenario using Opnet V.14 emulator, section five shows the results and analysis and finally section six conclude the paper.

2. Ad-hoc Networks

An ad-hoc network is a type of wireless networks, that works independently without the aid of any external nodes, like routers or access points, and for this reason, it is described as a less infrastructure network, this functionality makes Ad-hoc networks to become more powerful, but also this makes it vulnerable due to a lot of weak point such as, energy consumption, radio propagation mechanisms, processing, routing, data storage, security, and environmental vulnerabilities.

Ad-hoc networks can be seen in a lot of applications, these applications vary from military applications to civilian applications, and for this reason, the ad-hoc network can be classified into three main categories as Mobile ad-hoc network (MANET), Vehicle ad-hoc network (VANET) and finally Flying ad-hoc network (FANET), as shown in figure.1[1].

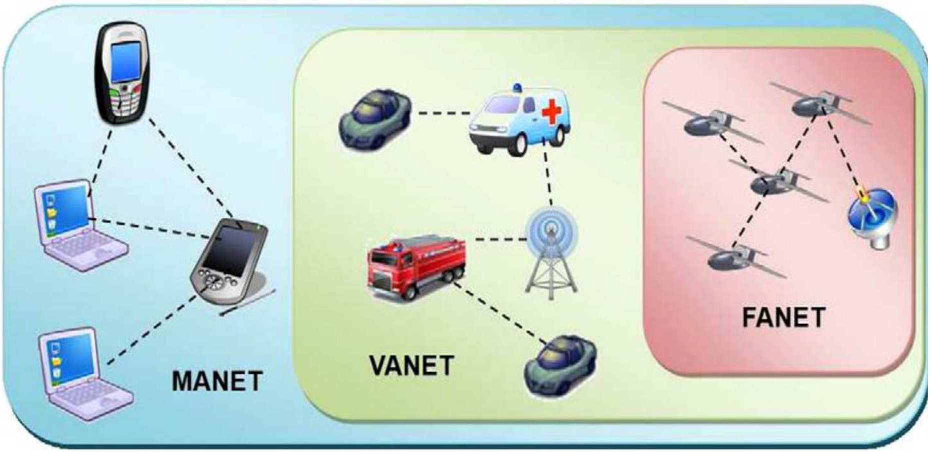

Fig 1. Types of ad-hoc networks [1].

These three categories are shown in the figure.1, must be studied briefly in order to highlight its efficiency. The main points that must be taken into consideration, when working or studying these categories are node mobility, node density, topology changes, radio propagation model, power consumption, network lifetime, computational power, and finally localization, all these points are shown as a comparison in the table.1 [1].

Table 1. Comparison Between The Three Types Of Ad-Hoc Network [1].

Point of comparison	MANET	VANET	FANET
Node mobility	Low	High	Very high
Mobility model	Random	Regular	Regular for predetermined paths, But special mobility models for Autonomous multi-UAV systems
Node density	Low	High	Very low
Topology change	Slow	Fast	Fast
Radio propagation model	Close to ground, LoS is not available for all cases	Close to ground, LoS is not available for all cases	High above the ground, LoS is available for most of the Cases.
Power consumption and network lifetime	Energy efficient Protocols	Not needed	Energy efficiency for mini UAVs, But not needed for small UAVs
Computational power	Limited	High	High
Localization	GPS	GPS, AGPS, DGPS	GPS, AGPS, DGPS, IMU

From table.1, it is cleared that node mobility is the most concerning issue, which is the worthiest variation between FANET and other ad-hoc networks. When the mobility is compared among the three categories, it is cleared that the highest mobility is for FANET then comes the VANET and finally the MANET[2], also the high speed of FANETs results sometimes in a huge problem related to the communication issues [3].

The mobility model can be seen for MANET mobility as in a definite ground surface area, VANET mobility is in crowded roads and also in highways while FANETS are different because the mobility operation is at the sky[3], while the node density was defined by many researchers as, the median number of nodes in a unit area, wherein FANET nodes are mostly dispersed in the sky, due to the range between the nodes which can be in the range of kilometers [4], and this was one of the reasons for the fast topology change in FANET.

The radio propagation features for FANETs are different from any other Ad-hoc network categories and this is due to the network operating environments, and by notification, it was found that the nodes for both categories MANETs and VANETs are relatively working on the ground.

Therefore, the transmission of these networks is affected by the line of sight (LoS), due to the nature of the ground surface. The key design issue for Ad-hoc networks is the network lifetime, where it can be clarified by the battery lifetime, which the whole system depends on to be powered and gaining the power needed for the computing devices. Thus, the network lifetime is increased by developing efficient energy communication protocols, and mathematically, the energy-efficient communication protocols are directly proportioned with the lifetime of the network, and this is another problem as the device developer aims to develop a small-sized battery to fit the size of such equipment [5]. And as stated before, that the Ad-hoc network nodes act as a router by themselves, therefore, they must have a certain computation capability to process the incoming data in real-time. Also, the power of ad-hoc networks appears from the localization process among the nodes, this is seen by the mean of global positioning system (GPS), Assisted GPS (AGPS), or differential GPS (DGPS) [6,7].

3. Ad-hoc routing protocols

The term routing can be defined in two terms, the first as it is the best path from the source to the destination, and the second is the shortest path from the source to the destination, the difference between the two definitions are the words, best and shortest, these two words are the key elements for Ad-hoc Routing Protocols. In Ad-hoc networks each node inside the network acts as a specialized router by itself [9]. Unlike traditional static networks, the assignment of IP addresses is a difficult task since they should indicate the position of the node.

Given the mobility of the nodes and the variability of the network topology, each Ad-hoc network node should register periodically all possible routes in the network, these constraints could increase the complexity of the network and decrease its scalability [8]. In general, Ad-hoc Routing Protocols are classified respectively as Proactive Routing Protocols, Reactive Routing Protocols, and Hybrid Routing Protocols as shown in the figure.2 [10].

3.1 Proactive Routing Protocols

In Proactive Routing Protocols, all the routing tables between nodes are periodically calculated (and even exchanged) regardless of the traffic demands on the network, were the most remarkable Proactive routing protocols are respectively, Optimized Link-State Route (OLSR) [11], Topology dissemination Based on Reverse path Forwarding (TBRF) [11] and Destination Sequenced Distance Vector (DSDV) [12].

Through a lot of researches [9,10,11,12,13,14,15], it was cleared that Proactive routing protocols provide an efficient routing solution for small and low-mobility networks, by giving the number of resources used to permanently calculate and transmit updated routes. Hence, these protocols are strongly conditioned by the node numbers or the node density in the network [11].

However, Proactive routing protocol performance improves (even in larger networks), if the traffic load is big or the number of interconnections (mesh) is high. In these cases, an upgraded technology is necessary to be able to manage the large amounts of traffic supported by the network [12].

3.2 Reactive Routing Protocols

Reactive Routing Protocols are quite different from Proactive Routing Protocols, due to the difference in routing table implementation. In Reactive Routing Protocols the routing tables are only computed on traffic demand when they are really necessary, were the most popular Reactive Routing Protocols are respectively, Ad-hoc on-demand Distance Vector (AODV) [13], Temporally Ordered Routing Algorithm (TORA), and Dynamic Source Routing (DSR) [14]. Reactive Routing Protocols show a better performance than the Proactive Routing Protocols in terms of scalability and data management. Hence, they are a perfect choice for large networks with low traffic loads and few topology changes.

3.3 Hybrid Routing Protocols

Hybrid Routing Protocols can be clarified as a combination of both Reactive and Proactive Routing Protocols, the most popular protocol is the Geographical – based Routing Protocol (GRP), where the network is divided into zones, providing a hierarchal architecture by the way that each node maintains additional information topology by requiring extra memory [15].

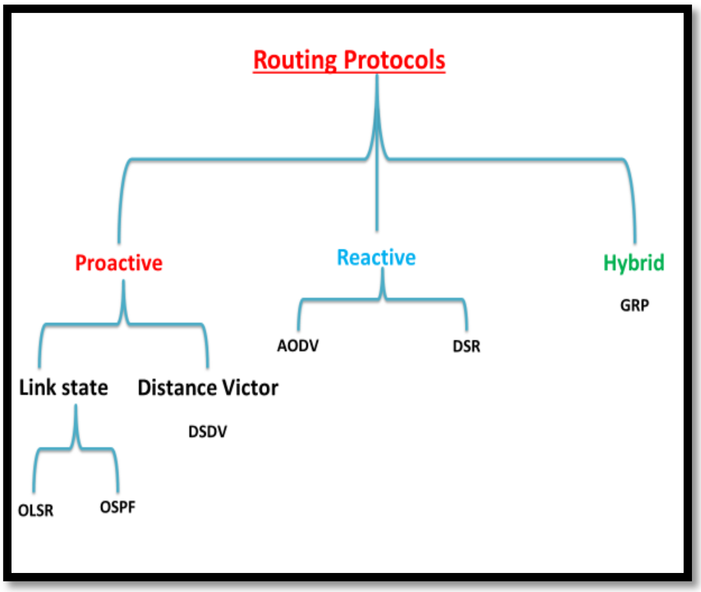

Fig 2. Ad-hoc Routing Protocols [10].

4. The Implemented Scenario

The Proposed scenario is represented by using Opnet V.14 Emulator, as shown in figure.3, in this scenario only two types of Ad-hoc networks were represented, respectively VANET and FANET in order to examine the effect of the mobility and the node density, among the different routing protocols. Whereas, for the Ad-hoc routing protocols, only three routing protocols were chosen respectively, OLSR representing the Proactive Routing Protocols, AODV representing the Reactive Routing Protocols, and finally GRP representing the Hybrid Routing Protocols.

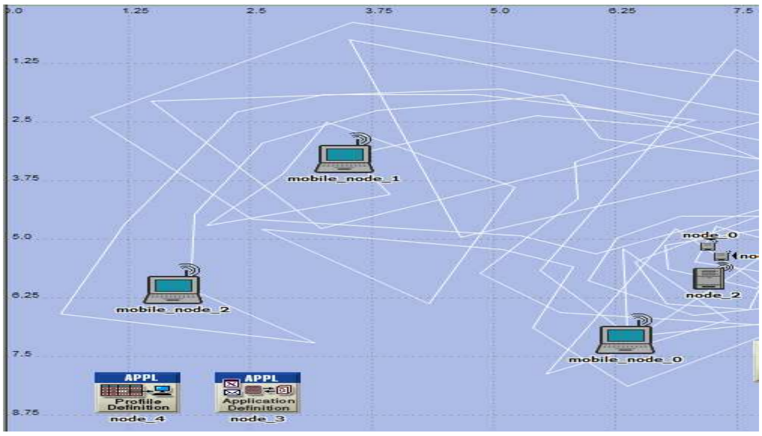

Fig 3. The Implemented Scenario.

In the scenario, the FANET is represented by three Unmanned Aerial Vehicles (UAVs), with speeds up to 80 m/sec and altitude from 500m up to 1000m, while the VANET is represented by three vehicles with ground speed 40 m/sec. The data sent and received between nodes are represented as high-resolution video, the Data measured are wireless LAN load (bits/sec), wireless LAN delay (sec), routing traffic sent (bits/sec), and routing traffic received (bits/sec). All the scenarios are based upon three nodes representing Ad-hoc networks, these three nodes will act in the first scenario as three UAVs, these three UAVs will use at the first time AODV, then it will be changed to OLSR and finally to GRP, all scenarios are under the same conditions discussed at section four, then the scenario will be repeated by applying three vehicles instead of the UAVs under the same circumstances.

5. Results and Analysis

During the Implemented scenarios accurate results were calculated shown wireless Lan load, wireless Lan delay, routing traffic sent, and routing traffic received, figure.4 shows wireless LAN Load (bits/sec) for both UAVs and VANETs. It is cleared that the highest wireless LAN Load is for VANET using respectively GRP and OLSR, then comes the UAVs using OLSR. While it was found that the value of the Wireless LAN Load for UAVs using respectively AODV and GRP, and VANETs using AODV is nearly half the amount of the Wireless LAN Load of the others.

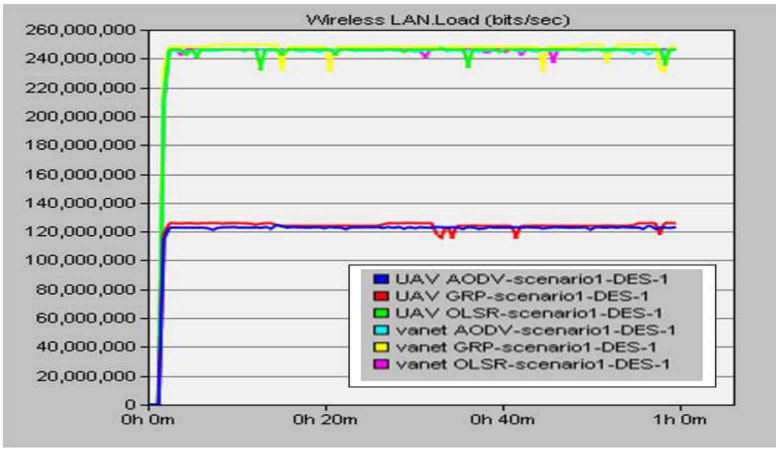

Fig 4. wireless LAN Load (bits/sec).

While in figure.5, the Wireless LAN Delay (sec) for both UAVs using OLSR and VANETs using OLSR are gaining the higher delay in the whole scenarios, whereas, the most two less delay takes place between UAVs using AODV and UAVs using GRP.

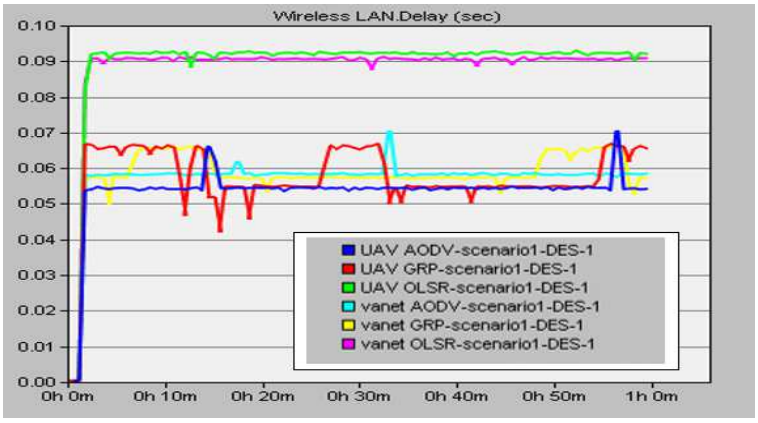

Fig 5. wireless LAN Delay (sec).

Also, In figure.6, it is cleared that the highest routing traffic sent is based between UAVs using AODV and VANETs using AODV, while the least amount of routing traffic sent is for UAVs using GRP and VANETs using GRP.

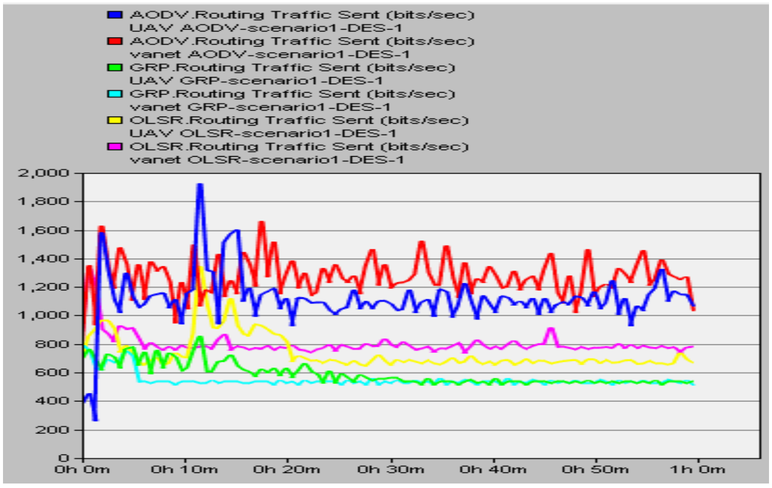

Fig 6. Routing Traffic sent (bits/sec).

Finally, figure.7, gives a similarity to the results taken in figure.6, by showing the high routing traffic received for AODV for both UAVs and VANETs, while the least amount is for GRP for both UAVs and VANETs.

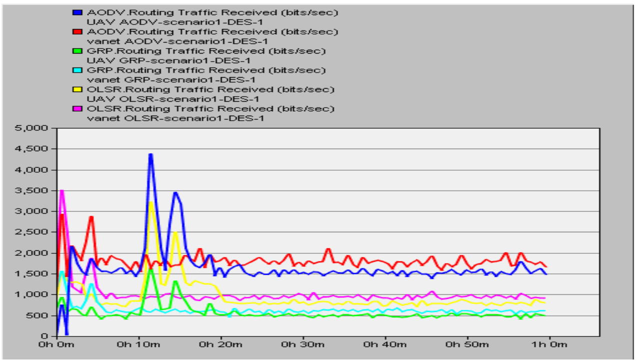

Fig 7. Routing Traffic Received (bits/sec).

From the above-mentioned results taken, it is cleared that using AODV in all scenarios gives a high performance than other routing protocols, this is due to the impact that AODV uses a route detection procedure to dynamically build new routes on a need basis. AODV is a distributed algorithm, using distance vector algorithms, such as the Bellman-Ford algorithm. When a route to a destination is unknown, the AODV originates a packet, works at route request, and broadcasts it to its neighbors [16]. It was observed from the results taken, huge benefits for using Ad-hoc on-demand Distance Vector, since AODV creates its route only when it is only needed, for this reason, the delay and the Load were less than the other protocols used.

6. Conclusion

Choosing the best performance routing protocol to be used with UAVs is the most significant point that makes any Unmanned Aerial System (UAS), to be stable and gives the best performance to the whole system. In this paper a clear deep examination where done, by examining and testing the three main Ad-hoc Routing protocols respectively Reactive Routing Protocols, Proactive Routing Protocols, and Hybrid Routing Protocols, by choosing one protocol from each category, in order to choose one of them to be suitable with UAVs. The results show that the best routing protocol to be used with Unmanned Aerial Vehicles is AODV. From the results taken, it is recommended to use AODV routing protocol with UAVs due to its high performance and low delay, which will give high throughput for any Unmanned Aerial System, this point leads us to continue working in this protocol to adjust its security and performance.

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