# FLYING AD HOC NETWORK - SURVEY ON THE MOBILITY MODELS AND ROUTING PROTOCOLS

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***Abstract :*** As the huge development in electronic, Computer Science and communication technologies, the Unmanned Aerial Vehicle system has been evolved from single UAV system to multi UAV system and their applications in military and civilian areas are becoming very popular. High mobility nature of UAVs caused many issues while using existing communication protocols and network models. The communication between UAVs can be implemented by establishing an ad-hoc network between them known as FANET. In this paper we are discussing different mobility models and routing protocols that are used in FANET by the ongoing researches.

***IndexTerms* - UAVs, Mobility Model, Routing, FANET.**

## I.INTRODUCTION

Unmanned aerial vehicle systems (UAVs) which can fly autonomously or operated remotely are used widely in military and civilian applications such as border surveillance, managing wildfire, disaster monitoring, remote Sensing and traffic monitoring. Two types of UAV systems are existing- Single UAV system and Multi UAV system. Multi UAV systems have the following advantages over single UAV system [1].

- Lower Maintenance cost
- Increased amount of coverage or scalability
- Increased survivability
- High speed operation

Even in multi UAV system some issues exist. In this system some UAVs are connected to ground base stations and others connected to satellite. So UAV to UAV communication is becoming infrastructure based. So they should be equipped with expensive and complicated hardware devices. This complication can be avoided by allowing only one or few UAVs to communicate with base stations and all the UAVS in the system to communicate each other.

The communication between the UAVs can be attained by establishing an ad-hoc network between them. This ad-hoc network known as Flying Ad-Hoc Network(FANET) is a sub set of the existing ad-hoc networks MANET and VANET. Fig 1 shows the relation between FANET MANET and VANET [4]. There are some differences existing between FANET and MANET / VANET .The mobility degree of FANET is much higher than MANET or VANET. Due to high mobility the topology changes in FANET is frequent. The communication range between the FANET nodes are more since the distance between the FANET nodes are much longer than MANETs and VANETs

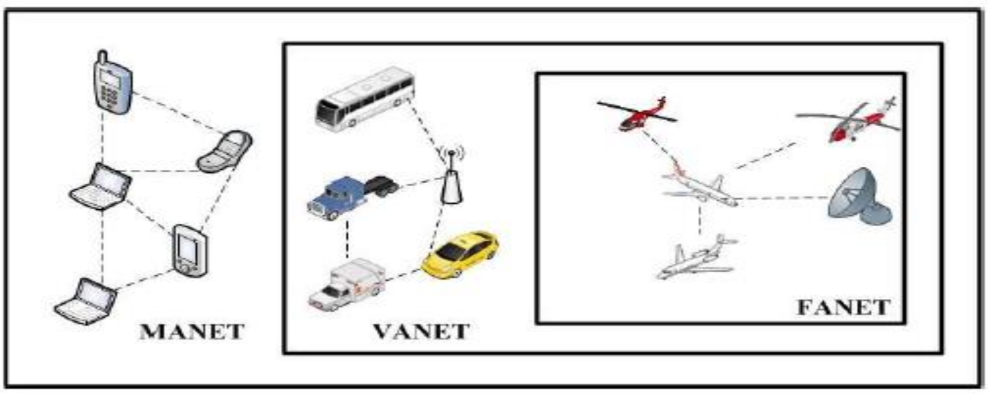


Fig1: FANET a subset of MANET and VANET

A typical FANET scenario for multi UAV system using the ad-hoc network communication is illustrated in Fig 2. The remaining sections of the paper is organized as, in section II different mobility models for FANET has been discussed, section III different types of routing protocols experimented in FANET are considered ,and in section IV the paper has been concluded.

Fig 2: A FANET application scenario for reliable multi-UAV communication network

## II. FANET MOBILITY MODELS

The mobility model of a network indicates the movement and position of nodes and how these positions changes according to the change in velocity and acceleration of the node movements. Using simulation environment it is possible to illustrate the mobility model for a network. Fig 3 shows the commonly used four mobility models in FANET [7].

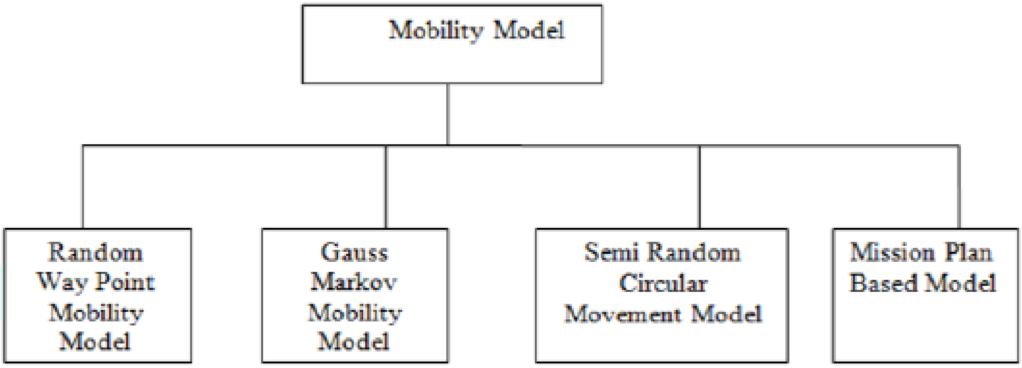


Fig 3: FANET mobility models

### 2.1 Random Way Point Mobility Model

In random based mobility models, UAV nodes are allowed to move randomly in any direction with in the simulation area. A node can select its speed and direction of movements independent of other nodes. But it is not suitable for UAVs because UAVs do not change their speeds and direction rapidly. Fig 4 shows the travelling pattern of a node in Random Way Point Mobility Model.

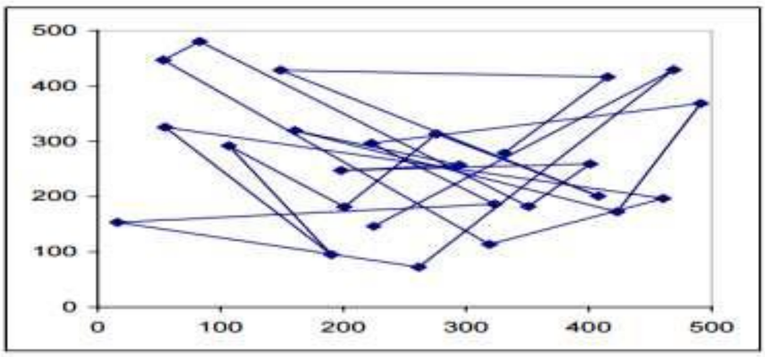


Fig 4 : Travelling pattern of a node in RWMM

### 2.2 Gauss Markov Mobility Model

The behavior pattern of UAVs in a swarm is simulated using Gauss Markov Mobility Model. In this model the path of a UAV is determined by the memory of the model. Current node position is determined by the previous position. The speed and direction at the nth instance of a time are calculated from n-1th instance speed and direction along with a random variable. The velocity of a node at time n can be given by

$$V_n=\alpha V_{n-1}+(1-\alpha)\mu+\sqrt{1-\alpha^2} * X_{n-1} \qquad (1)$$

$\alpha$ used to vary the randomness , $\mu$ is a constant representing the mean value of Vn as $n \rightarrow \infty$ and X is a random variable from a Gaussian distribution[9].

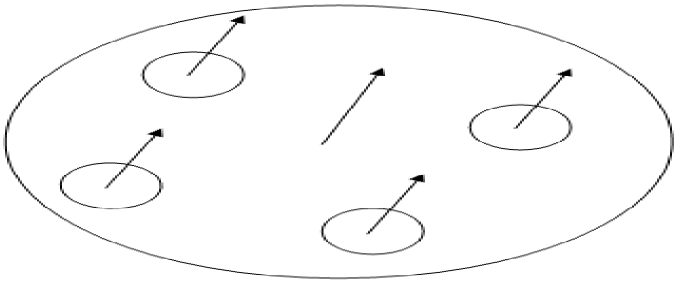

Fig 5: Gauss-Markov Mobility Model

Fig 5 shows the node movement depending up on the previous node position.

### 2.3 Semi Random Circular movement model

In this model the UAVs move in a circular manner. In this mobility model UAVs are simulated to rotate around a specified area to capture some information from that specific region. Fig 6 illustrates the semi random circular mobility in FANET.

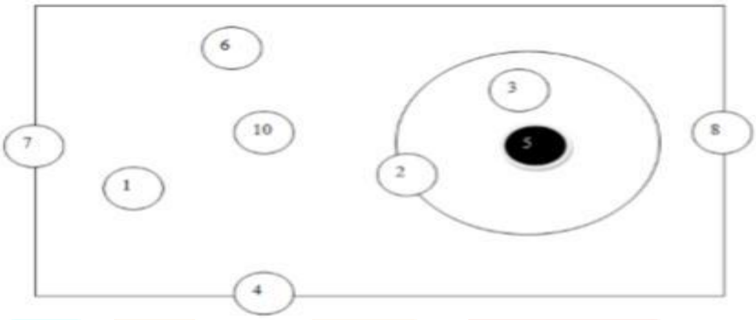


Fig 6: Semi-Random Circular Movement Model

### 2.4 Mission Plan Based Model

In this Mission Plan Based model the potential target and the path to reach to that target will be predefined [7]. That is the flight plan information is already defined in the mobility files. These mobility files are created and updated as time over. If an aircraft reaches destination before flight time is over, it changes direction to the starting point and continues flight as round trip. Fig 7 shows how the flight is planned based on the potential target.

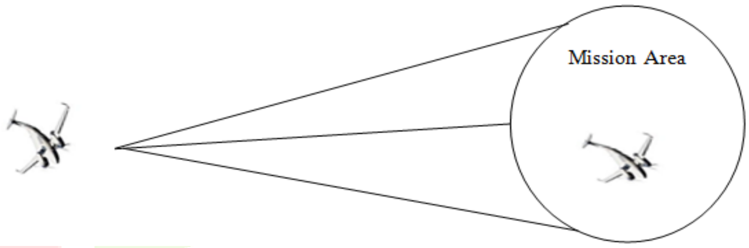


Fig 7: Mission Plan Based Model

## III. ROUTING PROTOCOLS IN FANET

Because of the high mobility degree of the UAVs in FANET the selection of routing protocol has been resulted to a greater issue. The routing protocols used in FANET are considered mainly from the following classes of protocols

- Static Protocols
- Proactive Protocols
- Reactive Protocols
- Hybrid Protocols
- Position/Geographic Based Protocols
- Hierarchical protocols

### 3.1 Static Routing Protocols

Routing between the UAVs performed based on the static routing tables loaded in each UAV. The pre calculated routing information in the tables cannot be changed during operation and hence results a fixed topology for the network. The disadvantage of this system is the lack of fault tolerant capacity. Commonly used static routing protocols in FANET are [2]

- Load Carry and Deliver Routing
- Multilevel Hierarchical Routing
- Data Centric Routing

*Load Carry and Deliver Routing (LCAD)* is well suited for delay tolerant system [2]. In this model a UAV collects data from a ground node and flies to the destination and delivers the data. There is no inter communication between the UAVs. The main objective of this protocol model is to provide highly secured data transmission. The major drawback of the system is as the communication path grows the resulting delay will be high. The unavailability of the single UAV also decreases the throughput of the system. To solve these problems multi UAVs can be used in the same path. Fig 8 illustrates this model

Fig 8: Load Carry and Deliver Routing Model

*Multilevel Hierarchical Routing* allows the UAV networks to be divided hierarchically into number of clusters to operate in different mission areas. Each cluster consists of a cluster head to communicate between the clusters, ground stations ,satellites etc. Fig 9 illustrates this model [2].


Fig 9: Multilevel Hierarchical Routing

*Data Centric Routing* is based on the data content which is needed, not on the IDs of the source and destination nodes [2]. In this model one to many transmissions is preferred over one to one transmission. When a node requires particular data(node can be a UAV or a ground station) from a particular region it forms a suitable message indicating the particularities of the data and multicasts to that region. Once the subscriber node's message reaches the producers or called as publishers, according to the requirement specified in the message the data dissemination starts. The advantages of this technique are space decoupling ( no need to know the identity or locations of communicating nodes), time decoupling(it is not compulsory that the communicating nodes to be online always) and flow decoupling( asynchronous communication structure can be used). The major drawback of this model is the communication of redundant data. Fig 10 illustrates this transmission technique.

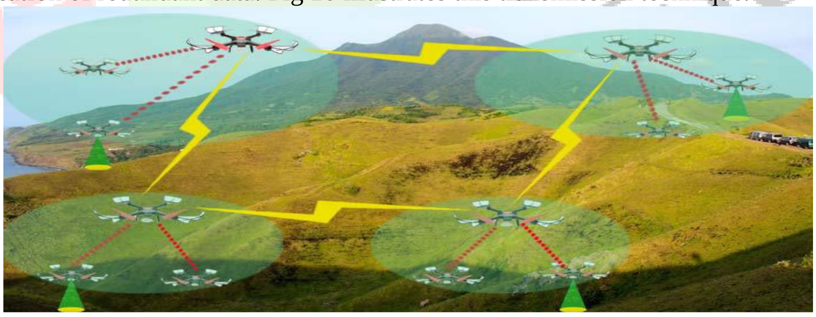

Fig 10: Data Centric Routing

**3.2 Proactive Routing Protocols**

The routing is done based on the stored information in the tables maintained in each node. These tables contain the information about all nodes in the network. As the topology of the network changes the updation of these tables are taking place. Hence the updated routes are always available for the communication. But an additional overhead results for preserving up to date information and results to high bandwidth utilization because control messages have to send even no data traffic is existing. Commonly used proactive protocols in FANET are Optimized Link State Routing (OLSR) and Destination Sequenced Distance Vector (DSDV).

*Optimized Link State Routing (OLSR)* protocol uses a Hello message to find the neighbors and a topology control message. Hello messages are used to detect one hop neighbors and will be broadcasted periodically to one hop neighbors. Topology control message used to provide the information regarding the topology change resulted in the network so that each node can recalculate the routes to all other nodes in the network. The periodic flooding of messages resulted to a big overhead. To reduce this overhead Multipoint Relay (MPR) mechanism is introduced [7]. When any node wants to broadcast information it will select the MPR to forward the message. Fig 11 illustrates the use of MPR in OLSR.

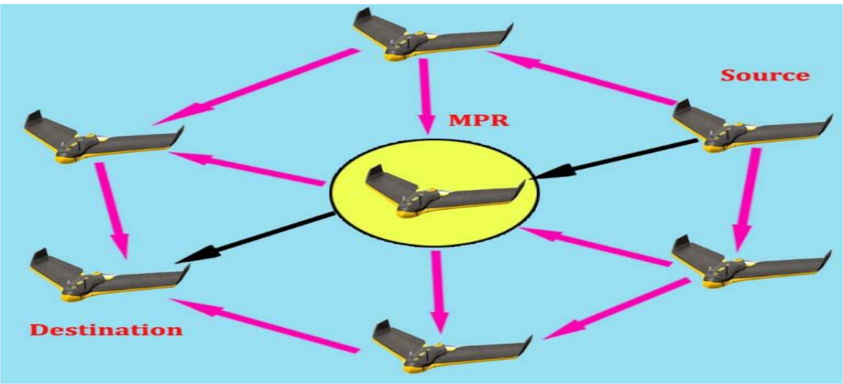


Fig 11: Multipoint Relay

*Destination Sequenced Distance Vector (DSDV)* routing is based on Distance Vector Routing algorithm with a modification to adhere to the ad hoc nature of the network. In Distance Vector Routing, a table in each node consists of the details of thebdestination, hop count and next hop. As each node sends its routing table periodically to its neighbors the nodes will be able to compute new shortest paths and update the tables. But it results to slow convergence and looping. DSDV added two parameters to solve these problems. They are sequence number and Damping. Sequence number avoids looping and Damping avoids unnecessary updates [5].

**3.3 Reactive Routing Protocols**

The high mobility and the frequent changes in network topology in FANET, the reactive structured protocols are preferred over the proactive structured protocols. Also the overhead problems in Proactive Routing Protocols can be overcome by Reactive Routing Protocols. Reactive Routing Protocols are also referred as On Demand Routing Protocols. If there is no communication between two nodes no need to compute and store the route details between these nodes. The route will be determined only when a source node demands a communication between another node. To implement this protocol two types of messages are used - Route Request message and Route Reply message. RRQ message will be flooded to the network by the source UAV and RRP will be generated by the destination UAV and communicate to source UAV in unicast mode

*Dynamic Source Routing (DSR)* use broadcast mode to communicate the request messages from source node to its neighbors. To avoid the confusion between the simultaneously existing requests in the route, source node adds a distinct id for its request. If the source node is not able to use the current route due to some link failure, a route maintaining mechanism is used to find another route. If such a route does not exist a new route discovery phase will be started. The repetitive route finding before each communication in FANET is exhaustive [6].

*Ad-Hoc on Demand Distance Vector (AODV)* is an enhanced version of DSDV and DSR [5]. It performs periodic updation as DSDV and hop to hop routing as DSR. It differs from DSR in maintaining the routing table. For AODV only single entry is existing for a particular destination while DSR multiple entries can be stored for a destination. In DSR complete path information should be there in the communicating packets but in AODV source node stores next hop information. AODV protocol has been implemented as three stages - route discovery, packet transmission and route maintenance.

**3.4 Hybrid Routing Protocols**

Hybrid routing protocols are the combination of different protocols to overcome the shortcomings existing in individual protocols. With hybrid routing protocols the time consumption due to route discovery phase in reactive protocols and the overhead caused by control messages in proactive protocols can be reduced [3].

*Zone Routing Protocol* considers the network to be divided as number of zones [4]. Each node belongs to a particular zone. The intra zone routing that is the routing within the zone is done using proactive mode while inter zone routing is done in reactive mode. Here the route discovery latency is solved by border casting technique.

*Temporarily Ordered Routing Algorithm (TORA)* is a hybrid routing protocol in which routers maintains only adjacent router details. It reduces the propagation of control messages. From the source node to destination node a Directed Acyclic Graph (DAG) will be generated and maintained [6]. Since multiple routes exist in DAG any link failure occurs it is easy to find out a new route and thus increases the adaptability. Increased adaptability is suitable for FANET where due to high mobility frequent topology changes happens.

**3.5 Position/Geographic Based Routing Protocols**

Physical position of the nodes is calculated by techniques like GPS. Sender find outs the destination position and forwards the packet to the destination.

*Greedy Perimeter Stateless Routing* can be used for compactly placed (densely deployed UAVs) FANET. But reliability becomes a great issue in sparsely placed UAVs [2].

*Geographic Position Mobility Oriented Routing* tracks the movements details of the UAVs using Gaussian- Markov Mobility Model [2]. The data collected in this way will be used to locate the next hop.

**3.6 Hierarchical Routing protocols**

These protocols are used to address the network scalability problem. Hierarchic level determines whether to choose proactive or reactive mode of communication. In FANET the most commonly used Hierarchical protocols are Mobility Prediction Clustering and Clustering algorithm of UAV networking [1].

*Mobility Prediction Clustering* – The high mobility structure of FANET results in frequent cluster updates. With the help of Trie structure Prediction algorithm and link expiration mobility model these updates will be predicted.

*Clustering algorithm of UAV networking*- it first constructs the updates on the ground and then updates it during the operation of multi UAV system.

## IV. CONCLUSION

One of the current emerging research fields in Network Technologies is FANET where a group of small UAVs are communicating in ad-hoc mode. Because of the high mobility of the nodes in FANET, many communication issues are arising. To overcome such issues many networking architectures and routing protocols are experimented by the researchers.

In this paper we introduced different mobility models which indicate how the movement and the position changes happen in FANET. We also discussed how various existing routing protocols will work on FANET. Many of these protocols are not directly applicable on FANET. So in future a new routing protocol should be designed to adhere to the special features of FANET.

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