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FANET Communication Protocols: A Survey

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Abstract: Since last few years the evolution of UAV have helped in finding many new applications and one of the latest trend is using multiple UAV's in place of single UAV. FANET is an ad-hoc network established between UAV's to overcome problems in infrastructure based network. FANET is different from other ad-hoc networks in many ways so it should be handled differently. The main problem with FANET is communication between UAV's. This paper describes the existing protocols and works done at different layers related to FANET. Along with these, some cross-layer approaches are discussed.

Keywords: FANET, UAV, network of UAV's, ad-hoc Network.

1. Introduction

The wireless connection can be used in scenarios to extend the network to different places as it removes the need to establish a point to point wired links. Wireless Networks can be either infrastructure based networks or ad-hoc networks. Infrastructure Based Networks have a central coordinator which manages every node while ad-hoc network does not have a central coordination or fixed topology which increases complexity in sending or receiving packets between nodes.

MANET & VANET are many popular parts of ad-hoc networks. MANET is an ad-hoc network of mobile nodes while VANET is an ad-hoc network of Vehicular nodes. In 2012, Ilker Bekmezci introduced the concept of FANET, an ad-hoc network of flying nodes and provided a detailed survey on FANET in [13].

UAV's are used in many applications such as Traffic Monitoring, Crop Monitoring, Search and Rescue etc. because of their low cost, easy installation, better flying capabilities etc.

Although there is much single UAV application but using multiple UAV systems co-operating with each other can be helpful in many ways. But different issues and challenges are needed to be addressed in the case of the multi-UAV system. Co-operation between UAV's is essential in a multi-UAV system which requires better communication and that is one of the major problems in FANET[13]. A typical FANET scenario is shown in Figure 1.

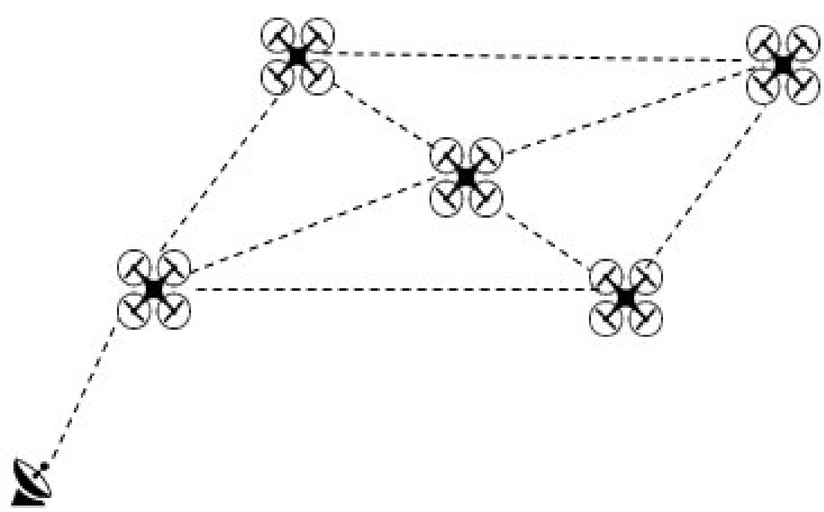

Figure 1. FANET Scenario

2. Communication Protocols for FANET

Much work has been done at different layers to improve the communication between UAV's. Some of the protocols, related to the same are discussed in this section.

2.1 Adaptive MAC protocol

The link quality fluctuates in FANET because of high mobility of nodes and continuously changing the distance between nodes. MAC design for FANET faces new challenges because of such link quality fluctuations and failures. Latency can also be another challenge.

A directional antenna can be helpful in scenarios to increase the range of communication, spatial reuse, enhancing security. In [3], an adaptive MAC protocol has been proposed which uses an omnidirectional antenna for control packets transfer and directional antenna for data packets transfer. End to End Delay, Throughput and Bit Error Rate were improved with the use of this approach.

2.2 Token MAC

A Token based approach was proposed in [9] to update target information, to overcome the problem in traditional contention based protocols and link failures due to high mobility. Full Duplex Radios and Multi-Packet Reception (MPR) were used to improve the MAC performance in a multi-UAV network environment. The delay is reduced with Full Duplex Systems as each node can transmit and receive at the same time and Multi-packet reception capabilities improve the throughput in multi-UAV systems.

2.3 Directional Optimized Link State Routing Protocol

In [8], a protocol is proposed which uses modified OLSR (Optimized Link State Routing Protocol) and uses directional antenna. In OLSR, the key step is selecting multi point relay (MPR). Reducing the number of MPR will result in reduced control packets transferred. In [8], as proposed by authors to transfer the packets, information about the destination is used and if the distance to the destination from source is less than half of maximum capacity of the directional antenna than DOLSR is used otherwise OLSR is used for routing. They have also proposed a new approach which reduces the number of MPR which results in reduced control overhead. The proposed approach reduces delay and enhances the overall throughput.

2.4 Time Slotted Ad-hoc on Demand Distance Vector routing

To reduce collisions, time slotted reservation scheme is used along with AODV. In [2] the authors proposed a hybrid approach to minimize the intermediate node communication. Time reservation mechanism used in this approach is similar to that of Slotted ALOHA. Each node is assigned a time slot to send data to a master node or cluster head and has communication privilege over other nodes in this particular time slot. The proposed approach reduces collisions and also improves packet delivery ratio.

2.5 Geographic Position Mobility Oriented Routing

In [12], a geographic-based routing protocol GPMOR is proposed which can find the best available next hop to effectively decrease the impact of intermittent connectivity caused by the highly dynamic mobility. Firstly, they used Gauss-Markov mobility model for predicting the node position to decrease routing failure. Secondly, they used the mobility relationship to select next-hop for routing more accurately [12]. The proposed approach improves the stability of cluster and cluster heads.

2.6 Mobility prediction clustering

In UAV networking, the existing clustering algorithms were not suitable because of high mobility and frequent cluster updates. To overcome such problems, in [10] a new mobility prediction which uses cluster weighted model is proposed which uses UAV attributes. It predicts the network topology using the Trie data structure dictionary prediction and link expiration time mobility model. It helps in constructing more stable cluster structure and improved network performance because of the reasonable cluster head electing algorithm and on-demand cluster maintenance mechanism.

2.7 Clustering algorithm of UAV networking

Before the operation, the clusters are created and UAV's are grouped together and then during the operation process the updates are sent at regular intervals of time [11]. UAV communication can be efficiently realized by utilizing near-space communication system. It helps overcome issues of the poor capability of networking and over horizon communication among UAVs. The proposed approach raises stability and flexibility in near space clustering and also reduces system cost and complexity in dynamic routing of UAV nodes.

2.8 IMAC UAV with DOLSR

A hybrid approach that works at MAC and network layer. It uses proposed intelligent MAC (IMAC) as the MAC layer and OLSR as the network layer protocol and uses a directional antenna. A shared data set sharing attributes like antenna type, bit error rate, multipoint relay (MPR) locations, aircraft altitude and locations is used to facilitate communication between the first three layers. The proposed techniques give better end-to-end delay than the IEEE 802.11 standard [6] and reduce the number of MPR selected which results in reduces the control overhead.

2.9 Meshed Tree algorithm

A hybrid approach that works at MAC and network layer to eliminate limitations of the layered protocol stack. Clusters of UAV's are formed and data is routed from UAV's to cluster heads. To schedule Time slots at MAC layer TDMA is used [13]. It allows the formation of multihop overlapped cluster to support data aggregation and scalability. It improves packet delivery ratio and end-to-end delay which are important for surveillance purposes [4].

2.10 Adaptive Forwarding Protocol

In [5], a new forwarding mechanism is proposed for FANET which is adaptive. In FANET, forwarding a packet may not always reach the destination. AFP uses adaptive forwarding scheme which uses forwarding probability and forwarding zone creation. To reduce redundant broadcast forwarding probability is used. Forwarding zone helps in controlling range of forwarding and reduce unnecessary broadcast and collision [5].The proposed approach improves End to End Delay, Packet Delivery Ratio and Energy Consumption per Packet Received.

2.11 Beaconless Opportunistic Routing

Beaconless Opportunistic Routing (OR) allows increasing the robustness of systems for supporting routing decisions in a completely distributed manner. In [1], LinGO is proposed which is a Geographical Beaconless OR protocol. The addition of a cross-layer scheme enhances the benefits of a beaconless OR, and also enables multimedia dissemination with Quality of Experience (QoE) support. This protocol delivers live video flows with QoE support and robustness in mobile and dynamic topologies [1].

2.12 Location-Oriented Directional MAC protocol for FANET

In [7], a novel MAC protocol, LODMAC is proposed. The proposed approach uses Directional Antennas and estimated the location of neighbour nodes within MAC layer. Along with Traditional Control Packets Request to Send (RTS) and Clear to Send (CTS) packets, a new Busy to Send (BTS) packet is used. Directional Antennas have a major problem of Directional Deafness which is better addressed by LODMAC. LODMAC improves throughput, Delay, network utilization. LODMAC performs better than DMAC (Directional MAC), LODMAC protocol outperforms the well-known DMAC (Directional MAC) which can be helpful for upcoming FANET MAC Protocols [7].

Table 1: Comparison of Protocols

Sr. No.	Protocol	Layer	Improves	Reduces
1	Adaptive Mac	MAC Layer	Throughput	End to End Delay, Bit Error Rate
2	Token Mac	MAC Layer	Throughput	End to End Delay
3	DOLSR	Network Layer	Throughput	End to End Delay, Control Packets Overhead
4	TAODV	Network Layer	Packet Delivery Ratio	Collisions
5	GPMOR	Network Layer	Packet Delivery Ratio	End to End Delay, No. of Hopes
6	Mobility Prediction Clustering	Network Layer	Stability of cluster and cluster heads	-
7	Clustering Algorithm with UAV Networking	Network Layer	Stability of cluster, Dynamic Networking	-
8	IMAC UAV with DOLSR	MAC and Network Layer	-	End to End Delay, Control Overhead
9	Meshed Tree Algorithm	MAC and Network Layer	Packet Delivery Ratio	End to End Delay
10	AFP	MAC and Network Layer	Packet Delivery Ratio	End to End Delay, Energy Consumptions
11	LinGO	MAC and Network Layer	Reliability, Robustness	Control Overhead
12	LODMAC	MAC Layer	Throughput, Goodput	End to End Delay

Conclusion

Flying ad-hoc Network (FANET) is a newly wireless ad-hoc network which has many open research issues. Due to high mobility and frequent network changes, Communication is one of the major issues in FANET. Although much work has been done on improving single UAV Communication, it can be improved further for multiple UAV Communication Systems. In this paper, we presented a survey on work done to improve communication of FANET. We gave a small description about different protocols and how they improve FANET communication. In Table 1, a comparison of protocols is done describing in which layer it works and the network parameters which it improves and reduces.

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