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An Overview of Routing Methods in Flying Ad-hoc Networks

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Abstract
Similar to MANET mobile peer to peer networks (Mobile ad-hoc network) and VANET vehicle peer to peer networks (Vehicular ad-hoc network), FANET are special type of peer to peer ad-hoc networks and they are based on unmanned aerial birds (UAV). Such communications are not only necessary for observing and monitoring, but also they are used for better harmonizing of bird movements and increasing the level of security (for example preventing accidents). FANET specifications are consist of high node mobility, dynamic changing of topology and three-dimensional movements and this has created other serious problems for network connections and it requires protocols with special goals. Node interactions are also limited because of allocated frequency resources, node energy, radio signaling conditions and so on. Even though, network nodes randomly interact with each other, connections between pairs of nodes are possible by means of intermediate chains. Network nodes, in addition to accepting and processing data, are supposed to get the direction to the intermediate nodes in the final destination path inside the network. In this article, we will try to review routing protocols in Flying Ad-hoc networks.

Keywords Fling Ad-hoc networks, Routing, Energy consumption, Improvement.

Introduction

Technology development in important systems, aerial connections and microelectronic mechanical systems are provided a new path to the new developed multi-UAV system with internal connection called FANET. In the beginning, the UAV system was an unmanned aerial vehicle and it was used more for searching, monitoring and identifying, but by developing micro-technologies, employing multi-UAV systems with better performances have become more. Nowadays, a group of UAV networks present variety of services from military services to civilians. One-third of agricultural –aerial transportations of Japan are under UAV controls and searching, border patrolling, traffic management, monitoring of pipelines, earthquake, volcano monitoring and environmental investigations are other usages of it [1].

Wireless ad-hoc Networks are classified according to purposes, layout, connection and task. By definition, FANET is a form of MANET and both have the same design. In addition, FANET is considered as a subset of VANET which is the subgroup of MANET. Routing in FANET is particularly important, especially because of large amounts of data, considering to the bandwidth has vital role in routing decisions. The newer technology of using optics solves the problem of high availability of data links [2].

In contrast to other networks which are under infrastructure, FANET specification is high mobility and mobility in displacement can lead to conflict along members and one of the main concerns in FANET is just preventing from confluence. Researchers in all over the world need to consider to the capacity and also exchange and transaction maintenances between payloads. Because increasing the capacity of payloads can increase the number of processor tools and this is the reason of

indirectly strengthening capability of multi-UAV system as a total system. In the meantime, increasing payloads can has effect on flying time of system. Flying and landing in FANET and multi-UAV system is so important. For refueling, multi-UAV system is constructed for landing and taking off, in that case the system is more vulnerable. There is an alternative method in FANET which presents laser power and it can be a solution to the problem above [3].

FANET is a group of cooperating and it is consisting of several devices and time and space of each device should be observed. Time is used for monitoring and detecting errors, while space is used to present secure and proper space and distance. In the beginning of FANET structure, multi-UAV with star connection is connected to the ground control station, but for automating the operations, conformity of UAV with the new system is required, in that case routing of multi-hop is happened without a fixed network structure. Advantage of this method is just working UAV group with ad-hoc network without directly connecting to ground control system [3].

Routing protocols in ad-hoc networks

- **Adaptive MAC protocol**

Given that the link quality in FANET is changed because of high mobility of nodes and constantly changing the distance between the nodes, therefore MAC design for FANET faces many challenges because of fluctuations in link quality and its impairments. Directed antenna in scenarios is fruitful in increasing connection range, recycling space and reinforcing security. In 2010 Alshabetat Abdullah et al [4], proposed MAC adaptive protocol which has a multi-directed antenna for sending control packages and a directed antenna for sending data packages. End to end delay, output (efficiency) and bit error rate are improved because of this method, but energy consumption was not considered in this method.

- **Token MAC protocol**

In [5], Kai Yogi et al proposed a method based on Token for updating target information and solving the problem in traditional competitive protocols and link failure due to high mobility. In this method, they improved full duplex radios and multi packet reception of MAC performance in multi-UAV network environment. The delay was decreased by means of full duplex systems because sending and receiving in each node is happened simultaneously and abilities of receiving multi packet improve the output in multi-UAV systems.

- **Optimized directed link routing protocol**

In [6], Alshabetat Abdullah et al proposed a protocol which uses the changed OLSR (Optimized link state routing protocol) and the directed antenna. The main stage in OLSR is just selecting multipoint relay. Decreasing number of MPR can decrease sending controlled packages. In this method, information related to destination is used during package sending and if the distance from source to destination is less than half of maximum capacity of directed antenna, DOLSR is used; otherwise OLSR is used for routing. In their method, number of MPR is decreased, so controlled overhead is reduced.

- **Time Slotted ad-hoc in distance vector routing according to demands**

In [7], Defence et al proposed saving and sending project which was using time slot with AODV protocol and it was used for decreasing collision of data.

This combined method is proposed for decreasing connection in intermediate node. Time saving mechanism which is used in this method is just similar to the Slotted ALOHA mechanism which was already presented by these writers and in that method, sending data in specific time periods was used. In this combined method, a time period was determined for each node, so data can be sent to the main node or the cluster head and in this time period, it has the priority in sending data compared to other nodes. The proposed approach can decrease data collision and package sending is improved as well.

- **Geographic Position Mobility Oriented Routing**

In [8], Lin et al proposed geographic routing protocol. In this method, the best next exited movement (the best next UAV) is found and the data is sent to it. The aim of this work is just decreasing the influence of intermittent connection caused by high mobility of nodes

in the network. They could reduce this influence significantly. Therefore, at first they used Gauss-Markov mobility model to predict node location and try to reduce routing failure. Then, they tried to choose the next step correctly. The proposed method improves stability of clusters and cluster heads.

- **Clustering of mobility prediction**

Clustering algorithms existed in UAV network, are not proper clusters because of high mobility and permanent updates. For this purpose, Zhang et al [9] presented a model for predicting mobility and node movements. In this model, the weighted cluster modeling with UAV features is used. This method uses data tree to predict the network topology and also the mobility and time of link expiring modeling. The mentioned method increases the stability of UAV cluster structure and improves the network performance because of logical algorithm of selecting cluster head and mechanism of maintaining the cluster according to demands.

- **Clustering algorithm of the UAV network**

In [10], Liev et al proposed a method for clustering the UAV network. In this method, before any operation, clusters are created and UAVs are clustered together, then during the operation process, updating clusters and also cluster heads are done at regular time intervals. This method can resolve the undesirable ability of networking and UAV connections mentioned above. Stability and flexibility in clustering are increased and the cost and complexity of system in dynamic routing of UAV nodes are decreased.

- **The IMAC UAV with DOLSR**

In [11], Alshabetat Abdullah et al presented a combined method for connections in FANET. Their combined method is worked in MAC and network layer. In this method, a software procedure named smart MAC, the OLSR protocol as network layer protocol and a directed antenna are used. Features of sharing common data sets such as antenna type, bit error rate, multipoint relay, height and location of airplane facilitate the connections between the first three layers. In contrast to the standard IEEE 802.11, the proposed method has a better end to end delay and number of selected MPR (UAVs between the sender and receiver) is reduced and hence, control overhead is decreased.

- **Reticular tree algorithm**

In [12], Bekmezsi et al presented a combined method for removing restrictions of network layer protocol in FANET. This method works in MAC and network layer. In this method, at first the whole network is clustered and then a cluster head is chosen for each cluster. In this method, data from UAVs to cluster heads are routed. They also used time slot method to decrease data collision. This method increases the package sending and the end to end delay.

- **Adaptive send protocol**

In [13], Kingone et al proposed an adaptive method for sending data in FANET. Since FANET may fail to send the packages to the destination, a solution is presented for this important challenge. In this presented method, they divided FANET into regions named sending zone. Sending zone can control the sending range and reduce the unnecessary collisions and propagations. Their proposed method can decline end to end delay, package delivery rate and energy consumption per received package. But it imposes large overhead to the network. Most of this overhead is used for zoning and finding proper zones for sending data.

- **Link quality and Geographical beaconless OR protocol**

In 2014, Denis Roserio [14] presented a method named link quality and geographical beaconless OR protocol (LinGo) which was used for reliable and efficient transmission of video in FANET networks. Their proposed method is based on two states for sending. The first state is called contention-based forwarding and the second state is called backbone-based forwarding. Given that in sending video, number of information packages are so many and generally send replication strategy is used to conquer the problem of losing packages, so in their proposed method, by considering the importance of packet frames, they prevent from wasteful reiterations in sending them. In this method, overhead and energy consumption is reduced.

- **Location-oriented directed MAC protocol for FANET**

In [15], Temel et al presented a new protocol named LODMAC. The proposed approach is using the directed antennas and estimated location of adjacent nodes in the layer MAC. In the presented method, in addition to request to send (a package that the sender sends to the receiver or network for declaring preparation to send data) for traditional control packages and memory clean packages for sending new data (clear to send), they also used a new package named busy to send (BTS). This package determines free or busy status of the receiver and sender about sending and receiving data, therefore this strategy can be helpful in increasing accuracy of sending and also decreasing the waiting time to receive packages. Their proposed method is the cause of improving the efficiency of operations, decreasing delay and increasing practical uses of network.

The comparison of protocols

In the following the amount of improvement or decreasing the criteria of a protocol is determined:

- Adaptive Mac is a two layer protocol which improves throughput and decreases End to End Delay and Bit Error Rate.
- Token Mac is a two layer protocol which improves throughput and decreases End to End Delay.
- DOLSR is a three layer protocol which improves throughput and decreases End to End Delay and Control Packets Overhead.
- TAODV is a three layer protocol which improves Packet Delivery Ratio and decreases Collisions.
- GPMOR is a three layer protocol which improves Packet Delivery Ratio and decreases End to End Delay and No. of Hopes.
- Mobility Prediction Clustering is a protocol from the third layer which causes improving stability of cluster and cluster heads.
- Clustering Algorithm with UAV Networking is a three layer protocol that resulted in improving stability of cluster and Dynamic Networking.
- IMAC UAV with DOLSR is a protocol from the second and third layers which causes declining End to End Delay and Control Overhead.
- Meshed Tree Algorithm is a protocol from the second and third layers which improves Packet Delivery Ratio and decreases End to End Delay.
- AFP is a protocol from the second and third layers which causes improving Packet Delivery Ratio and decreases End to End Delay and Energy Consumptions.
- LinGo is a two and three layer protocol which improves Reliability and Robustness and decreases Control Overhead.
- LODMAC is a two and three layer protocol which improves Throughput and Goodput and decreases End to End Delay.

Conclusion

Since in FANET, nodes are flying in the sky, the mobility rate of FANET is more than MANET and VANET. High mobility of nodes in FANET can create intermittent changes in its topology than in MANET and VANET. In ad-hoc networks, nodes have peer to peer connections. FANET uses this method to communicate between its nodes. Besides that, like wireless sensor networks, it collects data from the environment and other nodes to the command and control center. Therefore, the proper using of protocols and also efficient algorithms in a way that they can remove problems such as step by step routing, hierarchical routing and also hardware vacuities are so necessary. The usual distance between nodes in FANET is more than MANET and VANET, or in another word for creating connections between nodes, covering longer distances is required [7]. This will be the reason of creating changes in radio communications, hardware and physical circuits and also physical layer behaviors and this should be considered by the router procedure and the required plans should be thought it over. Another important issue is the difference and variety in sensors and nodes existed in these networks. Since in unmanned systems, there are several different sensors and each sensor has a different and special strategy for sending and receiving data, then the difference between these types of networks will be more. These differences will cause different procedures in FANET than in other networks, thereupon algorithms and protocols should be designed effectively to obviate the special requires of these networks according to the dynamic nature and high density of network nodes.

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