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Classification of Routing Protocols Used for Flying Ad Hoc Networks (FANETs)

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Abstract

In real world most important concept in communication is dynamic environment. Due to continuous changes in the environment it is not easy to communicate. As we know Flying Ad Hoc Network (FANET) is the recent technology that has come in the networking environment. FANET uses important protocols which are used for dynamic communication. Flying Ad Hoc Network is similar form of unmanned aerial vehicle (UAV) without human intervention. Most of the design issue in multi-UAV network is communication and without any networking protocol it is not easier. Some of the similar protocol are used in Mobile Ad Hoc Network (MANET) and Vehicular Ad Hoc Network (VANET). These existing networking protocols are further extended with the new concepts and enhanced technology. In this paper, we have discussed on different networking protocols used in unmanned aerial vehicle. These networking protocols will help the researchers that are working in this field.

Keywords— *Dynamic communication, Network utilization, Clustering head algorithm, Networking protocols, multi-UAV network*

1. INTRODUCTION

In today's world most of the researchers are working on Unmanned Aerial vehicles (UAVs) reason being many unresolved issues. UAVs are objects flying in the air with some equipment loaded on them. It consists of cameras, rotor motor, transmitter, receiver and wireless connectivity etc. Basically UAVs are of two types. First, Single UAV and other Multi-UAV. In Single UAV, flying nodes can't communicate with each other but can transmit useful data to the ground station. In Multi-UAVs the flying nodes can communicate with each other and can transmit useful data to the ground station. FANET is new form of traditional networks that like MANET and VANET. FANETs are used for many purposes such as military, surveillance, domestic use, security, disaster monitoring and other purposes. UAVs work independently in the air with the help of a remote operated by human being [1].

2. TYPES OF FANET NETWORKING PROTOCOLS

2.1 Static Protocol

In Static routing protocol, the topology of the network is fixed and no changes can be made during the operation [2]. Once the table is created for the routing, the information stored in the connected UAVs will

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remain the same as defined and no further changes or updates can be made. In case a failure occurs suddenly then no provision for update the routing table dynamically.

2.2 Proactive Protocol

In this protocol the network maintains their own route as well as their connected neighbor's node information. A routing tables' information with certain interval of time are refreshed periodically [3]. Drawback of this protocol is that it is not used for big network and maintain of the routing table for every node involved in such large networks.

2.3 Reactive Protocol

It is also known as On demand routing protocol, it discovers the path for the message, send the information according to the need [4]. This routing protocol uses two message passing techniques. (i) Route request message (RREQM); In this, the source node(SN) sends the request over network to destination node(DN). (ii) Route reply message (RRP); In this protocol the destination node(DN) sends the reply to source node(SN) over network as a result it maintains the same path mentioned earlier [5].

2.4 Hybrid Protocol

It is combination of the above two protocols such as proactive and reactive protocols. The reactive protocol discovers the route in the extra time while the proactive protocol controls the message with huge overhead. So, the networks are divided into zones for appropriate distinction between the two protocols discussed below.

2.5 Position / Geographical Based Protocol

This protocol is based on the particular area where we find the details of area to collect the information of particular area. It is also based on the position and geographical details by which we find exact location of area and position of the UAVs flying over the area.

2.6 Hierarchical Based Protocol

This protocol is similar as tree like structure, one node called parent node and other neighbor nodes are called a children node. Actually this protocol is based on the clustering concepts. Different clusters are used for the different mission area. There are two clustering algorithm protocols used for FANETs. (i) Clustering head algorithm (ii) Mobility prediction clustering algorithm.[5].

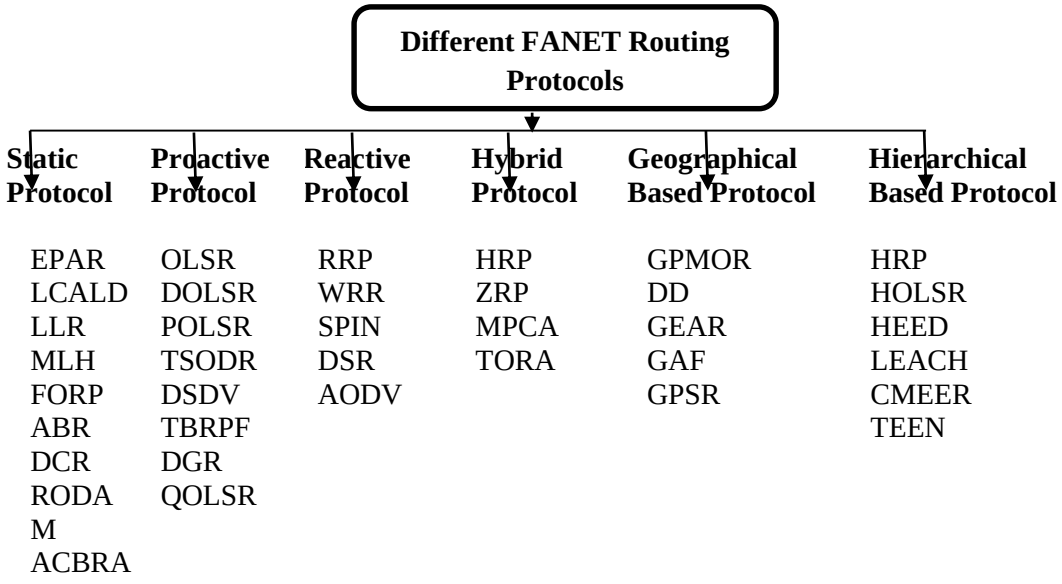

Figure 1: FANET Routing Protocols

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3.1 STATIC PROTOCOLS

3.1.1 Energy Power Aware Routing (EPAR)

This protocol is used for find life time prediction of battery. EPAR protocol identifies the multiple paths in the intermediate routers to find the maximum energy or life time. It selects the path which has maximum life time using the EPAR algorithm [6].

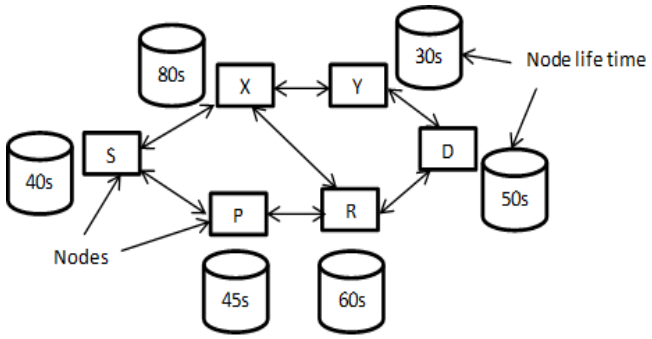

Figure 2. Architecture of EPAR

Let's take the example in the given Figure 2, S is represented the sender node and D is represented the receiver node. EPAR algorithm finds, path which has maximum life time from sender node to receiver node. This algorithm has different ways from sender to receiver defined as below:

$$\frac{40}{S}+\frac{80}{X}+\frac{30}{Y}+\frac{50}{D}=200 \quad (1)$$

$$\frac{40}{S}+\frac{45}{P}+\frac{60}{R}+\frac{50}{D}=195 \quad (2)$$

$$\frac{40}{S}+\frac{80}{X}+\frac{60}{R}+\frac{50}{D}=230 \quad (3)$$

$$\frac{40}{S}+\frac{45}{P}+\frac{60}{R}+\frac{80}{X}+\frac{30}{Y}+\frac{50}{D}=305 \quad (4)$$

Now, EPAR find the maximum life time path from equation (4) which is 305.13

3.1.2 Load Carry and Load Delivery Protocol (LCALD)

This protocol used to carry the load i.e. data or large information loaded on the UAVs and deliver it to the particular destination. The purpose of load carries and load delivery is to maximize throughput so that maximum data. The information from the ground to where the destination node is. Actually this protocol is used in military purposes because large amount of data is sent to the actual destination [4]. The ground level or the source (SN) carries data and deliver it to the destination node (DN). Let's depict with the help of diagram [7].

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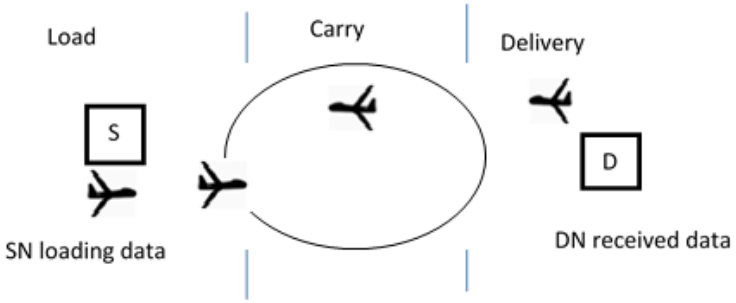

Figure 3: Source to Destination Delivery of Data

3.1.3 Long Lifetime Route (LLR)

This protocol is used to discover the new path whenever connection breaks. It suggests the best frequent route, shortest path improves the overall performance [8]. LLR reduces the connection discontinuation or path break. It could be happened on the base of route lifetime distribution. Route lifetime distribution: The route is made of different connected link in network. The best method to find the best route is the shortest hop or intermediate nodes between sources to destination and this easily gets the lifetime of route, which one is larger hop count or which is smaller. Consider the distance between sources to destination node is L, and connection made via a node link is N where N>L, nodes are connected via link source to destination, then calculate link distance using formula $D = \frac{L}{N}$ [9].

3.1.4 Multilevel Hierarchical Routing (MLH)

There are different bunches of UAVs flying in the sky and they make a clusters of nodes. They are connected with each other and communicate in their specific region. Each region consists of a cluster head which communicates with the other regions via their cluster heads. In the Figure 4 below the UAV shown in red color is the cluster head.

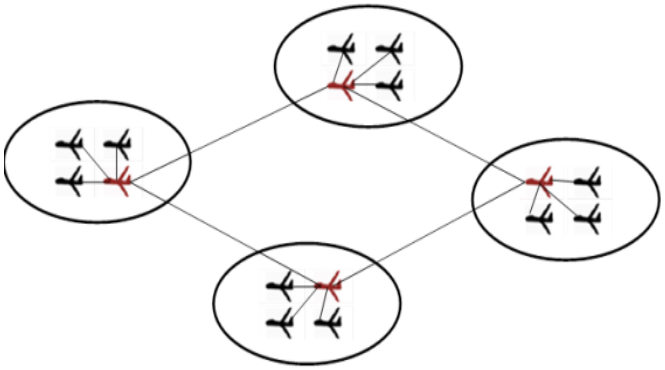

Figure 4. Multi-Level Hierarchical Routing

3.1.5 Flow Oriented Routing Protocol (FORP)

William Su & Mario Gerla [10] both were first introduced this routing protocol. FORP is based on multi-hoop handoff system, if one route disconnects and no other route is available then it reroutes the network. Another use of this protocol is to maintain the router information of the entire source and destination node which are active.

3.1.6 Associativity Based Routing (ABR)

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ABR protocol is created on query and reply base system for search destination node [11]. The source node sends the query to all the connected nodes in the network according to priority based system. It selects the consistent route first and then takes the better associativity preference [12].

3.1.7 Data Centric Routing (DCR)

Here routing is done depending on data characteristics and not on the IDs of the UAVs requesting it. The request from the ground station is sent to many UAVs each of which will decide whether to collect information or not to collect after that sends data to other UAVs nodes.

3.1.8 Routing On Demand Acyclic Multipath (RODAM)

M. Mosko and C. E. Perkins [13] have designed the ROADAM protocol. All the routers attached in the network maintain the tables which have list of the node distance, link, and cost of table. The routing table contain the distance of all destination node as well as neighbor node and accordingly router updates the routing table as per the requirement. There are some point that router must enter (i) destination nodes table entry (ii) updates regularly when requirement. Another main aim of RODAM protocol is design loop free path from source to destination.

3.1.9 Ant Colony Based Routing Algorithm (ACBRA)

The algorithm of Ant colony optimization was given by Colorni and Dorigo, which was studied from the communication behaviour of the ants in their colonies. The ants while moving, leave behind a chemical named as pheromone in the path which is perceived by other ants and they follow the same path for search of food. Thus, the pheromone guides the movement of large number of ants.This phenomenon provides positive feedback to the algorithm which can increase the routing selection. When a route is taken by many ants, the probability of the route chosen by other ants becomes high. [14].

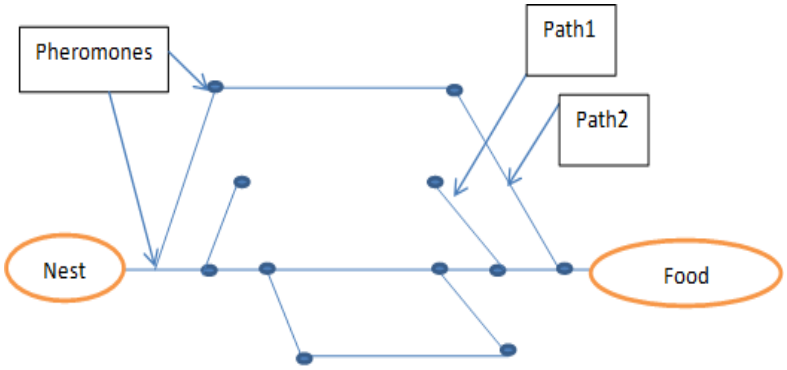

Figure 5: ANT searching shortest distance for food

4.1 PROACTIVE PROTOCOLS

4.1.1 Optimized Link State Routing Protocol (OLSR)

The OLSR was first introduced by T.Clausen & P.Jacquet [15]. The key concept was multipoint relay (MPR). MPR is the node which is selected during the broadcast of messages as flooding. Optimization is achieved in the network by reducing the flooding of messages from source to destination. MPR itself selects the node by one step neighbor to connect source node with destination node.

4.1.2 Directional Optimized Link State Routing Protocol (DOLSR)

DOLSR use the Multi-point relay (MPR), it is central node used to transmit information from one node to another. DOLSR is based on OLSR but having less number of relay points with the use of Omni-directional

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antenna [16]. If source knob has to transmit data to destination nodes that are calculated by compared formula Dmax/2 [17].

4.1.3 Predictive Optimized Link State Routing (POLSR)

According to Rosati et.al., [18] proposed, Here routing information is obtained through GPS. The relative speed between the two nodes is calculated using GPS and higher quality link is chosen. The authors are explaining the concepts of relative speed when two nodes are highly moveable in the sky.

4.1.4 Time Slotted on Demand Routing (TSODR)

This algorithm is based on the division of time, as the packets are going to send from one node to other it will first check path which must be free and provides a time slot [19]. In AODV, every packets before sending will contain time slot. This process decreases the collision and improve effectiveness in communication.

4.1.5 Destination Sequence Distance Vector (DSDV)

DSDV is step-by-step routing protocol where each connected node in the network requires periodical update in the routing table. The distance vector idea is basically the concept of Bellman-Ford routing algorithm [20]. Every node contains the sequence number. The route with highest sequence number is given the preference. This has an advantage of avoiding network loops.

4.1.6 Topology Broadcast Based on Reverse Path Forwarding (TBRPF)

According to A. Bujari et.al., [21] this protocol is designed in such a way that there is efficient dissemination of the packet. If there is any change in the link state, it will quickly identify and reschedule the immediate computation which is appropriate for FANETs.

4.1.7 Delay Guaranteed Touting (DGR)

Delay guaranteed routing (DGR) is created concept of time division multiple access (TDMA) protocol. It is an integrated MAC and routing protocol. In this protocol delivery provides delay guarantee in effective manner. The transmission of data is based on time slot. DGR requires a short signal phase to get node location and then utilizes the vacant slot available to reduce the latency between two successive media access by sensor nodes [22].

4.1.8 Quality of Service OLSR (QOLSR)

QOLSR is a wireless routing protocol used wireless connectivity IEEE 802.11 that provides an enhancement quality. This protocol creates routing metrics where one or more nodes communicate with each other [23]. Multi-point relay (MPR) used as forwarding packet and is responsible to mediate communication between connected nodes.

5.1 REACTIVE PROTOCOLS

5.1.1 Reactive Routing Protocol (RRP)

The reactive routing protocol also called as on demand routing protocol (ODRP), that represent no interaction takes place of two nodes then at this time no need to calculate the path between them. Basically it is designed to reduce the problems of proactive routing protocol (PRP).

5.1.2 Wireless Routing Protocol (WRP)

This protocol is used for the maintenance of loop freedom. It requires every connected node to overhead at each nub in the network. There are four methods used to connect nubs (i) Distance table (DT), (ii) Routing table (RT), (iii) Link-cost table (LCT), (iv) Message re-transmission list (MRL) table [24].

5.1.3 Sensor Protocol for Information (SPIN)

According to J. Kulik et.al., [25] this protocol is based on information dissemination through negotiation. SPIN is the data centric routing protocol. It has some following assumptions:

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a. The connected knob in networks are base station
b. The adjacent knob has same data values.

5.1.4 Dynamic Source Routing (DSR)

It is a convenient and effective routing protocol developed in context of multi-hop networks where nodes (UAVs) are self-organized and self-configured. This protocol is based on two mechanisms first is Route discovery and second is route maintenance.

(i) **Route Discovery:** When a node helps to send information for which the route is not known, a route finding process is initiated to find the route dynamically. Large number of route request packets are sent in the network. Each node receiving the request will rebroadcast it unless it has a destination route in its cache. Such a node will reply with a route reply that will be sent back to source node.

(ii) **Route Maintenance:** This plays important role while data sending between source node to destination node. If the network between source and destination has broken the source node is informed with route error packet and this link is erased from the network.

5.1.5 Ad hoc on Demand Distance Vector Routing (AODV)

This protocol is based on information of knob comprise next information for data flow. It deals fast revision to dynamic link, short network processing, low network utilization and retention overhead [26].

There are three types of messaging happens in the AODV (i) Route Requests (RREQs) (ii) Route Reply (RREPs) and (iii) Route Errors (RERRs).

(i) **Route Requests (RREQs):** When IP packet transmit source to destination node it maintains the path and first send the route request to the destination. The source node responsible for the establishment of route.

(ii) **Route Reply (RREPs):** The target node sends acknowledgment to starting node as a confirmation that now ready to send packet within the established network.

(iii) **Route Error (RERRs):** Some time due to connection break at that time error generated and route itself send the report to the router for the correction error.

6.1 HYBRID PROTOCOLS

6.1.1 Hybrid Routing Protocol (HRP)

This combines the previous protocols and is designed to overcome their shortcoming. HRP can reduce the large latency of the initial route discovery process in cases of reactive routing protocols, and also the overhead of control messages in relation to proactive routing protocols. It works well for large networks. A network is divided into a number of zones where intra-zone routing is done through proactive approach and inter- zone routing performed with reactive approach.

6.1.2 Zone Routing Protocol (ZRP)

According to Z. J. Haas and M. R. Pearlman [27] this hybrid routing protocol keeps the information of their connected neighbors only. It will work in the particular range that can be divided into zones and provide more effective routing to the connected nodes. The author explained the two zones in this protocol (a) Inter-zone routing (b) Intra-zone routing.

6.1.3 Mobility Prediction Clustering Algorithm (MPCA)

According to C. Zang and S. Zang [28] to overcomes the issues related to existing algorithms in network, a new algorithm based on weighted clustering is proposed known as MPCA. It is based on (a) link expiration time (b) dictionary of tri-structure.

6.1.4 Temporally-Ordered Routing Algorithm (TORA)

Here each UAVs only update data regarding neighboring UAVs. The important feature of this protocol is to limit flow control messages in extremely dynamic environment in order to reduce fast responses to topographical changes [29].

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7.1 GEOGRAPHICAL BASED PROTOCOLS

7.1.1 Geographic Position Mobility Oriented Routing (GPMOR)

These are position based routing protocol where the geographical position of the UAVs is assumed and the data is sent to the destination nodes without discovering the route [30].

7.1.2 Directed Diffusion (DD)

It is a data-centric (DC) routing protocol. The interaction among the node is localized within limited network neighborhood thus saving energy and increasing network lifetime [31].

7.1.3 Geographic and Energy- Aware Routing (GEAR)

It is based on the location and need all the information of connected nodes in the network. This protocol used GIS (Geographical information system) to find the location of particular sensor nodes in a network [32].

7.1.4 Geographic Adaptive Fidelity (GAF)

This algorithm is primarily designed for mobile ad hoc network but may applicable for ad hoc sensor networks. It is a hierarchical based routing protocol and clusters are based on the position or geographical location. The clusters are divided into zones and make a virtual grid for communication [33]. The virtual grids are designed in such a way that every nodes of A want to communicate with every node of B and vice versa. If the node has the same point in the grid are consider equivalent in the regards of packet routing. The cluster head informs all the activities in the network to the base station.

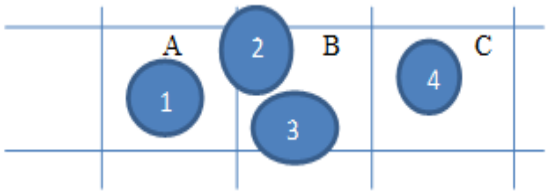

Figure 6: GAF (Virtual Gride)

In the Figure 6, the node 1 communicate to node 2 and 3 similarly node 2 and 3 communicate to node 4 thus the node 2 and 3 lying in the same grid are considered as a equivalent and rest are sleep node. GAF functions in three states: discovery, active and sleep.

7.1.5 Greedy Perimeter Stateless Routing (GPSR)

The Greedy Perimeter Stateless Routing is an innovative routing protocol for ad hoc networks which uses the location of router and packet of destination and make packet forwarding decisions. In this routing protocol, it makes greedy packet forwarding and decisions by information connected neighbors in the topology [34].

8.1 HEIRARCHIAL BASED PROTOCOLS

8.1.1 Hierarchical Routing Protocol (HRP)

This protocol is based on the cluster method. The networks are divided into cluster, each cluster having the cluster head. This cluster head will gather information from the cluster and will transmit data to the base station [35]. There is a periodic re-election of CHs within clusters based on their residual energy. This balances the power consumption of each cluster.

8.1.2 Hierarchical Optimized Link State Routing (HOLSR)

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According to L. Villasenor-Gonzalez et.al., [36] Hierarchical optimized link state routing (HOLSR) is an extension of OLSR, however hierarchical protocol has some advantages, it works in dynamic environment with the cluster nodes. Cluster is a group of nodes collectively that work in a self-organized pattern.

8.1.3 Hybrid Energy-Efficient Distributed Clustering (HEED)

The nodes are based on the connectivity of clustering and clustering head gets the responsibility to connect all the nodes in network. Cluster head may be increase as area increases depends upon the requirements. Only the sensor nodes having high residual energy has the efficiency to become cluster head [37].

8.1.4 Low Energy Adaptive Clustering Hierarchy (LEACH)

This algorithm is one of the most popular hierarchical routing protocols for sensor network. LEACH algorithm is a cluster based routing protocol based on random formation of random election to find the head from cluster. After that sensor node selects random number between 1 to 0 if sensor node gets value T(n) , less than the threshold value than the node become the head for the current session [38].
The threshold value can be calculated by:

$$T(n) = \begin{cases} \left(\dfrac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} \right) & , \quad n \in G \ldots\ldots\ldots\ldots\ldots\ldots (I) \\ 0 & , \ Otherwise \end{cases}$$

Where P = fraction nodes of cluster heads, r = current session or round and G= set that is not a part of cluster head in last $\frac{1}{P}$ round. After the election of cluster node, the cluster node will make a schedule of TDMA slot and assign time of each nodes connected in the cluster.

8.1.5 Clustering Method for Energy Efficient Routing (CMEER)

According to A. Mahboub et.al., [39] it is the another technique to find cluster heads. In CMEER nodes will increase or decrease as per the requirement. The nodes itself considers to be a candidate for cluster head, using the above equation (I).

8.1.6 Threshold Sensitive Energy Efficient Sensor Network (TEEN)

TEEN protocol is targeted to every cluster connected to a networks, in addition to every attributes, and the cluster heads. According to A. Manjeshwar and D. P. Agrawal [40] there are two threshold sets hard threshold (Ht) and soft threshold (St). In hard threshold it's a value of sensitive attributes. In soft threshold it is value of triggered or target nodes.

CONCLUSION

In this paper, we have covered atmost maximum aspects of routing protocols for flying ad hoc network. Most of the protocols used in FANETs are similar to that used in the previous wireless sensor networks such as MANET and VANET with few modificaitons in order to overcome their shortcomings. In the previous protocols some of the limitation include scalability, energy consumption etc. There needs to be continous development in the field of routing protocols to adapt to these drawbacks. This may widen the area of applications in the field of wireless sensor networks.It is important to know how the protocols work.and this paper would help the researchers to gain the concepts of routing protocols in the context of networking. In this paper we have discussed different types of routing protocols with some of their advantages and disadvantages. We have also tried to compare some of the routing protocols in relation to one another in respect to some of their important characteristics.

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