International Journal of Electronics and Communication Engineering (IJECE)
ISSN(P): 2278-9901; ISSN(E): 2278-991X
Vol. 9, Issue 5, Jul–Dec 2020; 1–24

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

THE ROUTING PROTOCOLS OF UNMANNED AERIAL VEHICLES IN FLYING ADHOC NETWORKS: A COMPLETE SURVEY

Mohamed Syed Ibrahim[1], P. Shanmugaraja[2] & Mary Theres Vini[3]

[1]Lecturer, Engineering Department, Ibra College of Technology, Oman

[2]Professor, EIE Department, Annamalai University, India

[3]Assistant Professor CSE Department, Thamirabarani Engineering College, India

ABSTRACT

In Adhoc network, absence of Centralized infra structure is a peculiar characteristics. The nodes in Adhoc can both acts as router and host. The topology of adhoc networks is said and meant to be more unpredictable. The most challenging issues starts from the design of routing protocol for this complex and rapid changing topology. A lot of researchers have gone through varieties of studies on these routing protocols. Actually a very good understanding of performance and characteristics of routing protocol will support the deployment of appropriate protocol for the networks based on the scenario and it extends to a better optimization. In most of the previous work complete reviews on all the suitable and available routing protocols were not done. In this paper a detailed description on all the possible routing protocols of MANET, VANET and FANET is done and this will really support to conduct a comprehension analysis on the performance of all suitable routing protocols based on its network and topology scenarios.

KEYWORDS: *UAV; Drones; FANET; Routing Protocols*

Article History

Received: *14 Aug 2020* | ***Revised:*** *17 Aug 2020* | ***Accepted:*** *11 Sep 2020*

INTRODUCTION

Unmanned aerial vehicle nowadays called as Drone UAV is popular in remote sensing. But nowadays they are mostly used in agricultural purpose popularly known as drones without pilot. The UAV can be operated either under remote control by a human operator or by on-board computers. Unmanned aerial system consists of an Unmanned Aerial Vehicle, Base station controller and a communication system between both of them. Variety of drones is being used nowadays. Especially one has to focus on the pay load (Type of camera it holds) as shown in figure 1. [1].

Figure 1: Payload.

Nowadays the drones become very simple to handle is a great advantage. The other good thing to be understood from the drone is, they are very stable. Because the Number of propellers as shown in figure is four also with quite good spacing so that good photography or remote sensing could be done. Also in this kind of drones, there won't be any pilot in the device but of course pilot is in the ground. Nowadays drones are equipped with GPS or GNSS receivers. They can be programmed or controlled by the controlling station. [1].

UAV used for missions which are more dangerous for humans. They are used in military applications. They are loaded with missiles and plan and executed. Commercially also it is used. Agriculture, crowd monitoring, delivery products (not heavy).Now even powerful drones are getting introduced. Aerial photography, remote sensing, Surveillance, police monitoring also some of its applications.[1].

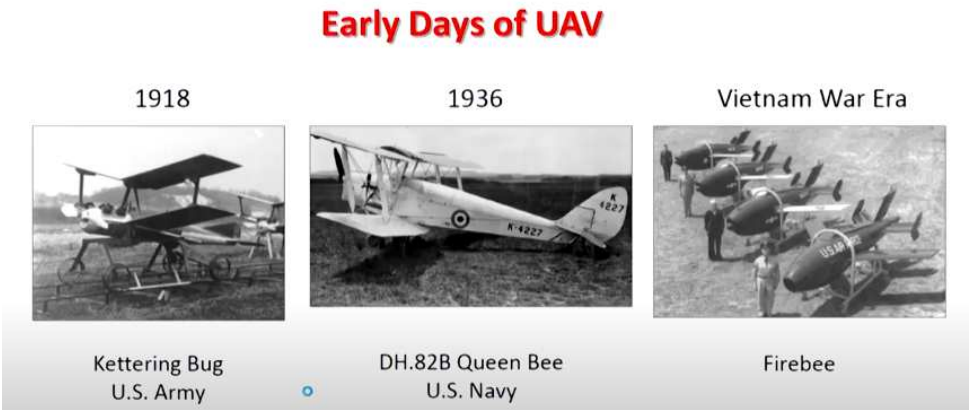

Figure 2: History of UAV.

Unmanned aerial vehicle was tested in 1918, and in 1936 improved version came in US navy. Also in Vietnam war which was used by US for very long time for about 30 years in firebee.

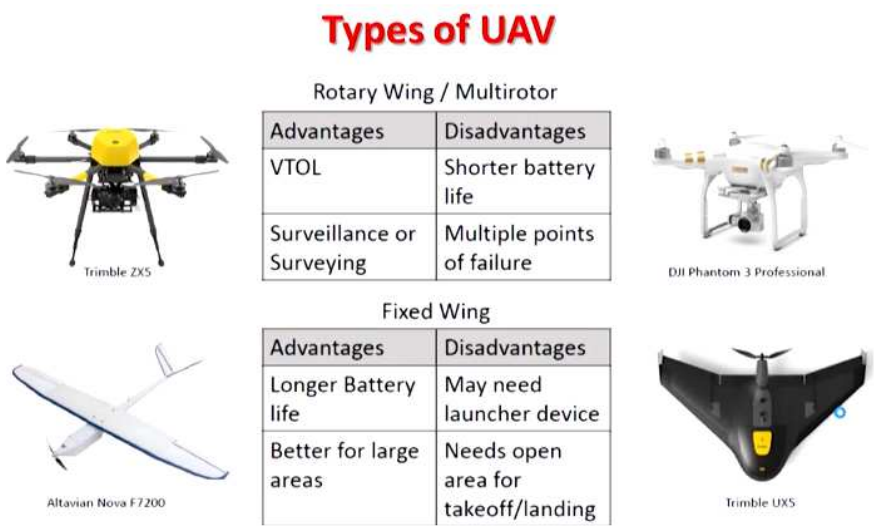

Figure 3: Types of UAV.

The most Important thing, nowadays the UAVs are Modern, Light weight stable and robust. They are having either Rotary wing or Multirotor or propeller as shown in figure 3.The most popular is Rotary wing. [1].

Payload is counted based on Weight of the drone or UAV can carry. The weight of the drone additionally includes the most important features such as sensors and Cameras and of course it includes the Packages for delivery. Usually the Military UAVs have more pay load than the popular drones. Greater pay load UAVs holds multi sensors and nowadays they are becoming popular. Camera also dual thermal, RBG imaging system LiDAR [light detection and ranging] technology, sticking on GPS systems and the number of sensors are also very high to process more data simultaneously. The flight time is guaranteed to be reduced when it carries extra weight because it requires additional power to lift it. For heavy payload more battery is needed will reduce the flight timing as shown in figure 4.Numbers of different payloads are available with different users and capabilities.UAV sensor payloads includes HD video and photography, FLIR thermal imaging, Radiation level monitoring, Volatile organic compounds. Used in Construction, mining, surveillance Fire fighting and rescue

Figure 4: UAV.

The following are the advantageous of UAV

- Accurate (GNSS receivers).
- Payload and survey cost can be changed [Flexible].
- Low cost for the measurement of 3 D mapping.

- Radiometric and temporal properties.
- In many times in a day survey could be done in many features and happenings in the mission.
- Quality Camera.
- GPS.
- Precise processing

Since UAV used to collect huge data's, the processing requires very special software's not the Standard one. Many times videos are recorded in the form of digital video or high definition video. Intense processing and lot of challenges are there.

- UAVs are available in wide ranges like many size shapes, with more rotating motors 4,6,10 based on the stability.
- Deployment easy.
- It is much cheaper than the conventional air borne systems.
- Height is 100 to 300 meters. [aerial path to few kms]
- Storage is necessary.
- Based on the storage facility, Transmission techniques are very important.
- Sometimes based on the application like real time UAV should transfer directly to receiver.This is the necessity for UAV based remote sensing.
- High efficient Storage capable and high payload drones are becoming popular nowadays.
- Remote sensing
- To cover large areas it is not fit (drawback)[1]

Figure 5: Applications of UAV.

Flying adhoc networks [UAV networks] is an adhoc network or hybrid of adhoc and infrastructure based networks.UAV are attractive in society. They are commonly called as Drones. Many applications are being used.

- UAV - un manned flying device flies because of trust.
- UAV has 4 different propellers

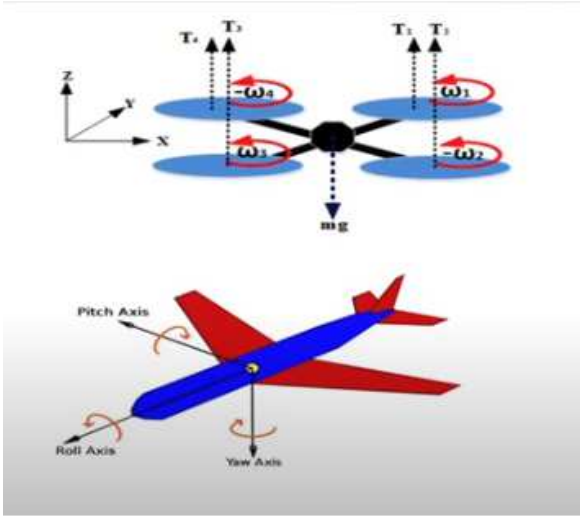

Figure 6: Basics of Aerial Systems.

Different forces acting on the UAVs are shown in figure 6 such as w1 w2 w3 w4

Weight of the UAV is mg [acting downwards]

Since UAV has to fly from the ground upwards all the 4 propellers runs so fast

Upward thrust such as T1 T2 T3 T4 as shown in figure 6.

Condition to fly: The total upward thrust T = T1+T2+T3+T4 > mg

Where T is the thrust

W is the angular velocity of the motors

These thrust and Angular velocity help UAV to climb up.

If you look at any aerial device, it can rotate in 3 different ways such as Yaw (along z axis), Pitch(along y axis) and roll (along x axis).UAV can show 3 different actions Yaw Pitch Roll.

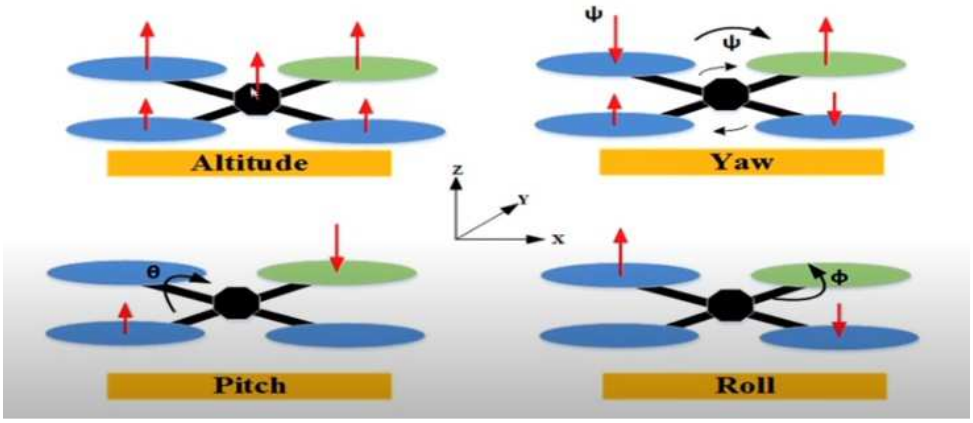

Figure 7: Aerial System.

Three types of operations are possible with UAV

- Manual by human operator
- Autonomous to achieve mission
- Autonomous with minor human interventions[2]

UAV networks is about multiple UAVs, communicate among each other, Fly together either in mode of synchronous or asynchronous. Individual UAVs must talk to each other in the network. They can deployed in star or mesh topology. They must have flexible in deployment and autonomous

UAV Networks

- Routing is very important
- Adaptive in nature
- Will help UAV nodes to send data
- Multitasking
- Task together
- Together will cover large areas
- They must be easily reconfigurable
- They should be reconfigure themselves to perform different mission for which they are deployed.
- UAV nodes move extremely fast, pitch role and yaw very fast
- Propellers also will move fast
- Will get more thrust to move fast
- UAV mobility will be high
- Topology keep on changing dynamically

The challenges of Routing Protocol of UAV are

- The routing protocol designed as proactive and reactive routing protocols
- Its very challenge to design routing protocol in this dynamically changing topology
- These networks must not consume power
- They should perform sensing communication
- So more energy needed
- Battery should survive long time
- Hardware software must be energy efficient

- Lots of environmental disturbances – wind, rain,birds
- Localization is very important issue
- Fast localization algorithm needed
- Coverage is very important issue
- Every area must be covered at least by single UAV
- Path planning is also important- Prediction is also important
- Malfunctioning of UAV must be considered
- Intermittent link nature
- Dynamic topology changing
- Lack of suitable routing algorithm.
- Due to the mobility they are prone to connectivity failure among the nodes
- A new class of solution is needed

Table 1: Classifications of MANET VANET and UAV Networks

	MANET	VANET	UAV NETWORKS
DESCRIPTION	Mobile wireless nodes connect with other nodes within the communication range in an adhoc manner. Centralized Infra structure is not available	Here vehicles are mobile wireless nodes. Communication takes place between vehicles to road side units and among vehicles	It has adhoc as well as infrastructure based airborne nodes. Communication takes place among UAVs and between UAV and control station.
Mobility	• Speed is low • 2m/s • Random moment	• High speed • 6 m/s to 10 m/s in Urban areas and 20 to 30 m/s in High ways. • Movement is limited by traffic and traffic rules	• Speed is 0 to 100 m/s • Movement could be 2 or 3 dimension controlled according to mission
Topology	Random, adhoc	Star with road side and adhoc among vehicles	Star with control unit,adhoc or mesh among UAVs.

Multi UAV network have the following limitations

- High power requirements
- Frequent link breakages
- Prone to malfunction
- Prone to Environmental effects
- Very complex[2]

Advantages are as follows

- High reliability
- High survivability
- Efficient speeded up missions
- The UAVs can act as both server and client
- It can transfer packets to other clients and control units[2]

The Connection between UAV and Control station is as follows

- It uses star topology to connect also it applies multi start too.
- In multi star topology, one node from each group connects to control station
- High latency
- Highly dependent on ground station.

Among UAVs the connection will be done by Mesh or Hierarchical Mesh network

- Flexible reliable
- Nodes are connected
- Secure

Table 2: Classifications of Star and Mesh Network

Star Network	Mesh Network
Point to point	Multi point to multipoint
Infra structure based	Infrastructure based or adhoc
Not self-configuring	Self-configuring
Single hop from node to central point	Multi hop communication
Devices cannot move freely	In adhoc devices are autonomous and free to move.In infrastructure based movement is restricted around the control centre
Links between node and central points are configured	Inter node links are intermittent
Nodes communicated through central controller	Nodes relay traffic for other nodes.

In this paper, viewed the routing protocols such as

- Topology based
- Position based
- Hierarchical
- Deterministic
- Stochastic
- Social network based routing

In our work, we introduce a comprehensive survey of 21 topology-based routing protocols, 22 positionsbased routing protocols, 5 cluster-based routing protocols, 6 different data forwarding-based routing protocols, and 6 field experiments of routing protocols in UAV networks and FANETs with their various categories.

After discussing network architecture, various routing techniques, and taxonomy of routing protocols in UAV networks, we compare the routing protocols qualitatively in terms of their major features, characteristics, and performance.

Then, we address important open issues and research challenges in designing routing protocols for UAV networks.

The Design Consideration of UAV networks is as follows

As we aware in the UAV networks the topologies changes dynamically and very fast so the routing protocol should have the quality of scalability, adaptability and robust communication protocols [3].

Topology

- It is the arrangement of Nodes in the network. To ensure the coordination and collaboration among the nodes, the UAV supports peer to peer communication in coordination with single or multi cluster moment in the network
- Single cluster is the best choice for small mission whereas Multi cluster is the best for the multiple missions. In this design the cluster head of each cluster is responsible for the communications with other cluster heads and down link communication. [4].

Mobility

- Mobility model plays vital role in ensuring the efficiency of communication among the UAVs.
- The mobility models are application dependent.
- If global path plan is preferred, then the movement of UAVs are regular.
- If the path plan is not defined then the mobility model will be autonomous.
- Group mobility model [Manhattan grid] is the best choice for the autonomous military mission.
- Random way point mobility [Gauss–Markov mobility model] model is the suitable choice for the patrolling applications because UAVs adopts flexible trajectories [6].
- Mobility model of FANET is highly challengeable than VANET and MANET.
- The speed of nodes in UAV network varies from 30 to 460 km/h. Also it control the efficiency of routing [5].

Latency

- It is impossible to create a network without latency, but it can be controlled.
- Remote sensing applications like disaster monitoring, Search operation as well as destroy operation should possess very low latency. Position based, congestion control protocol and adaptive delay-constrained routing plays vital role in minimizing the latency and it can also improve the QoS [7][8].

Frequent Link Disconnection

- In high density network, UAVs link disconnection probability is less whereas in low density networks, links are frequently disconnected.

Prediction

- It is very important to predict the future position of UAVs in every second.
- It's very challenging to predict the position due to rapid changing topology.
- Also it's highly important to choose the appropriate routing protocol which ensures the prediction of UAVs in FANET.

Flight Formation

- In the high speed UAV flight network, when a single UAV tries to enter or exit the design controller faces challenges.
- This is because of the nonlinear dynamic inversion control on the inner and outer loop controller [10].

Collision Avoidance

- Kalman filter based obstacle's position estimation and prediction algorithm calculates reference trajectory based on the information of other UAV's position[11]

Combat with External Disturbances

- In the critical application like mission accomplishment, the Mutual collision avoidance problem must be considered and treated seriously. Particle swarm optimization is used to overcome the collision avoidance and communication constraint problem.[12]

Scalability

- It's very important to propose a routing protocol which supports more number of UAVs in the multi UAV networks.
- Increase in the number of UAVs will faster the mission operations and accomplishment[13]

UAV Network Architectures and Communications

- Multi UAV networks are used in both military and civilian applications
- Multi UAV networks consist of UAVs and Ground control stations.
- Two types of communications exist in this type of networks, as like UAV to UAV and UAV to ground station.
- In case of any single UAV failure, the communication or coordination will be taken place by any of the other UAVs in the network which ensure reliability and survivability.

Design Issues in UAV Networks

- Latency
- Scalability
- Adaptability[14][15]

Communication in UAV Network

- Flying adhoc network is a subset of MANET and VANET. Researchers proposed 802.14.4 for the communication among UAVs because of the lower bandwidth requirement and 802.11 for UAV to ground communication because of the higher bandwidth requirement, larger data rate and long distance communication.
- For air to air communication adhoc network is used whereas for the communication between UAV and ground station only a specific UAV is selected.[16][17]

A. Design Techniques for Routing in UAV Networks

- The UAV network is different from other networks so they have unique routing mechanism. But some of the common techniques also could be utilized for data transmission.[18]
- Unicast, broadcast, multicast, and geocast routing are the different delivery schemes in data transmission.
- Hop-to-hop direct data communication is Unicast which is between a sender and a receiver.
- Flooding of messages to all the nodes in a complete network is Broadcasting, needs high bandwidth and overhead and shows efficient output in scattered networks.
- Geocast routing &position-based routing has same features.
- Geocast routing uses multi cast routing and delivers packets to all the nodes in a specific geographical area.
- Multicast routing construct networks based on tree or mesh structure.
- The main challenge in the tree based multicast routing approach is the necessity to rebuilt when the topology become unstable. Failure in rebuilding leads to frequent disrupted in a highly dynamic network.

B. Cooperative Routing

- Increases the communication reliability by implementing cooperative and direct transmission
- By using broadcast scheme, in the cooperative routing nodes support each other with information transmission
- Neighbouring node acts as relay node

C. Path Discovery

- It is the process of discovering the shortest and reliable path between the destination node and source node.
- It is done by transmitting the Route request (RREQ).
- The best and suitable path is selected based on the precise condition and response.

- This mechanism is being used in the existing routing protocols of UAV which in turn reduces the cost and time.

D. Single Path

- The single path routing protocol learns the route and select the best route to the destination.
- The routing path is calculated based on the predefined routing table
- In case of any failure in the network, alternative path cannot be found, and it leads to its limitation of packet loss

E. Multiple Paths

- It provides multiple routes and choices between source and the destination
- It has many routes and it is efficient and reliable
- Path failure or jamming attacks can be managed well in this multiple path routing
- Complexity is the major challenge in this routing technique[19]

F. Quorum-Based Routing

- It is developed to improve location service
- Forwarding scheme and location service which is intended to learn the position of specific nodes are very important for position based routing
- Four different approaches are there for location service such as some for some, some for all, all for some, all for all.
- Restricted directional flooding, greedy forwarding, and hierarchical approaches are the types of forwarding scheme

G. Grid-Based Rouitng

- The network area is divided into hierarchy of squares.
- Each node maintains routing table which holds the information of all other nodes
- This table is periodically broadcast
- The centre of the grid is considered as the position of node
- When a node closely reaches the position, the position information will be forwarded progressively.
- This will guarantee that the information reaches the correct nodes

H. Store-Carry and Forward

- Store carry and forward technique is being used if the network faces disconnection issues from its next relay node.
- It is more necessary if the network is faulty but there is more important to transfer data to its next relay node of course the next node is out of transmission range.
- The store carry and forward technique utilizes the current packet node to transfer the data until it reach the next

node or destination.

- But this technique does not work well in the fast moving or dynamic changing topology of UAV.
- It leads to the term inefficient. Also this works well if the UAV nodes are sparsely distributed.
- This technique assures high through put in delay tolerant routing protocol.

I. Greedy Forwarding

- This technique gives good output when the UAV nodes are densely deployed in FANET.
- The basic idea is to reduce the number of hopes in the connectivity.
- Also this technique chooses the relay node based on the availability of nodes geographically nearest to the destination node.
- It is a progress based forwarding strategy.
- In case if there is an absence of Nodes geographically nearer to Destination node, the algorithm fails and leads to Cal minimum.
- Overhead and local optimum problem are the limitations.

J. Prediction

Direction, geographic location and speed of the UAVs are some of the common tools to be considered for prediction.

Path discovery is also used to find the best and active path between the source and destination.

K. Routing Protocols

At the beginning the routing protocols of MANET and VANET were proposed to be used for UAV networks. Since parameters like dynamic changing topology, high mobility seeks researchers to recommend specific routing protocol for UAV.[20]

TOPOLOGY BASED ROUTING PROTOCOLS

Topology based Routing protocol uses the existing information of the node to transfer the packets from one node to another node. Also it exploits the IP address of the nodes in the network to accomplish this [21]. Static, Proactive, Reactive and hybrid are the types of topology based routing protocol.

A. Static Routing

Table 3

DATA-CENTRIC ROUTING (DCR)	b: LOAR CARRY AND DELIVER ROUTING (LCAD	c: MULTI-LEVEL HIERARCHICAL ROUTING (MLHR)
Better results in cluster based Topologies It is used in one to many transactions[22]	As shown in the figure the data gets transferred from one ground station to another suing flight Secure, throughput is the strength Challenge is transmission delay The transmission delay is avoided in Multi UAV	It can form flat based structure A hierarchical networks which connect several clusters[23]

B. Proactive Routing Protocol (PRP)

Table 4

Uses Routing table to store all the routes The routing table must be updates and shared periodically based upon the change in topology **Advantage :** It contains latest information by exchanging the routing messages among the communication nodes **Drawback :** Bandwidth Network delay[24]	
OPTIMIZED LINK ROUTING (OLSR)	OLSR is very popular The factors of Multi point relay affect the performance of OLSR; also it is selected by the sender which in turn covers two hop neighbors. In OLSR, Multi point relaying is used to avoid congestion and control messages. This is not very useful in the dense network and low density environments [26] D-OLSR M-OSLR and CE-OSLR are the types of OLSR[27-29]. OSLR routing is used for traffic monitoring in FANETS[30] In [31], OLSR performs well than AODV in terms of data delivery of UAV networks.
DESTINATION SEQUENCE DISTANCE VECTOR ROUTING (DSDV)	It is a table driven protocol routing protocol Increment and full dump are the two types of updating packets Uses numbered sequence to control freshness in the routes [33].
c: BABEL	It is a loop-avoiding distance vector protocol. Gives better result for the unstable communication networks and which operates in IPv4andIPv6networks. A metric is used to calculate the shortest path in the network Limitations It produces more traffic to update the routing tables during topology changes[34].
BETTER APPROACH TO MOBILE AD HOC NETWORK (BATMAN)	It maintains the information about the presence of all communication nodes. The best next hop is quickly recognized to communicate with the destination node. It does not calculate the complete route It is faster Packet size is very small Advantage It shows better results in data rate and packet loss It won't embed any routing information in the routing packets [35]
OPTIMIZED LINK ROUTING WITH EXPECTED TRANSMISSION COUNT (OLSR-ETX)	It shows good result for the criteria's rapid mobility and dynamic topology changes. (OLSR-ETX) performs good than the traditional OLSR Packe transmission, end-to-end delay, and overhead [34].

C. Reactive Routing Protocol (RRP)

- On demand routing protocol
- Stores a route between 2 nodes while communicating each other
- It overcomes the limitation of overhead problem of proactive
- It leads to high latency because of the time it takes during the process of finding new routes
- Source routing and hop by hop routing are the two categories of RRP
- Packet carries the address of destination when it starts from source
- In hop by hop routing the intermediate nodes are responsible because the packet carries the address of next hop.

D. Position-Based Routing

- GPS is used to define the nodes in Position based routing
- Suitable for highly dynamic UAV Communication networks
- Single path and multi path are the two types of position routing
- Those two types are further classified into heterogeneous networks, delay tolerant networks (DTNs), and non-delay-tolerant networks (Non-DTNs).

Single-Path Heterogeneous Routing

- It supports the interaction between the fixed nodes at the ground station with other UAVs.
- It extends the coverage.

A. Uav-Assisted Vanet Routing Protocol (UVAR)

- After modifying a few VANET routing protocols, it may be used in UAV networks.
- Traffic density, distance between the nodes, connectivity, and the distributions of vehicles are the 4 different parameters of UVAR.
- HELLO messages exchanged between nodes
- Dijkstra algorithm is used to send HELLO messages between the nodes. [51]

B. Connected-Based Traffic Density Aware Routing Protocol (CRUV)

- This is suitable for the scenario, if the current vehicle cannot find the connected segment, then UAV do for it.
- Periodically HELLO packets are exchanged between the vehicles.
- This supports efficient routing.
- If there is a connected segment, the source vehicle selects the UAV to which to deliver the data.[52-54]

C. Uav-Aided Vehicular Networks (UAV-VN)

- UAV VN solves the path availability problem in the vehicular network with the help of UAVs. Usually path availability depends on the number of vehicles and its cooperations.
- UAV mobility is considered to enhance the availability of path connectivity. [55]

D. UAV Relayed Tactical Mobile Ad Hoc Networks (UAVRT-MANET)

- This is used to implement UAV-aided relay in MANETs
- It acts better than geographical routing protocol
- Connect the ground vehicles during link breakage via UAV under reserved and congestion schemes
- Avoid link breakage and traffic congestion [56].

E. Predictive-Optimized Link State Routing Protocol (P-OSLR)

- It works under the prediction of GPS.
- The HELLO packets are flooded with the support of GPS.
- It modifies OSLR.
- P- OSLR is used in highly dynamic networks.
- This approach uses Expected transmission count to find the neighbouring nodes.[57]

F. Predictive Routing for Dynamic UAV Networks (PR-DUAV)

- It modifies Dijkstra's shortest path algorithm.
- It reacts faster to find the shortest path.
- Enhances delivery path and reduces end to end delay [58]

E. Cluster-Based Routing

Hybrid Routing Protocol (HRP)

- Reactive routing protocol requires more time to discover routes also proactive routing protocols suffers overhead issue.
- Used to reduce overhead problem also suitable for large scale networks [36].

Table 5

a: ZONE ROUTING PROTOCOL (ZRP)	It works in the concepts of zones. A set of nodes are assigned to a node. Zone routing protocol is used inside the zone among the nodes which is also call it as intra zone routing. In case of both source and destination in the same zone, sources starts to send its packets immediately. Inter zone roting methodology is used to connects the nodes of different zones.[37].
b: TEMPORARILY ORDERED ROUTING ALGORITHM (TORA)	It is used in the multi hop networks. In TORA the routers maintains the information of other routers. It reacts less to the topology changes. It maintains acyclic graph. It increases network adaptability by finding the new routes quickly in case of failure. Advantage: loop-free and multipath routing method
HYBRID WIRELESS MESH ROUTING PROTOCOL (HWMP)	Proactive tree-based routing protocol Supported by IEEE 802.11s standard Path selection Applications : video surveillance in multi-hop networks[38]
ON-DEMAND ROUTING WITH BOIDS OF REYNOLDS PROTOCOL (BR-AODV)	It's a combination of on-demand routing and Boids of Reynolds mechanism Maintains Routes and connectivity Results shows its better than AODV in terms of packet delivery ratio, end-to-end delay, and packet loss[39]
Link stability ESTIMATION-BASED PREEMPTIVE ROUTING (LEPR)	Based on AODV protocol Link stability metric is used for LEPR design Broken path and end to end delay is reduced[38-39]
REACTIVE FLOODING ROUTING (RFR)	Good results in precision agriculture scenario Advantage : Packet delivery ratio

- The swarm intelligence topology management approach is used in FANTs for cluster-based network [45].

Cluster-Based Routing Protocol (CBRP)

- The geographical areas are divided into several square grids, consisting of cluster members.
- One of the cluster members will act as cluster head, it is responsible for data routing.
- It's not necessary by individual nodes to discover routes so this approach reduces over head

Modularity-Based Dynamic Clustering Relay Routing Protocol (MDCR)

- This aims at the transmit power of the mobile devices and the energy efficient UAV aided mobile
- During clustering the UAVs are relocated to the positions based on the centroids of the cluster.
- Graph based clustering approach is used in MDCR [47]

Bio-Inspired Clustering Scheme for Fanets (BICSF)

This approach uses the hybrid mechanism of grow worm swarm optimization and krill herd Uses energy-aware cluster formation. Cluster building time, energy consumption, cluster lifetime, and the probability of delivery success with the clustering algorithms based on grey wolf optimization and ant colony optimization evaluates the performance of BICSF.[48]

Hybrid Self-Organized Clustering Scheme (HSCS)

Its work good in drone-based cognitive IoT. HSCS uses glow worm swarm optimization (GSO) and dragon fly algorithm (DA). GSO manages cluster head. DA manages effective cluster member tracking methodology. It improves the network stability by identifying the dead cluster [49]

Swarm Intelligence-Based Localization and Clustering (SIL-SIC)

It is based on the particle swarm optimization (PSO). The location of the target UAV is identifies through Anchor UAV by SIL SIC. Energy-efficient swarm-intelligence-based clustering (SIC) algorithm is also expanded based on PSO. Improves the cluster energy efficiency SIL-SIC identifies the cluster head based on particle optimization approach. For energy-efficient clustering, cluster heads are selected based on improved particle optimization. Advantage: consumes less energy and prolongs network lifetime.[50]

F. Deterministic Routing Protocol

This is very useful if the future availability and the location of other nodes are known in terms of mobility, availability, and motion. A tree approach is used in the design of selection process between the source and the destination. In tree approach the source node is root all the other nodes are child nodes.

G. Stochastic Routing Protocols

It is very useful for the network which holds random and unknown behaviour and this protocol minimizes end to end delay [40].Types of stochastic routing protocols are epidemic routing-based approach ,estimation-based routing ,node movement and control-based routing ,and coding-based routing [40-44].

Epidemic Routing-Based Approach

It is very useful if all the routes in the networks are disconnected. This approach spread the messages to all the nodes as like flooding. The intermediate nodes forward by guessing the probability of the link. Limitations: large buffer sizes, bandwidth, and power.

Estimation-Based Approach

It works well in smaller network whereas in the larger network it leads to over head. Based on the estimation process the intermediate nodes take decision to forward the packets

Node Movement and Control-Based Approach

In this approach nodes will wait for reconnection in case of any sudden failure. Two types are there to address this approach. Proactive and reactive cases. In proactive, source ferry data to destination. Reactive cases leads to unacceptable delay.

Coding-Based Approach Coding

It works in network coding. Avoid built in redundant information and retransmission

Social Network (Sn)-Based Approach

It is useful if the mobility of the nodes is not random and so it is fixed. Node stores the visiting place in the database when it visits a new place. Needs higher buffer size and higher bandwidth.

REFERENCE

1. *https://www.youtube.com/watch?v=P9adBgSz--g*
2. *https://www.youtube.com/watch?v=m7FS41zJn6c*
3. *W. Zafar and B. M. Khan, ''Flying ad-hoc networks: Technological and social implications,'' IEEE Technol. Soc. Mag., vol. 35, no. 2, pp. 67–74, Jun. 2016. doi: 10.1109/mts.2016.2554418.*
4. *C. Y. Tazibt, M. Bekhti, T. Djamah, N. Achir, and K. Boussetta, ''Wireless sensor network clustering for UAV-based data gathering,'' in Proc. Wireless Days, 2017, pp. 245–247. doi: 10.1109/wd.2017.7918154*
5. *J. Y. Yu and H. P. J. Chong, ''A survey of clustering schemes for mobile ad hoc networks,'' IEEE Commun. Survey Tuts., vol. 7, no. 1, pp. 32–48, 1st Quart., 2005. doi: 10.1109/comst.2005.1423333.*
6. *X. Chen and K. Michael, ''Privacy issues and solutions in social network sites,'' IEEE Technol. Soc. Mag., vol. 31, no. 4, pp. 43–53, Dec. 2012. doi: 10.1109/mts.2012.2225674.*
7. *N. Jabeur, S. Zeadally, and B. Sayed, ''Mobile social networking applications,'' Commun. ACM, vol. 56, no. 3, pp. 71–79, 2013. doi: 10.1145/ 2428556.2428573.*
8. *S. Wen and C. Huang, ''Delay-constrained routing based on stochastic model for flying ad hoc networks,'' Mobile Inf. Syst., vol. 2018, Aug. 2018, Art. no. 6056419. doi: 10.1155/2018/6056419.*
9. *R. Xue and G. Cai, ''Formation flight control of multi-UAV system with communication constraints,'' J. Aerosp. Technol. Manage., vol. 8, no. 2, pp. 203–210, 2016. doi: 10.5028/jatm.v8i2.608.*

10. *J. Zhang, J. Yan, P. Zhang, D. Yuan, and X. Hou, ''Design and flight stability analysis of the UAV close cooperative formation control laws,'' in Proc. Chin. Control Decis. Conf.(CCDC),2018,pp. 142–147.doi:10. 1109/ccdc.2018.8407120.*
11. *J. Zhang, J. Yan, M. Lv, X. Kong, and P. Zhang, ''UAV formation flight cooperative tracking controller design,'' in Proc. 15th Int. Conf. Control, Automat., Robot. Vis. (ICARCV), 2018, pp. 856–861. doi: 10.1109/ icarcv.2018.8581093.*
12. *S.-L. Zhou, Y.-H. Kang, H.-D. Dai, and Z. Chao, ''Multi-UAVs formation autonomous control method based on RQPSO-FSM-DMPC,''Math. Problems Eng., vol. 2016, Aug. 2016, Art. no. 4878962. doi: 10.1155/ 2016/4878962.*
13. *H. Peng, A. Razi, F. Afghah, and J. Ashdown, ''A unified framework for joint mobility prediction and object profiling of drones in UAV networks,''J.Commun.Netw.,vol.20,no.5,pp. 434–442,2018.doi:10. 1109/jcn.2018.000068.*
14. *W. Li, X. Cheng, T. Jing, and X. Xing, ''Cooperative multi-hop relaying via network formation games in cognitive radio networks,'' in Proc. IEEE INFOCOM, Apr. 2013, pp. 971–979. doi: 10.1109/infcom. 2013.6566886.*
15. *V.Sharma and R.Kumar,''Cooperative frameworks and network models for flying ad hoc networks: A survey,'' Concurrency Comput., Pract. Exper., vol. 29, no. 4, p. e3931, 2016. doi: 10.1002/cpe.3931.*
16. *V. Sharma, F. Song, I. You, and H.-C. Chao, ''Efficient management and fast handovers in software defined wireless networks using UAVs,'' IEEENetw.,vol.31,no.6,pp. 78–85,Nov./Dec.2017.doi:10.1109/mnet. 2017.1700003.*
17. *S.Uluskan,M.Gokce,andT.Filik,''RSSbasedlocalizationofanemitter using a single mini UAV,'' in Proc. 25th Signal Process. Commun. Appl. Conf. (SIU), 2017, pp. 1–4. doi: 10.1109/siu.2017.7960239.*
18. *D. Reina, M. Askalani, S. Toral, F. Barrero, E. Asimakopoulou, and N. Bessis, ''A survey on multihop ad hoc networks for disaster response scenarios,'' Int. J. Distrib. Sensor Netw., vol. 11, no. 10, 2015, Art. no. 647037. doi: 10.1155/2015/647037.*
19. *C. Pu, ''Jamming-resilient multipath routing protocol for flying ad hoc networks,'' IEEE Access, vol. 6, pp. 68472–68486, 2018. doi: 10.1109/ access.2018.2879758*
20. *H. R. Hussen, S.-C. Choi, J.-H. Park, and J. Kim, ''Performance analysis of MANET routing protocols for UAV communications,'' in Proc. 10th Int. Conf. Ubiquitous Future Netw. (ICUFN), Jul. 2018, pp. 70–72. doi: 10.1109/icufn.2018.8436694.*
21. *M.A.Khan, I.U.Khan, A.Safi, and I.M.Quershi, ''Dynamic routing in flying ad-hoc networks using topology-based routing protocols,''Drones, vol. 2, no. 3, p. 27, Aug. 2018. doi: 10.3390/drones2030027.*
22. *M. Erdelj, M. Król, and E. Natalizio, ''Wireless sensor networks and multi-UAV systems for natural disaster management,'' Comput. Netw., vol. 124, pp. 72–86, Sep. 2017. doi: 10.1016/j.comnet.2017. 05.021.*
23. *Y. Zhou, N. Cheng, N. Lu, and X. S. Shen, ''Multi-UAV-aided networks: Aerial-ground cooperative vehicular networking architecture,''IEEEVeh. Technol. Mag., vol. 10, no. 4, pp. 36–44, Dec. 2015. doi: 10.1109/mvt. 2015.2481560.*

24. J.-J. Wang, C.-X. Jiang, Z. Han, Y. Ren, R. G. Maunder, and L. Hanzo, ''Taking drones to the next level: Cooperative distributed unmannedaerial-vehicular networks for small and mini drones,'' IEEE Veh. Technol. Mag., vol. 12, no. 3, pp. 73–82, Sep. 2017. doi: 10.1109/mvt.2016. 2645481.

25. M. H. Tareque, M. S. Hossain, and M. Atiquzzaman, ''On the routing in flying adhoc networks,''in Proc. Federated Conf. Comput. Sci. Inf. Syst., 2015, pp. 1–9. doi: 10.15439/2015f002.

26. W. Zafar and B. M. Khan, ''A reliable, delay bounded and less complex communication protocol formulticlusterFANETs,''Digit.Commun. Netw., vol. 3, no. 1, pp. 30–38, 2017. doi: 10.1016/j.dcan.2016.06.001.

27. A. I. Alshbatat and L. Dong, ''Cross layer design for mobile ad-hoc unmanned aerial vehicle communication networks,'' in Proc. Int. Conf. Netw., Sens. Control (ICNSC), 2010, pp. 331–336. doi: 10.1109/icnsc. 2010.5461502.

28. A. B. Paul and S. Nandi, ''Modified optimized link state routing (M-OLSR) for wireless mesh networks,''in Proc.Int. Conf. Inf. Technol., 2008, pp. 147–152. doi: 10.1109/icit.2008.67.

29. M. Belhassen, A. Belghith, and M. A. Abid, ''Performance evaluation of a cartography enhanced OLSR for mobile multi-hop ad hoc networks,'' in Proc. Wireless Adv., 2011, pp. 149–155. doi: 10.1109/ wiad.2011.5983303.

30. A. V. Leonov and G. A. Litvinov, ''Considering AODV and OLSR routing protocols to traffic monitoring scenario in FANET formed by mini-UAVs,'' in Proc. 14th Int. Sci.-Tech. Conf. Actual Problems Electron. Instrum. Eng. (APEIE), 2018, pp. 229–237. doi: 10.1109/ apeie.2018.8545667

31. A.V.LeonovandG.A.Litvinov,''Simulation-basedpacketdeliveryperformance evaluation with different parameters in flying ad-hoc network (FANET)usingAODVandOLSR,''J.Phys.,Conf.Ser.,vol.1015,no.3, 2018, Art. no. 032178. doi: 10.1088/1742-6596/1015/3/032178.

32. C. Pu, ''Link-quality and traffic-load aware routing for UAV ad hoc networks,'' in Proc. IEEE 4th Int. Conf. Collaboration Internet Comput. (CIC), Oct. 2018, pp. 71–79. doi: 10.1109/cic.2018.00-38.

33. H. R. Hussen, S.-C. Choi, J.-H. Park, and J. Kim, ''Performance analysis of MANET routing protocols for UAV communications,'' in Proc. 10th Int. Conf. Ubiquitous Future Netw. (ICUFN), Jul. 2018, pp. 70–72. doi: 10.1109/icufn.2018.8436694.

34. J. Chroboczek, The Babel Routing Protocol, document RFC6126, Apr. 2011. [Online]. Available: http://www.rfc-editor.org/rfc/rfc6126.txt

35. D. Johnson, N. Ntlatlapa, and C. Aichel, ''Simple pragmatic approach to mesh routing using BATMAN,'' in Proc. 2nd IFIP Int. Symp. Wireless Commun. Inf. Technol. Developing Countries, Oct. 2008, pp. 1–10. [75] P. Xie, ''An enhanced OLSR routing protocol based on node link expiration time and residual energy in ocean FANETS,'' in Proc. 24th Asia–Pacific Conf. Commun. (APCC), 2018, pp. 598–603. doi: 10.1109/ apcc.2018.8633484.

36. M.A.Khan, I.U.Khan, A.Safi, and I.M.Quershi,''Dynamic routing in flying ad-hoc networks using topology-based routing protocols,''Drones, vol. 2, no. 3, p. 27, Aug. 2018. doi: 10.3390/drones2030027.

37. *Z. J. Haas and M. R. Pearlman, Zone Routing Protocol (ZRP): A Hybrid Framework for Routing in Ad-Hoc Networks. Reading, MA, USA: Addison-Wesley, 2001, pp. 221–253.*
38. *A. Nayyar, ''Flying adhoc network (FANETs): Simulation based performance comparison of routing protocols: AODV, DSDV, DSR, OLSR, AOMDV and HWMP,'' in Proc. Int. Conf. Adv. Big Data, Comput. Data Commun. Syst. (icABCD), 2018, pp. 1–9. doi: 10.1109/ icabcd.2018.8465130.*
39. *N. El H. Bahloul, S. Boudjit, M. Abdennebi, and D. E. Boubiche, ''A flocking-based on demand routing protocol for unmanned aerial vehicles,'' J. Comput. Sci. Technol., vol. 33, no. 2, pp. 263–276, 2018. doi: 10.1007/s11390-018-1818-3.*
40. *I. Cardei, C. Liu, and J. Wu, ''Routing in wireless networks with intermittent connectivity,'' in Encyclopedia of Wireless and Mobile Communications. New York, NY, USA: Taylor & Francis, 2013, pp. 1–23.*
41. *S. Jain, K. Fall, and R. Patra, ''Routing in a delay tolerant network,'' in Proc. Conf. Appl., Technol., Architectures, Protocols Comput. Commun. (SIGCOMM), 2004, pp. 145–158. doi: 10.1145/1015467.1015484.*
42. *Z. Zhang, ''Routing in intermittently connected mobile ad hoc networks and delay tolerant networks: Overview and challenges,'' IEEE Commun. Surveys Tuts., vol. 8, no. 1, pp. 24–37, 1st Quart., 2006. doi: 10.1109/ comst.2006.323440.*
43. *Q. Li and D. Rus, ''Communication in disconnected ad hoc networks using message relay,'' J. Parallel Distrib. Comput., vol. 63, no. 1, pp. 75–86, 2003. doi: 10.1016/s0743-7315(02)00033-3.*
44. *E. Ashraf, A. F. Hossam, and S. Hassanein, ''Routing schemes for DTN an applications perspective,'' Dept. School Comput., Telecommun. Res. Lab(TRL),Queen'sUniv.,Kingston,ON,Canada,Tech.Rep.2012-588, 2012.*
45. *D. Kim and J. Lee, ''Integrated topology management in flying ad hoc networks: Topology construction and adjustment,'' IEEE Access, vol. 6, pp. 61196–61211, 2018. doi: 10.1109/access.2018.2875679.*
46. *J. Yu, R. Zhang, Y. Gao, L.-L. Yang, ''Modularity-based dynamic clustering for energy efficient UAVs-aided communications,'' IEEE Wireless Commun. Lett., vol. 7, no. 5, pp. 728–731, Oct. 2018. doi: 10.1109/lwc. 2018.2816649.*
47. *J. Yu, R. Zhang, Y. Gao, L.-L. Yang, ''Modularity-based dynamic clustering for energy efficient UAVs-aided communications,'' IEEE Wireless Commun. Lett., vol. 7, no. 5, pp. 728–731, Oct. 2018. doi: 10.1109/lwc. 2018.2816649.*
48. *A. Khan, F. Aftab, and Z. Zhang, ''BICSF: Bio-inspired clustering scheme for FANETs,'' IEEE Access, vol. 7, pp. 31446–31456, 2019. doi: 10.1109/access.2019.2902940.*
49. *F. Aftab, A. Khan, and Z. Zhang, ''Hybrid self-organized clustering scheme for drone based cognitive Internet of Things,'' IEEE Access, vol. 7, pp. 56217–56227, 2019. doi: 10.1109/access.2019.2913912.*
50. *M. Y. Arafat and S. Moh, ''Localization and clustering based on swarm intelligence in UAV networks for emergency communications,'' IEEE Internet Things J., to be published. doi: 10.1109/jiot.2019.2925567.*
51. *A. Rovira-Sugranes and A. Razi, ''Predictive routing for dynamic UAV networks,'' in Proc. IEEE Int. Conf. Wireless Space Extreme Environ. (WiSEE), Oct. 2017, pp. 43–47. doi: 10.1109/wisee.2017.8124890.*

52. *O. S. Oubbati, A. Lakas, F. Zhou, M. Güneş, N. Lagraa, and M. B. Yagoubi, ''Intelligent UAV-assisted routing protocol for urban VANETs,'' Comput. Commun., vol. 107, pp. 93–111, Jul. 2017. doi: 10. 1016/j.comcom.2017.04.001.*

53. *O. S. Oubbati, A. Lakas, N. Lagraa, and M. B. Yagoubi, ''CRUV: Connectivity-based traffic density aware routing using UAVs for VANets,'' in Proc. Int. Conf. Connected Vehicles Expo (ICCVE), 2015, pp. 68–73. doi: 10.1109/iccve.2015.54.*

54. *O. S. Oubbati, N. Lagraa, A. Lakas, and M. B. Yagoubi, ''IRTIV: Intelligent routing protocol using real time traffic information in urban vehicular environment,'' in Proc. 6th Int. Conf. Technol., Mobility Secur. (NTMS), 2014, pp. 1–4. doi: 10.1109/ntms.2014.6814028.*

55. *O.S.Oubbati, A.Lakas, N.Lagraa, and M.B.Yagoubi,''ETAR:Efficient traffic light aware routing protocol for vehicular networks,'' in Proc. Int. Wireless Commun. Mobile Comput. Conf.(IWCMC),2015,pp. 297–301. doi: 10.1109/iwcmc.2015.7289099.*

56. *W.Fawaz, R. Atallah,C. Assi, and M. Khabbaz,''Unmannedaerial vehicles as store-carry-forward nodes for vehicular networks,'' IEEE Access, vol. 5, pp. 23710–23718, 2017. doi: 10.1109/access.2017.2765498.*

57. *B.-S. Kim, K.-I. Kim, B. Roh, and H. Choi, ''A new routing protocol for UAV relayed tactical mobile adhoc networks,''in Proc.Wireless Telecommun. Symp. (WTS), 2018, pp. 1–4. doi: 10.1109/wts.2018.8363941.*

58. *S. Rosati, K. Krużelecki, G. Heitz, D. Floreano, and B. Rimoldi, ''Dynamic routing for flying ad hoc networks,'' IEEE Trans. Veh. Technol., vol. 65, no. 3, pp. 1690–1700, Mar. 2016. doi: 10.1109/tvt.2015. 2414819.*

BIOGRAPHY

Mr. M. Mohamed Syed Ibrahim received B.E (Electronics and Communication) from Mohamed Sathak Engineering College and M.E. (Communication systems) from Anna University Chennai, in 2002 and 2004 respectively and pursuing Ph.D. from Annamalai University, India since 2017. He is presently a Lecturer and On the Job Training coordinator in the department of Engineering at Ibra college of Technology, Sultanate of Oman. In his 16 years of teaching experience, he has been honoured four times with the Staff of the Year Awards, 5 times with On the Job training Excellence Awards. He serves on the program committees for 4 National level Technical Industrial gatherings. He has organized more than 50 Industrial visits and 20 Technical workshops/Seminars. He has published 11 papers in International Journals and National level conference proceedings. His current research interests include ad hoc networks, unmanned aerial networks with a focus on network architectures and protocols.

Dr. P. Shanmugaraja was born in 1970 in Tirunelveli. He has obtained B.E (Electronics and Communication) from National Engineering College and M.E. (Medical Electronics) from Anna University Chennai, in 1992 and 1995 respectively and then Ph.D. in Micro Electronics from Annamalai University, Chidambaram in 2015. He is presently a Professor in Instrumentation Engineering Department at Annamalai University where he has put in 23 years of service. He is presently guiding six Ph.D. scholars and has guided twenty five M.E students. His areas of interest are: Nano electronics, Embedded system, Medical electronics. He is a life member of Indian Society for Technical Education and annual Member in Instrumentation Systems and Automation.

Ms. Mary Theres Vini was born in 1980 in Tirunelveli. She has obtained B.E (Computer Science) from The Rajas Engineering College- Vadakkangulam, TN, India and M.E. (Computer science) from PSN College of Engineering & Technology- Tirunelveli, Tamil Nadu, India in 2003 and 2018 respectively. She is presently an Assistant Professor in Computer Science Engineering Department at Thamirabarani Engineering College. She was honoured as M.E Gold Medalist outstanding performer in the Year 2018. Her areas of interest are: Adhoc networks, Wireless sensor networks and computer architecture.