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A STUDY ON DYNAMIC ROUTING FOR FAST FADING FANETS

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Abstract

In recent years, the capabilities and roles of Unmanned Aerial Vehicles (UAVs) have rapidly evolved, and their usage in military and civilian areas is extremely popular as a result of the advances in technology of robotic systems such as processors, sensors, communications, and networking technologies. High altitude platforms (HAPs) and Flying Ad Hoc Networks (FANETs) are some of the most promising technologies for both military and civilian near space wireless networks. HAP systems usually reside on stratospheric altitudes up to 25 km and have the advantages of flexible deployment, wide area coverage and line-of-sight propagation, compared to ground or satellite based systems. Also Unmanned Air Vehicles (UAVs) have the ability for persistent flight over periods of days to weeks which cannot be achieved by manned aircrafts. The topology of these networks is more dynamic than that of typical mobile ad hoc networks (MANETs) and of typical vehicle ad hoc networks (VANETs). As a consequence, the existing routing protocols designed for MANETs partly fail in tracking network topology changes. In this paper the routing protocols that can be adopted for FANETs are discussed.

Keywords: UAV, High altitude Platform, Flying ADHOC Network, Routing, Topology.

1. INTRODUCTION

The technological advancement in the critical embedded system ,avionics and micro electro mechanical system has paved the path to new fully fledged inter connected multi UAV system , also acronyms as fanet . UAV system started with single unmanned aerial vehicle mainly for surveillance, reconnaissance and monitoring, but with increase in miniature technology deployment of coordinated Multi UAV to perform better in group is being developed.

Group of networked UAV are now providing a wide range of service from civilian to military. Third of the agricultural aviation in Japan is being governed by UAV, surveillance, border area patrolling, traffic management, monitoring pipeline, seismic activities, volcano monitoring, environmental surveillance are the other area of its application. Routing in fanet is of major importance, mainly due to large amount of data the bandwidth consideration play critical role in routing decisions.

Newer technology of applying optics could handle some of the high data link availability problem in fanet. Fanet are characterized by high mobility rate compared to other infrastructure based network, mobility could lead to collision among the members, and one of the major concerns in fanet is to avoid the collision. To do that sense and avoid method, based on receive

Signal strength are being applied. Maintaining tradeoff between the payload and endurance capacity is also seeking attendance of researcher form all over world. As increase in payload capability can increase the count of onboard instruments, which indirectly enhance the capability of multi UAV system as a whole.

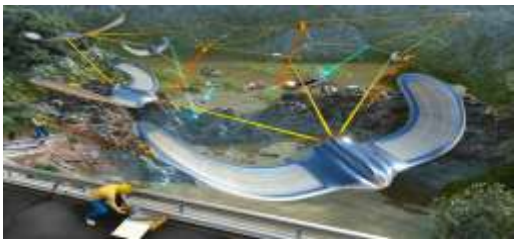

Figure.1.1 a typical fanet scenario

Meanwhile increase in payload effect the flight time of the system. Takeoff and landing in fanet and multi UAV system is crucial. For fuelling a multi UAV system is made to take off and land, which made system more prone to damage. In fanet, an alternative method providing laser based power could be solution of above. The fanet mainly consists of a group of multi devices, in order to coordinate and collaborate, the different object must respect temporal and as well as spatial space of each other. The temporal aspect consist of monitoring and threat detection area ,while the spatial deals with providing appropriate distance to act safely.

To initiate a fanet structure the multi UAV are attached to ground control station by a star topology, but to act autonomously the UAV should be adapt a new system where the multi hop routing without a fixed network structure is supported, the advantage of this approach is that group of UAV with Ad-Hoc network could perform without direct link with ground control system.

Multi-UAV systems can be classified based on the coupling between the UAV's. Multi UAV's are as follows:

Physically coupled

The UAVs are connected by physical links and their motions are constrained.

Formations

The vehicles are not physically coupled, but relative motions constrained to keep the formation.

Swarms

They are homogeneous teams of vehicles; by interactions form collective behaviours.

Intentional cooperation

The UAVs of the team move according to trajectories defined by individual tasks that should be allocated to perform a global mission (Parker 1998).

The persistence patrolling problem in multi uav architecture which solution could ,make durable and long range fanet system which could work autonomously in military and civilian airspace . The communication in multi UAV is either a) in vehicle communication (IVC), (b) airplane-to-airplane communication (A2A), and (c) airplane-to-infrastructure communication (A2I) A2A communication is important for decision making and mainly can be applied by providing a mesh network, in such a network difficulty is that each individual UAV is occupied with heavy communication instrument which in fact effect the payload and endurance capacity. This could be one scenario where the application of fanet is beneficial, as maintaining fanet architecture the individual communication can be reduced while keeping each connected indirectly .However there are few more scenario where the fanet could be applied:

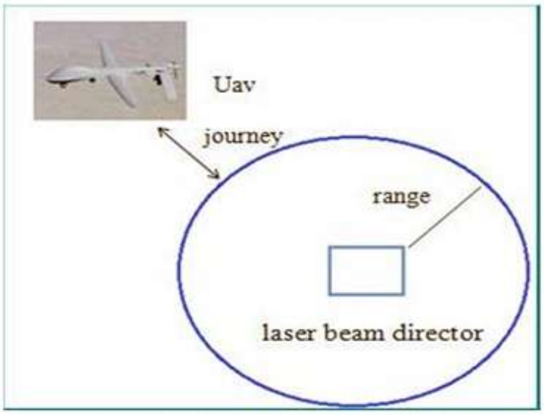

Figure. 1.2 Example of FANET.

In military scenario a frequent pop up threat may appear towards a group of UAV, the UAV due to environmental effect may not be directly connected with ground control system, a fanet module extending the connectivity may be applied and pop up threat could be avoided. Fanet could act to integrate the heterogeneous system in military scenario; different specialized agent could be coordinated and controlled with fanet. Through routing control information many complex task can be performed such as new route updating and deployment of specialized agent to his allotted work could, while each agent doing other thing but connected by fanet. Some of other aspect**s** where the deployment of fanet: an Ad-Hoc network among the flying vehicle could be effective than each unit is swarm.

2. CONNECTIVITY IN FANET

The nature of fanet network layer is mostly based on Manet and vanet, the underlying approach being similar. The network layer mainly considers the hop by hop routing of data considering the shortest route. Most of fanet networking deal the same, but considering the mobility higher than the other two of network, fanet is considered as a sub class of VANET. Routing in fanet is mainly based on hierarchical flat geographical position based rapid topological change advice the dynamic protocol to be more effective. Xlingoi is a protocol based on link quality, a modification of Lingo protocol. Xlingo is a cross layer, human interaction parameter based routing. The protocol shows efficient performance based on packet delivery ratio, Qos. The network protocol must be able to cope the high mobility as well as data link level connectivity. According to the UAV fanet communication network is based on parameter such as

- No. of UAV's
- Degree of UAV Mobility
- Onboard processing / computational ability
- Data Storage
- Energy capacity and power consumption capability

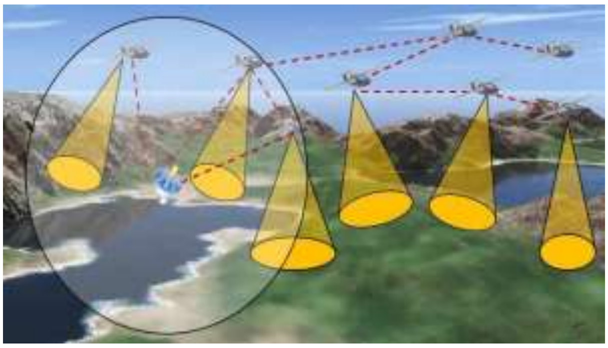

Figure.2.1 connecting multi fanet nodes

Hierarchical protocol could also be one of possible solution of routing in fanet; the different hierarchy of the protocol could reduce the congestion. The hierarchical protocol divides the plan of action into different level and routing i**s** performed according to this level. UAV**s** interconnection forms a single hierarchy while the base station form**s** another.

Unfortunately, such mechanisms are not sufficient to dispatch the rescue teams into the disaster area to find the survivors and provide them with the first aids in a short time. Moreover, the response time for some of these mechanisms is too long during a chemical disaster. The efficiency of any approach strongly relies on the time to gather the data and send it back to the rescue teams very quickly.

A feasible alternative to mitigate the above difficulties is to use a quad rotor unmanned aerial vehicles. The characteristics of such UAVs make them an attractive choice for communication application. Their small size, which simplifies the take-off and retrieval, presents many advantages in developing a fully functional autonomous UAV. They have the ability to gather and broadcast the information in a short period of time. Implementation of fully decentralized architectures in a UAV may provide higher level of cooperation in mobile Ad-Hoc networks and thus makes them equivalent to low altitude satellites.

3. ROUTING FOR FANETS

A few unmanned aircrafts design analyze the networking for systems of small UAVs. They characterize four different network architectures: direct-link, satellite, cellular, and ad hoc (also called mesh networking). The direct-link and the satellite architecture are star networks where all the UAVs are either directly connected to the ground control or to a satellite connected to the ground control. This is simple network architecture: it does not require dynamic routing, because all the nodes are directly connected with the control center. The nodes require, however, long-range (terrestrial or satellite) links, hence they are not suitable for small UAVs. Furthermore, UAV-to-UAV communication is inefficiently routed through the control center, even if the nodes operate the same area. This might cause traffic congestion in the control center, which is also a weakness of the system in case of attack.

In the cellular architecture, the UAVs are connected to a cellular system with many base stations scattered on the ground. UAVs can do a handover between different base stations during the flight. This architecture does not need a single vulnerable control center. However, the operating area of the UAVs is limited by the cellular network extension. In the case of a catastrophic event, the UAV system can be deployed only if the cellular network is present and functioning in the area.

Figure.3.1 Hierarical routing in FANET

In the ad hoc architecture, every node can act as a router. These networks are also known as FANETs: they have no central infrastructure; therefore, they are very robust against isolated attacks or node failures. Moreover, as these networks do not rely on any external support they can be rapidly deployed anywhere. These characteristics, on one hand, make FANETs the most suitable solution for many applications, but on the other hand, they raise a challenging networking problem. In fact, due to the rapid and erratic movement of the UAVs, the topology of a FANET can vary rapidly and the nodes must react by automatically updating their routing tables. Therefore, in a FANET it is crucial to employ a fast and reactive routing procedure.

A few routing protocols fail to track the fast topology changes of a FANET. For this reason, we introduce P-OLSR. To predict how the quality of the wireless links between the nodes is likely to evolve, P-OLSR exploits the GPS information, which is typically available from the UAV's autopilot.

4. COMMUNICATION PROTOCOL FOR FANET

Many routing protocols exists in wireless and ad-hoc networks such as precomputed routing, dynamic source routing, on-demand routing, cluster based routing, flooding, etc. Due to a shortage of energy, to increase the FANET operation time, there are some needs to decrease transmitting power by sending a message to closer nodes (UAVs) and by using multi-hop routing between the sender and receiver nodes over highly mobile UAVs as relay nodes. FANET is a subclass of VANET and MANET; therefore, firstly typical MANET routing protocols are preferred and tested for FANET. Due to the UAV-specific issues, such as quick changes in link quality, most of these protocols are not directly applicable for FANET. Therefore, to adopt this new networking model, both some specific ad-hoc networking protocols have been implemented and some previous ones have been modified in the literature. These protocols can be categorized in four main classes;

- **Static protocols** have static routing tables there is no need to refresh these tables.
- **Proactive protocols**, also known as table driven protocols, are periodically refreshed routing tables.
- **Reactive protocols**, also called on-demand protocols, discover paths for messages on demand.
- **Hybrid protocols** use both proactive and reactive protocols. By using these routing protocols, a FANET can dynamically discover new routes between communicating nodes, and this network may allow addition and subtraction of UAV nodes dynamically.

4.1. OLSR PROTOCOL

OLSR is currently one of the most popular proactive routing algorithms for ad hoc networks. It is based on the link-state routing protocol. The original OLSR design does not consider the quality of the wireless link. The route selection is based on the hop count metric, which is inadequate for mobile wireless networks. However, by using the ETX metric, the OLSR link-quality extension enables us to take into account the quality of the wireless links. The ETX metric is defined as

$$\mathrm{ETX}(\mathcal{R}) = \sum_{\eta\in\mathcal{R}} \mathrm{ETX}(\eta) = \sum_{\eta\in\mathcal{R}} \frac{1}{\phi(\eta)\rho(\eta)}$$

Where R is the route between two nodes, η is a hop of the route R. $\phi(\eta)$ is the forward receiving ratio that is the probability that a packet is sent through the hop η is successfully received. $\rho(\eta)$ is the reverse receiving ratio that is the probability that the corresponding ACK packet is successfully received. ETX estimates the expected number of transmissions (including re-transmissions) necessary to deliver a packet from the source to its final destination. Then OLSR selects the route that has the smallest ETX, which is not necessarily the one with the least number of hops. If all the hops forming *R* are errorless (i.e.),$\varphi(\eta) = \rho(\eta) = 1$) the ETX(*R*) is equal to the number of hops of *R*.

The receiving ratios are typically estimated by link-probe messages. The OLSR link-quality extension uses the control messages named Hello messages as a link-probe. φ is computed by means of an exponential moving average, as follows,

$$\begin{cases} \phi_l = \alpha h_l + (1-\alpha)\phi_{l-1} \\ \phi_0 = 0 \end{cases}, \quad 0 \le \alpha \le 1$$

Where

$$h_l = \begin{cases} 1 & \text{if the } l\text{-th } \textit{Hello} \text{ message is received} \\ 0 & \text{otherwise} \end{cases}$$

And α is the OLSR parameter, named link-quality aging that drives the trade-off between the accuracy and responsiveness of the receiving ratio estimation. On one hand, with a greater α, the receiving ratios will be averaged for a longer time, thus yielding a more stable and reliable estimation. On the other hand, with a lower α, the system will react faster. Another important OLSR parameter is the Hello Interval (HI) that indicates how frequently Hello messages are broadcasted.

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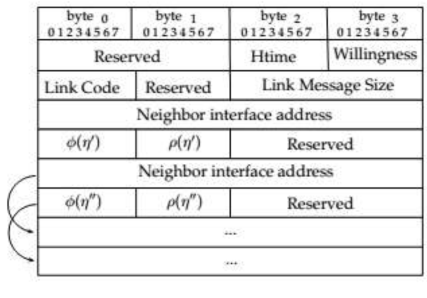
4.2. P-OLSR IMPLEMENTATION

In order to implement the P-OLSR protocol, divide an open-source implementation of OLSR called OLSRd. In the modified version, the Hello messages are augmented to contain position information. Thus, every node knows its neighbors' positions and can compute the corresponding ETX. OLSRd uses link-quality sensing and ETX metrics through the so-called link-quality extension. It replaces the hysteresis mechanism of the OLSR protocol with link-quality sensing algorithms that are intended to be used with ETX-based metrics. To do so, the link quality extension uses the OLSR Hello messages to probe link quality and to advertise link-specific quality information, (i.e. receiving ratios, φ and ρ), in addition to detecting and advertising neighbors. Likewise, it includes the link-quality information also in OLSR Topology Control (TC) messages that are to be distributed to the whole network. Clearly the modified messages are not RFC-compliant anymore because they include new fields for link-quality information. Therefore, all the nodes in the network have to use the link-quality extension.

To implement P-OLSR, we have to share the coordinates (i.e. longitude, latitude, and altitude) of each node with its neighbors. This is done through the Hello messages. Subsequently, each node uses its neighbors' coordinates to compute the corresponding relative speeds, and share them across the whole network via both Hello and TC messages.



Format of the original (i.e. OLSRd) *Hello* message.

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4.3. DISTANCE AWARE ROUTING

The nodes location and mobility are not aware of the approaching node such that no reinforced path can be gropped. To overcome this DAR technique can be used in which each FANET node is aware of its location and shares the information with the approaching base station at a defined frequency. The base station computes the distance with the received location value from the approaching node.

4.4. RELATIVE ROUTE SELECTION

In this technique after sharing the location information the FANET node is free to move in the possible paths to reach the destination. Any probabilistic information that are same in the base station, then the base station broadcasts a scheduling acknowledgement to the approaching FANETs. In such cases either the FANETs with low priority or back up node need to share the path to the destination with one node acceptance. the next route selection as defined by the base station the least prioritized FANET is made to undergo a switch over through other nodes or base station.

5. CONCLUSION AND FUTURE WORK

In this paper we describe about the Flying Ad-hoc Network (FANET). Communication is one of the most challenging design issues for multi-UAV systems. The existing routing protocols designed for MANETs partly fail in tracking network topology changes. We described the most challenging task i.e. communication between the multi- UAV's. We formally define FANET and routing in FANET. We also discuss the communication protocols that are used in FANET.OLSR protocol is adapted for dynamic path shifting process in FANETs. Yet the routing procedure is incomplete without fore hand information from the approaching nodes. A distance aware routing procedure determines the next path node selection that is adaptive with the available number of nodes in the network region .the relative route selection technique prepares the available routes for the approaching node such that the node has least probability of disconnection due to its variable mobility. In future pre estimation of mobile links and lateration based node identification can avoid data drops and link failures.

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