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Support of Mobility Models for the Decentralized Multi-layer UAV Networks Assisting VANET Architecture (DMUAV)

N. Vanitha[1,*], G. Padmavathi[2]

[1]*Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, University, & Department of IT, Dr.N.G.P. Arts and Science College, Coimbatore, India.*

[2]*Department of Computer Science, Avinashilingam Institute for Home Science and Higher Education for Women, University Coimbatore, India.*

Abstract

Unmanned Aerial Vehicles (UAV) gains the prominent role in this pandemic era. UAV assisting Vehicular Ad-hoc Network architecture holds U2V/V2U communication, applied in enormous applications most importantly in search and rescue operations during disasters. Unmanned Aerial Vehicles (UAV's), can fly alone or it can be functioned remotely without carrying any operator. Nowadays Unmanned Aerial Vehicles are applied almost all the applications. Flying Ad-hoc Networks (FANET) are formed by Ad-hoc networking between UAVs, this can resolve the difficulties rising from an entirely infrastructure-based UAV network. This paper presents various communication architectures and checks the fitness of the various mobility models with the decentralized multi-layer UAV ad-hoc network assisting vehicular ad-hoc network architecture (DMUAV) and analyses the various architectures by means of evaluating the network performance with the mobility metrics, Network Diameter and Average clustering co-efficient with chosen mobility models, routing protocol OLSR. The communication architecture is simulated using Network Simulator (NS3). Simulation results shows that the DMUAV architecture is robust and reduces interference and increase in routing performance.

Keywords: Architecture, mobility, multi-layer, radio communication, routing.

INTRODUCTION

Drones or Unmanned Aerial Vehicles (UAV) systems play a vital role in this pandemic era, which can be operated remotely. Due to ease of accessing drones remotely, UAV's can be extensively applied for lot of applications like search and rescue operations, health care, military, delivery, monitoring etc. FANET's can resolve the complications that arise due to the infrastructure-based UAV network. Centralized and Decentralized architectures are simulated and tested for performance. The proposed research work concentrates on the evaluation of the DMUAV architecture. The DMUAV architecture is tested for chosen Mobility Models selected routing models to prove the robustness of the architecture.

A. Significance of Architecture

- Organizing UAV's in a network, recognize the roles mandatory for the entire communication procedure and allocating tasks between the UAV's.
- Connecting multiple UAV's in ad-hoc network is a big challenge.
- Co-ordination between UAV's and Vehicles to UAV's/ UAV's to Vehicles.
- Establishing a highly secure and robust architecture.
- Passing Control and scheduling information to and from Ground station to UAV.

B. Classification of Architecture of UAV Networks

The various communication architectures for networking between UAVs has been discussed in this work. Based on communication and coupling between the UAV's, the architecture has been classified. Fig. 1 illustrates the various classifications of UAV network architectures [1],[12].

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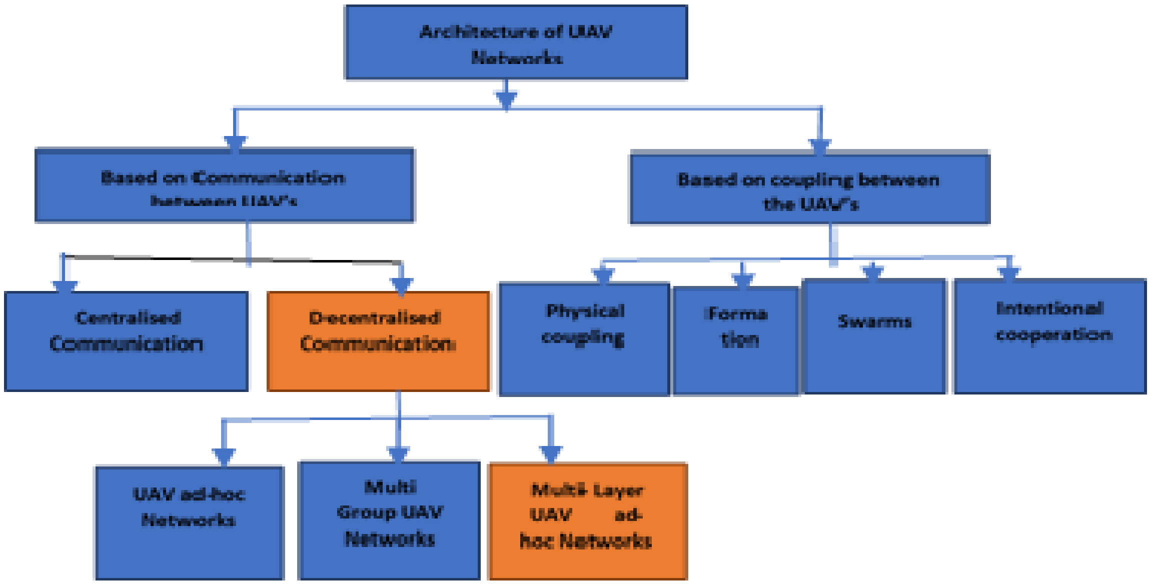

Fig.1. Classification of Architecture of UAV networks.

C. Problem Statement

To evaluate the integrated robust communication architecture that can support assorted mobility models.

D. Objectives

The proposed works main objective is, suitability checking of the various mobility models in the DMUAV architecture.

The secondary objectives are:

- Reduce the communication overhead.
- Robust Communication Architecture.
- Reduce interference and increase the routing performance.

E. Significant Contribution of the Paper

Evaluating Integrated Decentralized Multi-Layer UAV network assisting VANET (DMUAV) architecture with Mobility models (Random Waypoint and Smooth turn model) with chosen OSLR routing protocol.

F. Literature Review

Some of the significant works are studied and analyzed. Muhammed Asghar Khan et al, introduced the three decentralized UAV network architectures and they have investigated the existing protocols on these architectures in 2017. Fanhui Zeng and his team projected UAV-assisted data broadcasting and arrangement approach in VANETs and during the process of data dissemination, projected a maximum vehicle coverage (MVC)algorithm to plan the 2D schedules of the UAVs in 2018. In 2019 Muhammad asif khan et al, in Wi-Fi Direct networks projected the uses of UAVs along with ground station. In UAV-aided Wi-Fi Direct network, the UAV is installed along with the P2P Group Owner or so called Soft-AP, and the UAV placement in the restricted environment is the issue here, and not for UAV assisted VANET's. In 2019, Qixun Zhang et al, used closed – form coverage boundaries and theoretically proved the layered UAV network architecture with the lowest number of upper layer UAVs and proposed the low latency routing algorithm (LLRA) for the connectivity of higher layer UAVs and the limited location data, here the authors have concentrated on UAV's not for UAV assisting VANETs. O. S. Oubbati et al, presented a novel routing structure named UVAR, it implements a novel method built on density and connectivity to pick the best routing sector, here the protocol not handles the different Mobility Models in 2016. Jean-Daniel Medjo Me Biomo et al, investigated UAV ad-hoc network architecture stand on various mobility models with mobility metrics. Kuldeep Singh et al surveyed and presented assorted mobility models that explain the movement activities of diverse mobile nodes beneath diverse geographic conditions in 2015.

MATERIALS AND METHODS

The Decentralized Multi-layer UAV networks assisting VANET architecture

The Integrated DMUAV that facilitate the air-ground cooperation. Fig.2 depicts the networking architecture of the DMUAV that is a decentralized architecture, collection of a multi-UAV subnet work and a ground vehicular sub network. This work, investigates the two-layer networking. There are three different variations of communication links were presented within the multi- layer UAV ad-hoc network assisting VANET, they are Aerial Networking or UAV to UAV networking (A2A/U2U), Ground networking or Vehicle to Vehicle (V2V), Air–ground networking/ UAV to vehicle or Vehicle to UAV(U2V/V2U) [1] [2], [12],[16].

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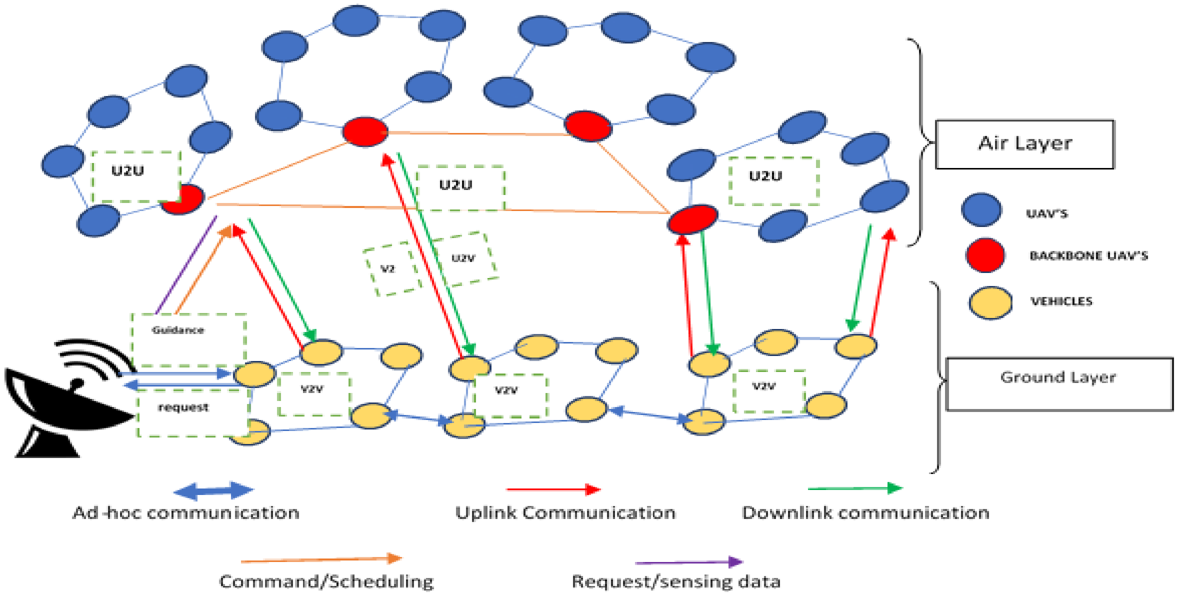

Fig. 2. The DMUAV architecture.

- Air-layer networking: The aerial network nodes provide A2A relations for packet delivery between UAVs. Like Wi-Fi (IEEE 802.11), Assorted radio interfaces can be considered in A2A connectivity [3].
- Ground-layer networking: The ground layer network nodes are a variety of sparse VANET, in this communication network, V2V connectivity's are used for the inter node (vehicle) packet conversation. In this vehicular environments, OLSR proactive routing protocol is an available wireless access protocol, uses channels of10-MHz bandwidth in the 5.9-GHz band. The scheduling and guidance commands sent by Ground station to the rescue vehicle and the vehicle desires to transmit real-time road situations to further ground nodes (vehicles) [4], [5].
- Air layer–ground layer networking: Taking into consideration of sparse networking condition, both the aerial and ground sub networks have to cooperate to improve the networking competence. Air layer to Ground layer links can simplify three foremost roles, with subnet administration, component plan, and communication relaying. The aerial subnet gathers the image data and conveys the recognizing information to the ground position via U2U and U2V links. The ground posting works with the image data and bring out the road circumstances, and it distributes them to the ground subnet over V2V links. At the same time, the ground station transmits the updated scheduling commands to the aerial sub network through A2G / U2V links. As soon as the links are broken up due to evil channel condition or lengthy link distance, the air–ground networking can assistance to set up a DTN, in which the UAV can serve as a middle relay node to improve the connectivity [1], [2], [5].

Pseudocode for the DMUAV architecture

Begin

If line of sight is available between source and destination Vehicles then

Transfer the packet to destination

Else

send the request to the ground station to pass control and schedule information to the backbone UAV's

If the destination is in the range of backbone UAV's then

packet will be delivered to destination

Else

packet will be delivered to next layer UAV for forwarding to destination

End

Features of the DMUAV

- Robust and Scalable.
- No single point failure and Low Communication overhead.
- Minimized packet loss and Low Energy consumption.

Assumptions

The explanation of conventions that are considered in this paper are as follows:

All the nodes are armed with a Global Positioning System (GPS) and with a fixed digital road map to trace the adjacent

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intersections and the acquaintance of the end point position is expected to be known. All vehicles are periodically maintained and updated with its neighbors and also table of neighbors is maintained. All UAVs are maintained with enough battery power and within a line-of-sight a node can communicate with other nodes. In order to permit nodes to compute the total number of nodes, the format of hello message is changed by adding novel fields. Having a worldwide vision of the connectivity among two consecutive connections, and sharing them with the current UAVs that can then contribute to make the routing choice carried out by the (source/forwarder) node situated at the juncture. Completely powered VANET is permanently available in the ground and associated with ground station.

System Model

System model of DMUAV network architecture contains, a group of all UAV nodes in a DMUAV network architecture is represented as UAV_a, and two kinds of UAV nodes are expected (backbone UAV and next layer UAVs). The groups of backbone and next layer UAVs are represented as UAV_b and UAV_n, correspondingly. That is, $UAV_{b,'s}$ are working for probing things and UAV_n are only employed as data ships. Here, UAV_b □ UAV_a and UAV_n □ UAV_a. Therefore,

Total network elements = $\{(UAV_a \cup UAV_b) \cup (UAV_a \setminus UAV_b = UAV_n)\}$.

In the considered scenario, each UAV is placed in a specific position, and position material is accessible to UAV_n. Next layer UAV_n practices the meticulous mobility, and the ground station controls the mobility. Next layer UAV_n gathers data (D_{cl}) from the backbone UAV_b and directs to the ground station over a high throughput link (HT). UAV_a may modify the flight area and performance after getting a command communication (C_{msg}) over a long, low-throughput (LT) communication connection. Hereafter, the total data will be,

$$(D_{Tot}) = D_{cl} + C_{msg}.$$

In order to store data, all UAV_a have the greater memory size, therefore not at all buffer overflow would happen in the network.

Proposed Methodology

The proposed methodology checks the suitability of the chosen mobility models in DMUAV network architecture, and proved that smooth turn model provides no sharp turns and robust and scalable architecture. The Fig. 3 Shows the mobility models that this paper concentrates to evaluate the DMUAV.

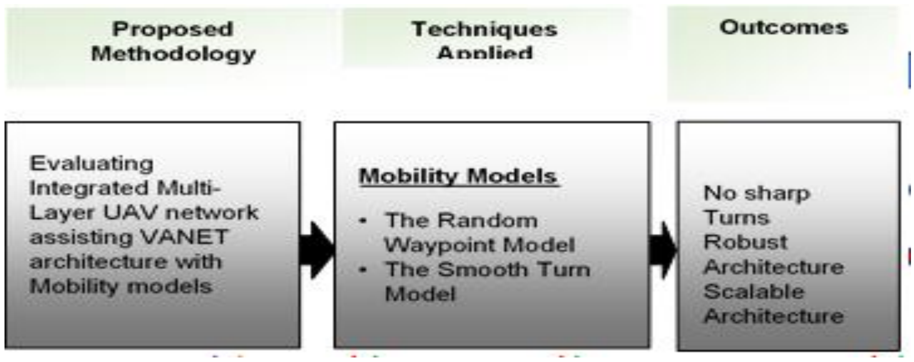

Fig. 3. Contribution of the Work.

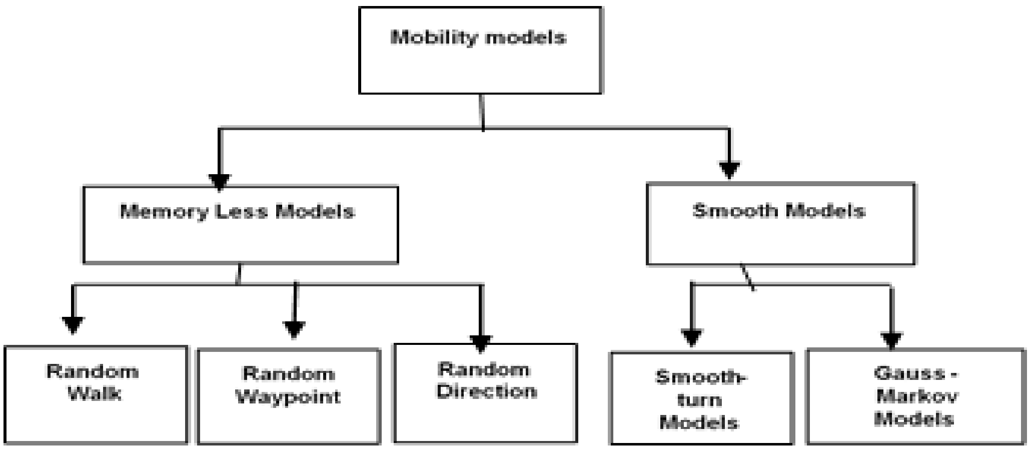

Fig. 4. Classification mobility models based on memory.

Evaluating the integrated architecture Based on Mobility Models for UAV Networks

- **Random waypoint model:**

Johnson and Maltz coined the Random waypoint model (RWPM). Now this typical model converted standard to offer equivalence of various Mobility models, since of its ease and widely usage [8][9][10][14].

Algorithm:

Step 1: The UAV's practices random speed among preset range [min-speed, max-speed] and direction amongst $[0, 2\pi]$.

Step 2: The RWPM contains break in proceedings between fluctuations of rapidity and route. The UAV's

re liberal to move in any route and at any speed, but it is controlled by ground station.

Step 3: UAV's moves near the definite fact, after picking random rapidity and route and after attainment that time all UAV's yield pause time and once more repeat Step 1 and stay till UAV's aren't spreads to simulation portion.

Comparative speed of two UAV's fixes whether the connection among two nodes cracked or designed rather than well-defined their specific rapidity.

Johnson et al well-defined the relative speed among node p and q at the time t is

$RS(p,q,t)= | V_p(t) - V_q(t) |$ ----------(1)

To calculate the relative speed of the general node pairs over all the time is defined by Mobility metric $\vec{M}$

$\vec{M}=1/| p, q |\sum_{p=1}^{Z} \sum_{q=1}^{Z} 1/t \int_0^t RS\ (p,q,t\ )dt$-------(2)

Where p,q is that the dissimilar node couple, Z is that the total quantity of nodes inside the simulation. RS is that the relative speed of couples of node and t is that the time of simulation [8] [9].

Smooth Turn Model (STM)

Liang and Hass, proposed the Smooth turn Model (STM). The drawbacks of random mobility models are unexpected and high-pitched turns and unexpected stops. To exhaust this problem, STM calculates current speed and direction using previous velocity and direction of UAV. With the present speed and velocity of UAV, p the longer-term position is frequently calculated. Straight forward is the thought behind the ST random mobility model. An UAV picks some range inside the interplanetary along the road vertical to its header direction and loops around it until the UAV picks another rotary centre. This vertical guarantees even flying trajectories. Additionally, since a UAV frequently favours straight paths and minor turns than very high-pitched turns, Y. Wan, K. Namuduri et al, modelled the opposite length of the rotary circle to be Gaussian distributed.[14] [15]

We use lx(t), ly(t), vx(t), vy(t), R(t), and A(t) to represent the x and y directs, rapidity in x-direction and y-direction, angular velocity, and so the header angle at time t, similarly. For easiness and genuine thoughts, we adopt a continuing forward speed V during a 2-D plane; hence, the tangential acceleration $a_t(t)$ is 0. This hypothesis is cheap for UAV's, as they have a tendency to take care of a corresponding rapidity in trip and "reduce speed" over twisting and rotating [8][9][11].

The dynamic forces of the vital ST mobility model through the interval $Ti \leq t < Ti+1$ is exposed in the next,

$at(t) = 0$ -----------(3)

$an(t) = \frac{V\ 2}{r(Ti)}$ -----------(4)

$A\ (t) = - R(t) = -\frac{V}{r(Ti)}$ ------------(5)

$lx(t) = vx(t) = V \cos(A\ (t))$ ------------(6)

$ly(t) = vy(t) = V \sin(A\ (t))$ ------------(7)

Metrics of Mobility models for Evaluating the DMUAV Architecture

The following are the performance metrics of the Mobility models,

- Network Diameter
- Average coverage
- Average clustering coefficient
- Average path length
- Average Relative speed

This work concentrates on Network Diameter and Average clustering coefficient.[13] Because the communication architecture provides low Network Diameter gives low interference and increasing the routing performance and highest Average clustering coefficient provides dynamic communication between nodes in the network.

RESULTS AND DISCUSSIONS

The projected method is assessed for its effectiveness by means of the succeeding parameters [13]:

- Network Diameter(ND):

Let lg (m, n) be the minimum number of edges mandatory to seek out an associated track between m and n within the two-dimensional space V^2.

The Network Diameter is given by,

$ND = \max \{ lg (m, n) \} \ \forall (m, n) \in V^2$

- Average Clustering Co-efficient:

The clustering coefficient is defined as:

Clustering Co-efficient $Cj=\frac{2Pj}{qj(qj-1)}$

Here, q_j is that the degree of node j and P_j is that the sum of edges between the q_j neighbors of node j. The average clustering coefficient of complete graph and it can be calculated as,

$<C>=\frac{1}{N}\sum_{j=1}^{N} Cj$

Simulation Environment

The projected method is simulated beneath the Linux Ubuntu 14.04, using the Network Simulator -3 (NS3) version ns-allinone-3.26. Table I. Shows the simulation constraints of the network atmosphere.

TABLE I. Simulation Constraints

Constraints	Value
Period of Simulation	1500 s
MAC Protocol	802.11
Simulation Area	2000 * 2000
Routing Protocol	OLSR
Traffic	CBR
Number of nodes (UAV's & Ground vehicles)	5,10,15 & 5
Transmission Range	1000 m
CBR data rate	50 kbps
Packet size	1 MB
Speed	20 (m/s)
Pause Time	10 Seconds
Channel capacity	11 Mbps
Mobility models	Random Waypoint mobility model (RWP) Smooth -Turn mobility Model
Propagation Model	Free Propagation Model

TABLE II. Numerical comparisons of Network Diameter for Mobility models in DMUAV Architecture

No of UAV's Ground Vehicles: 5 Nos.	Network Diameters (In Hops)	
	RWP (In hops)	STM (In hops)
5	3	2
10	2	2
15	2	2

Table II shows that the DMUAV architecture is scalable which produces the minimum and same network diameter for 5 to 15 nodes. From the Fig.5, When number of nodes increased from 5, 10 and 15 the STM model 's network diameter didn't get changed it remain always 2. When number of UAVs will get increased the network diameter gets unchanged, this result shows that our DMUAV architecture is scalable under these two mobility models.

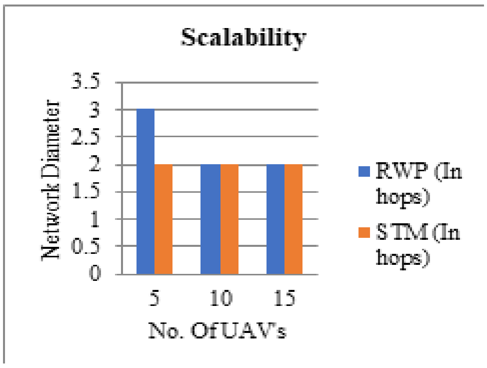

Fig 5. Scalability with 5,10, and 15 UAVS.

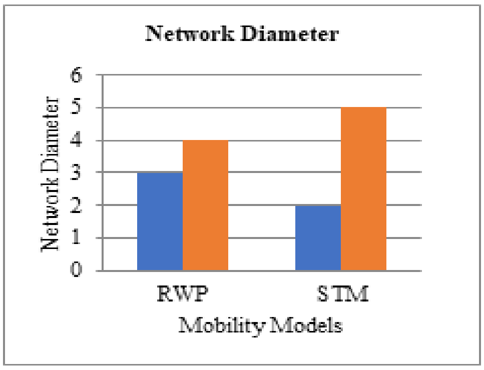

Fig. 6. Network Diameter

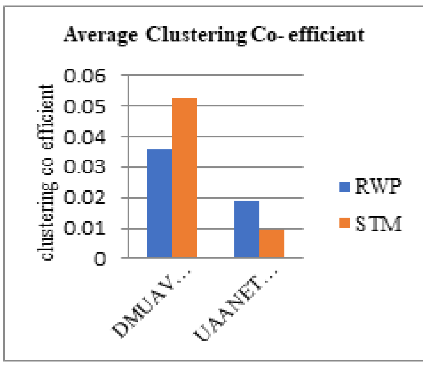

Fig. 7. Average Clustering coefficient.

The Mobility model which makes a small diameter will, expand the routing act and diminish the interfering. Table III shows that, in the DMUAV architecture STM mobility model works well and produced low network diameter and Fig.6 shows the result. From Fig. 6, routing performance of DMUAV is good when the number of UAV's increased compared to UAANET architecture.

TABLE III. Network Diameter for Mobility models in DMUAV and UAANET Architecture

ARCHITECTURES/Mobility Model's	Network Diameters (In Hops)	
	RWP	STM
DMUAV Architecture	3	2
UAANET Architecture	4	5

TABLE IV. Average Clustering coefficient for DMUAV and UAANET architecture

Architectures / Mobility models/	Clustering Co-efficient (Between 0 and 1)	
	DMUAV Architecture	UAANET Architecture
RWP	0.03578972	0.0189960
STM	0.05263157	0.0097378

Table IV and Fig 7. Shows the Average Clustering coefficient for the UAANET and DMUAV architecture with the mobility models. Low Clustering co-efficient shows that the links between the nodes are low, so that there is no dynamic communication between nodes in the network. Our proposed architecture's clustering co-efficient is high compared to existing UAANET architecture. The values of the Clustering co-efficient shows that the efficiency of the DMUAV architecture is increased when compared to UAANET architecture.

CONCLUSIONS

Massive growth of UAVs has been witnessed nowadays. This work relates the DMUAV architecture with the UAANET architecture and identifies that overhead arises in UAV ad-hoc network architecture, UAANET architecture is having single point link failure, the multi-group UAV network architecture was not much strong and multi-layer UAV ad-hoc architecture offers scalability and more resourceful networking competences with robustness. For Smooth Turn mobility model, the DMUAV architectures work well compared to UAANET architecture. The simulation results show that the DMUAV architecture is scalable, performs better routing with Smooth turn mobility model compared to UAANET architecture. In future work hybrid mobility models are implemented and tested to improve the performance of the DMUAV architecture.

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