UAVs Reliable Transmission for Multicast Protocols in FANETs

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***Abstract*—"Communication in the sky" is a trend because the increment of Unmanned Aerial Vehicles (UAVs) use in wireless communications. UAVs have diverse applications in civil and military domains. Swarm of UAV system is able to combinedly finish the operations more reliably and financial more than single UAV. UAV system has rapidly changing topology due to high mobility devices. Currently, Mobile adhoc networks (MANETs) routing is used for communication in UAV networks, the standards for communication system in Flying adhoc Networks is yet to be developed. UAV system streaming information needs protocol with high bandwidth, high mobility, varying link stability and high energy consumption compare to adhoc networks. It leads to abruptly breaking communication in between UAV-to-UAV and UAV-to-ground. In this paper, we discuss the link stability issues in UAV communication systems. Link stability estimation is required for reliable communication in between end-to-end flying nodes. We have simulate the MANETs protocol for reliable communication in flying adhoc networks. We evaluate the performance of Flying adhoc networks (FANETs) communication model based on multiple performance metrics, and also suggested deployment scenarios on EXata/Cyber 2.0 to analyze the network performance.**

I. Introduction

The growing requirement of UAVs in military and other area made it extensive research topic. After second world war the unmanned air craft controlled by radio signals and other aircrafts. The remotely piloted aircraft (unmanned) with high mobility and low cost of deployment are in extensive use since last few decades. Use of single large UAV is less feasible and more costly than small multi-UAVs Systems [1]. Multi-UAV Systems benefits more than single UAV system. In multi-UAVs system, UAV are either connected to ground base stations or to satellites, communication between UAVs can be infrastructure based but it needs each UAV should have complex hardware connection with ground base stations or satellites. The solution to this problem is Ad-hoc based communication between UAVs in this a subset of UAVs is connected to ground stations or satellites. The FANETs (UAVs using Ad-hoc network) have intermittent links, rapid topology changes and challenging communication link stability between the nodes due to their high mobility as compare to MANETs and VANETs.

Communication between UAVs also get affected by different types of terrain and obstacles which make communication among UAVs challenging in multi-UAV system. UAVs have feature like they may have either star topology or mesh topology both topology have their respective pros and cons. The UAVs applications are emerging in various domain as surveillance, Science and Research, Environment and climate disaster recovery, Communication relaying, in Journalism (Journalist uses this for information and image gathering). It was a Predator (i.e. an American UAV) mission that located Osama bin Laden in Afghanistan in 2000, after Al Qaeda had been tied to the 1993 World Trade Center bombing and the 1998 bombings of two U.S. embassies in Africa.

Motivation of this paper is to elaborate the communication issue in UAV networks and provide techniques to overcome the problems. UAVs are highly in use due to their unique characteristics and features that facilitate users as per their requirement. More than half population of the world lack of internet access but with purchase of Titan Aerospace in April 2014 [2], Google could bring millions of more people online. Amazon announced that it aimed to begin delivery by using UAVs. By this, product will deliver to customers in 30 minutes. Facebook also showed interest in UAVs and there was news that Facebook spent $60 million on buying Titan Aerospace, So we can see how much UAVs are in use or will be in use of many applications. So it is necessary to to ensure the communication issues to UAVs and research for solutions related to these issues such as mobility of UAVs, intermittent communication links, dynamic topology.

Proposed article has the following contribution, it presents the scenarios for air communication from multiple source to multiple destination. The performance metrics of FANETs is analysed on defined simulation parameters. We have address the various issues in communication between UAV devices due to their extended features from adhoc networks. We have provided a $3D$ scenarios for surveillance of border area by UAV devices and transmitting streaming data to destination nodes with the help to UAV and UGV [3] nodes. Three proposed protocols of MANETs are simulated on FANETs simulation parameters to examine the reliabile communication in extended networks.

The rest of this article is organized as follows. Section II presents the overview of previous works on the FANETs and discussed the protocols for stable communication in MANETs. Section III, shows the communication between UAV devices and requirement of reliable communication. Simulation param-

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eter and various scenario are proposed in Section IV. Result analysis are presented in Section V followed by concluding remarks in Section VI.

II. Related Work

There are various protocols for FANETs proposed by Physical, MAC, Network, Transport layer [4]. The physical layer conditions should be well defined for effective communication in FANETs, FANETs first example used the IEEE 802.11 radio model with omnidirectional antenna, with MAC layer the issue related to FANETs are weak link quality due to high mobility of nodes and also the packet latency is a design issue of MAC layer with FANETs.

The FANETs have high mobility of their nodes so in Network layer protocol the existing routing table methods are not effective and needs a routing method based on the location information of these UAVs nodes. In highly dynamic environment FANETs needs good Transport layer protocols for better results. In FANETs, communication reliability, congestion control and flow control are controlled by Transport layer which are important issues in communication. Use of small UAVs swarms benefit more than use single large UAV if in UAVs swarms one node is failed or discharge and leave the link to charge itself then other nodes can fill the gap and the communication is not affected by it but in case of single large UAV the communication get affected by failure of single node. So multi-UAVs Systems are more useful than large Single UAV System. In [5] has presented a method for efficient deployment of multiple UAVs for particular application.

A. Issues Related to UAVs Networks

UAVs have high demand in area of boarder surveillance[28], wind estimation [6], relay for communication and Adhoc networks [7], disaster monitoring [8]. Although they are high in demand they are not completely acceptable in the world of networks due to many research issues related to them. Zheng [9] has presented the summay of adpative routing protocols in flying adhoc networks. So strong communication between UAV to UAV (can use 802.15.4n) and between Ground Control Station (GCS) and UAVs (can use 802.11n) for information transfer is an essential requirement. Routing for UAVs can be position based routing, hierarchical routing, proactive routing, reactive routing. For disaster affected area or military uses, area coverage is an important issue for UAV network. Since the efficiency of area coverage solution depend on the coverage percentage i.e. the ratio between how much area is given and how much area is covered by UAVs. For successful completion of military operations area coverage approach should be efficient. According to the current UAVs uses in mobile communication area, enhance the capacity of network.

One of the most concerned issue is how many number of UAVs are required for a particular mission. There are various issues related to tracking of target by UAVs like target is static or moving, if it's moving speed is constant or continuously changing. The UAVs need to move from source to destination for this the main requirement is the path from source to destination should be smooth, flyable, obstacles and terrain free. Path planning is an important issue related to every mission of UAVs. It effects mission delay and efficiency of results. There are various uses of UAVs as communication relay so issues related to downlink communication and uplink communication in various domains should be point of consideration.

In military and disaster recovery scenario, the most important issue is how well UAVs monitor the provided area. In area coverage by UAVs corporation is challenging, how well they interact to each other and if a node failure occur due to some reasons then how well other nodes maintain the network and communication among them [10]. There are various area coverage issues related to UAVs network such as connectivity, obstacles and terrain, ability of coverage, mobility and lifetime, etc. Multicast routing protocol in MANETs is an emerging area that effectively improves the performance while lowering the energy consumption and bandwidth usage. The existing routing protocols focus on hop-count metrics and are not adaptable to densely distributed and highly mobile networks. Therefore, multicast communications with Quality of Service (QoS) metrics in highly dynamic networks poses interesting research challenges.

Multimedia applications such as the onboard data received by UAVs and transmitted to ground station need to support multiple QoS metrics such as throughput, energy, and jitter with limited bandwidth, energy constraints, dynamic topology, transmission errors and fluctuating link stability. The links between adjacent nodes are often not reliable and may break due to node mobility. Link breakage initiates the process of re-routing at the sender node (source node) i.e., the node at which the link breaks, leading to packet loss, delivery delays and control overheads. Hence to overcome link breakage, stability in the links is required for the duration of route refresh interval. Link stability metrics are used to improve network performance in terms of end-to-end delay, packet delivery ratio and available route time-span.

B. Proposed Protocols

We have proposed three protocols, for reliable communication in adhoc networks for multimedia streaming data. In first protocol (Moralism [11]), a node mobility model that considers stable link for route construction is used as the basis to predict the future positions of the nodes in the network in first protocol. The links with long active duration time are identified, and the variation in signal strength parameter is used to identify whether the direction of the node is towards or away from the estimating node. Signal strength is considered as a QoS metric to calculate link stability for route construction.

In second protocol [12], Link and route stability are considered as the basis for reliable network communication has been proposed in the second work. These protocols identify and remove the weakest link in a stable route that causes during in first work. The probability of successful transmission of periodic packets is used as a link stability metric which helps in the estimation of a stable path. Increased probability of successful transmission implies that the selected link will sustain for the longer duration (stable link) and it can deliver packets with improving reliability.

In third protocol [13], a multi-constrained QoS aware routing metric that determines a reliable forwarding node based on Link Stability cost Function (LSF) is proposed in third work. The primary theme of underlying protocol is to find average contention count link, that is estimated with the help of received signal strength. LSF is based on contention count, hop count and the received signal strength at a node. A mobile network is created in which no node remains isolated, as well as nodes face lesser contention. A comparative analysis of the proposed protocols that consider multiple QoS metrics was also made with the existing Hop count based protocols.

III. UAVs Communication Model

Single UAV device is used in communication applications from the decade. Because of their limitations like limited range, lack of multi-hop network, cost of making one big UAV, centralized access. In Figure 1, we have shown single UAV device communication with main node (Head Quarter (HQ)). In this scenario, UAV is on border surveillance for intruder

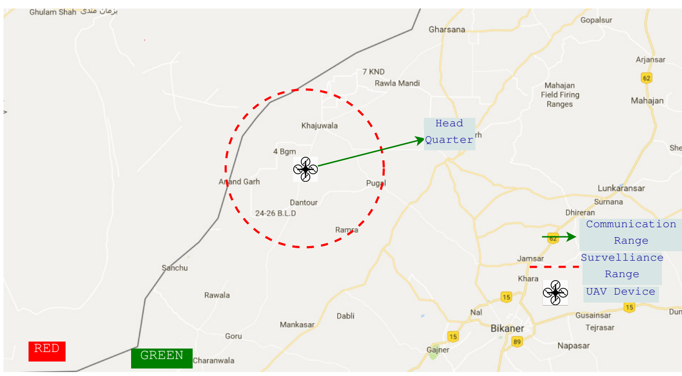

Fig. 1. UAV device transmitting video streaming data to Head Quarter

detection from RED to GREEN. UAV device continuously surveillance the allotted border area and transmitting the streaming data to HQ. Due to security reason, it is not possible to apply HQ to nearby the border area. We have to place it to the secure region. Now we are not able to communicate directly to HQ, because of limited communication range (red circle) of UAV device.

In Figure 2, we have created one another scenario of multiple UAV and UGV (Unmanned Ground Vehicle) nodes communicating data to multiple HQ. This scenario can be represent by MIMO system. In this scenario, we have placed swarm of UAVs for surveillance the complete border area. UAV device has higher transmission range as compare to UGV device for transmitting data to long distance with high reliability. Swarm of mini-UAVs are placed in 3D nearby the border of green and red zone for complete surveillance. Swarm of UAVs has various advantages over single UAV system, such as distributed system (single node failure will not breakdown

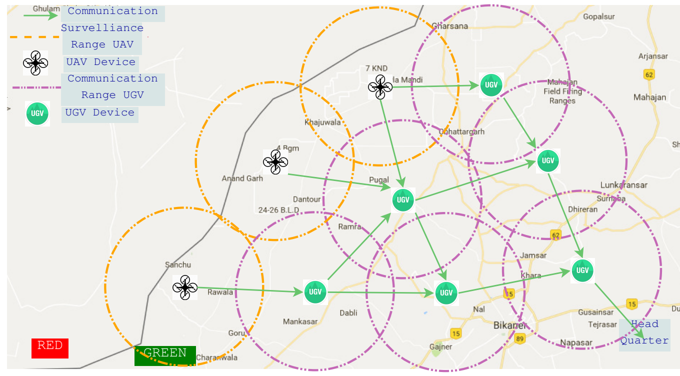

Fig. 2. UAV devices capturing and communicating surveillance Data to Head Quarter

complete system), cost reduction, efficient, reliable and packet transmission to unlimited range.

IV. Simulation Environments

Simulations have been run on EXata/Cyber v2.0 [14] simulator, 56 node network over 1.5 sq. km. terrain dimensions. All simulation parameters are listed on the Table IV. In this simulation, we have also placed nodes with some heights around 500meters. We are transmitting data from multiple source to multiple destinations (Multicast Group). We have

Simulation Parameter	FANETs
Simulator	EXata/Cyber v2.0
Simulation Time	500 Seconds
Scenario Dimension	(1-10) Sq.km.
Height of Node	0-500m
Transmission Range	500m
Mobility Model	Random mobility model
Mobility	10-30 m/s
Routing Protocol	ODMRP, LSMRP Moralism, MCLSPM
Traffic Type	Multiple MCBR [15]
Size of Packet	512 bytes
Data Rate	2-54 Mbps
Multicast Group Size	2-5
Number of nodes	(10-50)

TABLE I
Simulation Parameters of FANETs

created a path from multiple source to multiple destination for the duration of Route refresh interval [16]. During the simulation around 20k packets send to receiver from each source UAV with the MCBR traffic generator. We have run various simulations on multicast routing protocol to analyze the effects on the performance metrics. Also, we have done 10 numbers of simulations (i.e. different seed value) for validate the each result.

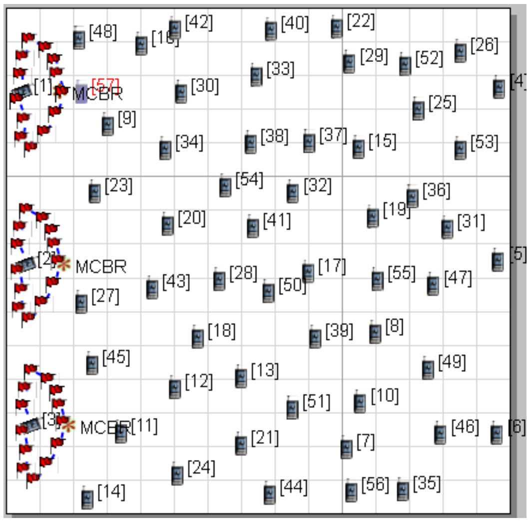

Fig. 3. Nodes positioning in the Scenario 2D Plane

A. *Scenario Configuration*

In Figure 3 and 4, we have created the scenario and view in 2D plane and 3D plane in the EXata/Cyber 2.0. In this example, we have taken three sources and three destinations over 1.5 Sq. Km. All sources are placed on with height around 100-500 meters and red flags are showing their mobility patterns. Source nodes have to surveillance the area by moving in the particular area (red flag) and transmit the data to destination nodes. Three nodes on the right side of Figure representing fixed destination nodes. For lack of direct communication between sources and destinations, we have placed 50 intermediate mobile nodes to forward the data.

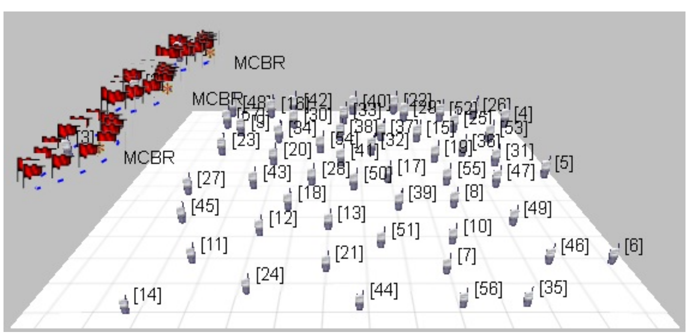

Fig. 4. Nodes positioning in the Scenario 3D plane

V. Result Analysis

In this section, performance metrics will be analyzed on different receivers with above-defined simulation parameters.

Packet Delivery Ratio: Total number of successfully received packets over total number of sent packets between source to destination is called packet delivery ratio (PDR).

$$PDR = \frac{\sum \text{Number of Data Packets Received}}{\sum \text{Number of Data Packets Sent}} \quad (1)$$

In Figure 5, the effect of our scenario configuration on packet

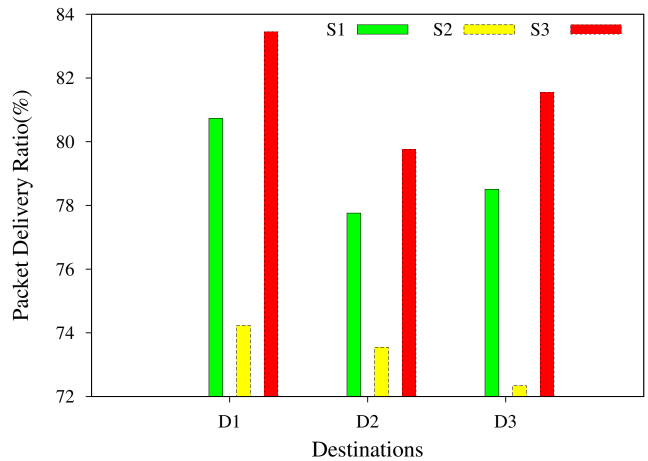

Fig. 5. Packet Delivery Ratio on various Destinations

delivery ratio at different receivers is shown. In this, PDR is around $72-84\%$. It totally depends on nodes position in the scenario because some receiver may be easily getting complete path with variation in fewer nodes. Single Destination receiving data from multiple sources at same data rate, because of that the destination will not be able to capture all the packets.

Average End-to-End Delay: This is the time required for transmitting a packet across network from a source to a destination.

$$AEED = \frac{\sum(Receiving\_time - Sending\_time)}{\sum Total\_Packets} \quad (2)$$

Figure 6, shows the differences in End-to-End delay of packet to various destinations. The delay is varying from $8-11$msec. Due to simultaneous arrival of the packets from different sources to same receiver node the delay is increasing. At the end nodes, intermediate nodes are sending duplicate packets again and again even after timeout.

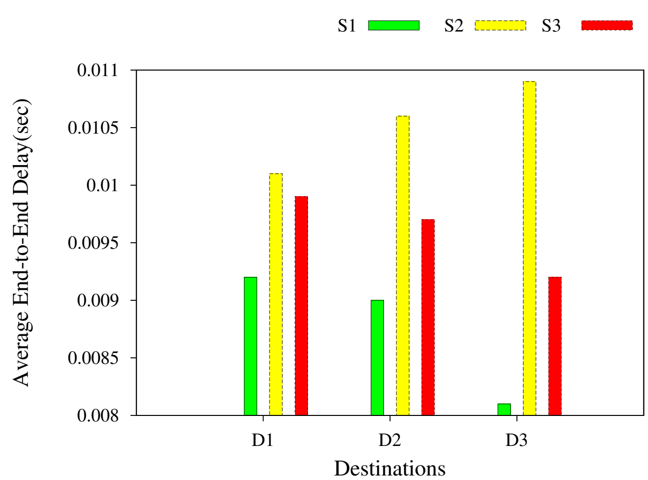

Fig. 6. Average End-to-End Delay on various Destinations

Coverage v/s Communication Reliability: Performability combines performance and reliability to analyze the network performance or system Quality of Services. In Figure 7, the curve has been plotted for reliability (Connected will remain active) versus coverage area, the reliability value is shown in the range [0-1]. Initially, the reliability is low and it improves as per increment in coverage area because number of nodes in the communication range will be increased. The network

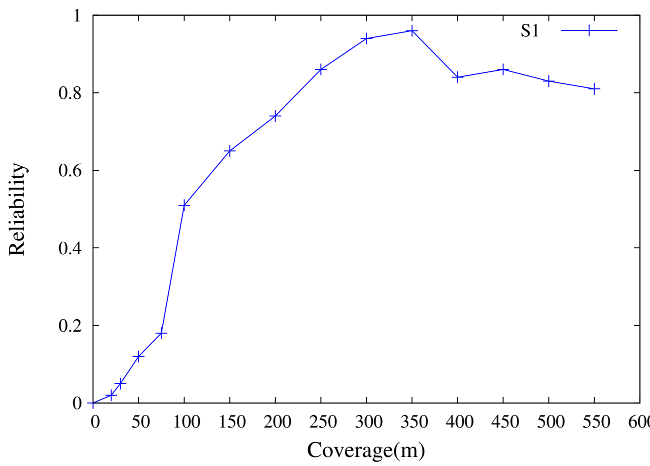

Fig. 7. Communication Reliability by increasing Area Coverage

performance is increasing rapidly that is directly proportional to the reliability.

After the threshold coverage area, the reliability is going down or may be slope is constant due to multiple reasons such as node contention, congestion or hidden terminal problem in the wireless network. Now the node will affect other nodes communication range due to high coverage area and disrupt the communication reliability.

A. Comparisons of existing proposed routing protocols

We have proposed three solutions [11], [12], [13] for reliable communication in between end-to-end mobile devices. We are presenting the comparisons between the proposed routing protocols with simulation configurations of UAV networks. All the parameters have been set according to the requirements of UAV networks. In Figure 8 and 9, a comparison of PDR and average end-to-end delay is shown.

The PDR is higher in all proposed approaches as compared to existing routing protocols (ODMRP, LSMRP, SMR, MMRNS) as shown in Figure. First two proposed protocols (Moralism and route stability) are getting higher PDR, but last one proposed protocol (MCLSPM) get higher PDR because of multi-objective approach that helps to identify a stable route of longer duration. In first routing protocol, the pdr is going down after a threshold mobility, because it is not suitable for high mobility scenarios.

The average end-to-end delay is reducing in the proposed routing protocols because the reconfiguration cost is reduced. It is directly affecting the average time of a packet traveling

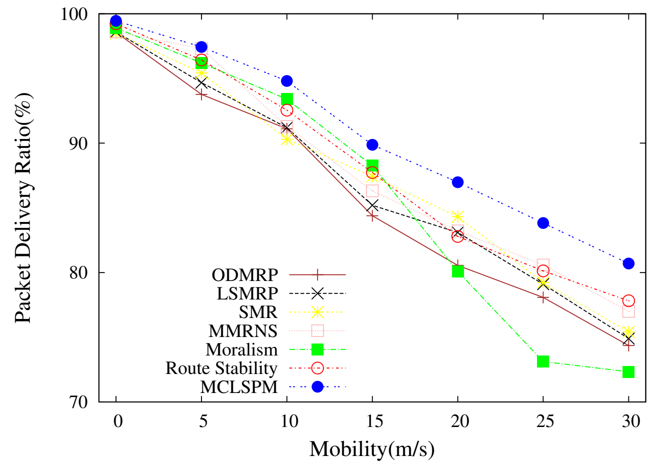

Fig. 8. Packet Delivery Ratio (%) by increasing node mobility

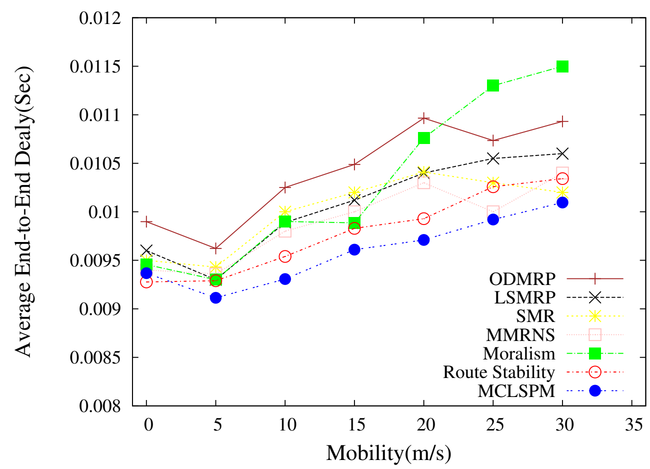

Fig. 9. Average end-to-end Delay (sec) by increasing node mobility

from source node to destination node. In UAV networks, the nodes are placed in three dimensional (3-D) scenario. The scenario configuration has been changed according to simulation parameters as shown in Table IV. Our proposed routing protocols have performed significant well with the consideration of FANETs parameters in the simulation environment. In figure, general trend of average end to end delay is increasing as per the increment in mobility, but at 5m/s the delay is reducing.

VI. Conclusion

This paper is giving an performance analysis of UAV based adhoc network with different scenarios based on performance metrics. We have shown a scenario for multiple input and multiple output system, three source devices are surveillance the border areas and transmitting the streaming data to all the destinations. We have performed a comparison study using UAV devices to see the reliability of existing proposed protocols. In future, we can try to build the system for Unmanned

Aerial Vehicles that will improve the device communications. We are also working on real time border surveillance system using Artificial intelligence and machine learning to predict unwanted threat and identification of border trespassing.

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