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FANET routing protocols: Review

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ABSTRACT

FANETs is most evolved research area in today's time it makes use of multi-UAV. Use of UAVs is increasing day by day due to the advancement of sensors, processor, and applications. FANETs is mostly used in an undeployed area such as flood, Drought and most importantly for military reason. The main challenge of FANETs is routing of these multiple UAVs due to high speed which required highly dynamic routing protocols. In this paper, we tried to study already proposed routing protocols.

Keywords: *UAVs, FANETs, Routing protocols.*

1. INTRODUCTION

FANETs(Flying Ad-Hoc Network) is a wireless ad-hoc network of multiple UAVs which communicate with each other to complete their applications for which they are designed instead this network make use of location finding system and have a central co-ordinator such as Satellite. FANET is a subcategory of MANET (Mobile Ad-hoc Network). As UAVs are cheap, easily installed, have flying capabilities thus these are used in undeterministic areas.

Characteristics of FANET are

Highly mobile

The low density of nodes

Access of LOS (Location of Sight)

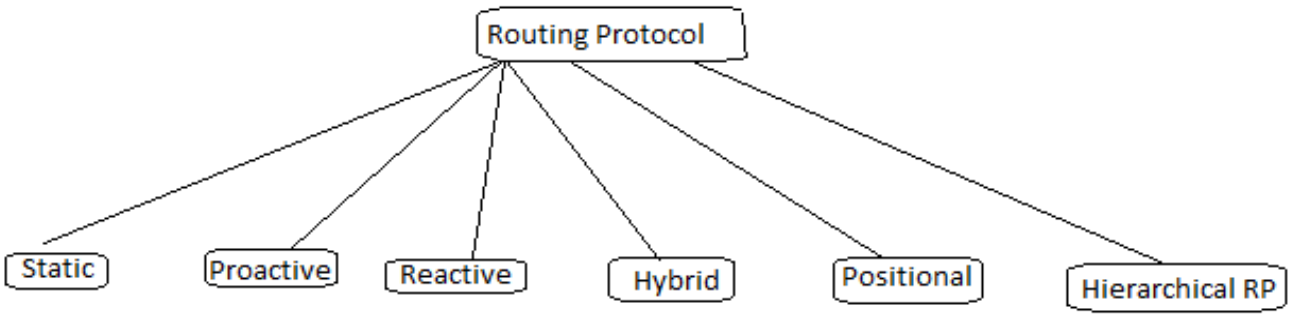
High computation power of nodes

GPS provided for Geospatial localization

FANETs ROUTING PROTOCOLS: Routing is a process to find out an efficient path to deliver data with the help of UAVs. Efficient path in term of less delivery time, high delivery ratio, less number of relay nodes, less number of control messages etc,

Predefined routing protocols of MANET or wireless ad-hoc network such as flooding, Destination Sequence Distance Vector etc, are not applicable for FANETs because of the high speed of UAVs, Flying capacity leads to frequent changes in routing and collisions; thus new protocols should be introduced and predefined protocols should be redefined.

Classes of FANETs Routing Protocols:



A) STATIC ROUTING PROTOCOLS:

As the name suggests STATIC (Constant) thus the routing table, task, topology or application is calculated or defined once and feed to the UAVs System and once the operation starts its information can't be updated or changed. The UAVs are connected to few UAVs or ground base stations thus a number of communication links are minimum in static routing protocols. If there is link failure or data is lost then its table can't be updated dynamically and operations can't be altered. To update information the network has to wait for the completion or termination of the current operation or mission thus these routing protocols are not able to tolerate faults dynamically.

There are 3 types of routing protocols in static routing protocols:

1) Data-Centric Routing Protocol (DCRP)

2) Load Carry And Deliver Routing Protocol (LCAD)

3) Multi-Level Hierarchical Routing Protocol (MLHRP)

1) DCRP (Data-Centric Routing Protocol): This protocol involves the one-to-many or one-to-one transmission of data. Here data aggregation and dissemination is based on data attributes not on the location or senders or receivers ID. The sender UAV or Ground station broadcast its request in the form of QUERY MSG to get required data from the required area. the UAVs are divided into clusters, communication between ground nodes or UAVs are based on broadcasting mechanism. Sender node broadcast query msg, this message is received by all nodes lies in its vicinity now its depend upon the nodes received query msg to collect data or not. If data is received by intermediate UAVs then decide whether to forward data or not.

Disadvantage: a) redundant data is available in the network.

b) No unique IDs for a node in the network

Advantages: a) increased efficiency

b) it consists of three techniques such as Space Decoupling; Time Decoupling: Flow Decoupling

i. Space Decoupling: The sending or receiving nodes can be anywhere, not necessarily in its direct range and does not need to know Particular IDs or location of all communicating parties of the network.

ii. Time Decoupling: The communicating nodes that are sending node or receiving node need not be online all the time the data can be received later on.

iii. Flow Decoupling: In this method, delivery is accomplished constantly. This method is most suitable for a minimum number of UAVs in a planned path, communication between network parties is not blocked or disturbed by any third party.

B) LCAD (Load Carry and Deliver Routing Protocol):

This protocol is used for data transmission between source or destination and UAVs with a single hop or multi-hop communication. Communication between the source and the destination node depends upon the speed of UAVs and distance between source or destination. This routing protocol involves communication in three layers or stages.

• In First layer data is loaded into UAVs from Source node this stage is known as LOAD;

• Then UAVs by flying deliver or communicate between Relay UAVs or intermediate UAVs this stage is known as CARRY ;

• Then this data is delivered to the destination node DELIVER.

The source and destination nodes can be ground base station or satellites. In this algorithm pipelined or fixed algorithm is used for communication

Disadvantages: a) Longer delivery delay

b) Demand high bandwidth

Advantage: a) High throughput as delivery is for sure because of the pipelined routing path

b) Deliver bulk data

c) More Secure

C) MLHRP (Multi-Level Hierarchical Routing Protocol):

In this routing protocol whole number is divided into a hierarchy of clusters (a cluster is a definite group of UAVs). Each cluster is designed to provide different functionalities thus a mission area contains a different type of activities and these activities are conducted by each different group of clusters. Each cluster consists of Cluster Head (CH) and these represent the whole cluster and do most of the processing that is within a cluster even cluster members not directly connected or communicated each member communicate through CH even they are a just single hop away. To use energy efficiently the CH should be periodically changed and these choosing of cluster head is depend upon lower ID or higher connectivity in the cluster with cluster members. Thus these

clusters are arranged in multiple layers and these layers are connected with each other directly or indirectly that's by using intermediate these layers can be Ground, UAVs, Satellite etc, CH broadcast all the control information or data to its members, members who are interested in data accept it otherwise ignore it and communication between two clusters is depend upon gateways that is an intermediate nodes which is in the vicinity of both clusters. Each cluster member nodes have a local routing table which have CH as its next node always Whereas CH maintain a local table for Cluster members and routing table for directly connected CH of other clusters and a gateway table for indirectly transmission to other CH using Gateway.

Disadvantages: a) High Energy depletion of CH due to high processing

b) If CH fails due to any fault then whole cluster performance is collapsed

Advantages: a) Processing of Cluster members is very less thus energy is saved

b) Different activities processed simultaneously

c) Less processing delay thus mission is completed relatively fast because work is divided into different levels processed by different cluster group.

Factors	DCRP	LCADRP	MLHRP
Security	Less secure	More secure	Less secure
Data transmission	Broadcasting	Unicasting	Broadcasting within the cluster and unicasting using routing table outside the cluster
Topology	No fixed topology	The pipelined topology that is prefixed and communication is within these routing	No fixed topology except the whole network is divide into levels of clusters
Time coupling	Exist	Not Exist	Not Exist
Unique IDs of sending and receiving nodes	Not required	Required	Required
Redundancy of data	High	No redundancy	Redundancy within cluster only
Simultaneously processing	No	No	Yes
Data aggregation	Yes	No	No
Bulk data transfer	No	Yes	No
Delivery delay	Less	High	Less

D) PROACTIVE ROUTING PROTOCOLS:

Proactive or Table Driven routing protocols in which each node carry routing table in order to store whole networks topology information of each and every node; the routing information is broadcasted and updated periodically to maintain update information. Proactive routing protocols don't have a path setup delay as we have a route in hand maintained in a table. The route is easy to find out but it needs regular updating of tables by periodical exchange of table. Once there is link failure due to high mobility a large number of control messages are flooded in the network and each node have to wait for the exchange of table thus delay is increases in the network in case of link failure. In this protocol information exchange or link control message are broadcasted. In PRPs first finding route process is initiated then data is collected and transmitted.

1) DOLSR (Directional Optimized Link State Routing)

2) DSDV (Destination Sequence Distance Vector)

1) Directional Optimized Link State Routing:

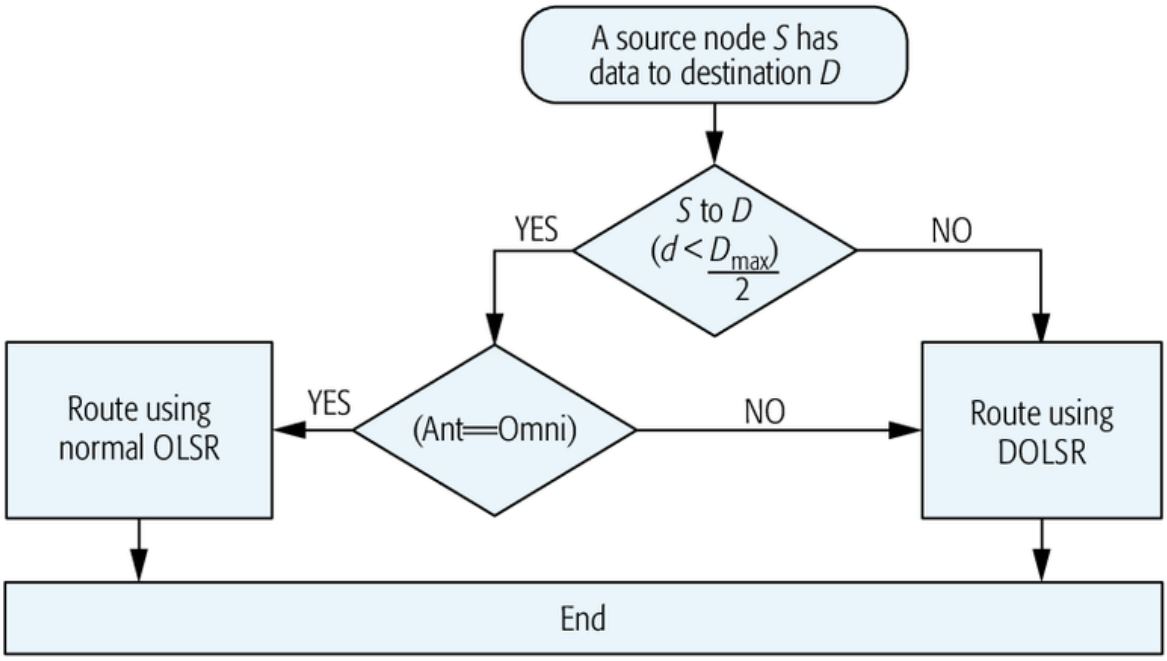
This protocol is the extension of OLSR (Optimized Link State Routing) which uses Directional Antennas to the reduced number of MPR (Multi-Point Relay Nodes). Each node performs two basic operations:

I. calculate next Hop distance for every other node using shortest path and

II. Select a number of MPR nodes that covers two Hop neighbors using HELLO messages and perform distributed election.

OLSR uses Hello and Topology Control messages to Discover and disseminate topology information. Source node broadcast hello messages that broadcast its unique address and list of its neighbor nodes, the nodes within the 1 hop vicinity reply and then these nodes broadcast hello messages and through reply messages 2 hop neighbors have recognised now these 2 hop neighbors nodes are MPR for the source node. Only These MPR nodes broadcast Topology Control (TC) messages that broadcast its network information of nodes which selected the node as MPR node that now sources node communicates with MPR node thus reduced flooding of control messages.

E) ALGORITHM:



Advantages: a) Reduced flooding with the help of broadcasting through MPR Nodes by reducing the area of operation By using directional antennas

b) Information of neighbors is maintained at each node thus easy to recognize next neighbour if there is link failure.

c) Throughput increases

d) Reduced redundancy

Disadvantages: a) more storage pace required

b) Link quality is not sensed it only assume the link is up if the reply of hello message is received

c) Not suitable for devices that sleep most of the time to reduce energy conservation

d) Large bandwidth and CPU power is used

2) Destination Sequence Distance Vector (DSDV) routing protocol:

DSDV is the extension of distance vector algorithm. In DSDV, each node saves a routing table that contain sequence number (unique identification of each packet issued by destination because DSDV is a destination initiated routing protocol), destination(all the nodes of the network except node ID which act as a source node to transfer messages), node ID (the node from which message is being transmitted), next node (next node from node ID in the route to destination which specifies from this node data is being transmitted) and hop distance (distance in the form of hops from source node to destination node) for all other nodes. This table is initially empty each node exchange its table periodically then by using neighbor node routing table each node maintain its shortest distance for a particular destination. Route discovery and information dissemination are based on shortest distance. Whenever the topology of the network changes, the Routing table is exchanged periodically, as a result, number of exchange messages exchanged in the network. Destination Sequence Number (Issued by Destination Node) is used to eliminate routing loops and maintain fresh information as an anode can accept update sequence number and ignore old sequence no. if sequence number are same then node ID associated with a sequence number is used to identify the message source.

Advantages: a) simple to implement

b) Maintain the shortest distance for each destination

c) No route setup delay

d) Update information is maintained

Disadvantages: a) More storage space required

b) More control message overhead

c) Unnecessary broadcasting because tables are exchanged periodically even if there is no link failure

3) Topology Broadcast Based on Reverse Path Forwarding (TBRPF):

TBRPF is a proactive routing protocol which maintains every link status along with other topology information. Each node maintain tree structure "min-hop path tree" for shortest path for its neighbour nodes and a routing table and it shares only a partial amount of its tree structure (it helps to easily identify the shortest path based on tree structure as it is easy to travel tree structure than other databases structure) and whole routing table after accepting these information of topology each node maintain its own tree structure for shortest path and routing table. Here link status helps to reduce the number of control messages as there is no need to exchange Routing tables periodically when there is a change in link status only then information is exchanged. Only non-leaf nodes of tree exchange routing information to help the updation of tree dynamically.

Each node N contain

a) Routing table with link state information

b) List of neighbors

c) For each update:

• It maintains new parent node which is the next min_hop for updated node

• List of new children nodes which are children of this parent node

• The sequence number of latest updated node

If there is link state update is generated by node then it calculates (n1,n2, seq_no, cost)

• where n1 is the source node that is updating link state and

• n2 is the destination and

• cost is the cost of the link (if cost =infinity then there is link failure) and

• seq_no is the latest sequence number of information.

There are two steps involved to perform this protocol:

1) neighbor discovery

2) broadcasting of link state updates.

The tree is updated using reverse path forwarding.

Advantages: a) less number of control overhead messages as link are updated only when its state is changed

b) easily traversed and maintained the tree structure

c) more efficient as there are no periodic updates

Disadvantages: a) more storage space is required as there is tree structure along with routing table

b) broadcast all link states in the network

c) maintain hop to hop path

F) COMPARISON OF DOLSR, DSDV, TBRPF:

Factors	DOLSR	DSDV	TBRPF
Space required	More then DSDV	Less than DOLSR	More than DOLSR and DSDV
Control overhead	Less than DSDV	More	Less then DOLSR
Link state information	Not maintained	Not maintained	Maintained at each node
Broadcasting	Less than DSDV	More	Less than DOLSR
Information Exchanged	Information broadcast by 2 hop neighbors	Information broadcast by each node	Information broadcast by non-leaf nodes to its children
Throughput	High	Less	Highest
Capability for execution in a mobile environment	Work Moderate with mobility	Applicable to Less mobility	Work efficiently for high mobility
Directional antennas	used	Not used	Not used
Storing Database	Tables	Tables	Tress plus table

G) REACTIVE ROUTING PROTOCOL (RRP):

RRP referred to as On-Demand Routing Protocol in the path is setup only when it has data to transfer and If there is no data to transfer there is no need to find a route between two nodes thus route setup time is more than proactive routing protocols. These protocols don't broadcast their routing table thus there is no need to maintain up-to-date information or periodic exchange of control messages which result in less overhead. These protocols are more vulnerable to security attacks as route finding process is on demand. These protocols spend more time to locate a new route for a destination than data delivery. These protocols work in a Request-Reply fashion that are whenever a node has to find a route then it broadcast its request packet known as RREQ ; the node in its vicinity or want to participate in packet delivery send a reply message known as RREP. These protocols use bandwidth efficiently as there is no need to store path if there is no packet to transfer. In RRPs first data is collected then route finding process is initiated.

H) TYPES OF REACTIVE ROUTING PROTOCOLS ARE:

1) DSR (Dynamic Source Routing)

2) AODV (Ad-hoc On Demand Vector Routing)

3) TSOD (Time Slotted On-Demand Routing)

1) Dynamic Source Routing (DSR):

DSR is a dynamic routing protocol that is no route is fixed whenever there is a data to send then only a route finding process is initiated and this process is initiated by the source node(a node who wants to send data) that's why this protocol is named as Dynamic Source Routing(DSR). This is a kind of virtual circuit setup process by using two messages

I. RREQ(Route Request) which acts as a query or hello message and this message is broadcasted to its neighboring nodes and nodes within the vicinity of sender node received the message &

II. RREP(Route Reply) which acts as a acknowledgement and this message is indicated to the nodes which have a route to a destination that is a process of backtracking from destination to source.

RREQ message include (Source ID, Destination ID, Path, Source Seq-no, TTL)

Source ID: a node which has a data to send and initiate route finding process (1st node in the path)

Destination ID: a node at which data has to be delivered (Last Node in the path)

Path: list of intermediate nodes that helps in delivering data

Source Seq-no: Unique Identification number is allotted to a packet for each transmission; if the sequence number is even then there is valid route/ link but is sequence number is odd then there must be link failure.

TTL (Time To Live): It can be a Counter (the Highest number that is decremented for each intermediate nodes) / Highest Duration in nanoseconds to reach destination / Highest number of intermediate nodes from a source to Destination.

RREP message include (Source ID, Destination ID, Path, Source Seq-no)

Now the source is the node who is unicasting RREP and Destination ID is the Node who Receive RREP at last & Source Seq-no is the number allocated by node who is sending RREP message.

If TTL if zero then drop the packet to preserve bandwidth because there is the possibility of approaching in the wrong area otherwise broadcast RREQ message. If any node receives RREQ, it first checks whether it is a destination or not if yes, then it forms an RREP message and backtrack and unicast to previous node path stored in path field of RREQ and if not, then itself broadcast RREQ message by changing Source with its own Node ID. This protocol maintains Route Cache to avoid unnecessary usage of bandwidth and Duplicate packets.

If there is link failure then there are a number of possibilities Some of which are:

• The node at which link failure occurred, itself initiate route find out process and accept the incoming packets from the source.

• The link failure node backtrack RREQ path and reach to Source and the Source itself find out a route to Destination.

Advantages: a) Save Storage Capacity

b) maintain Route Cache to discard unwanted or already received messages

c) Set up Route whenever needed

Disadvantages: a) More Route Setup time

b) Delay in the actual transmission

c) Source initiate Route finding when there is link failure

d) Dynamic RREQ packet Size

2) AODV (Ad-Hoc On-Demand Vector Routing):

In AODV, there is a single record for each destination and nodes stores next hop, not the complete path as in DSR. This protocol consisted of three phases: a) Route Discovery b) Packet Transmission c) Route Maintaining.

Route Discovery Process:

This phase consists of route finding process using two messages RREQ and RREP.

RREQ consist of (Source ID, Destination ID, Source Seq-no, Destination seq-no, Broadcast ID, TTL).

Broadcast ID is the ID allotted for each transmission, if there is reinitialization then the Broadcast ID of that node is incremented by 1. In AODV a route Cache is maintained by each node to keep an information of Packet it has broadcasted to avoid unnecessary bandwidth utilization or duplicate packets. If an intermediate node has a valid route to the destination than that intermediate node or Destination can Form an RREP message and Duplicate messages are indicated by BID-SID pair (BID: Broadcast ID; SID: Source ID). This protocol makes use of TIMERS to active paths on the intermediate node to a particular destination and this timer is expired if RREQ packet is not received.

Route Maintenance:

This phase consists of maintaining Route if there is link failure. RERR (Route Error) messages are used to indicate link failure in the network. This message is sent by intermediate nodes to the end nodes.; Then End Nodes delete that entry from its table by initializing Hop Count to INFINITY. Then Source node reinitialize route to the same destination with different Broadcast ID.

Advantages: a) Smaller Storage Space required

b) Route Cache preserve Bandwidth

c) reduce delay

d) maintain Active Routes Using a timer

e) Broadcast ID used to indicate each different transmission

Disadvantages: a) High mobility leads to more link failure and packet drop

b) bandwidth wasted on the regular beacon to check nodes in its vicinity

c) do not repair broken link only inform them

d) multiple RREP packets to the same destination

3) TSODR(Time Slotted On-Demand Routing):

This protocol is Time slotted version of AODV, each node is allocated with a dedicated time slot and they can send data at its dedicated time slot only, Route Discovery and Route Maintaining process are same as AODV only Packet transmission phase has been changed.

This protocol increases the use of network bandwidth as time factor is provided to transmit packets but minimize the packet collisions and maximize packet delivery.

Factors	DSR	AODV	TSODR
Size of RREQ & RREP	Less	More Than DSR	More Than AODV
Path storage	Yes from source to destination	Only next hop is stored	Next hop is stored
Packet transmission	Path stored in source route cache then the packet is transmitted on that path	Using next hop at each intermediate node until the destination is reached	First, check whether the node has its dedicated time slot or not if yes then the only packet is transmitted as in AODV
Time assigned for packet transmission	No	No	Yes
Bandwidth preservation	Less	More then DSR	More than AODV or DSR
Packet delivery	Less	More	Highest
Route setup initialization	Source	Source/ Destination	Source/ Destination
Retransmission identification	No	Yes, using BID	Yes, Using BID
Active Route	No	Yes	Yes
Duplicate packet identification	Same Source sequence number	SID-BID pair	SID-BID

I) HYBRID ROUTING PROTOCOLS (HRP):

These protocols combine advantages of RRSPs and PRPs and overcome the limitations of RRPs and PRPs. These protocols are appropriate for larger network and overcome the factor of mobility efficiently by minimizing issues of RRP 's large route setup time and huge overhead of PRP's.

TYPES OF HYBRID ROUTING PROTOCOLS:

1) ZBRP(Zone Based Routing Protocol)

2) TORA(Temporarily Ordered Routing Algorithm)

1) Zone-Based Routing Protocol (ZBRP):

ZBRP is based on the concept of Zones that is the whole network is divided into zones, Zone's area is defined by Radius R which can be prefixed. This protocol makes use of table-driven approach of PRPs within the zone; each node maintain detailed information of R hop distance zones as in DSDV to decrease route setup delay and route can find out easily by sing hop count /distance stored in the table of each node lies within the radius R zones. Then it processes RREP by sending RREQ packet for highest hop distance nodes that are multicasting RREQ message. The routing inside the zone is called as intra-zone routing, and it uses the proactive method. If the source and destination nodes lie in the same zone, the source node can start data communication instantly. When the data packets need to send outside the zone the inter-zone routing is used and reactive method is applied using Multicasting that is to the nodes who have highest hop distance that is equal to R.

Advantages: a) preserve bandwidth of broadcasting

b) less time required for route setup and packet delivery if Source and Destination lie in same zone.

c) Less storage space is required as a number of hops limited by R.

Disadvantages: a) may fail in High Mobility

b) CPU process is increased as it has to maintain tables as well as form an RREQ or RREP packets in case of multicasting.

c) battery drain out quickly

2) Temporarily Ordered Routing Algorithm (TORA):

TORA is a Distributed routing protocol, Here routers only preserve information about adjacent routers not about the whole network. TORA mainly uses a reactive routing protocol but it also uses some proactive protocol. Rather than using the Shortest path TORA construct DAG that is Directed Acyclic Graph From Source to the destination. Each node has a parameter value termed as "height" using 5 tuples (t,oid, ref,h, id) in DAG, which is unique for each node. Where

• t: Time at which the failure occurred

• oid: ID of the node at which failure occurred and its broadcasting QRY message

• ref: reference level of the node

• h: height of node with respect to (wrt)destination

• id: node id which is broadcasting messages

DAG is formed in Downstreaming strategy that is from highest height node to lowest Height node thus Data also flow in the Direction of DAG. The graph used in TORA is loop-free because data always flow in the downstream path not upstream. Out of 5 tuples first three tuples used only when there is link failure and other two tuples are used as offset used initially.

It consist of 3 mechanism:

1) Route Creation

2) Route Maintenance,

3) Route Erasure.

Route Creation:

I. When a node wants to initiate a route finding process it first broadcast QRY (Query Packet) to its neighbors by sending first 4 tuples as null indicated by (_) and 5th tuple as node ID

(_,_,_,_,nodeID)

II. It also used RRD to ignore duplicate packets it acts as Route Cache factor whenever a node broadcast query packet it initializes its RRD=1.

III. Above process continues until the destination is achieved, when a node comes to know itself as a destination it changes its first 4 tuples from null to zero and the 4th tuple is the height thus destination initialize its height as zero and the 5th node is destination node ID thus at destination height becomes

(0,0,0,0,dest ID)

IV. Now destination broadcast UPT (Update Message) to its neighbor node

V. The neighbor nodes maintain its height according to the hop distance from destination, this process of maintaining height according to the hop count of particular node from the destination is continuing until source node received its update message.

VI. Now a DAG is from a highest height that is highest 4th tuple value to lowest value thus DAG is formed we can start data transmission.

Route Maintenance:

I. If there is link failure and we have another downstream path to the destination then no action is required

II. If the link is Broken and we don't have any other Downstreaming path to the destination then we have to generate a new downstream path. Now first 3 tuples used where t incremented 0 to 1 because it's the first time failure occurred, oid the id of node broadcasting this message, ref still 0. Thus these updates broadcasted. DAG is formed and the downstream path is graphed.

Route Erasure:

CLR message is used to erase the route which is not required anymore. The node from which network is split and have no link to destination broadcast this message to its neighbors and node which accept this message check whether they have a connection to the destination if yes update the link to other nodes and if no, update its table for the destination node and initialized it with NULL.

J) COMPARISON BETWEEN ZBRP & TORA

FACTORS	ZBRP	TORA
Division of network	Network divided into zones	No division of the network
The directed graph to the destination	No direction used	DAG is formed
Route setup messages	The first table is formed such as Proactive protocols and then multicast RREQ & RREP to setup route	Broadcasting
Information transmission	Bidirectional	Unidirectional
Techniques used	Shortest path technique is used to find an efficient route	DAG used to find out an efficient route
Link failure	Handles as in proactive and reactive	Handles using other downstream paths
Distance from destination	Use hop distance for a particular destination	Maintain height
Intermediate Nodes	Maintain next hop and previous node to explore the route to the destination	No next or previous node stored in the table

K) POSITIONAL BASED ROUTING PROTOCOL:

In PBRP each node calculates its own geographical location using GPS and broadcast its location and speed at which they are moving to its neighbors too. Then source calculates destination's location and speed and formed a region by calculating intermediate node who has shortest distance towards Destination to decide which routing technique it should use as different techniques have different criteria.

For example:

MFR: uses the greedy technique to forward packets.

DREAM: Directional Flooding

These protocols functioning same as Reactive Routing Protocols as route should be explored only when it is needed and in these too there is no need to update routing tables at regular intervals. If there is link failure then the optimum path is difficult to locate thus these protocols use RECOVERY techniques.

TYPES OF PBRP:

1) Greedy Perimeter Stateless Routing (GPSR)

2) Geographical Positional Mobility Oriented Routing (GPMOR)

1) Greedy Perimeter Stateless Routing (GPSR):

GPSR is very responsive and efficient routing protocol in mobile and wireless network. In these protocols each node have information of each and every node's location thus it becomes greedy and forward packet to one of the neighbour node which has a very short distance to destination thus this forwarding is known as greedy forwarding of packets but it has no idea about the next neighbour of the node to which packet is delivered firstly. If no path exists in the network from a sender to destination then there is no method according to which packet is delivered on the same link there will be a high possibility for packet drop if no path exists and no method is provided to recover lost packet.

Advantages: a) loop-free routing

b) no use of any type of control messages thus no control overhead

c) secure

Disadvantages: a) implementation cost increases

b) no method to locate packet drops

c) not sure about the full path from source to destination

d) if GPS malfunctioned the whole network will collapse

2) Geographic Position Mobility Oriented Routing:

In traditional positional routing protocols we used external devices such as GPS for location information of nodes but in GPMOR uses the concept of Gauss- Markov mobility model and mobility relationship of nodes to predict the next node in the route from source to destination to decrease the impact of interconnectivity due to dynamic mobility. It used to improve the stability of cluster and cluster heads in the network.

Advantages: a) efficient in mobility environment

b) eliminate the cause of failure of the network due to GPS malfunction

c) no greedy approach

Disadvantages: a) no exact location identified

b) more computation power required to find out location each and every node and distance between them

c,) battery drain out faster

L) COMPARISON BETWEEN GPSR & GPMOR

Factors	GPSR	GPMOR
Location identification	Using GPS	Using Gauss-Markov mobility model
Packet forwarding	Use greedy forwarding method	Select next according to mobility relationship
Computation power needed	Less	More
Use of external devices	Yes	No
Chance of failure	Low	High

M) HIERARCHICAL ROUTING PROTOCOL:

In HRPs whole network is divided into a number of clusters that are grouped to perform a specific kind of function. Thus it forms a hierarchy of clusters that indicate different layers/ hierarchy of network. Type of routing protocols depends upon the specific functionality of clusters/ hierarchy. Primarily proactive routing protocols are used to establish a route between source and destination and then if there is an update or link failure any node can use the reactive protocols process.

N) TYPES OF HIERARCHICAL ROUTING PROTOCOLS:

1) Mobility Prediction Clustering (MPC)

2) Clustering Algorithm of UAV Networking

1) Mobility prediction clustering (MPC):

It operates on the basis of the Tree structure as it is easy to travel and communicate and it also uses "Link Termination Time Mobility Model" to guess updates in the network topology thus it can form more constant clusters. These protocols work free from any external devices such as GPS to keep track of the location of nodes. All nodes are divided into three type of states such as Orphan state (OS), Cluster Member(CM), Cluster Head(CH). CH carry most of the functions such as routing and information/data dissemination and communication between CMs. Orphan node doesn't belong to any other state of nodes that is neither CM nor CH. These protocols mainly use Dopplers Shift to calculate the relative speed of the particular pair of nodes, which are forwarding or exchanging HELLO messages. With the help of this relative speed staying time of CM is calculated for a particular CH that is the vicinity of that CM.

All nodes are orphan nodes initially that is they are neither a CM or CH thus these nodes broadcast HELLO messages carrying information about its speed, direction, current state and its identifications, then every node's relative speed is estimated/ calculated by using hello packets and the reply of these messages using Doppler Shift which are associated with hello messages.

Advantages: a) consider all states of a node

b) energy of CM preserved

c) size of hello message increases

d) locate CH using past information about relative speed between a pair of nodes

Disadvantages: a) energy of CH drain out quickly

b) network fails if CH halt

c) different hierarchy used different techniques of routing

2) Clustering algorithm of UAV networking:

The whole network is divided into clusters, each cluster has a Cluster Head (CH) which is responsible for establishing an efficient route, data dissemination & communication between cluster members. Each CH is elected by cluster members and selection of CH is based on high connectivity, lower mobility or high node ID. This algorithm first form the clusters on the ground that is at the very basic level then CH is elected then actual data transmission

Two type of Clustering algorithms are there:

1) LEACH (Low Energy Adaptive Clustering Hierarchy)

2) EECA (Energy Efficient Clustering Hierarchy)

I.) LEACH (Low Energy Adaptive Clustering Hierarchy):

LEACH is one of the most important hierarchical Clustering Algorithm, which is specifically designed to improve the battery lifetime of UAVs in the network. Cluster members send their data to CH, CH aggregate data from all CM thus avoid replication and forward this data to sink.

LEACH mainly perform three tasks:

1) periodic selection of CH in a randomized manner

2) transmit the aggregated data directly to sink

3) Create TDMA(Time Division Medium Access) based schedule where each CM assigned a time slot to transfer their data. This schedule is communicated to the CM through Broadcasting. CDMA with TDMA schedule is used to eliminate the chances of collision during intercluster communication.

This algorithm works in two phases:

a) Setup Phase

b) Steady Phase

a) setup phase consist of a selection of CH by periodic elections

$$T_n \begin{cases} 0 & \text{if n doesn't belong to G} \\ p/(1-p(r \bmod 1/p)) & \text{for all n that belongs to G} \end{cases}$$

where G: is the set of nodes that have not been selected as CH in last 1/p rounds

r: current round

p: predetermined fraction of nodes

n: current node

thus, the node which has not been selected in the previous round and has greatest battery life that is selected as next CH.

b) Steady Phase consists of data transmission Phase that data transfer from CM to CH and aggregation of data at CH and transfer this aggregated data to sink.

Advantages: a) Efficient use of a battery as CH is rotated

b) avoid replication of data

c) no need to communicate all CM to sink i.e. efficient bandwidth utilization

d) CMs energy preserved

Disadvantages: a) CH are not always 1 hop distance from Base Station

b) length of steady phase is critical to achieving efficient energy saving that is the length of steady phase is more thus CHs energy depleted more quickly.

II.) EECA (Energy Efficient Clustering Algorithm):

In this algorithm, we combined the feature of MPRs and CH selection. In this protocol node out of MPRs nodes which have more battery, or have the shortest distance to base station selected as CH and then sub-clusters are selected from MPRs list and then sub-sub-clusters and process continue till the last node is covered thus it forms a better hierarchy level.

This algorithm consists of 5 steps ;

1) neighbor sensing

2) selection of MPRs (Multi-Point Relay nodes)

3) CH selection

4) hierarchy levels formed

5) aggregation of data from CMs to CH and data transmission from CH to sink / Base Station

Advantages: a) energy loss per cluster decreases

b) better transmission

c) more level of the hierarchy

d) include the shortest path

e) if CH halt then it can send data by forming a hierarchy of data aggregation

Disadvantage: a) required more processing time

b) more chances for data collision as no specific time is scheduled

O) COMPARISON BETWEEN LEACH AND EECA

Factor	LEACH	EECA
Selection of CH	Based on energy level or whether it has already selected as CH or not	Based on highest energy level among MPRs and the shortest distance between that node and destination
Hierarchy level	1 level (only cluster)	Multiple levels till the last node covered that is cluster then sub-cluster then sub cluster
Shortest distance	Not included	Included
Phases included	2 phases	5 phases
TDMA scheduled	Included	Not included

P) COMPARISON BETWEEN MPS (MOBILITY PREDICTION SCHEME) & CLUSTERING ALGORITHM

Factors	MPS	Clustering Algorithms
Type of hierarchy	Tree-based	Cluster-Based
State of nodes	3 states (Orphan state, Cluster members, Cluster Head)	2 states (Cluster Members, Cluster Head)
Updation	Topology updates are performed by Link Termination Time Mobility Model	Updates in CH only
Association of Doppler Shifts with HELLO packets	Yes	No
Communication between CM	Possible	Not possible

2. CONCLUSION

The routing protocols for FANET are currently taking more interest of researchers due to their different characteristics. Here we have tried to mention the almost maximum number of protocols used for FANET. Since there is a lot of work to do in this particular field and there is a need to find more efficient routing protocols.

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