A Hybrid and Robust Delay and Link Stability Aware (DLSA) Routing Protocol for Unmanned Aerial Ad-hoc Networks (UAANETs)

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Research Article

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A Hybrid and Robust Delay and Link Stability Aware (DLSA) Routing Protocol for Unmanned Aerial Ad-hoc Networks (UAANETs)

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Abstract: Unmanned Aerial Ad-hoc Network (UAANET) also knows as by the name of Flying Ad-hoc NETwork (FANET) is a new class of Mobile Ad-hoc NETwork (MANET) in which the nodes move in three dimensional (3-D) ways in the air simultaneously. These nodes are known as Unmanned Aerial Vehicles (UAVs) that are operated live remotely or by pre-defined mechanism which involve no human personnel. Due to high mobility of nodes and dynamic topology, the link stability is a research challenge in FANET. From this viewpoint, recent research has focused on link stability with highest threshold value by maximizing Packet Delivery Ratio (PDR) and minimizing End-to-End Delay (E2ED). In this research, a hybrid scheme named Delay and Link Stability Aware (DLSA) routing scheme has been proposed with the contrast of Distributed Priority Tree-based Routing (DPTR) and Link Stability Estimation-based Routing (LEPR) FANET’s existing routing schemes. Unlike existing schemes, the proposed scheme possesses the features in collaborative data forwarding and link stability by merging the positive features of DPTR and LEPR. The link stability via maximum threshold value has been introduced to acquire and select the most feasible route from source to destination. The simulation was carried out using Matrix Laboratory (MATLAB) tool for the concerned research. Simulation results have showed improved performance of the proposed protocol in contrast to the selected existing ones in terms of E2ED, PDR, Network Lifetime and Transmission Loss. Average E2ED in (milliseconds) of DLSA measured 0.457, while DPTR was 1.492 and LEPR was 1.006. Similarly, Average PDR (in %age) of DLSA measured 3.106, while DPTR was 2.303 and LEPR was 0.682. Average Network Lifetime in (seconds) for DLSA measured 62.141, while DPTR was 23.036 and LEPR was 27.298. Average Transmission Loss in (dBm) for DLSA measured 0.975, while DPTR was 1.053 and LEPR was 1.227.

Keywords: MANET; FANET; UAANET; UAV; MATLAB; E2ED; PDR; DPTR; LEPR; DLSA.

I. INTRODUCTION

1.1 Mobile Ad-hoc Networks (MANETs)
As modern scientific enhancements and their application needs, different kinds of wireless ad-hoc networks have arisen as Mesh networks, Sensor networks and Ad-hoc networks. These networks are infrastructure independent networks; one of them is Mobile Ad-hoc Networks (MANETs). A MANET is a self-governing group of portable device, which communicates over comparatively “slow” wireless links. Subsequently, due to movable nodes, the topology of the network changes rapidly and unexpectedly over time. A scenario of MANET is shown in Figure 1.1 (AL-Dhief et al., 2017).
MANETs are performing a significant role in the field of communication. These networks are used for communication in battlefield, manufacturing uses, and Emergency operations such as rescue and crowd control. The difference among Infrastructure based network and MANET is the communication way. The physical medium is required for wired networks. Although, MANET doesn’t need any physical source (infrastructure) (Zafar and Khan, 2017).

MANETs are developed by wireless standard for different uses like easy installation, reliability, low cost, bandwidth, total energy consumption, security and efficiency of the network. The network is reorganized, where all nodes interconnects for delivering messages and the topology must to be organized themselves by the nodes. Therefore, routing feature will have to be combined into movable nodes. Since the nodes in MANET use wireless communication (radio), they have to face the issues like interference, fading and noise. In addition, as compared to wired network, the links have low bandwidth in MANET. MANET has no static topologies that can cover a large area of interest, because topologies can change randomly and dynamically. (Joshi, 2011).

1.2 Applications of MANETs
MANET can be used for small range ad-hoc networks like connectivity of multi-media network by using the notebook computers for sharing information, Bluetooth and Personal Area Network (PAN). Furthermore, MANET can be used in emergency and disaster situations like, forest fire, flood, volcanic eruptions and earthquakes. Following are the main types of MANETs (Joshi, 2011).

1.3 Types of MANETs
MANETs are further divided into different sub-types one of them is Flying Ad-hoc Networks (FANETs) as shown in Figure 1.2.
1.4 Flying Ad-hoc Networks (FANETs)
The latest development of wireless technology has been countersigned in our everyday life. Mainly, due to massive accessibility of low-cost Wi-Fi radio interfaces and other devices such as sensors, micro-embedded computer, GPS, etc. These novel devices have paved the path for the development and design of flying vehicles known as Unmanned Aerial Vehicles (UAVs), that form of a novel type of network called Flying Ad-hoc Networks (FANETs) (Oubbati et al., 2017).

1.4.1 Communication Scenario of FANETs
There are two types of communications in FANETs (i) UAV-to-Infrastructure and (ii) UAV-to-UAV. In the Infrastructure based network or UAV-to-Infrastructure, all the UAVs are linked to a satellite or a ground base station (BS) (Mittal and Singh, 2017).

The Figure 1.3 shows communication scenario in which there are seven UAVs connected with each other and with Infrastructure. The communication between UAV-to-UAV, UAVs to BS is known as UAV-to-Infrastructure, and the overall communication setup can be operated and administered from Ground Control Center (GCC) (Singh and Verma, 2018).

![Communication Scenario of FANETs](image_url)

FANET is the sub-type of MANETs where the UAVs communicate with each other for sharing and exchanging the information. It works on two types of sensing capabilities that are active and passive sensing for collecting and gathering of data. In active sensing the UAVs gather data from the target area and then on the ground station the user integrate and modify that image or real time video which is passive sensing. In such activity, the two operators perform their tasks, like one capture and gather data. After the gathering of data, then the second user modify, and give a proper order to the sensed data by combining of images and compilation of concurrent videos (Mittal and Singh, 2017).

FANETs consists of coordination, communication and sensing capabilities through which it communicates and form an ad-hoc network by collection of UAVs where its nodes fly in the air. Every UAV is equipped and embedded with sensors, on-board monitor, autopilot and Global Positioning System (GPS) receiver. These UAVs are motionless wings aircrafts with autopilot, talented of flying from 12 m/s up to 300 m/s in disaster circumstances. UAVs are presented in various sizes for different uses; these are Micro-UAVs, Small altitude and low survival UAVs and high altitude and high survival UAVs. The group of UAVs interconnects with each other and with the ground station (Yanmaz et al., 2018).

In UAV-to-UAV communication, UAVs interconnect with one another to complete the assigned duty. Two UAVs may have straight interconnection with each other or over other UAVs. For indirect communication using multi-hops, communication path is decided based on different routing schemes like pro-active, re-active and hybrid. UAVs have long or short-range communication that depends on required data transmission rate. While
in UAVs to ground station communication, UAVs communicate with the ground station to deliver or collect information about various processes (Singh and Verma, 2018).

UAVs systems can fly independently or can functioned remotely. The applications of UAVs are growing every day. Previous, UAVs were modest remotely directed airplanes and commonly used for military operations. Moreover, in current decade, UAVs have diverse applications like controlling and firefighting, non-military safety work, etc. The usage of single-UAVs system is actual common, but the usage of a collection of small multi-UAVs has recognized advantageous. Multi-UAVs systems decreases the processing time for achieving and maximizes reliability of the system for flying activities as compared to a single-UAV system (Hasan et al., 2015).

FANETs are considered with high degree of mobility that using multi-UAVs and single UAVs. The capability of single UAVs is insufficient. The routing and cooperation of multi-UAVs can generate a network that is beyond of the ability of single UAVs (Marconato et al., 2017). Nodes of FANETs are UAVs and these are simply known as drones, quad-copters and flying robots. Small multi-copters are of specific attention in training and practice because of their easy utilization that are less costly. Investigation and growth in small multi-copters starts with addressing control issues, like flight stability, design life of UAVs, follows by planning and designing independent automobiles of flying without the interference of external entity (Yanmaz et al., 2018).

With improvements in equipment and commercially presented automobiles, the attention is growing near cooperative UAVs systems. Particularly, for assignments that are time-dependable or that span a large geographic region, single small UAVs is inadequate because of its restricted energy and data delivery. In addition to authorizing coverage of bigger areas, many automobiles offer noticeable heterogeneity by witnessing and sensing an area of attention from diverse points of view that expedites the trustworthiness of the sensed data (Yanmaz et al., 2018). By the consequence of the quick scientific improvements on electronics, sensors and communication tools, it has been probable to yield UAVs networks that can fly independently or can be functioned distantly with-out transporting any human recruits. Due to their adaptability, lightweight, easy connection and installation, comparatively small operational expenditures UAVs are playing important role in secure communication. Small UAVs are lightweight and have limited capabilities of data delivery (Bekmezci et al., 2013).

In addition, due to the limited capabilities of UAVs, the aircrew performance of small multi-UAVs can achieve difficult assignments efficiently. The Aircrew (swarm) performance of UAVs needs organized and coordinated features and UAVs must interconnect with one another to accomplish the coordination and direction. Due to limited data delivery of small UAVs, it is not probable to transport heavy UAV-to-infrastructure communication hardware. FANETs that need rather cheaper and lighter hardware may be used to create a network between small UAVs (Bekmezci et al., 2013).

FANETs may consist of similar or dissimilar flying automobiles that have the ability to interconnect with one another in nearby environment, and interconnect with their nearby nodes to collect some form of significant information. In this perspective, a special type of FANET is introduced that communicate like a group optimization i.e. these air vehicles only communicate within their nearby nodes like in swarm behavior to interconnect and share the meaningful data with each other (Yanmaz et al., 2018).

FANETs are used in different types of situations that depend on different type of altitudes from lower level to upper level as shown in Figure 1.4. As for military drones (that operating in upper altitude), it uses the IEEE standard 802.11 b/g/n, but for civilian applications (that operating in lower altitude), like usage of small UAVs it uses the IEEE standards XBee 802.15.4 and Bluetooth 802.15.1 (Yanmaz et al., 2018).
1.5 Applications of FANETs
The advantages of FANETs by using UAVs that are flexible and have less operating cost makes it useful for a number of potential applications as described and shown in Figure 1.5.
1.5.1 Commercial Drones (UAVs)

During the last report by the use of UAVs, it has been concluded that these UAVs may be used for marketing purposes to earn money by it and to deliver the goods by smart delivery like pizza and other stuffs etc. such kind of UAVs are placed in the category of commercial drones. In the time of the initiation of the US news program named ‘60 minutes’, a guy named the Amazon’s Founder Jeff Bezos showed a demonstration about the smart delivery of Drone to carry package from Amazon ware bouts to the doorstep of the customers. In additional article that was published latest, they showed that by the usage of Drone in practical field. In their desired phenomena they have used a Drone named (octacoper) that was delivering the Pizza of the Domino’s to the home of the client (Sun et al., 2011).

By using these kinds of UAVs, it opens new areas and opportunities to diverse usages in scenarios of urban. Though, the authority of US Federal Aviation is recently been working for the regulations and rules of these UAVs in environments of domestic. These kinds of spectacular usages may lead to open novel issues and problems relate to the network of UAVs that may be found by the community of research. In this scenario of the commercial drones’ usage, it has to identify the ad-hoc wireless networks that may takes place in the urban situations. Like Wi-Fi, WiMAX, cellular and diverse networks are included in these aforementioned networks. For e.g. different smart cities are being built by the use of these diverse ad-hoc wireless networks like WSN had been placed for dissimilar needs. As both of these networks like Wi-Fi that operate by the use of ISM band, so it is crucial to explore that how UAVs may be interoperable in the existence of these networks (Sun et al., 2011).

1.5.2 Traffic Surveillance

In urban monitoring and planning, traffic surveillance is the most significant and crucial task to perform by the UAVs. Usually, it has been done via many cameras fixed on high building’s tops, cameras placed on roadways and helicopters.

Lately, usage of UAVs has been started for traffic surveillance by the US Department of Transportation (US-DOT). These UAVs assist and neglect or avoid any problems that can be handled from the air by using flying agents and also having abilities to provide conditions of traffic and emergency situations to the ground control room or center as shown in Figure 1.6 (Srinivasan et al., 2004).

![Figure 1.6: Usage of UAVs for traffic surveillance (Oubbati et al., 2017)](image)

In Figure 1.7, a scenario is shown in which a drone (UAV) is monitoring continuously the situations of the traffic with the help of connected to the control stations that may change over time suddenly. So, it proves that when some disaster like energy situation occurs of takes place, the instructions are given to the concerned department form the control stations via UAV. UAVs perform a vital and robust task in this manner. There may exist many usages of UAVs for such circumstances to handle it carefully and thoroughly.

Figure 1.7 depicts a model type scenario of the usage of UAVs for traffic surveillance and management.
Figure 1.7: Traffic surveillance by the use of UAVs (Srinivasan et al., 2004)

Usually, the surveillance of traffic is furnished by the usage of UAVs in urban scenarios, in which there may be occurrence of many possible accidents of situations like emergency. However, urban regions are very overcrowded, so it may lead to the goals that there may be opportunities that the scenario may be full of crowd. Henceforth, it is a significant and efficient use of UAVs to have the technology of CRT, where it has so great importance in the perspective to enable UAVs to switch the information of traffic quickly and suddenly with the control station (Zarco-Tejada et al., 2008).

1.5.3 Crop Monitoring

During the initial past days, the agricultural technologist were using different methods for monitoring the situations of the crops like visual inspection, mold localization and color estimation. But after some time, the monitoring of crop was changed to some advanced machineries and tools like gas sensors, pH scale, thermometers and anemometers. Though, there was problem arising with the usage of these tools that was availability of non-real-time and the issues concerned with the acquisition of data. For solving these kinds of problems, WSNs had been projected and shown a better solution and placed in the fields near with the crops in the targeted area. In this scenario of crop monitoring usages, WSNs nodes were placed in the fields in a manner of random that they operated themselves in mesh network. This network was improving the efficiency and reliability. Though, this network was not enough to monitors efficiently because of the dynamic scope of the conditions like animals’ intrusion and continuous climate changes. A setting of crop monitoring is displayed in Figure 1.8 (Valente et al., 2011).

Figure 1.8: Crop Monitoring by the use of UAVs (Marino et al., 2009)
The application of the UAVs for the monitoring of crop was portrayed by Japan in early 1980s. At that time Yamaha worked to design and develop a novel unmanned helicopter for the task of spraying crops. After that, the usage of UAVs introduced in the field of agriculture to solve the problems and issues of remote sensing of the crops like manned crafts of satellite, that have some restrictions and limitations for meeting the needs of agricultural necessities. The usage of UAVs had been officially integrated for crop monitoring and sensing by the use of placed sensors in the fields. These UAVs were able to deliver high quality images and videos that were the major limitations in the aforementioned agricultural techniques because of very small time window to gain very high quality images (Zarco-Tejada et al., 2008).

1.5.4 Border Patrolling

Now a day, the need of agencies for the sake of country is increasing day by day due to some intrusions and terrorists that may hack into the system and halt or damage it. For the requirements of national security in the area of border patrolling the usage of UAVs has been growing very rapidly. Normally the patrolling system needs active and vigorous human personnel. That may be contains of some border troops and check posts. These necessities are made and performed on international levels to check and monitor the incoming and outgoing vehicles for restricted and prohibited actions and things. The troop of border is the group of humans that checks and monitors their border domain for intrusion and other activities within the given interval of time shifts. In some normal patrol systems of borders, the most active and well aware humans are appointed for the border surveillance via patrolling system of manual. Many technologies of surveillances have been introduced for the real-time patrolling of border with minimal human consisting and high accuracy. The sensor nodes are places for detection of any activity, movements’ etc. that crossing the line of the border. Due to this, the human involvements are reduced because of high mobility and paving a large area within less times faster than humans with clear LOS of UAVs. So, the assets may be projected to decide activates of management on the basis of UAV’s information’s received from it (Zarco-Tejada et al., 2008).

1.5.5 Disaster Management

In this scenario, if there available any infrastructure-based network it may sabotage because of the current disaster activities and then there will be no way to communicate of gain information from that area. Hence, the UAVs have the efficient and only solution for usage that have embedded cameras like thermal of heat, sensors so that they can deliver information like the bird’s eye view from the effected region. These UAVs are capable of having the CRT that can assist to the access of the spectrum bands dynamically without the intervention of any central entity. Henceforth, the UAVs equipped with CRT may be very beneficial in situations like these via focusing on area from the sky with covering large area. These UAVs fly from one place to another and capture high resolution images and videos like in circumstances of earthquakes, flooding, disaster, and fire in the forest. After the compilation of these images and videos, these are delivered to the end users for further analysis and
giving information to the search and rescue and disaster teams and takes actions accordingly. The technology of CR is most efficient for the networks in these situations (Ghafoor et al., 2014).

1.5.6 Wildfire Monitoring
Woodland flames are a significant issue for some nations and they cause a huge monetary expense and in long haul, they bring about natural life environmental harm and can likewise influence the atmosphere. A few times, they likewise cost human lives. Therefore, UAVs may be exceptionally useful in untamed life observing. The principle focal point of this application is to discover problem areas soon after an out of control fire has happened. In this application the UAVs fly over the consumed territory and catches temperature, pictures and recordings. Accordingly they send the caught information about the problem area focuses to clients on the ground where fitting moves can be made if necessary (Barrado et al., 2010).

Here, much the same as harvest observing, out of control fire checking can be additionally enhanced by outfitting UAVs with CRT. Here CRT may choose range groups as indicated by the sort of data and application prerequisites, for example, high transfer speed, low postponement, less parcel misfortune and high throughput.

1.5.7 Relaying Network
Independently worked UAVs are being utilized as air-borne correspondence transfers to proficiently and safely transmit the data gathered by ground gadgets to inaccessible control focuses, for instance, the conveyance of information delivered by wireless sensor network (WSN) nodes on the ground to the client. UAVs can likewise be utilized for expanding the correspondences scope of ground handing-off nodes, including IoV (Internet of Vehicles) situations.

1.6 FANET Design Considerations
Because of particular highlights of FANET, it requires diverse plan contemplations than conventional impromptu systems. Here it’s being stated talk about real structure contemplations: flexibility, dormancy, versatility, UAV stage imperatives, and adaptability and transmission capacity prerequisite.

1.6.1 Adaptability
The nodes of FANETs are very versatile in nature. Because of this conduct of nodes, they continue altering their area. The courses between UAVs preserve changes and separation between them is additionally not steady. Additional issue is UAV disappointment that diminishes amount of UAVs in systems. Thus, the FANET configuration ought to think about these UAV disappointments and continuous way changes. By and large execution of system relies upon the flexibility on these way fluctuations and topology alters (Lin et al., 2012).

1.6.2 Latency
It is measured as one of the principle plan necessity of any system. Delay is fundamentally use ward factor. For ongoing uses of FANET like pursuit and salvage activities, military applications dormancy ought to be low for moving data. For non-time basic applications, for example, city design arranging and so on the inertness factor can be little bargained (Rosati et al., 2013).

1.6.3 Mobility
Mobility of UAVs assumes a significant job in the exhibition of FANETs. There are a few minute examples for nodes of an ad-hoc network. Moving example may be for gathering or separate node. It is extremely vital to distinguish what moving example of UAVs may be reasonable to finish task viably and in time bound way (Rosati et al., 2013).

1.6.4 UAV Platform Constraints
UAVs utilized in FANETs have restricted consignment ability, thus they have definite limitations. Equipment weight impact the presentation of UAVs, light payload expands the continuance. Therefore, a UAV with lighter payload have the degree for extra assets, for example, sensors and other fringe gadgets. Another constraint looked by the UAVs utilized in FANETs is area restriction (Saleem et al., 2015).

1.6.5 Scalability
Multi-UAVs can upgrade the general execution of system as contrast with single UAV frameworks. Execution is improved by expanding amount of UAVs in the system. Greater the quantity of UAVs, quicker will be the assignment culmination and increasingly solid will be the system. Adaptability is significant aspect for time-oriented uses (Yap et al., 2015).

1.6.6 Bandwidth Requirement
In each FANET uses, UAVs gathers information from condition with the assistance of cameras and various sensors, gathered information is transmit to ground base over multipath course. Information gathered in
applications, for example, observing, salvage, reconnaissance and war zone is essentially high goals video, pictures and sound. Likewise caught information is critical and required to transmit with exacting postpone bound. Thus, FANETs needs high transmission capacity asset to finish activity productively with in time-bound (Yap et al., 2015).

1.7 FANET Challenges

FANET is the individual from MANET's members. It confronts certain extra difficulties alongside effectively existing difficulties in MANET member because of its high node speed, high topology alterations and portability representations.

In view of the finding of these issues and problems, upcoming are the zones recognized that need huge research to be finished:

1.7.1 Dynamic Topology

Shared associations are shaped among UAVs to keep up coordination and cooperation, and they can be successfully accomplished by means of grouping. For similar and little balance tasks, a solitary bunch is the top decision. At the point when specific UAVs must play out numerous tasks, the requirement for multi-group systems emerges. In this structure, the CH of every bunch is in charge of downlink correspondence and between group correspondences (Tazibt et al., 2017).

1.7.2 Network Formation

It is firmly combined with the development of UAVs in multi-UAV systems. To deal with an enormous amount of UAVs and a few stationary ground centers is one of the noteworthy difficulties. A broad arrangement of small scale UAVs may be available as a lot of savvy swarms. Self-sorted out UAV arrangement is a case of a keen group development. In smart bunching, UAVs can adjust to dynamic availability variation. Afterward a disturbance in association, UAVs may self-sort out to relink themselves (Han et al., 2009).

1.7.3 Routing

Routing in FANETs is not the same as other specially appointed systems family. Node development is moderately extremely high in it. So the topology changes all around habitually. Probably the greatest test is to build up an effective routing calculation that not just ready to work with high versatility hubs yet ought to rush to refresh its directing table every now and again as the topology changes (Zafar and Khan, 2016).

1.7.4 Security

Guaranteeing privacy, accessibility and Reliability of data throughout the correspondence between UAV-to-UAV correspondence and UAV-to-ground node correspondence is one of the serious problems looked by FANETs. Because of absence of physical security node bargain turns out to be simple in it. Dependence controlling between nodes is additional test because of high topology variations. Nodes connect and disconnect the system in all respects often. Protected routing is additional purpose of worry in FANET (Sahingo et al., 2014).

1.7.5 QoS (Quality of Service)

The UAVs transfer data that includes GPS location, text, images, video and audio in FANETs. For transferring such type of data, there must be some constraints to keep in mind that are to have a good QoS along with minimum end to end delays and having less error rates (Yap et al., 2015).

1.7.6 UAV Mobility and Placement

The arrangement of UAVs at proper area is one of the real investigation worries in FANETs. UAVs of various limit and ability are utilized for various reasons. Smaller than normal UAVs are intended for conveying less payloads, similar to a thermal camera, single radar, camera, picture sensor, and so forth. In this way, this is an open test to streamline the UAV situation to reduce vitality encouraging when the recovered data is taking additional time (Yap et al., 2015).

1.7.7 Reliable Data Delivery

The applications of FANETs deliver very essential information in different scenarios that needs to be carried there within s specific deadline. Thus, the network consistency should be very high. This kind may be defined with the finest delivered data (Yap et al., 2015).

1.7.8 Variable Communication Links

As of now, most open and non-military personnel applications may be achieved utilizing multi-UAV systems. In multi-UAV frameworks, the system can have various sorts of correspondence connections, for example, UAV-to-UAV and UAV-to-ground joins. The main highlights of multi-UAV systems are unwavering quality and
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survival over excess. Disappointment of a solitary UAV makes the system revamp and keep up correspondence by utilizing different nodes (D et al., 2015).

1.7.9 Base Communication Technology

In UAV systems, the IEEE-802.11 standard innovation is broadly utilized. For fewer data transfer capacity necessities, the IEEE-802.14.4 standard can be successfully utilized for UAV-to-UAV correspondences. The IEEE-802.14.4 empowers a little power and less convoluted usage with lesser information rate. The IEEE-802.11 may be utilized for UAV-to-ground correspondences since it may deal with further transmission capacity with high information rates and long-go inclusion. Throughout constant correspondence among UAVs, the MAC layer should address a couple of difficulties, for example, bundle delays, ideal channel use, high portability, and variable connection quality. In UAV systems, connect quality variances happen because of changing separations among hubs and high portability. So, as to maintain a strategic distance from confinement on the transmission goes, UAVs can speak with one another utilizing an impromptu style. This remote system is utilized to transfer information between nodes in multi-bounce correspondences for different uses. In group based UAV systems, not all UAVs can speak with the ground station or satellites: no one but CHs can speak with ground stations (Ouyang et al., 2014).

Table 1.1: Technologies with frequency ranges used in communication for FANETs.

| Network | Technology | Communication device | Computing platform | Usage |
|---------|------------|----------------------|-------------------|-------|
| FANET   | IEEE 802.11s | OMIP from Open-Mesh (universal 802.11b/g interface) | PC enables Alix boards | • Connect separated ground nodes • Multi-hop relaying mesh network |
|         | IEEE 802.11b | 2.4GHz 802.11b card Fidelity-Comtech bidirectional amplifier | Soekris single board computer | • UAVs and ground nodes in several configuration • Connecting ground nodes multi-hop mesh network |
|         | IEEE 802.11n | Compex WLE300NX 802.11a/b/g/n mini-PCIe | Intel Atom 1.6GHz CPU with 1GB RAM | • AANET single-hop and two hop performance analysis with the ground station • Infrastructure mesh |
|         | IEEE 802.11ac | Compex WLE900NS-18 miniPCIe Doodle Labs ACM-5500-1 802.11ac 5GHz miniPCIe | | |
|         | IEEE 802.11a | Compex WLE300NX 802.11a/b/g/n mini-PCIe modules | Intel Atom 1.6GHz CPU with 1GB RAM | • Two hop analysis • Infrastructure and mesh configurations • Connection with the ground station |
|         | IEEE 802.15.4 | XBee Pro Zigbee class 2-4GHz radios [Maxstream] | CUPIC avionics board (Microchip PIC18F8722 8-bit) | • Generic monitoring tasks • Temperature • Gases Others |
|         | Infrared   | VICON system         | Intel Atom Processor Z530 | • Collaborative assembly and construction tasks |
Unmanned airborne vehicles have increased much notoriety for applications which don't require human administrator or are unreasonably perilous for human administrators. They work on IEEE L-Band, IEEE S-Band and ISM band. Be that as it may, with late advances in innovation, new remote gadgets have been created which additionally work on these groups (Saleem et al., 2015).

1.8 Routing Protocol Stack for FANETs

Protocol stack shows the classification of routing protocols for FANETs based on different sub-classes according to their diverse functionalities as shown in Figure 1.10.

Figure 1.10: Routing Protocol Stack for FANETs (Oubbati et al., 2017)
1.9 Existing Wireless Communication Technologies for FANETs

Numerous present wireless technologies were applied for UAVs network. These all allow less energy consumption and almost they use the ISM-Band for communication (Mouna et al., 2016).

1.9.1 Wi-Fi (IEEE 802.11)

The IEEE-802.11ac and IEEE-802.11n allow for gaining the best performances. Efficient features of version-n that is based on such as space time block coding, cyclic delay diversity, beam forming transmission, Multiple Input and Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM). Also, this allows the enhancement of the network throughput (bandwidth) (by data rate up to 150mbps) and the enhancement of the range of the coverage (up to 250m) for the outdoor settings. Additional efficient and achievable features in version-ac are the usage of Multi-User MIMO (MU-MIMO), reliable modulations and enhanced throughput that allows the upcoming enhancement of the network bandwidth (in which data rate is up to 6.77Gbps). Apart from this, this standard has some restricted range of communication up to 100m and it maintains mobility of limited range. The IEEE-802.11n standard may be utilized for the division and dispersion the sensor’s data to the ground stations from a UAV. To satisfy the data of the sensors for distribution requirements on the basis of image quality, frame rate and acceptable delay of diverse UAV usages like forestry, 3-D reconstruction and precision agriculture this technology is efficient and able (Boehm and Schult, 2013). Wi-Fi radio may be utilized between the Incident Management System (IMS) and UAVs to stop disasters from happening because of gas leaks, fires in sabotaging the building (Rao and Vidyapeetham, 2014).

1.9.2 Bluetooth (IEEE 802.15.1)

This standard works in the unlicensed 2.4GHz recurrence band with a correspondence scope of 10 to 200m. Bluetooth innovation may be found in different adaptations with an information rate going from 1 to 3Mbps. Although, the most extreme information rate may be come to up to 24Mbps. In the Bluetooth 4.0 determinations the Bluetooth Special Interest Group (SIG) suggested and introduced Bluetooth Low Energy (BLE). Bluetooth 5 mostly spotlights on progress in transmission run, speed, vitality effectiveness, and conjunction with other short-go innovations. Moreover, Bluetooth 5 is likewise ready to communicate more extravagant information, which stretches out a long ways past the area data and incorporates mixed media and URL’s documents. Thinking about the critical enhancements, it appears Bluetooth 5 is in a genuine sense, a probable contender for the minimal effort and low-control organization of future FANET (Muhammad et al., 2019).

1.9.3 XBee (IEEE 802.15.4)

The first XBee radios were presented under the Max Stream brand in 2005 and depended on the standard 802.15.4-2003 that intended for point-to-point and star interchanges. It accomplishes an information rate of 250kbps. XBee hubs can expand their inclusion (up to 1.6km) using explicit steering methodologies (multi-jump). XBee isn’t sufficient for the trading of a lot of information, for example, pictures and recordings, yet it is suitable for moving information identified with sensors checking and control. An Xbee-PRO 900HP component may be embraced as remote correspondence module; it may be deliver constant information to the ground station for additional preparing and investigation and can get order from the beginning. The transmitted information could be flag, for example, pneumatic force, speeding up and temperature recognized by the UAVs (Qin et al., 2014). For operating it securely and safely within some harsh surroundings e.g. after some disaster like earthquake, a kind of UAV knows as quad-copter may be utilized along with one link of data transmission and different two video links. This module of XBee has to utilize and exploit for the sake of link of data transmission. That is a bi-directional link utilized to transmit some telemetry data down to the ground stations from aerial vehicles, also to deliver the control data in the opposite direction (Crespo et al., 2014).

1.9.4 Long-Term Evolution (LTE)

It is a standard of remote correspondence that enables administrators to accomplish high bandwidth in higher range data transmission. The targets for LTE are to allow full vehicular speed versatility and conjunction with HSPA and prior systems. This standard maintains high portability, long separation, low inertness, all the necessity for automaton’s correspondence. In any case, it must be utilized in authorized groups. In a swarm of Unmanned Aerial Vehicles (UAVs) outfitted with cell innovation can be utilized to incidentally offload traffic into neighboring cells in LTE/4G systems (Rohde and Wietfeld, 2012).

1.9.5 WiMAX (IEEE 802.16)

WiMAX standard preserves speeds up to 120-km/h and a range up to 30-km. It permits effective use of throughput, higher data-rates with longer distances and deals with negligible interfering. This standard is more desirable associated to other present technologies for drone’s communication in mountainous setting (Rahman, 2011). In fact, it was selected as a key due to its safety, thigh bandwidth, easy installation, efficiency to pave
large area, ability to control the QoS, low cost and the usage in both unlicensed and licensed bands. At the time of emergency situations like terroristic attack, natural event, solution of a network based on WiMAX and UAVs technology may be introduced and realized. The UAVs may be embedded with this technology standard to communicate with the ground stations and with each other’s. Actually, some UAVs are placed over a disaster of emergency oriented areas with the creativity of a wireless mesh network as a backbone that permit the communication in emergency situations (Dalmasso, 2012).

1.9.6 Fifth Generation (5G)
By following and leading 2G (GSM), 3G (UMTS), and 4G (LTE/WiMAX), fifth era, or 5G, is the most recent age of cell portable correspondence. Its conspicuous highlights incorporate a high information rate, decreased dormancy, vitality sparing, improved framework limit, and universal network. The International Telecommunication Union (ITU) predicts the dispatch of 5G adaptable systems by 2020. Such frameworks will have, per client, a speed of 100GB/s with a limit extending as much as 1000times. Attributable to such highlights, 5G innovation is ready to assume a basic job in UAV correspondence frameworks and, in this manner, clear ways for novel applications. For example, on account of UAVs in a 5G situation, less powerful system fragments of the FANET design may be connected with the center system. This will facilitate the arrangement of administrations, for example, reconnaissance interactive media gushing. The prerequisite of backhauling for consistent availability be that as it may, in any case obscures the characteristic lucidity of UAVs in a 5G organizes. Activities, for example, associating UAVs with a base band unit (BBU) and including a full scale mobile base station (MBS) do guarantee satisfaction of the backhauling prerequisite. Additional, the availability varies relying upon the variables identified with administration arrangement and system arranging. In (Muhammad et al., 2019), the creators proposed a multi-layer various leveled engineering with disseminated highlights that easily empowers the mix of UAVs with cutting edge remote correspondence systems. In addition, creators in (Muhammad et al., 2019) gave an outline on a portion of the ongoing examination attempts in UAV correspondence frameworks that address 5G strategies from the points of view of the physical layer, the system layer, and joint correspondence, registering, and storing. The situation where UAVs convey base stations (BSs) for giving 5G arrange availability in provincial settings is investigated in (Muhammad et al., 2019).

1.9.7 Satellite Communication (SATCOM)
For sending electromagnetic signals from ground stations to space stations, or satellites, and for the other way around this technology is utilized. In SATCOM, different recurrence groups are utilized by various satellites. C/Bands, which are as yet tied up with certain frameworks, use an uplink band of 6GHz and a downlink band of 4GHz. X-Bands, then again, which are ordinarily utilized by the military and administrative frameworks, utilize 8GHz for uplink and 7GHz for downlink. The alleged Ku-Bands, works on 14GHz for uplink and 11–12GHz for downlink. Additionally, these groups are likewise getting to be executed with the time. Ka-Bands take a shot at a 30GHz uplink and a 20GHz downlink. In (Muhammad et al., 2019), the creators concentrated key details, for example, satellite downlink, UAV uplink transmission control, and the picture transmission rate. It was indicated that satellite transfer accomplishes a bigger overlay run and furnishes a huge inclusion picture transmission with a high picture quality. Furthermore, the creators featured the principle issues behind applying SATCOM for live picture and video transmissions with the assistance of smaller scale and little UAS. The two noteworthy issues are lacking transfer speed and a staggering expense of information transmission (Muhammad et al., 2019).

From the above conversation, it very well may be presumed that short-extend communication technologies like Bluetooth, XBee, or Wi-Fi might be measured for medium-go FANET applications dependent on the range and bandwidth necessities. Be that as it may, if the inclusion zone is enormous and these short-extend advancements are not ready to help the required throughput requests, long-go correspondence innovations, for example, WiMAX, LTE, 5G, and SATCOM might be unmistakably increasingly fitting.

In synopsis, in view of the transmission attributes the transient advancements were utilized in light of the fact that there are legitimate purposes behind picking these advances: they work in the unlicensed range; they don't need severe LOS; and they propose a sensible information rate and inclusion. Besides, they may be effectively coordinated with little UAV. Additionally, because of the noteworthy enhancements in speed, control utilization, limit, and inclusion, Bluetooth 5 is the best choice among the previously mentioned short-go remote innovations (Muhammad et al., 2019).
Table 1.2: Evaluation between Various Communication Technologies for FANET.

| Communication Technology | IEEE Standard | Frequency/ Medium | Spectrum Type | Device Mobility | Theoretical Data Rate | Range Indoor- Outdoor | Network Topology | Latency | Advantages | Limitations |
|-------------------------|---------------|-------------------|---------------|----------------|-----------------------|------------------------|-----------------|--------|------------|------------|
|                        |               |                   |               |                |                       |                        |                 |        |            |            |
| Wi-Fi                   | 802.11        | 2.4GHz LR         | Unlicensed    | Yes            | Up to 54Mbps         | 20m-100m               | Ad-hoc, star, mesh, hybrid | <5ms   | High Speed and Cheap | Limited Range |
|                        | 802.11a       | 5GHz              | Unlicensed    | Yes            | Up to 54Mbps         | 35m-120m               | Ad-hoc, star, mesh, hybrid |        |            |            |
|                        | 8.2.11b       | 2.4GHz            | Unlicensed    | Yes            | Up to 11Mbps         | 35m-140m               | Ad-hoc, star, mesh, hybrid |        |            |            |
|                        | 802.11a       | 2.4GHz            | Unlicensed    | Yes            | Up to 600Mbps        | 75m-250m               | Ad-hoc, star, mesh, hybrid |        |            |            |
|                        | 802.11g       | 2.4GHz            | Unlicensed    | Yes            | Up to 54Mbps         | 35m-140m               | Ad-hoc, star, mesh, hybrid |        |            |            |
|                        | 802.11e       | 5GHz              | Unlicensed    | Yes            | Up to 3166Mbps       | 35m-120m               | Ad-hoc, star, mesh, hybrid |        |            |            |
| Bluetooth 5             | 802.15.1      | 2.4GHz            | Unlicensed    | Yes            | Up to 2Mbps          | 40m-200m               | Ad-hoc, star, mesh, hybrid | 3ms    | Energy-efficient | Low data rate |
|                        | 802.15.4      | 2.4GHz            | Unlicensed    | Yes            | 250kbps              | 10m-100m               | Ad-hoc, star, mesh, hybrid | 15ms   | Low-cost    | Low data rate |
| WIMAX                   | 802.16e       | 3.11GHz           | Licensed      | Yes            | Up to 15Mbps         | Up to 43km             | Wide area, wireless backbone | 10ms   | High throughput | Interference issues |
| LTE                     | LTE           | Up to 200MHz      | Licensed      | Yes            | Up to 300Mbps        | Up to 100km           | Flat, IP based | 3ms    | High bandwidth | Expensive |
|                        | LTE           |                     |               |                |                       |                        | IP based         |        |            |            |
|                        | 5G (5G MB)    | 28GHz             | Licensed      | Yes            | Up to 200Mbps        | Wide area             | IP based         | 1ms    | High data rate | Expensive |
| Satellite               | Satellite     | Up to 40GHz       | Licensed      | Yes            | Up to 1Gbps          | World wide            | Wide coverage   | 500ms  | Wide coverage | High-delay and cost |

1.10 Motivation and Background

In the current years, too much attention has arisen in FANET's routing protocols for the sake of link stability that have the ability to deliver data with high PDR in different scenarios. The characteristics of link stability along with the highest priority of the node selection as inner part of the network and guider node have been developed to reduce E2ED and decrease packet loss ratio. The selection criteria in this procedure will be selected by using the appropriate route and node from source to destination.

The proposed work is based on the two FANET's existing routing protocols that are DPTR and LEPR. Each protocol performs different kind of functionality according to their algorithms and methodologies. The only thing that differentiates the proposed work from existing work is that in proposed work two parameters Network Lifetime and Transmission Loss were applied but that were not in the simulation results with the existing work. Due to some lack in the existing schemes, the current research work has focused to overcome it and by taking the positive features of both schemes. In both schemes, the network partitioning by using R-B tree and using the link stability metric are separate features. By merging these both functionalities makes the proposed schemes different from the existing works. In short, the proposed work is motivated from the existing work by taking their algorithms and methodologies into considerations and by merging their positive features in a proposed hybrid routing protocol named DLSA. This keeps apart/differ the propose scheme from the existing schemes by merging their positive features and applying them in stand-alone hybrid routing protocol for the sake of FANET's link stability and choosing the highest priority node selection.

1.11 Problem Statement

The nodes of FANETs have high mobility and dynamic topology, therefore to maintain communication among these high mobility nodes is a research challenge. DPTR and LEPR are routing schemes that are used for nodes link stability and selection of nodes having highest priority in FANETs. In DPTR (Distributed Priority Tree-based Routing) protocol, the communication becomes possible by combining two ad-hoc networks of ground and aerial to solve the problem of network partitioning. This protocol assumes neural interface (relay nodes) for communication between sending and receiving nodes. Though, this scheme doesn't consider link stability among nodes that causes higher delay and packet loss ratio. On the other hand, LEPR (Link Stability Estimation-based Preemptive Routing) protocol utilizes link stability metric procedure for connectivity of links between nodes. This
protocol uses the above procedure for pre-emptive estimation of link stability. The selection criterion is carried out via maximum metric (threshold) value of the nodes from sender to receiver to find the suitable route. This scheme undergoes from unnecessary requests at the link formation stage, which eventually affects the nearby nodes and at the end, the network becomes dense results in increasing packet loss ratio.

1.12 Proposed Solution
The main problems with the existing routing protocols are high delay and high packet loss. To overcome these problems, a hybrid routing protocol named Delay and Link Stability Aware (DLSA) routing protocol for FANET has been proposed.

1.13 Objectives
i. To design Delay and Link Stability Aware (DLSA) Routing Protocol for FANETs.
ii. To compare DLSA with DPTR and LEPR routing schemes in terms of End-to-End Delay and Packet Delivery Ratio (PDR).

1.14 Significance of the Study
The significance of the proposed research work consists to route data in FANETs with minimum delay and high PDR over the link in which merits of every node has been properly utilized. The suggested routing scheme used the network partitioning of the Ground and Aerial ad-hoc networks along with the new link stability estimation metric procedure to select and most reliable and appropriate route by pre-emptive mechanism. The stability metric value has been calculated based on their given estimation metric values to choose the highest values of the nodes from source to destination. From the applications of FANETs, it has been concluded the major and key significance of the desired study. Due to vast availability of FANET, it can enhances the communication of the advance technologies by using the efficient algorithms to deliver data from source to destination within reliable time having increased PDR and minimize End to End Delay in relative to the compared schemes.

1.15 Limitations of the Study
Well it has been concluded that the suggested routing scheme has improvised many tasks to overcome and make it easy. However, along with that some issues may arise like the need of communication platform, energy constraints, reliable data delivery, consistency of the nodes, need of high bandwidth, node scalability, geographic scalability and some security issues may arise with FANET that needs to be solved properly by using some efficient and robust routing schemes. Apart from the positive and negative or pros and cons, the existing study possess many limitations that needs to be solved properly by robust and reliable algorithms.

1.16 Organization of Thesis
The rest of the structure of this thesis is:

Chapter II: Describes review of the related literature about routing protocols and their performance based on the desired evaluation parameters in FANETs.

Chapter III: Discusses about the proposed mechanism and system model of the research along with the implementation work of thesis about MATLAB simulator. And, also describe how to generate the desired results by using the performance evaluation parameters.

Chapter IV: Shows the MATLAB simulated results and discussion of DLSA routing protocol with the comparison of DPTR and LEPR. The existing routing protocols comparison with the new one is measured and simulated on the basis of E2ED, PDR, Network Lifetime and Transmission Loss.

Chapter V: Discusses the summary, conclusion, contribution and future recommendation of the proposed DLSA routing protocol for FANETs.

1.17 Summary
This chapter gave the overview and types of MANETs and also discussed a detail overview about FANET with its characteristics, applications, routing issues and challenges. In this section, significance, limitations, motivation, problem statement and proposed solution of the concerned research have also been briefed. The organization of the thesis gave the overall structure of the thesis.

II. LITERATURE REVIEW

This chapter explains all the previous reviews in which the works have been done on the routing for Flying Ad-hoc Networks (FANETs). This chapter summarizes the solution of the open issues and challenges that causes a severe problem to the network. Some of the previous works like seamless handover procedure, node placements, network stability period, node mobility with highly dynamic topology and many more are discussed in the
previous papers. Most of the researchers used the mobility models and novel routing schemes for the sake of the improvement of FANETs. The stability metric was used to measure the link dis-joint paths between source and destination.

Qingwen et al. (2015) proposed a versatile sending scheme (AFP) for 3D Flying Ad Hoc Networks (FANETs). The principle goal was to compute sending likelihood adaptively so as to expand the proficiency of sending in FANETs. The Unmanned Air Vehicle (UAV) nodes with longer separation to the last bounce forwarder and closer to the goal rebroadcast the message with higher likelihood. Moreover, a sending zone basis was incorporated into the proposed scheme to decrease the messed up connections because of mobility of nodes among the middle of the road nodes. They depicted the scheme, actualized it and assessed its exhibition utilizing NS-2 organize test system. Reenactment results uncovered that the proposed scheme accomplished better execution as far as the normal parcel drop part and normal start to finish delay, which is individually contrasted and VBF.

Singh and Verma (2015) investigated AODV, DSDV and OLSR routing schemes under the various parameters for example start to finish Delay, Average Throughput and Packet Delivery Ratio as for speed of portable hub. Through the recreation (NS-2) results it has been unmistakably observed that, OLSR routing scheme performed superior to anything the other two steering scheme AODV and DSDV as far as End to End Delay, Average Throughput and Packet Delivery Ratio. So the presentation of FANET had been enhanced by picking OLSR as a routing scheme.

Temel and Bekmezci (2015) presented a new routing MAC (Medium Access Control) scheme for FANET named Location Oriented Directional-MAC (LOD-MAC), which had incorporated the appropriate use and utilization of the directed antenna and the estimation of the location of the nearby nodes within that MAC layer. For this purpose, they had defined a novel Busy-to-Send (BTS) packet along with the Clear-to-Send (CTS) and Request-to-Send (RTS) packets, LOD-MAC successfully addressed the well-known directional deafness problem. On the basis of utilization, throughput, fairness and average delay of the network, LOD-MAC protocol performed well than well-known D-MAC (Directional-MAC) scheme which put LOD-MAC to be a robust mile-stone for the upcoming MAC routing schemes of FANET.

Kaur and Talwar (2016) proposed and compared Data Centric Routing (DCR), Destination Sequence Distance Vector (DSDV), Load Carry and Delivery Routing (LCDR) and Optimized Link State Routing (OLSR) the existing routing schemes for FANET. The proposed routing schemes were analyzed for FANETs using MATLAB simulations in terms of various performance parameters like, channel utilization, transmission delay, path loss, stability period of the network, throughput, and packet loss. Finally, the simulated results were compared with each existing schemes in terms of these parameters. At the end, they also recorded various open research issues like consumption of energy, topological formation and mobility models for FANETs.

Rosati et al. (2016) compared the efficiency and performance of Predictive-OLSR (P-OLSR) along with the Optimized Link-State Routing (OLSR) in FANETs, which is an ad-hoc network, consists of UAVs. Such networks were characterized by high degree of mobility of the nodes, which create a challenging issue to the routing scheme in FANET. The basic routing schemes were designed and developed for MANETs had some critical issues, like those that they fail in evaluating the development of the network topology. They have addressed this problem by designing an OLSR extension, called P-OLSR; which collects the information by the help of GPS to find and predict the suitable link for the network that is not going to change. They have analyzed the routing schemes by the practical implementation of the simulation based study. With P-OLSR, the routing has to follows the change in topology without interruptions, which were not the case with OLSR.

Bilal and Khan (2017) performed experimental performance evaluation of available mobility models that can generate realistic scenarios for FANET applications. Both reactive (AODV and DSR) and proactive (OLSR) routing protocols were compared for Reference Point Group, Gauss Markov, Random Waypoint and Manhattan Grid Mobility models. Average routing overhead, Packet Delivery Ratio (PDR) and end-to-end delay were used as performance metrics values for examining and analyzing maximum reliability and minimal latency requirements for FANETs. Proposed system showed that Dynamic Source Routing (DSR) had outperformed Ad-hoc On Demand Distance Vector (AODV) and Optimized Link State Routing (OLSR) schemes on the basis of PDR, latency and routing overhead for proposed mobility models.

Gankhuyag et al. (2017) analyzed the efficiency of well-known ad-hoc schemes under different models of propagation for FANETs. The concerned study was conducted by two ray ground, free space and shadowing model of propagation. They also experimentally analyzed the impact of these models on the existing DSDV, DSR and AODV routing schemes. The experimental analysis of the simulation had shown remarkable results of the existing propagation models that have a specific role in signal processing along with the antenna gain. These
propagation models had placed an extension to the antenna gain and travel of a signal with the omnidirectional and directional antenna. The performance parameters for simulations were transmission loss, PDR and packet loss. Along with the mentioned parameters, the results had also showed efficiency and improvements in comparison with the static directional type antenna with a non-adaptive antenna by applying the proposed approach.

Ghazzai et al. (2017) suggested the problem of data routing in FANETs an ad-hoc network collection of nodes known as UAVs that fly in the air. They suggested an analytical simulation based study for existing routing schemes such as AODV, DSDV, P-OLSR and DSR of FANETs. The main goal and objective was to efficiently deliver a message from sender node to receiver node that possesses dynamic topology and high mobility. Due to high mobility of the flying nodes, they had used different kinds of mobility models to link the ground nodes with the flying nodes. Simulations were obtained in NS-3 by using random waypoint and gauss markov mobility models. The mobility models were performed by inspirings from the Hooke-Jeeves algorithm to efficiently deliver messages from ground nodes to flying nodes that have dynamic topology. From the simulation results it had concluded that for UAV network these two mobility models can perform efficiently.

Li and Yan (2017) presented a novel routing scheme named Link Stability Estimation-based Pre-emptive Routing (LEPR) scheme that had aimed FANET by the help of AODV, a current routing scheme for ad-hoc network. To take information regarding GPS location, a new metric was introduced named link stability metric procedure, which uses the link threshold value for the upcoming-targeted node. The working procedure of this new stability metric was to make the estimation of the safety degree, mobility and link quality, to take into the consideration of the past, current and future statuses of the link stability correspondingly. By the help of this novel stability approach, the LEPR had the ability to calculate many robust link-disjoint routes at the time of route discovery process. In accumulation, a semi-proactive process of route maintenance was also generated to check for the link stability in advance when an anticipated path is about to break. This new schemes had reduced the number of broken paths and latency of packets by discovering and hand overs early to an efficient and reliable path. The suggested approach had shown and demonstrated that LEPR had efficiently and significantly best performed two existing AODV and DSR routing schemes on the basis of PDR, Delay and routing overhead, in a highly or either low settings of mobility.

Mittal and Singh (2017) evaluated the performance and efficiency of two routing protocols of FANETs are DSDV (pro-active) and AOMDV (re-active) under different models of mobility. The performance and efficiency of DSDV and AOMDV routing schemes were explored under the Random Waypoint, Gauss-Markov, and the proposed Chain Mobility Model. The simulation had done by using NS-2 (Network Simulator-2) Tool. The results had showed that DSDV scheme achieved well based on End-to-End Delay but AOMDV scheme had achieved well in based on PDR when the amount of nodes increases under the suggested Chain Mobility Model instead of Gauss-Markov and Random Waypoint Mobility Models.

Oubbati et al. (2017) recommended the perspective of UAVs to cooperate with VANETs on the ground in an ad-hoc fashion. For improvement and assessment of the routing process and to enhance the efficiency and reliability of the delivery of data by connecting the gap of communication when it is possible. In this suggested work, they had introduced a novel routing scheme named UAV-Assisted VANET Routing (U-VAR) scheme that increases that routing of data and the connectivity of the ground nodes with the air nodes. However, U-VAR does not completely operate the UAVs in the air for forwarding of data; the reason is that is utilizing only UAVs when the network is completely dense or poor. Here, they have proposed an improvement extension of this scheme by taking the advantage of the alternate ways of the data routing (i) data packets delivering completely on the ground surface utilizing UAV-G and (ii) data packet transmitting in the air by utilizing a reactive routing on the basis of UAVAR-S. Proposed mechanism demonstrated that the hybrid transmission and connectivity between vehicles and UAVs was perfectly suitable for VANETs matched to previous vehicle-to-vehicle (V2V) communications.

Zafar and Khan (2017) presented the concept of multi-cluster FANETs engaging the standard of IEEE 802.15.4 MAC layer scheme for communication of UAV-to-UAV. To the best the author’s knowledge, it was the initial of this type of the proposal. The suggested routing scheme had allowed the features of reliable, time dependent and collision free transmission by emerging and utilizing the GTS and virtual TDMA schemes in modes of beacon-enabled and beaconless of the standard 802.15.4 accordingly. In the proposed scheme, they had examined by utilizing the ad-hoc routing schemes AODV, DSDV and OLSR. The simulated results had clearly revealed that this scheme had meets the best achievement the QoS in comparison to the single-cluster based network along with employing further complex routing schemes. 802.15.4 Had promised and proved the best and efficient level of showing 80-97% PDR rates and also compared the delays of networks to IEEE 802.11 that involved time complexity and have high bandwidth. Here, IEEE 802.15.4 had the best and suitable choice for not exhaustive bandwidth applications and need fewer rate of data for communication. The presented study had been performed considering networks that have fixed number of air vehicles i.e. UAVs.
Zheng et al. (2017) suggested a probability assumed routing scheme for FANET named Adaptive Density-based Routing Protocol (ADRP). The key objective of this scheme was to calculate the probability adaptively of the forwarding data rate to maximize the forwarding performance in FANETs. ADRP randomly and dynamically refined and probability of broadcasting and re-broadcasting of the flying nodes that need full successful data delivery and less delay to take into account the amount of the nearby nodes of the network. Perhaps, it was much suitable and interesting to give privilege to the transmission and retransmission of the nodes with having less number of nearby nodes. The proposed scheme had revealed that ADRP had gained much better results on the basis of PDR, average End-to-End delay, throughput, normalized MAC load and normalized overhead, that were respectively matched with the existing routing scheme AODV. The suggested scheme had significant role for the efficiency of routing schemes for FANETs. ADRP calculated the probability adaptively of the forwarding data rates to maximize the routing discovery efficiency. The nodes that have less number of nearby nodes had to forward the RREQ (Route Request) packet with absolute possibility that decreases the average End-to-End Delay and re-broadcast of redundant data.

Alnuami (2018) compared between the main ad-hoc wireless networks i.e. VANET, MANET and FANET. Furthermore, Mobility is the greatest interesting problematic for FANET network. On the other hand, in this research there are different parameters (PDR, E2E delay and throughput). In addition, AODV more appropriate for FANET environment than DSR with different number of nodes in the FANET network) in different number of nodes with two types of routing protocol. The estimation results of (NS-2) focused on the AODV routing was better than DSR routing on FANET network, because the first routing was flexible for the environment of the FANET and could be developing this protocol to be more suitable.

Arafat and Moh (2018) proposed a location-aided delay tolerant routing (LADTR) scheme for UAV systems for use in post-calamity activities, which endeavors area helped sending joined with a store-convey forward (SCF) procedure. Shipping UAVs were acquainted with empowering an effective SCF, and this was the main endeavor at presenting and utilizing shipping UAVs for steering in UAV systems. Apparently, Shipping UAVs improved the accessibility of association ways between looking UAVs and the ground station, in this manner lessening start to finish delays and expanding the parcel conveyance proportion. Future, UAV areas were evaluated dependent on the area and speed of UAVs outfitted with a worldwide situating framework. The sending UAV hub anticipated the situation of the goal UAV hub and afterward chosen where to advance. The proposed LADTR guaranteed that the contact rate between UAV nodes stays high, which empowered a high parcel conveyance proportion, and guaranteed single-duplicate information sending to dodge replication of each message. Their exhibition study demonstrated that the proposed LADTR outflanked the four regular steering schemes detailed in the writing as far as parcel conveyance proportion, normal postponement, and routing overhead.

Choi et al. (2018) presented a geo-location-based routing protocol for FANET with multi-hop network communication. Their proposed protocol showed robust and reliable performance to the dynamic multi-hop network topology. A network topology composed of UAVs is highly dynamic due to the high speed of UAVs while executing missions. In this circumstance, their protocol used geo-location information of neighbors and then finds the routing path to the destination by only considering the neighbor information, which in turn resulted in low overhead and robustness to the dynamic network topology in FANETs. They also provided implementation of the proposed geo-location-based protocol and test-bed environments.

Fabra et al. (2018) proposed a novel plan that depended on the occasional accommodation of state data, and estimations concerning future UAV positions, permitting crash dangers to be identified early. Crash shirking was accomplished by driving UAVs to stop when they are flying basically close to one another, and building up a need to figure out which UAV will experience the basic territory first. This choice depended on a for every UAV extraordinary identifier. They demonstrated that their answer was powerful enough to keep away from crashes in every one of the circumstances tried. Also, the overhead presented by their scheme as far as extra UAV flight time was low.

Hong et al. (2018) analyzed the effect of hub movement on the exhibition of routing schemes of Flying Ad Hoc Network (FANET). Regardless of whether the exemplary MANET routing schemes are reasonable for the profoundly powerful situations was talked about dependent on investigations. Reenactments (ns-3) were completed in three mobility models condensed from genuine FANET application situations with very unique condition. The concerned network performance metrics including average end-to-end delay, packet delivery fraction, network throughput and average jitter were compared respectively. The network showed different performance of different mobility models under the same conditions, the reason for which was that nodes do not have the same mobility behaviors. This paper revealed that the variation of the network topology caused by the relative speed of nodes was the main reason of the fluctuation of network performance.


Hussen et al. (2018) analyzed the performance of different MANET routing protocols for the communication of UAVs. Using riverbed OPNET modeler, they evaluated the performance of four MANET routing protocols that are AODV, DSR, GRP and OLSR for UAV communication based on scenarios of various data rates supported by IEEE 802.11p WAVE standard. The evaluation results has revealed that (a) varying the data rate values has an impact in the delay performance of all protocols (b) AODV has experienced the least load followed by DSR and GPR (c) the DSR has exhibited the least routing traffic overhead, the lowest throughput and the highest delay as compared to other protocols (d) GRP has experienced higher load than AODV and DSR (e) the OLSR protocol has experienced the highest routing traffic overhead followed by GRP and AODV (f) the OLSR protocol has showed the highest throughput performance followed by GRP and AODV (g) the OLSR protocol has showed the lowest delay followed by AODV and GRP (h) the OLSR protocol has showed maximum load followed by GRP and AODV.

Khan et al. (2018) proposed an assortment of customary ad-hoc systems administration schemes and tried for FANETs to build up an effective and strong correspondence among the UAVs. In this unique circumstance, topology-based steering was viewed as the most noteworthy methodology for settling the routing issues in FANETs. Along these lines, in this article they explicitly centered on topology-based routing schemes with the point of improving the productivity of the system as far as throughput, start to finish postponement, and system load. They exhibited a short survey of the most significant topology-based steering schemes with regards to FANETs. They gave them their working highlights for trading data, alongside the upsides and downsides of every scheme. In addition, reproduction examinations of a portion of the topology-based routing schemes were additionally assessed as far as to finish deferral, throughput and system load by utilizing streamlined system designing instruments (OPNET) test system.

Mehrdad et al. (2018) exhibited a separation based insatiable routing scheme for UAV organizes exclusively dependent on UAVs’ neighborhood perceptions of their encompassing sub arrange. Accordingly, neither a focal chief nor a tedious course arrangement and support instrument was required. To assess the proposed strategy, they determined an expository destined for the normal number of jumps that a bundle navigates. Likewise, they found the normal start to finish separation gone by every bundle just as the likelihood of fruitful conveyance. The recreation results checked the exactness of the created scientific articulations and indicated extensive improvement contrasted with incorporated most brief way steering calculations.

Park et al. (2018) presented particularly the use of UAS Traffic Management (UTM) framework dependent on Wireless Access in Vehicular Environment (WAVE) scheme as one of most proficient and stable schemes in situations with rapid mobility and dynamic evolving topology. Besides, they planned a system design that bolstered direct correspondence among UAVs just as UAV and ground station inside the UTM structure. By applying WAVE scheme in the UTM framework, it was conceivable to transmit messages quickly and precisely to forestall impact in case of a crisis, and to design the UTM framework to deal with all UAVs by applying a WAVE-based specially appointed system.

Pu (2018) proposed a jamming-resilient multipath routing protocol, additionally called Jarm-Rout, with the goal that purposeful sticking and disturbance, or detached and restricted disappointments don't intrude on the general system execution of FANETs. To accomplish this objective, the Jarm-Rout depended on a mix of three noteworthy plans, which are connecting quality plan, traffic burden plan, and spatial separation plot. They exhibited a basic systematic model and its numerical outcome as far as RREP parcel gathering rate of source hub. They additionally assessed the proposed steering scheme through broad recreation tests utilizing the OMNeT++ and contrasted its exhibition and three delegate routing schemes, which are dynamic source steering (DSR), advanced connection state routing (OLSR), and split multipath steering (SMR), separately. Reenactment results demonstrated that the JarmRout cannot just improve bundle conveyance proportion and parcel conveyance dormancy, yet in addition can decrease start to finish correspondence blackout rate without presenting additional correspondence overhead, showing a suitable way to deal with improve arrange strength within the sight of malignant jammers in FANETs.

Sadiq et al. (2018) exhibited a novel information and coordinated control routing scheme which is Flying Adhoc Network (FANET) explicit. The created FANET explicit routing scheme laid accentuation on the course availability in the system by considering the caught information estimate, least reasonable separation between arbitrarily moving nodes and association time. The presentation of the proposed FANET explicit steering scheme was reproduced utilizing NS-3. The acquired throughput esteem for the routing scheme changed somewhere in the range of 754.023kbps as information was traded between nodes. This demonstrated when all the UAVs are on the system and speaking with each other, the throughput was level line and not plunges. This suggested consistency as nodes join and leave the system. The parcel conveyance proportion got for the FSRP during reproduction was 96.13 %. These outcomes suggested that information is effectively transmitted between the UAV going about as server and UAV going about as customer on the system.
Sharma et al. (2018) proposed a new Optimized Fruit Fly Routing Protocol (OFFRP) which utilized the properties of existing natural product fly advancement calculation for discovering suitable courses. The inquiry of sustenance sources by organic product flies utilizing their smell record shapes the premise of the proposed scheme. The scheme not just upgraded the system arrangement between the elevated and ground nodes yet additionally given clog free information transmission. The proposed scheme was assessed utilizing standard system reenactments (NS) and was contrasted and all the major routing schemes just as existing TCP-arranged blockage control calculations.

Sharma et al. (2018) proposed a hybrid tree-based routing protocol that had divided the FANETs into mutually connecting of two ad-hoc networks with the collaboration of the network partitioning between the ground and aerial ad-hoc networks. For the purpose of the network partitioning and mutually coordinating of two ad-hoc networks, they had proposed a novel hybrid routing scheme that fixed the problems that were associated the creation of topology and routing between concurrently in operation of nodes of two different ad-hoc creations. The suggested routing scheme was originated and had extended the properties of the distributed Red-Black (R-B) tree, which had formed a priority based network that permits the selection of the suitable nodes also selection of the channels as a relaying nodes. This novel scheme named Distributed Priority Tree-Based Routing (DPTR) Protocol. The DPTR scheme was examined and analyzed using NS-2 and MATLAB with the contrast of the current state-of-the-art routing schemes. The simulation results showed that DPTR had significantly gained higher performance in terms of PDR, End-to-End Delay, and network throughput, probability of connectivity, channel utilization and routing overhead.

Wu et al. (2018) proposed a FANETs multi-channel MAC scheme called FM-MAC, which joined the benefits of multi-channel and directional reception apparatus to give distinctive QoS ensures. Right off the bat, a booking plan dependent on versatile forecast was proposed to address the connection intrusion issue brought by high portability of UAVs. Furthermore, they proposed an appropriation instrument to give need to support bundles. Reproduction results (OPNET recreation) demonstrated that contrasted and other two agent schemes, FM-MAC improved the throughput of administration parcels, yet in addition accomplished lower delay and higher unwavering quality for security bundles.

Xie (2018) presented forward another type of the Optimized Link-State Routing (OLSR) scheme: that can suit quick powerful topology changes and avert the interference of correspondence. The key thought was to utilize Global Positioning System (GPS) data to ascertain hub interface lapse time and consider remaining vitality. The improved multi metric ETX (Expected Transmission Count) reproduction in OLSR was done in the NS-3 test system. In this way, this paper announced the trial aftereffects of routing schemes conveyed by little flying robots in marine scenes, and these numerical outcomes demonstrated that the new scheme was essentially better than the customary OLSR as far as bundle transmission rate, End-to-End delay and steering overheads, giving dependable correspondence in the sea FANETs.

Zheng et al. (2018) proposed an adaptive novel hybrid communication scheme having a new Position-Prediction-Based Directional MAC (PP-MAC) and a Self-learning Routing Protocol on the basis of Reinforcement Learning (RLSRP) routing schemes. The simulated results of the PP-MAC had showed that this scheme countersigned and overcome the problem of directional deafness along with the directional antenna. While RL-SRP had given a self-independent changing and much efficient routing scheme. Their proposed hybrid adaptive communication schemes had showed best performance and had the ability to deliver a highly autonomous and intelligent communication solution for the sake of FANETs. They also specified the main research direction of the FANET schemes.

Zheng et al. (2018) proposed a Stable Ant-based Routing Protocol (SARP) for Flying Ad Hoc Networks. SARP is based on the Ant Colony Optimization meta-heuristic, which selects the next hop node according the stable value, pheromone and the energy of the link. The stable value was calculated by the transmission range of the node and the distance between the current node and the next hop nodes. SARP let the nodes broadcasted HELLO messages periodically to obtain the neighbor information. They described SARP, implemented it and evaluated its performance using NS-2 network simulator. Simulation results revealed that SARP achieved better performance in terms of the packet delivery fraction, throughput and normalized routing load, which is respectively compared with AODV.

De Rango et al. (2019) proposed a bio-inspired routing protocol for Unmanned Aircraft Vehicles (UAVs) the board in the agribusiness area. In exactness agribusiness the nearness of parasites or the unexpected climatic changes speak to a significant issue for ranchers as a result of the debasement of yields and development quality. At that point, the utilization of the new advancements, for example, UAVs gadgets, the new systems, for example, Flying Ad-Hoc NETwork (FANET), and the usage of new sensors and actuators inside UAV sweep speak to a significant guide to the keen horticulture area. A significant perspective is, clearly, the satisfactory administration
and coordination of these new gadgets so as to design explicit systems ready to help sufficiently the agribusiness people's administrators. Since automatons are asset compelled and constrained, adaptable coordination procedures such those proposed can improve the system execution keeping up higher proficiency in the assignment execution.

Elfar et al. (2019) combined cooperation protocol for human-unmanned aircraft vehicle (H-UAV) order and control frameworks, where the human administrator helps in verifying the UAV by discontinuously performing geo area errands to affirm its announced area. They originally exhibited a stochastic game-based model for the framework that records for both the administrator and a foe fit for propelling stealthy false-information infusion at-tacks, making the UAV veer off from its way. They additionally portrayed an amalgamation challenge because of the UAV's concealed data imperative. Next, they performed human analyses utilizing a created RESCHU-SA proving ground to perceive the geo area methodologies that administrators receive. Besides, they conveyed AI systems on the gathered exploratory information to foresee the rightness of a geo area task at a given area dependent on its topographical highlights. By speaking to the model as a deferred activity game and formalizing the framework destinations, they used off-the-rack model checkers to blend schemes for the human-UAV alliance that fulfill these goals. At long last, they exhibited the handiness of the H-UAV scheme combination through a contextual investigation where the schemes were tentatively examined and further assessed by human administrators.

Hong and Zhang (2019) proposed a routing scheme suitable for highly dynamic FANET for the quick variation of topology in complex and difficult situations. In this protocol, they have introduced that the movable node will have to read and sense the environment and change the topology of the network with time dependent manner. Also the existing scenario of mobile was assured by taking the information from the retrieved results of simulation. Additional, an efficient and reliable routing scheme was chosen to maintain the performance of the network at high degree and level. For this study, they have taken PDR, average E2E Delay, network throughput and average jitter. The simulation experiments were gathered by using three kinds of mobility models that are the reference point group mobility model, the pursue mobility model and chain scenario models with the simulation a huge alterations of the topology of the network. From the Network Simulator (NS-version 3.25) the concerned results have shown that the desired routing protocol may change to the fast variations within the topology of the network and had efficiently enhanced the performance of the network.

2.1 Summary
The previous studies have presented that most of researchers were worked on different routing schemes like Distributed Priority Tree-Based (DPTR), Link Stability Estimation-base Preemptive (LEPR) and Ad-hoc On-demand Distance Vector (AODV) routing schemes for FANETs. Most of the researchers have used the different routing strategies and mobility models for routing in FANETs and different routing schemes. On the basis of the literature review, the current study has designed a novel Delay and Link Stability Aware (DLSA) Routing Protocol in which priority base node selection and link stability metric procedure have been used as proposed mechanism. The link stability mechanism is used for the increasing of link lifetime, reliability of link stability and also the protocol is transmission delay aware that has achieved higher performance in FANET.

Table 2.1: Summary of the Literature Review.

| Year | Author(s) | Title | Aim and Objective |
|------|-----------|-------|-------------------|
| 2017 | Li and Yan | LEPR: Link Stability Estimation-based Preemptive Routing Protocol for FANETs | Proposed LEPR on the basis of DSR and AODV. With the help of taking the advantage of GPS location information. Though LEPR suffers from unnecessary requests. |
| 2018 | Sharma et al. | DPTR: Distributed Priority Tree-based Routing Protocol for Flying Ad-hoc Networks | DPTR protocol was based on the concept of R-B tree that forms nodes and balances the nodes at both sides. Also this protocol used the three ad-hoc networks concepts that are aerial, ground and mutual link (relay nodes). This scheme suffers from end to end delay by using the alternative ones. |
| 2018 | Alnuami | Comparison Between | Compared between the main ad-hoc wireless networks |
| Year | Authors | Title | Description |
|------|---------|-------|-------------|
| 2018 | Choi et al. | Geolocation-Based Routing Protocol for Flying Ad Hoc Networks (FANETs) | Presented a geo-location-based routing protocol for FANET with multi-hop network communication. Their proposed protocol showed robust and reliable performance to the dynamic multi-hop network topology. |
| 2019 | De Rango et al. | Scalable and light-way bio-inspired coordination protocol for FANET in precision agriculture applications | Proposed a bio-inspired routing protocol for Unmanned Aircraft Vehicles (UAVs) the board in the agribusiness area. In exactness agribusiness the nearness of parasites or the unexpected climatic changes speak to a significant issue for ranchers as a result of the debasement of yields and development quality. |
| 2019 | Elfar et al. | Security-Aware Synthesis of Human-UAV Protocols | Combined cooperation protocol for human-unmanned aircraft vehicle (H-UAV) order and control frameworks, where the human administrator helps in verifying the UAV by discontinuously performing geo area errands to affirm its announced area. |
| 2019 | Hong and Zhang | A Topology Change Aware-Based Routing Protocol Choosing Scheme of FANETs | Proposed a routing scheme suitable for highly dynamic FANET for the rapid change of topology in complex scenarios. In this scheme, the moving nodes sense changes of the surrounding network topology periodically, and the current mobile scenario was confirmed according to the perceived result. |

### III. RESEARCH METHODOLOGY

The purpose of this research was to design and compare the efficiency of new routing protocol in terms of different parameters at different evaluation methods. The goal has achieved by using the proposed mechanism for the design of new routing protocol. The methodology of this research work has proceeded in the given sequence as shown in Figure 3.1 and the steps are described as follows:

In methodology, eight steps are involved in design of DLSA based on priority selection and link stability procedure. In Figure 3.1, the initial step is proposed mechanism for proposed solution, which indicates that how the research has to be carried out. In second step, MATLAB simulation tool is implemented. In third step, various simulation parameters are used for simulation. In fourth step, DLSA routing protocol was designed. In fifth step, performance evaluation parameters are selected. In sixth step, comparison of DLSA routing protocol with DPTR and LEPR were carried out. In seventh and eighth steps results, discussion and conclusion for the research work are obtained and discussed.
3.1 Proposed Mechanism

In our proposed mechanism, first step is the initialization phase. Next step is deployment phase in the perspective of routing phase which ultimately checks for the routing i.e. to check for the communication that is about to take place from source to destination. Then comes the network partitioning phase, in this phase the network will be divided into partitions i.e. to separate both the aerial and ground ad hoc networks. For this procedure, in the next step the given condition will check firstly that if the collaborative mode is active. The collaborative mode will express that either the communication is one sided or from both collaborative mode (ground and aerial).

After network partitioning and collaborative communication, the next phase is here to construct the Red Black (R-B) priority tree for three networks (M, N and K) i.e. Aerial (M), Ground (N), and by using the Neural interface as a virtual layer works an intermediary as a Neural (K). N, M and K are symbols that represent three separate networks as described. The R-B priority tree selects the nodes on the basis of the highest priority. After that the top node selection phase will come which were derived from the previous phase. Now here comes the condition that if the highest priority node is selected then proceeds and if not then repeat the highest priority node selection phase.

After the node priority, the next phase is to check for the link stability, as the highest priority nodes are selected but to maintain the communication through link stability. The next step is based on condition, in which the nodes stability metric values will be pre-defined. This condition will check that either the threshold value of the current link stability is greater than the defined value. If yes, then the data will direct transfer through the direct transfer phase. If no, then the link stability metric procedure will be followed. In link stability metric procedure, first task will be route discovery to discover the nearby link disjoint paths. The Route Request (RREQ) and Route Reply (RREP) process will be obtained to find the nodes which have the highest stability metric value and which are fully in the range of communication. By doing this process the next phase will select the highest stability metric path to transfer the data. The second last step will take place by forwarding data in mutual mode in which when the ground and aerial i.e. sender and receiver interact with each other via wireless link then the process will becomes stop in the last step.
**Algorithm-1**: Pseudo code for the proposed mechanism:

1. **Initialization phase**;
2. **Deployment phase**;
3. **Network partitioning**;
4. IF (collaborative mode = true); THEN
   GoTo Step 5;
   Else
   Repeat Step 1;
5. ENDF;
6. Construct R – B priority tree for Ground (N), Aerial (M) and Mutual Link (K);
7. Selection of top nodes on the basis of highest priority;
8. IF (top priority node is selected); THEN
   GoTo Step 8;
   Else
   Repeat Step 6;
9. ENDF;
10. Check for link stability;
11. IF (Stability Metric ≥ TH(Threshold Values (0.3, 0.3 and 0.4))) THEN;
    Direct Transfer;
    Else
12. Use route discovery for estimation of stability metric (to generate 1);
13. ENDF;
14. Use highest stability metric path for data transfer;
15. Forward data in Mutual mode;
16. END;

Algorithm-2: Pseudo code for R-B priority tree of ground, aerial and neural set:

Require: M ≥ 3 & N ≥ 3
Ensure: Neurons ← K ≥ 3
Ensure: Aerial_Network: A(M) ← initialized
Ensure: Ground_Network: G(N) ← initialized
while final_route ≠ true do
  fetch_g ← node_data(G)
  P_g ← max(P_g[M])
  P_Tree(G, P_g, Guider) → T_g/* ground network
  fetch_a ← node_data(A)
  P_a ← max(P_a[M])
  P_Tree(A, P_a, Guider) → T_a/* aerial network
  find(G) ← priority_node(G)
  find(A) ← priority_node(A)
  Re – initialize ← neurons_tree(K)
  P_Tree(A, G, K, Guider) → T_a/* neural tree
  if priority tree = true then
    identify link ← link_matrix(weight with highest priority)
    update ← T_a(link)
  else
    T3 ← no_update
    set path = true
  end if;
follow priority order of nodes
if (R – B priority tree = true) then
  proceed accordingly to the proposed scheme
  maintain highest priority for N, M and K
end if;

• Initialization Phase
In this step the network initialization phase takes place for the upcoming simulation.
• **Deployment Phase**  
In this step, the network nodes for aerial and ground deployment are defined and placed accordingly.

• **Network Partitioning**  
In this step, the network is divided into partitions that are ground ad-hoc network and aerial ad-hoc network and these networks are divided by the use of relay nodes known as neural structure in the proposed scheme.

In next step, the loop takes place in the form of condition of (yes or no).

• **Construct R-B Priority Tree for Aerial, Ground and Mutual Link (N, M, K)**  
In this step, the R-B priority tree for N, M and K are constructed which shows the highest priority nodes for the network. The highest category takes place by the use of R-B tree which provides the guider node functionality for the proposed scheme.

• **Selection of Nodes Based on Highest Priority**  
In this step, the highest nodes among other nodes are selected for data transmission. The highest nodes are selected by the use of R-B priority tree. The highest priority node means those nodes which are in the communication range with the other node. In short, these are the nodes that possess the highest priority having the highest threshold value with highest weighting coefficient as shown in Equation 3.16 and 3.17.

In next step, the loop takes place in the form of condition of (yes or no).

• **Check for Link Stability**  
In this step, the link stability is checked which is carried out by the upcoming step by the use of threshold values with the help of defined link stability metric. The next step consists of condition for link stability that if the link is stable with highest threshold value then direct transfer if not then follows the link stability procedure.

• **Use Route Discovery for Estimation of Link Stability**  
In this step, the link stability procedure is implemented by the use of RREQ and RREP.

• **Use Highest Stability Metric Path for Data Transfer**  
In this step, the highest threshold value path is selected for data transfer. When the highest value is selected it indicates the link stability. In this scenario 1 is the link stability threshold value and 0 shows that link is not stable.

• **Forward Data in Mutual Mode**  
In this step, the data is forwarded both from the source and destination’s link that is currently made by the use of route discovery and threshold value. When the two different operating networks combined with each other and they have to send data so this is the step in which they take place. Mutual mode indicates a corridor from source and destination which by combination they make two network corridors. At the end after successful data forwarding the cycle of the proposed mechanism completed and finishes with the end state.

### 3.2 Simulation Tool
The tool used for simulation of the proposed work is MATLAB (Matrix-Laboratory). MATLAB is a simulation tool used for simulation-based studies that shows the animated scenarios of the reality. About one million users are using MATLAB in the fields of industries and universities. The tool MATLAB was generally designed for education and investigation purposes for the scholars and scientists in the field of physical sciences. It’s a language that was developed by Math Works for copyrights of programming. It uses procedures and alteration of matrix schemes, design an interface, strategy of users interface, fulfillment of algorithms that are written in additional languages like Python, Fortran, C#, C++, C sharp, C, Java and Java++.

For the proposed work, MATLAB has been implemented for the simulations and the results are portrayed and discussed in Chapter IV. The reason for using MATLAB for the proposed work is that in one of the baseline papers the authors have used MATLAB for simulations. Because, MATLAB supports high level of mathematics and the proposed work is consist of high mathematical formulas and equations. By combining both the mathematical models of existing work for the proposed work whose mathematics were supported by MATLAB. Hence, the best and main reason is the high level of mathematics. As, MATLAB tool was created by math works that can supports mathematics. Inspiring from that features coding and implementation of MATLAB for the proposed work yielded a better simulation scenario and hence portrayed for DLSA.

### 3.3 Simulation Parameters
The design of Delay and Link Stability Aware (DLSA) routing protocol has used the routing approach for simulation. Table 3.1 demonstrates that the desired study has used diverse aspects for the analysis of simulations.
Simulation parameters are those aspects which are used for results and evaluation with the key factors that how many parameters will take place that shows the values and ranges of these parameters with their specific names. These are Simulation Tool, Network Volume, Network type, Evaluation parameters, network volume, simulation time, communication range of node, amount of nodes takes for simulation, proposed routing scheme, existing/compared routing schemes. In simple words, it the simulation setup for the proposed DLSA routing scheme which shows that what kind of data has been carried out for the simulation, results and evaluation along with discussion.

**Table 3.1: General Simulation Parameters.**

| Parameter                  | Value                      |
|----------------------------|----------------------------|
| Simulator                  | MATLAB                     |
| Network Volume              | 500m x 500m x 500m         |
| Number of nodes             | 100                        |
| Ground Node maximum speed   | 25 m/sec                   |
| Aerial Node maximum speed   | 200 m/sec                  |
| Transmission Range/Node     | 350 m                      |
| Performance Evaluation Parameters | End to End Delay (Milliseconds) | Packet Delivery Ratio (in %age) |
|                            |                            | Network Lifetime (Seconds)    |
|                            |                            | Transmission Loss (dBm)       |
| Channel type                | Wireless IEEE 802.11s      |
| Network                     | FANET                      |
| Our Proposed Scheme         | DLSA                       |
| Compared Schemes            | DPTR and LEPR              |
| Packet Size                 | 256 bytes                  |
| Simulation Time             | 1000 (seconds)             |

3.4 Design of DLSA Routing Protocol

The design of DLSA has already given in the proposed mechanism flow chart and given two algorithms along with the R-B tree and threshold values. However, this section provides the system mathematical model accordingly for the design of hybrid DLSA routing scheme inspiring from the existing two routing schemes. The reliability and stability of DLSA routing protocol have been proposed based on mathematical formulas. The designed hybrid routing protocol known as Delay and Link Stability Aware (DLSA) for FANETs on the basis of highest priority node selection and link stability metric procedure in the proposed mechanism. The given scheme will be applied on different evaluation parameters to show the results compared with existing protocols.

![Figure 3.3: Design of DLSA Routing Protocol](image)

3.4.1 System Model

It is very challenging and difficult task to formulate and design a routing scheme for a network that is composed of two different kinds of ad-hoc units i.e. ground and aerial. The key functionality of a routing protocol is to distinguish and decide the intercommunicating nodes in both the routing units that will create a network corridor (NC) to permits the routing in diverse mode. The DLSA proposed protocol in this research has the capabilities of the R-B tree i.e. it has extends the positive features of that tree for the formation of two different operating units along with some changes and modification of the tree. It suits possible for having two nodes operating with each other. So, for the solution of the partitioning of network the proposed DLSA protocol takes action in the given three parts:

- Ground nodes Identification (N)
- Aerial Nodes Identification (M), and
- Using neural structure for Interfacing (relay nodes K)

The terms N, M and K are the symbols that represent the Ground, Aerial and Neural Structure of the Network. The routing scheme operates the neural interface/structure for its operating environment and senses the formation
of the tree form a routing table arising from both ground and aerial nodes (Sharma et al., 2018).

3.4.1 Collaborative (Two-Way) Data Forwarding

For efficient and robust routing, the hierarchy of the network is self-included bound along with having formation of multiple topological map and the decision from end to end analysis. It is need-based that a protocol ought to have the capabilities enough for two ways collaborative data transfer of the information. For an efficient interacting, the self-included parameter is hierarchy of the network, but to have numerous topology-map creations and head to head conclusion examination, it is compulsory that scheme must be proficient sufficient to collaboratively transfer the data. In this mode, the amount of the network corridors may be more than single and utilizes the excessive level of the channel for transferring i.e:

\[
G_s = \left\{ NC_1, \ldots, NC_{ \frac{s}{2} } \right\} \quad (3.2)
\]

Where,

\[
NC_i = \max \left\{ C_1, \ldots, C_{ \frac{s}{2} } \right\}, \quad 1 \leq i \leq \frac{s}{2} \quad (3.3)
\]

Where NC shows the network corridor and NCi shows the initials of the corridor \( \frac{s}{2} \) shows the session of the network divided into 2 for ground and aerial with multiplication of NC (Sharma et al., 2018).

3.4.1.2 Route Discovery Estimation

This procedure is performed out by utilizing pre-existing operations of network known as discovery of the links via neighbor nodes. This allows the identification of the active and connected nodes, and additionally permits estimation of the connectivity times of nodes and examines the design of a random oriented graph for data transmission. Henceforth, the discovery time of route may be introduced as it is the lowest time in which every edge of the network is recognized that leads to the connectivity of two nodes or it is the shortest time interval for forming the routing table created by every active nodes.

For this technique, let’s assume that \( m \) is the number of aerial nodes, \( n \) is the number of ground nodes, \( k \) is the amount of neural interface’s nodes in the layer of collaborative network, \( t' \) reveals the exchange of time beacons within two nodes and \( t'' \) expressed the time for updating the table of routing like:

\[
t_e = (t' + t'') \quad (3.4)
\]

In Equation 3.4, the term \( t_e \) express the overall time for formation of route initially. In worst case scenario, assume that every node switches beacons with all other nodes. The amount of beacons for the ground nodes are given as:

\[
\frac{n(n - 1)}{2} \quad (3.5)
\]

while for aerial’s nodes,

\[
\frac{m(m - 1)}{2} \quad (3.6)
\]

These two ad-hoc network performs their functionality in parallel mode to each other.

Now, the discovery time of route for aerial nodes \( t_a \) and ground nodes \( t_g \) are given in the Equation as:

\[
t_g = t_e \frac{n(n - 1)}{2} \quad (3.7)
\]

and

\[
t_a = t_e \frac{m(m - 1)}{2} \quad (3.8)
\]

Accordingly, Henceforth, the shortest and minimum time of route discovery \( D_{\min} \) for networks operates in parallel fashion will be stated as:

\[
D_{\min} = \max \left( t_a, t_e \right) \quad (3.9)
\]
$D_{min}$ is too the starting/initial interval of timings to be fixed for route discovery operation of the protocol.

For the transmission of top-down, the overall time is taken to design a mathematical expression for route is expressed as:

$$t_{t-d} = \max \left( t_u + t_c, t_g \right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.10)$$

while for 'bottom – up transmission', it is can be expressed as:

$$t_{b-u} = \max \left( t_u, t_g + t_c \right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.11)$$

where,

$$t_c = k_c \times L_g \times t_{lg} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.12)$$

In this scenario of formulation, $k_c$ shows the amount of neurons connected, $L_g$ shows the maintained logs at the collaborative layer and $t_{lg}$ indicates the time for maintaining logs (Sharma et al., 2018).

3.4.1.3 Tree Formation for Aerial, Ground and Neural Set

The probability-based tree creation and formulation permits the revealing of the nodes along with the slots of time in difficult manner in the network, i.e. it indicates and introduces the nodes in the network that may causes highest and lowest modifications at the time of operation of network in a routing tree. Apart from this, it also delivers and helps for maintaining the logs of the nodes of network. A network that has time slot $t$ for operating units are given as, average rate $Avg_{rate}(g)$, $Avg_{rate}(a)$ and $Avg_{rate}(n)$ for ground, aerial and mutual network. Every Equation indicates different network by showing their symbols are formulated as:

$$\sum_{i=1}^{N} \sum_{i=1}^{M} \sum_{i=1}^{K}$$ \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.13)

$$Avg_{rate}(g) = \sum_{i=1}^{N} x_i - N_{ini} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.13)$$

$$Avg_{rate}(a) = \sum_{i=1}^{M} x_i - M_{ini} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.14)$$

$$Avg_{rate}(n) = \sum_{i=1}^{K} x_i - K_{ini} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.15)$$

Where, $N$, $M$ and $K$ are symbols that represent three different operating ad hoc networks. Whereas, $N_{ini}$, $M_{ini}$ and $K_{ini}$ are the initial amount of nodes in ground, aerial and neural ad hoc networks, accordingly.

3.4.2 Link Stability Estimation and Mathematical Formulation

First of all it is very significant and mandatory part to have such a reliable and robust routing maintenance scheme for FANET. For this purpose, the key idea of the proposed DLSA scheme is to formulate and calculate many stable dis-joint routes by utilizing the proposed link stability metric (threshold) scheme for finding suitable and best paths for switching the current link with that if the link is about to break soon. This is remarkably proposed and designed for FANET in which the connectivity of the network via links are mandatory and major part during transmission of data. The proposed DLSA is designed based on DPTR and LEPR schemes. In the current section, the new stability link procedure has been proposed and then formulated with mathematical models accordingly (Li and Yan, 2017).

3.4.2.1 Estimation of the Link Stability Metric

A best metric (threshold value) is not about to only efficiently representing quality of the links but also should be active and aware when the topology of the network changes particularly in FANET scenarios. For meeting the desired needs as mentioned procedures, it is particularly being specific to introduce and comprehensive and robust scheme having the features of link stability metric along with the knowledge and awareness of the current, past and future status of the link. Also specially, this novel metric contains of having three parts that are quality of link, degree of safety and prediction factor of mobility, in response these all relate to a single sequence of the status.

For stability of the DLSA routing scheme the highest metric threshold values have been taken into account for the proposed work that are $\lambda_1 = 0.3$, $\lambda_2 = 0.3$ and $\lambda_3 = 0.4$ which combines and generate 1 as shown in Equation 3.17. This 1 threshold value shows that the link is stable but if the value is 0 of less than 1 then it represents that there exists no link stability. The stability have further shown in Equation 3.19 and 3.20 which clearly shows that 0 represents no link stability and 1 represents that link is stable. The proposed mechanism differs from the existing
work is that because in existing work only 0.34 threshold value have been taken but in proposed work three different values have been taken from different perspectives.

Consider there are existing two nodes indicated by \( i \) and \( j \) and these are in the communication range to each other. The term \( D_{ij} \) indicate the stability of link between \( i \) and \( j \) that can be mathematically expressed as the mixture of the link quality \( LQ_{ij} \), safety degree \( Y_{ij} \) and prediction factor of mobility \( S_{ij} \) as shown in Equation 3.16:

\[
D_{ij} = \lambda_1 LQ_{ij} + \lambda_2 Y_{ij} + \lambda_3 S_{ij} \quad \ldots \ldots \ldots \ldots (3.16)
\]

Where, \( \lambda_1, \lambda_2 \text{ and } \lambda_3 \) are the weighting coefficients controlled by the given state:

\[
\lambda_1 + \lambda_2 + \lambda_3 = 1 \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.17)
\]

This is worth prediction that every of the aforementioned three costs are controlled to a cost unit. By the circumstance, the value of \( D_{ij} \) is restricted from 1 to 0 ranges. So forward and reverse ratios of delivery has to measure the quality of the link that can be indicated as:

\[
LQ_{ij} = \gamma^f \times \gamma^r \quad \ldots \ldots \ldots \ldots \ldots (3.18)
\]

Where, \( \gamma^f \) is the forwarder ratio of delivery, such that the possibility in which node \( j \) becomes able to receive a packet from node \( i \). Similarly, \( \gamma^r \) is the ratio of delivery in reverse mode, if there is a packet that received successfully from reverse and forwarder direction, then the value of quality is equal to 1. The ratio of delivery, either \( \gamma^f \) or \( \gamma^r \) can be indicated mathematically as:

\[
\begin{align*}
\gamma_n &= \alpha \times \gamma_n - 1 - (1 - \alpha) \times h_n \\
\gamma_0 &= 0
\end{align*} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.19)
\]

\[
hn = \begin{cases} 
1, & \text{if the nth hollow message is received} \\
0, & \text{otherwise}
\end{cases} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.20)
\]

The restricted value of parameter \( \alpha \) redirects the time relationship, changing in the ranges (1, 0). When \( \alpha \) equivalent to 0, the ratio of delivery just is dependent on the existing link quality, so the scheme will respond quicker. By increasing value of \( \alpha \), the additional estimation of stability and average is depicted. To allocate the GPS directions through the network, there will be added field-loc to the Hello packet.

Consider \((X_i, Y_i, Z_i)\) be the coordinates of UAV \( i \). The degree of safety \( Y_{ij} \) signifies the nearness of the UAV \( i \) and \( j \) based on their space presently as shown:

\[
Y_{ij} = \frac{R - dt}{R} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.21)
\]

The term \( R \) is the radius of communication of a UAV, and Euclidean Distance \( d_i \) is indicated of two nodes as:

\[
d_t = \sqrt{[X_j(t) - X_i(t)]^2 + [Y_j(t) - Y_i(t)]^2 + [Z_j(t) - Z_i(t)]^2} \quad \ldots \ldots \ldots \ldots \ldots (3.22)
\]

When the values of \( Y_{ij} \) are greater than the two nodes becomes in movement to stay close with one another. There will be longer time interval taken when a communication link between UAVs becomes no longer i.e. becomes break. The comings are the mobility prediction factor \( S_{ij} \) that are discussed. In scenario of real world, a UAV can’t move in unsorted propagation due to the dynamic and kinetic restrictions. So, for this it has to formulate and measure the sudden and fast speed between the UAV \( i \) and \( j \) to evaluate their trends of moving within the upcoming time interval for the next connection with another UAV.

The rapid speed of UAVs between \( i \) and \( j \) is shown as:

\[
V_{re} = \frac{d_t - d_t - \Delta t}{\Delta t} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.23)
\]

Where \( t \) and \( t - \Delta t \) shows the time interval to the Hello Messages incoming of the last and second to last Hello messages arriving. \( d_t \) and \( d_t - \Delta t \) are the matching spaces between UAV \( i \) and \( j \). Even, if the existing two UAVs travel separately near contrary path at extreme speed \( V_{max} \), \( V_{re} \) is up to highest rate \( 2V_{max} \). Despite this, if these UAVs are near to one another at highest speed, \( V_{re} \) had to reach at lowest value \(-2V_{max}\). Thus, it has introduced the prediction factor of mobility \( S_{ij} \) such as:

\[
S_{ij} = e^{1 - \frac{V_{re}}{2V_{max}}} \quad \ldots \ldots \ldots \ldots \ldots (3.24)
\]

\( S_{ij} \) is controlled to a cost unit cost in Equation 3.24. The lowest the value of \( V_{re} \) is the highest \( S_{ij} \) generates, and the further stability of the link leads to.

The path of metric of stability relies on the lowest link stability threshold values starting this route. The basics of this path is that if there disconnect a stand-alone path, and then the overall links will have to be disconnected. Henceforth, the route stability is expressed as:
The highest value of $P$ shows that the route has better and efficient stability, ideal for transmission of data packet (Li and Yan, 2017).

3.4.2.2 Route Discovery
DLSA transforms the base scheme LEPR mechanism of route discovery to measure and calculate many link disjoint routes utilizing the above stability metric of link. These two link disjointness and node disjointness may create every route fail autonomously indebted to the feature of having not any common link. By comparison with the link disjointness is an excessive and extra limited alteration characterized by not possessing any similar link. However, it can affect lesser changes to the paths to be generated, particularly environment of sparse. This procedure makes UAV disjointness affective with less quality. This scheme uses the RREQ and RREP procedure for the route discovery to find an alternative and suitable route for the existing link with the current communication scenario when an anticipated route is about to break. So, it has to introduce and design link disjoint route in this research (Li and Yan, 2017).

3.4.2.3 Semi-Proactive Route Maintenance
Since several retransmission time-out are mandatory to expire early before a connection is assumed broken then the detecting of cost for link failure may be high. Also, this failure of the early route due to the motion of a node too affects the diverse route. To deliver a service of unbroken connection as probable, it has to evaluate periodically the primary path of communication quality and it response in advance the early breaking of the connectivity. That is the reason this scheme has the features via which it is designated as semi-proactive. Once the identifying a link in connection is probable to break early, the semi-proactive route preservation approach originates a recovery action by detecting the maximum quality route to switch the early route. This different route may fit to one of the reserve routes of a novel gained from the process of route discovery (Li and Yan, 2017).

3.5 Performance Evaluation Parameters
The parameters designated for performance of evaluation are End-to-End Delay, Packet Delivery Ratio, Network Lifetime and Transmission Loss.

3.5.1 End to End Delay
The term End-to-End delay indicates the complete delay from source to destination within the specific interval of time. The delay consists of the transmission delay, propagation delay of the signal, processing delay of the data and the queuing delay in the entire network. From sender to destination, when a signal travels and carry data, which undergo through these mentioned delays, are counted as the end-to-end delay of the network (Sharma et al., 2018).

This metric can be calculated using the Equation 3.26.

$$d_{\text{end-end}} = N(d_{\text{trans}} + d_{\text{prop}} + d_{\text{proc}} + d_{\text{queue}}) \ldots \ldots \ldots \ldots \ldots \ldots (3.26)$$

Where,
- $d_{\text{end-end}} = \text{End – to – End Delay}$
- $d_{\text{trans}} = \text{Transmission Delay}$
- $d_{\text{prop}} = \text{Propagation Delay}$
- $d_{\text{proc}} = \text{Processing Delay}$
- $d_{\text{queue}} = \text{Queuing Delay}$
- $N = \text{Number of connections}$

3.5.2 Packet Delivery Ratio (PDR)
The term PDR indicates the amount of packets that have been sent from sender to receiver and the amount of packets that have been acknowledged back i.e. amount of packet acknowledged divided by amount of packets sent multiply with hundred (Li and Yan, 2017).

This metric can be calculated using the Equation 3.27.

$$\text{PDR} = \frac{\text{Number of packets acknowledged}}{\text{Number of packets sent}} \times 100 \ldots \ldots \ldots \ldots \ldots (3.27)$$

3.5.3 Network Lifetime
The term network lifetime describes as, the total operational time of the network in the given intervals of simulations. In other words “break of the time in which from the beginning of the network until the death of the
first node. It expresses that for how long the existing network is/was stable”. The lifetime of the network is measured in seconds or rounds. The lifetime of the network can also be expressed in term of connected and disconnected nodes i.e. active and non-active nodes. When the node is dead, we can say the network is not stable, also when that node is no longer in communication with another node then it also express that the network is not stable. Because the network completely depends upon the nodes, which can be in the communication range with another node (Li and Yan, 2017).

The lifetime of a network can be calculated using the Equation 3.28,

\[ N_{\text{Lifetime}} = \begin{cases} \frac{1}{\sum_{i=1}^{n} W_i} & \text{if } n \geq 1 \\ 1 & \text{if } n = 0 \end{cases} \]  

\hspace{1cm} (3.28)

Where,

\( N_{\text{Lifetime}} = \) Lifetime of Network

\( n = \) Amount of weak modules

\( W_i = \) Weight of every weak modules

### 3.5.4 Transmission Loss

The term transmission loss indicates the reduction in power that happens throughout transmission from one point to another i.e. from source to destination or from one node to another node (Zeng et al., 2017).

Transmission loss (TL) is generally measured in dBm (decibels milliwatt), as shown in Equation 3.29.

\[ TL = 10\log_{10} \frac{W_i}{W_t} \text{ dBm} \]  

\hspace{1cm} (3.29)

Where:

\( W_t \) is the power of incident signal coming towards a defined area i.e. destination,

\( W_t \) is the power of transmitted signal going away from the defined area i.e. destination.

### 3.6 Comparison of DLSA with DPTR and LEPR routing protocols

This unit offers the enhancement and design of DLSA routing protocol, inspired from the design of DPTR and LEPR. DPTR routing protocol works on the basis of the top priority node selection for which it uses Red Black (R-B) tree to check and choose nodes having highest priority for transmission. For this scenario it combines three kinds of ad-hoc networks i.e. Ground Ad-hoc network (N), Aerial Ad-hoc network (M) and using neural interface as an intermediary relay nodes (K), K connects Ground and Aerial Ad-hoc networks. LEPR routing protocol works on the basis of the link stability metric (threshold value) procedure to stable the link by utilizing Route Request (RREQ) and Route Reply (RREP) for checking the highest value of the link for transmission. Hence, for the functionality of DLSA the positive features of both routing schemes is taken and then designed a hybrid routing scheme with the probability that has shown more promising and efficient results with the comparison of DPTR and LEPR routing protocols.

### 3.7 Results and Discussion

After the simulation-based operation and modeling of mathematical formulation, the newly designed protocol has been compared with current protocols using simulations to check the efficiency of Delay and Link Stability Aware (DLSA) Routing Protocol. The results are obtained from MATLAB simulation. The different parameters taken for the comparison are End-to-End Delay, PDR, Network Lifetime and Transmission Loss. This section has been discussed further in detail with graphical and tabular representation of the simulated results in Chapter IV (Results and Discussion).

### 3.8 Conclusion

On the basis of the proposed parameters i.e. E2E Delay, PDR, Network Lifetime and Transmission Loss, it has been concluded the performance of Delay and Link Stability Aware (DLSA) routing protocol associated to existing DPTR and LEPR routing protocols. This section has been discussed further in detail with future research directions in Chapter V (Summary, Conclusion and Recommendation).
IV. RESULTS AND DISCUSSION

4.1 Introduction
This chapter shows the simulated results along with discussion of each and every concerned evaluation parameter. The results are collected from many simulation parameters are evaluated and debated. The simulations were carried out in MATLAB by taking the network volume of 500m x 500m x 500m. The network volume is taken in 3 values each of 500m because the nodes of FANET move in 3-D ways that are x-axis, y-axis and z-axis. In FANET, diverse kind of nodes are used, like ground nodes, aerial nods, and cluster head and for the mutual link of these nodes an intermediary nodes are used known as relay nodes that work on the principal of taking the message from one node and pass it to another node. In short, they work as third party in the formation of FANET.

The key factor for DLSA that gives the best results in all scenarios is the merging of the positive features of DPTR and LEPR. Inspiring from existing routing schemes that proposed DLSA routing scheme have the ability to select the highest priority node among different nodes by the use of R-B priority tree and taking the maximum threshold values from source to destination to find the accurate and ultimate path for data transmission. Apart from that, DLSA gives better results because it follows the preemptive mechanism which is an activity that takes place earlier when a route is about to break soon. So, DLSA calculates the dis-joints paths and beacon one node with another before the occurring of an anticipated event that causes the link breakage.

Performance evaluation parameters for DLSA, DPTR and LEPR are discussed and depicted in the following Tables and Graphs accordingly.

4.2 End-to-End Delay
End-to-end delays w.r.t three schemes are portrayed in Table 4.1 that characterizes an assessment between the average E2ED of DPTR, LEPR and DLSA. The results are achieved from the simulation. Assessment has shown that E2ED in DLSA is less than DPTR and LEPR due to minimum distances between the nodes by using relay nodes. In DLSA, the average E2ED is 0.457 as compared to DPTR, which is 1.492, and LEPR that is 1.006. The results were taken for 1000 (seconds) as shown in the Figure 4.1. The X-axis displays simulation time in seconds while the Y-axis displays End to end delay in milliseconds.

Table 4.1: End-to-End Delay (ms) after equal intervals w.r.t simulation time (sec).

| Protocol Name | E2ED after 100sec | E2ED after 200sec | E2ED after 300sec | E2ED after 400sec | E2ED after 500sec | E2ED after 600sec | E2ED after 700sec | E2ED after 800sec | E2ED after 900sec | E2ED after 1000sec | Avg E2ED |
|---------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---------|
| DPTR          | 8.658             | 2.340             | 0.961             | 0.751             | 0.359             | 0.523             | 0.183             | 0.473             | 0.399             | 0.274             | 1.492   |
| LEPR          | 4.625             | 3.847             | 0.787             | 0.309             | 0.256             | 0.091             | 0.050             | 0.030             | 0.039             | 0.031             | 1.006   |
| DLSA          | 0.675             | 0.675             | 0.675             | 0.549             | 0.586             | 0.390             | 0.345             | 0.294             | 0.270             | 0.168             | 0.457   |
As depicted from Table 4.1, E2ED of DLSA, DPTR and LEPR are calculated and the results have presented that value of DLSA is 0.675 after hundred seconds, while value of DPTR is 8.658 and LEPR is 4.625. After two hundred seconds, E2ED of DLSA is 0.675, while DPTR is 2.340 and LEPR is 3.847. After four hundred seconds, E2ED of DLSA is 0.549, while DPTR is 0.751 and LEPR is 0.309. After eight hundred seconds, E2ED of DLSA is 0.294, while DPTR is 0.493 and LEPR is 0.030. After thousand seconds, E2ED of DLSA is 0.168, while DPTR is 0.274 and LEPR is 0.031. The overall E2ED in percentage of DLSA is calculated and measured less than DPTR and LEPR routing protocols.

### 4.3 Packet Delivery Ratio

PDR is the percentage of the sent packets from source to destination in a given interval of time. When the packet arrival time is lesser, the higher traffic is sent from source nodes. This rises packet accident tends to a lesser PDR. DLSA scheme increases the likelihood of getting packets effectively by forwarding packets on alternative routes and joining at the destination. It is clear from Figure 4.2 that DLSA has achieved higher PDR than DPTR and LEPR. During the early periods of the simulation PDR of DLSA is not much high as compared to other schemes. But using the collaborative and choosing high threshold value from source to destination, it has clearly shown that PDR of DLSA has drastically increased. Comparison has shown that PDR in DLSA is higher than DPTR and LEPR due to minimum distances between the nodes by using relay nodes that possess clear LOS. In DLSA, the average PDR in percentage is 3.106 as compared to DPTR, which is 2.303, and LEPR that is 0.682. The results were taken for 1000 (seconds) in 10 intervals as shown in Figure 4.2 and Table 4.2. The X-axis shows simulation time in seconds while the Y-axis shows PDR in percentage w.r.t simulation time.

The main reason for DLSA that shows the highest values in PDR is that this protocol uses the highest priority nodes among different nodes and using the maximum threshold values those impacts the high PDR generation in the desired scenario by keeping link stability. When the link is stable it will deliver packets successfully but along with keeping minimum E2ED.

### Table 4.2: Packet Delivery Ratio (in %age) w.r.t simulation time (sec).

| Protocol Name | PDR after 100sec | PDR after 200sec | PDR after 300sec | PDR after 400sec | PDR after 500sec | PDR after 600sec | PDR after 700sec | PDR after 800sec | PDR after 900sec | Avg PDR |
|---------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|--------|
| DPTR          | 3.448            | 3.453            | 3.440            | 2.801            | 2.435            | 2.107            | 1.875            | 1.663            | 1.620            | 0.194   | 2.303  |
| LEPR          |                  |                  |                  |                  |                  |                  |                  |                  |                  |        |        |
| DLSA          |                  |                  |                  |                  |                  |                  |                  |                  |                  |        |        |
As portrayed in Table 4.2, PDR of DLSA, DPTR and LEPR are determined and the outcomes have demonstrated that estimation of DLSA is 0.064 following one hundred seconds, while estimation of DPTR is 3.448 and LEPR is 0.056 following hundred seconds. Following two hundred seconds, PDR of DLSA is 0.089, while DPTR is 3.453 and LEPR is 0.175 following two hundred seconds. Following four hundred seconds, PDR of DLSA is 0.713, while DPTR is 2.801 and LEPR is 0.445. Following eight hundred seconds, PDR of DLSA is 7.179, while DPTR is 1.663 and LEPR is 0.890. Following one thousand seconds, PDR of DLSA is 8.940, while DPTR is 0.194 and LEPR is 1.195. The general PDR in level of DLSA is determined and considered higher than DPTR and LEPR routing schemes because of preemptive mechanism and link stability threshold of the DLSA scheme.

4.4 Network Lifetime

It illustrates the total executional time of protocol. This metric shows the duration of the network that for how long the existing network has performed until the death of first node has occurred. DLSA is not dealing with the energy of the nodes, but lifetime also indicates the link stability of the current nodes. The network lifetime for DLSA, DPTR and LEPR is shown in Figure 4.3. The lifetime of DLSA is much greater than DPTR and LEPR routing protocols. Increased network lifetime of DLSA comparative to DPTR and LEPR is because of non-continuous data transmission and flooding mechanism. Data is transmitted only if there exist some active node within the network with having the highest threshold value. Hence, DLSA shows much better results in comparison with the DPTR and LEPR routing protocols. By calculating the overall network lifetime, it has been concluded that the lifetime of DLSA is much higher in comparison with DPTR and LEPR. The average network lifetime of DLSA is 62.141 sec as comparison with the DPTR whose lifetime shows 27.298 sec and LEPR shows 23.036 sec. DLSA shows a much greater improvement over all protocols as depicted in Table 4.3.

Table 4.3: Network Lifetime (sec) w.r.t simulation time (sec).

| Protocol Name | Lifetime duration at 100sec | Lifetime duration at 200sec | Lifetime duration at 300sec | Lifetime duration at 400sec | Lifetime duration at 500sec | Lifetime duration at 600sec | Lifetime duration at 700sec | Lifetime duration at 800sec | Lifetime duration at 900sec | Lifetime duration at 1000sec | Avg Network Lifetime (sec) |
|---------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
As depicted in Table 4.3, the stability period of DLSA, DPTR and LEPR are calculated and shown w.r.t different connective time in seconds. First of all, at hundred seconds the value of DLSA in seconds is 1.292 while the value of DPTR is 34.48 and LEPR is 2.271. During the first connectivity time DLSA has shown poor performance but then the end the result of DLSA has drastically improved as shown in Figure 4.3. And by calculating the average network lifetime of DLSA has also shown significant changes by carrying the graph towards the highest value. Hence, DLSA shows better network lifetime as compared to DPTR and LEPR routing protocols. DLSA has shown effective presentation because of non-unnecessary transmission by flooding of data that yielded better network lifetime in seconds.

4.5 Transmission Loss

Figure 4.4 shows the transmission loss investigation of DLSA with different FANETs protocols DPTR and LEPR. Proposed DLSA decreases the transmission loss because of the way that a high stability metric value is taken and figured and based on this multi jump transmission pursues various ways to reduce transmission loss. DPTR scheme demonstrates an improvement over LEPR protocols by decreasing the estimation of transmission loss from 5dBm to 1.148dBm, while LEPR estimation of transmission loss is diminished from 5dBm to 2.353. By demonstrating the most reduced estimation of transmission loss in DLSA, it has reasoned that DLSA is fundamentally improved the productivity in examination with DPTR and LEPR. Since, when the transmission loss value is radically going down then it is by all accounts the ideal execution of the scheme. The proposed scheme DLSA demonstrates a sensational enhancement for them two by dropping the transmission loss to 0.975dBm as appeared in Table 4.4 which is an extensive improvement over every one of the two under-thought FANETs protocols.
As depicted in Table 4.4, the evaluation of DLSA with DPTR and LEPR on the basis of transmission loss are calculated and shown that the transmission loss occurred after two hundred simulation time in seconds by applying DLSA routing protocol. First of all the calculating results of DLSA dropped at hundred seconds and shown the value of transmission loss that is 4.525 dBm. Then it was compared with DPTR and LEPR. The average transmission loss ratio of DPTR is 1.053 dBm, while average transmission loss ratio of LEPR is 1.227 dBm. After two hundred seconds the value of DLSA is dropped down to 2.398 from 4.525 dBm. Then it’s compared with DPTR and LEPR, which has shown that the transmission loss ratio of DPTR is 1.139 dBm and LEPR is 1.099 dBm. After four hundred seconds, the transmission loss ratio of DLSA is calculated 0.434 dBm. Then it’s compared with DPTR and LEPR which has shown that ratio of transmission loss of DPTR is 1.076 while average transmission loss ratio of LEPR is 0.774 dBm. After eight hundred seconds, the transmission loss ratio of the DLSA is calculated 0.190 dBm, while DPTR is 0.870 and LEPR is 3.901 dBm. By presenting the lowest ratio of average transmission loss in the network for DLSA is considered efficient in comparison with DPTR and LEPR. Due to link stability mechanism by taking the lowest value of threshold which reduces overhead and avoid from high transmission loss, the positive features of DPTR and LEPR are taken; thus, DLSA has shown the lowest average transmission loss ratio which is considered efficient.
4.6 Summarized results of DLSA vs DPTR and LEPR

The simulation results of DLSA routing protocol is evaluated and compared with DPTR and LEPR protocols of FANET on the basis of the following performance evaluation parameters End to End Delay, PDR, Network Lifetime and Transmission Loss as depicted in Table 4.5.

Table 4.5: Comparison of DLSA with DPTR and LEPR.

| Protocol Name | Average E2ED (ms) | Average PDR (in %age) | Average Network Lifetime (sec) | Average Transmission Loss (dBm) |
|---------------|------------------|-----------------------|-------------------------------|-------------------------------|
| DPTR          | 1.492            | 2.303                 | 23.036                        | 1.053                         |
| LEPR          | 1.006            | 0.682                 | 27.298                        | 1.227                         |
| DLSA          | 0.457            | 3.106                 | 62.141                        | 0.975                         |

Table 4.5 depicts the overall average of PDR, E2ED, Network Lifetime and Transmission Loss of three routing protocols DPTR, LEPR and DLSA. Figure 4.5, 4.6, 4.7 and 4.8 are derived from Table 4.5. These Figures shows different kinds of values w.r.t their desired evaluation parameters. Each Figure shows separate values in Average perspectives like Figure 4.5 shows the overall average E2ED of DPTR, LEPR and DLSA routing protocols. Also it shows that which one is giving better result in contrast to each other’s. Similarly, same is with Figure 4.6 that shows the overall average PDR of each protocol i.e. DPTR, LEPR and DLSA and shows that which one is efficient and gives much better result. From Table 4.5, the given four parameters E2ED, PDR, Network Lifetime and Transmission Loss are depicted here in separate graphs; each graph shows the desired value of each protocol. The key factor of DLSA for showing the best result in each graph is that DLSA has the ability to keep minimum delay with high PDR along with high network lifetime and low transmission loss as possible. It has been clearly seen that DLSA routing protocol have given magnificent and drastic results in terms of each scenario accordingly. The key factor is that it uses the positive features of the DPTR and LEPR routing protocols for the proposed mechanism. And it also uses different threshold values that keep the link stable which gives high PDR and uses R-B priority tree which keeps low E2E delay.

Figure 4.5: Average End to End Delay (ms) of DPTR, LEPR and DLSA
In addition, each graph gives different results w.r.t the required value. In this scenario, DLSA routing protocol the proposed one has given much better results in contrast to the existing ones on the basis of End to End Delay,
Packet Delivery Ratio, Network Lifetime and Transmission Loss. By using the R-B priority and introducing the link stability metric (a threshold value) for the DLSA routing protocol. This procedure has done made it possible that DLSA has outperformed well in comparison to the existing routing protocols by taking their positive features and merging them. It allows DLSA to keep minimum end to end delay and keep PDR increased in all scenarios for FANET.

4.7 Summary
After successful simulation for the proposed DLSA routing scheme the overall performance has been witnessed in all scenarios. The proposed DLSA routing scheme has given much better results in E2ED, PDR, Network Lifetime and Transmission Loss. The existing routing scheme has also given good results but in contrast to DLSA their results are poor. The key factor is the use of link stability and network partitioning in which the R-B tree takes place. By combination the both efficient features in DLSA is the main factor that it has given dramatic results. The Average E2ED in milliseconds of DLSA was measured 0.457 while DPTR was 1.492 and LEPR was 1.006. Similarly, Average PDR in %age of DLSA measured 3.106 while DPTR was 2.303 and LEPR was 0.682. Average Network Lifetime of DLSA measured 62.141 while DPTR was 23.026 and LEPR was 27.298. At finally, Average Transmission Loss in dBm of DLSA measured 0.975 while DPTR was 1.053 and LEPR was 1.227.

V. SUMMARY, CONCLUSION AND RECOMMENDATION
This chapter describes the overall summary of the research from chapter first to chapter five. It consists of summary, contribution, conclusion and recommendation. These are discussed below in detail.

5.1 Summary
This section gives the summary of the overall research process and the proposed methodology along with the results and discussion. In chapter first, the detail overview of Flying Adhoc Networks (FANETs) have been discussed along with its key issues, challenges and applications and proposed solution. At the end of chapter first, the problem statement and objectives of the study is also given. In chapter second, the detail overview of the related literature have been given from the perspectives of different authors related to the concerned study of the interest. In chapter third, the proposed mechanism of the research methodology and system model along with the simulation tool have been discussed in detail. In chapter fourth, the results have been obtained from MATLAB simulation and discussed each and every scenario accordingly.

5.2 Conclusion
This research has been successfully done to minimize End-to-End Delay (E2ED) and maximize Packet Delivery Ratio (PDR). In this research, a stability metric value for DLSA has been taken that aims to minimize E2ED and reduces the broken paths thus enhance lifetime of the network. After final simulation results in this research, the DLSA routing protocol is compared with the existing DPTR and LEPR routing schemes for FANETs. Each parameter has given different values which are shown in Chapter IV. The best results have been generated by DLSA by using an efficient and robust scheme for routing and focusing on reducing E2ED and rising PDR for the proposed mechanism to prove the objective 1 and 2 that are stated in Chapter I.

After effective MATLAB simulations, it has been witnessed that the DLSA routing protocol outperformed than the existing FANETs routing schemes in all parameters because of the merging the positive features of the existing routing protocols. The DLSA routing protocol gives much better results by using the link stability mechanism. At last, it has been verified with proper justification that DLSA routing scheme offers major enhancement in E2ED, PDR, Network Lifetime and Transmission Loss over existing FANETs routing protocols i.e. DPTR and LEPR.

5.3 Contribution
In this research, the main contribution is the trend from negative to positive aspect that is the proposed work. By detecting the limitations and flaws in the existing routing schemes and then merging and taking the positive features of the existing work which lead this research to achieve the major goal of delay and link stability by designing a new hybrid scheme. The main aspects were to minimize E2ED and maximize PDR in the concerned proposed work. In short, the overall thesis is the contribution which has focused on the reliable and efficient design of a hybrid routing protocol for FANET. The main contribution was also to improve the performance of routing for FANET on the basis of newly designed DLSA routing scheme. This research is a writing for publication especially one of a collection of writings as an article about FANET and the constricted point is routing in this network. To enhance the routing in FANET by link stability this ultimately affects the increase of PDR and decrease of E2ED as compared to the existing DPTR and LEPR routing schemes. So, therefore this research has contributed a tremendous advantage towards the future generation wireless communication in FANET especially in routing.
The performance of DLSA routing protocol was evaluated by using MATLAB simulations. The efficiency of newly designed protocol are tested based on the concerned parameters End to End Delay (E2ED), Packet Delivery Ratio (PDR), Network Lifetime and Transmission Loss. The results have been concluded from the simulations that shows the effects of these parametes in the perspective of DLSA routing protocol. In short, the overall thesis is the contributio in which the enhancement of new hybrid routing scheme has been achieved.

5.4 Recommendation and Future Work
In this research the concerned study was conducted to check the performace and efficiency of different evaluation parameters for DLSA in comparison with DPTR and LEPR. For the purpose of minimizing end to end delay and increasing PDR on the basis of the performance evaluation parameters End to End Delay, PDR, Network Lifetime and Transmission Loss by taking the positive features of DPTR and LEPR protocols.

It is suggested that link stability aware with minimum delay has presented better results. Henceforth in future, some other issues arise in this network that needs to be estimated first and then properly solved. These issues include congestion control that can be utilized along with these parameters and tested under new conditions. Additionally, the nodes and geographical scalability of the network can also be analyzed by increasing or decreasing the number of nodes and results can be obtained through experimental simulations. This research also gives directions for upcoming challenges and issues to be solved.

In future, these protocols can also be evaluated under different evaluation parameters along with different mobility models in FANETs. Also, jitter, path loss, network stability period, total energy consumption etc. can be used as performance evaluation parameters to generate the best and alternative results in comparison with the existang state-of-the-art solutions. NS-2, NS-3, OPNET, OMNET++ etc. can also be used as simulation tools for the concerned study.

Research work on FANETs is still in infancy and it offers many issues and challenges that need effective results and solutions. Numerous new technologies in relative to UAV software, hardware and routing schemes are developing and some of them may be easily adjustable to FANETs. Incorporating these new technologies with the existing ones is a main research challenge. FANETs needs to be open-ended and should be capable to accommodate any new technology. Nevertheless FANET still needs robust and reliable routing algorithms that solve the vulnerability issue to protect the UAV network from perpetrators.

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