Binary Spray and wait routing Protocol with controlled replication for DTN based Multi-Layer UAV Ad-hoc network Assisting VANET

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Abstract: Unmanned Arial Vehicle (UAV) Network is an autonomous wireless communication network, mainly used for natural disaster recovery operations to forward the captured images or video information to the ground vehicle. The UAV network can be applied in various applications essentially, search and rescue operations. This work concentrates on Delay Tolerant Network DTN based Decentralized Multi-layer UAV ad-hoc network assisting VANET for post-disaster scenarios. Because of unbalanced links in highly dynamic UAV networks, packet forwarding is a challenge. This work proposes a Binary Spray and wait routing protocol (BSnW) with controlled replication for DTN based Decentralized Multi-layer UAV networks. The Next Layer UAVs are presented to empower a well-organized Store and carry forward (SCF), in Multi-Layer UAV ad-hoc networks. Next Layer UAVs expands the accessibility of connecting tracks among the all DTN UAVs and the ground vehicle, hence reducing end-to-end delays and growing the packet delivery ratio and drop the packet drop ratio. The proposed BSnW with controlled replication protocol enables a high packet delivery ratio, which enables, and guarantees single-copy data forwarding to evade duplication of every message. Proposed protocol has been experimented using Opportunistic Network Environment (ONE) Simulator. Our simulated experiment show that the proposed protocol outstrips the epidemic routing protocols reported in the literature in terms of the packet delivery ratio, average delay, throughput and the routing overhead.

Keywords: DTN, Spray and Wait, store and carry forward, Unmanned Aerial Vehicles

1. Introduction

Unmanned Aerial Vehicles (UAV) systems are self-governing systems, that are operated with remote by the human in the ground station. High mobility is one of the characteristics of drones so, UAVs has been used for many of the applications like search and rescue, delivery, monitoring etc. The Ad-hoc networking among UAVs or drones (FANET- Flying Ad-hoc Networks), rectify the difficulties rising from entirely infrastructure-based UAV network. In this paper authors proposed a protocol that provides good throughput, minimum end to end delay, no single point of link failure, and reduces communication overhead. This work paper concentrates on DTN based decentralized multi-layer Unmanned Arial Vehicle (DDMUAV) assisted Vehicular ad-hoc network (VANET) architecture. The Proposed protocol named Binary Spray and wait routing protocol (BSnW) with controlled replication. In this protocol DTN routing technique with store-carry-forward mechanism. This work builds a protocol that provides good throughput, less delay and a packet drop ratio. Our performance study show that the proposed protocol outperforms the existing routing protocols reported in the literature in terms of packet delivery ratio, average delay, and routing overhead.[1][2] [3]

Routing Protocols for UAV networks

Routing protocols for UAV networks are classified into two different sections, they are the network architecture-based and based on data forwarding routing protocols. Network architecture-based routing are the single path and the multipath routing. Fig. 1. Show that this work concentrates on multipath routing with DTN flooding Strategy protocols, Epidemic and Spray and wait.[4][10]

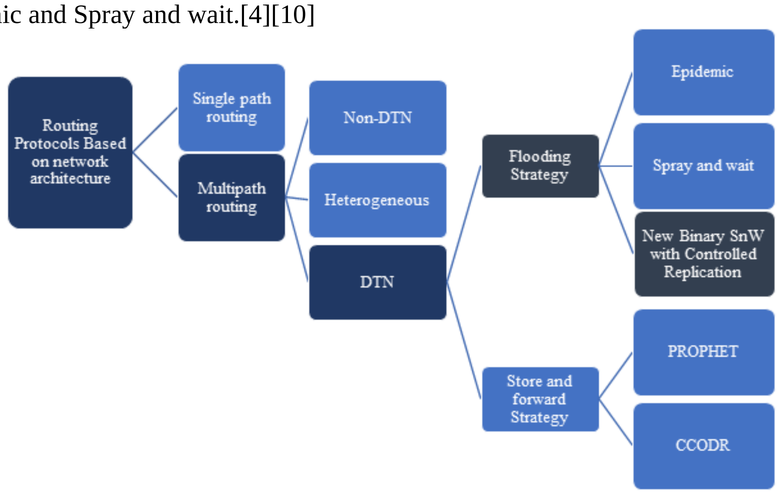

Fig. 1. Classification of Routing protocols for DDMUAV networks

Objective

The primary objective of the work paper is to propose a DTN based protocol for DDMUAV network to improve throughput, minimize delay and packet drop ratio.

2. Related Works

Routing protocols for UAV networks have been investigated by Muhammad Yeasir Arafat And Sangman Moh et al, in 2019. The routing protocols are then compared qualitatively in terms of their major features, characteristics, and performance. The open issues and the research challenges in the perspective of design and implementations were openly discussed by the authors.

F. Nordemann and R. Tönjes, University of Applied Sciences Osnabruck, investigated the store and carry forward protocol for the manet based DTN network, authors found that this technique provides high throughput and low delay in MANET based DTN network.

Mohammed J.F. Alenazix, Yufei Cheng, The University of Kansas, USA, conducted a workshop and implemented the Epidemic routing protocol in Network Simulator 3 (NS-3), Authors have implemented Epidemic protocol in DTN based Manet using NS 3, which provides Good packet delivery, Minimum overhead and Delay compared to Manet Routing protocols.

In 2015, Nahideh Derakhshanfard et al, used Spray and wait routing system and they have proposed the method that continuously chooses the next node and studies the number of replicas a node can transport. Authors got the good delivery ratio and minimum delay for Opportunistic Network.

R. Silva, P. Braga et al, proposed Adaptive routing protocol for DTN networks, based on the predictable contacts concept and to determine the best way to route and drop packets on network it uses the history of meeting nodes, which provides the greatest delivery rate up to 300 meters.

3. The Groundworks

A. Motivating Set-up

The search and rescue operation as a demonstrative example scenario for DDMUAV networks. Where the UAVs search for things and lost people and monitors the disaster-affected area with a geo-tagged camera. Lot of incisive UAVs can be directed to all the areas to yield pictures. High throughput links were employed to transmit a large-size images from the Next layer UAVs to the ground station. The vehicles are aware of their own positions.[8][9][12]

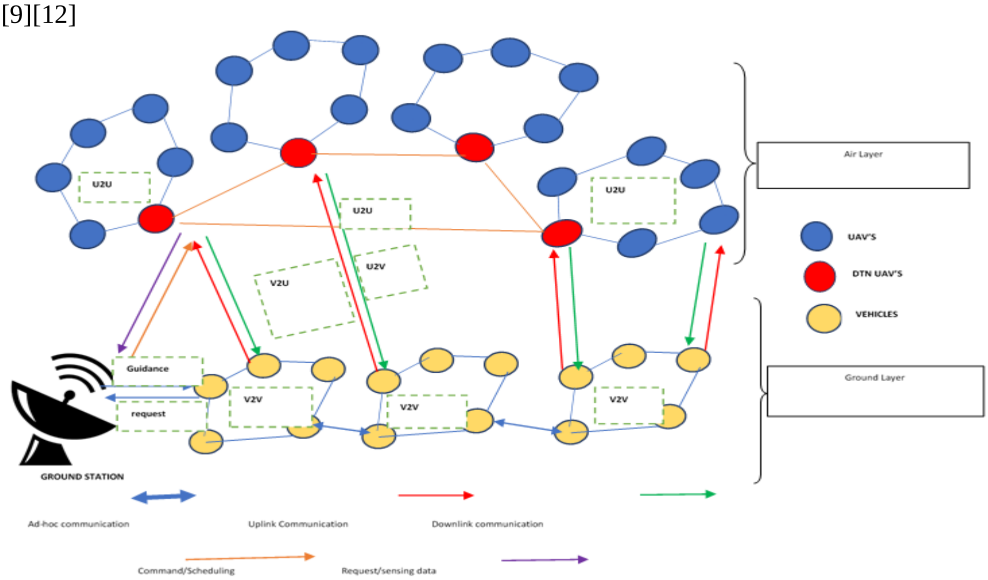

Fig. 2. DTN based DMUAV Network Architecture

B. Assumptions

We assumed that the GPS and Digital map is always available with UAV's. All vehicles in this network knows the location of a ground station, position of itself, and its direct neighbour. When monitoring the large area, a majority of outdoor UAVs may function in a plane area for safety. With the help of rechargeable batteries, the vehicles didn't have any energy restrictions. The recharging stations or the ecological energy possessions like solar energy is available. The Wireless interface, IEEE 802.11p with high-speed communication range is expected to be used by each node. Full powered VANET is always available. Source node has a message with L_a number of tokens and there is a met node with a message delivery probability higher than that of the transporter node.

4. Materials And Methods

A. Methodology of the work

Overall Methodology of Implementation and evaluation of DDMUAV with BSnW with replication control protocol is depicted in the figure 3,

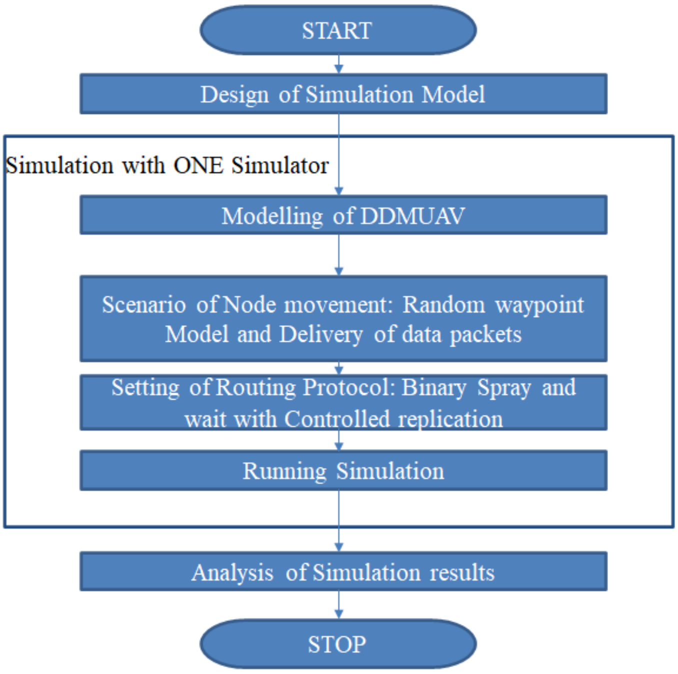

Fig. 3. Research Methodology of the Work

B. Proposed Binary Spray and Wait with Controlled Replication (BSnW with Replication Control)

In this section presents in detail about the proposed BSnW with controlled replication algorithm. There are two phases the Binary spray and wait algorithm operates. The are spray phase and wait phase. The node carrying the message forwards a portion of the tokens to the met node in the spray phase. The wait phase initiates after the spray phase are done. The source node scrutinizes the likelihood of distributing or not distributing the message to the terminus, in this phase. The forwarding progression is over, in case one of the neighbors of the node carrying the message is the terminus. For each terminus, each node has a prediction variable, the variables value ranging from 0 to 1 indicates the probability ($P_{a,b}$) of the positive delivery of the message to the terminus. [5]

There are 3 parts in manipulating the delivery probability. When 2 nodes meeting one another, the delivery probability is appraised over the 1st equation. Here, P_{ini} stands for the booting constant. When two nodes do not meet each other, delivery probability is restrained via 2nd equation. Here, λ refers to the elderly constant. When three nodes join with one another, transitive property is got through 3rd equation. Here in the equation, б represents the scaling constant.

$$P_{a,b} = P_{a,b}old + (1-P_{a,b}old) * P_{ini} \qquad \text{---------(1)}$$

$$P_{a,b} = P_{a,b}\ old * \lambda k \qquad \text{----------(2)}$$

$$P_{a,d} = P_{a,d}old + (1 - P_{a,d}old) * P_{a,d} * P_{b,d} * \text{б} \qquad \text{----------(3)}$$

Binary spray**:** The delivery probability of the two nodes denotes, the ratio of the remaining time of the message and the number of L_a tokens, hence, L_a tokens remain in the transporter node and L_b tokens are forwarded to the met node that is calculated through Eqs. (4), (5) and (6).

The node (either the transporter node or the met node) that has a higher delivery probability, the token is allocated to it if, L_a is equal to one.

Fig. 4 denotes the replication control of packets through TTL value. Fig. 4. Shows the controlled replication in BSnW protocol in DDMUAV.

$$La(t+1)=\frac{Pad}{Pad+pbd}*Rab*La(t) \qquad \text{--------(4)}$$

$$Lb=La(t)-La(t+1) \qquad \text{--------(5)}$$

$$Rab=\frac{RTTLa-t\ ab\ carry}{RTTLa} \qquad \text{---------(6)}$$

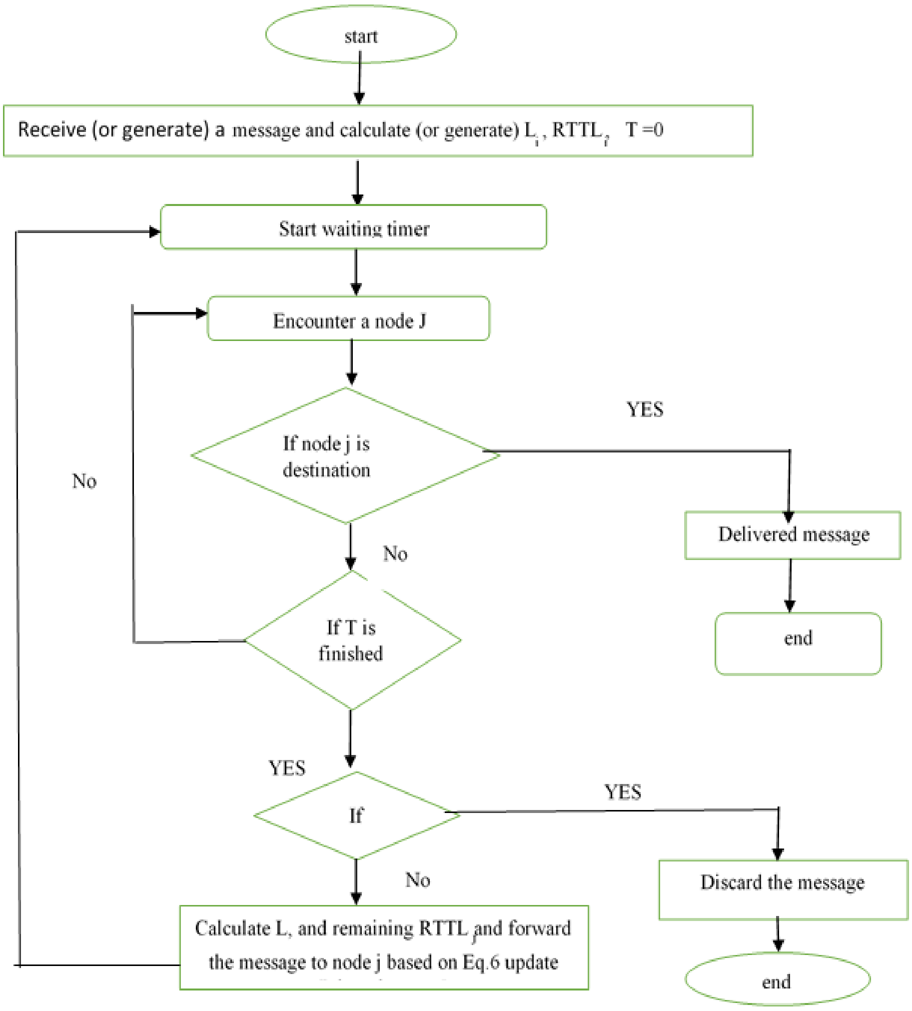

Fig. 4. Replication Control in BSnW Routing Protocol

C. Metrics for Evaluating the protocol

Following metrics were used to evaluate the simulated protocols, the Epidemic and the BSnW with controlled replication

1. *Throughput*: T is Throughput, TBS is Total bytes sent, TLPS is Time of Last packet sent, TFPS is time of First Packet sent.

$$\text{Throughput T} = \frac{8*TBS}{TLPS - TFPS}$$

2. *Average End to end Delay*: The delay is calculated using the following formula,

$$\text{End to End Delay} = N\frac{L}{R}$$

where, N denotes the Number of links, L denotes the Packet Length, R denotes the Transmission rate.

3. *Packet Drop Ratio*: Calculated as a ratio between the number of packets lost and the number of transmitted packets.

$$\text{Packet Loss Ratio} = \frac{\text{Packets Lost} * 100}{\text{Number of Transmitted Packets}}$$

5. Simulation Results And Discussions

The scenario of the DDMUAV network with epidemic and a proposed BSnW with controlled replication protocol is simulated using ONE Simulator using the simulation parameters available in the table 1 and results were discussed.[11]

Table 1. Simulation constraints

Parameter	**Value**
Simulator	ONE Simulator

Routing Methods	Epidemic routing, BSnW with controlled replication routing
Map Size	4500m*3400m
No. of Nodes	13 UAVs
Simulation Duration	12000 s
Message Formation Pause	10 s
Message Extents	256 bytes
Message TTL	300 m
No of Packets	500
Node Buffer Size	50 MB
Interface	High Speed Interface IEEE 802.11p
No. of Groups	3

Fig. 5 and 6 shows the simulated network architecture of DDMUAV with Epidemic and Proposed BSnW with Controlled Replication protocol using ONE Simulator. There are 3 groups 1 ground station, 2Backbone UAV's and each 5, 10 Next layer UAV's. The simulation runs for 5000 seconds and generates various reports like, the message status report, the message creation report, the message delivery report, the event log report, and the message graph viz report etc. Each protocol is implemented in one simulator using java program and run for 100 times to get the average report.[6][7]

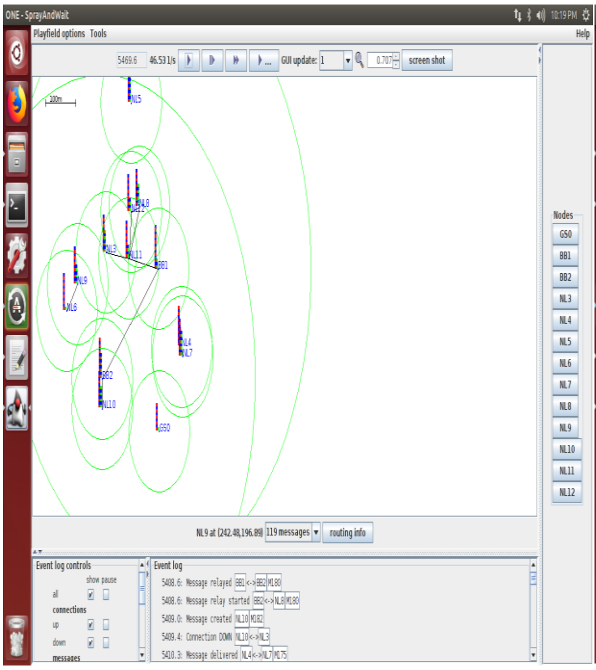

Fig. 5. Simulating with BSnW with CR

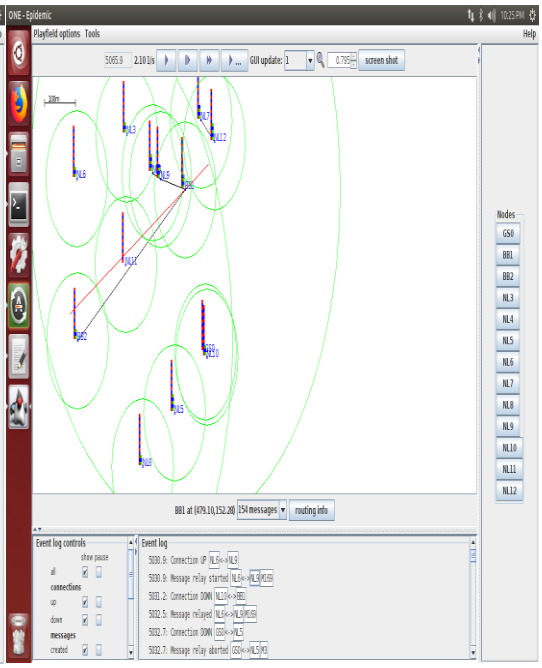

Fig. 6. Simulating Epidemic Protocol

Performance of the protocols Epidemic and the Proposed BSnW with Controlled Replication protocol has been evaluated based on the metrics, throughput, average delay , packet drop ratio and the results are represented as a graph in Fig. 7.

Table 2. The Percentage of Improvement

Metrics	**Epidemic**	**BsnW with the controlled replication**	**Percentage of improvement**
Throughput	5.85	6	2.5
Average delay	0.584	0.5	14.38356
Packet loss percentage	0.1	0.05	50

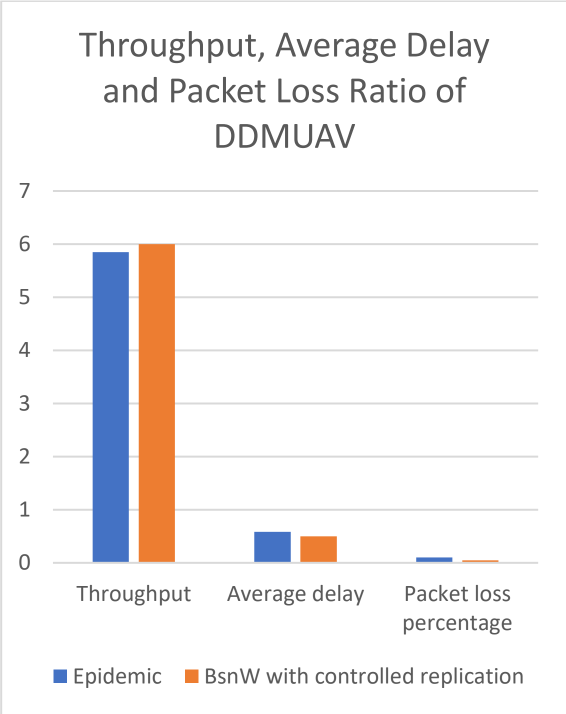

Fig. 7. Throughput, Average Delay and the Packet Loss Ratio of DDMUAV

From Table 2. the proposed protocol works well in the DDMUAV network provides good throughput, average delay and reduced packet loss ratio compared to the epidemic protocol available in literature. From Fig. 8. BSnW with controlled replication provides 2.5 % of improvement in throughput , 14 % of improvement in the case of average delay, 50% of improvement in the packet drop ratio compared to the epidemic protocol.

6. Conclusion And Future Work

Search and rescue are the most prominent work in the case of disaster and recovery situations. Drones or UAVs in the form of DDMUAV's are employed for search and rescue applications to identify the missing people where the humans are not able to go and rescue the human beings. The delay is the most prominent metric in this search and rescue operations. Our proposed protocol in DDMUAV provides at the maximum reduced delay and packet drop in the case of DDMUAV networks Search and rescue operations. The proposed protocol has been simulated and the results were compared with the already available protocol. The maximum packet loss will be reduced with the proposed Protocol. The proposed BSnW with the controlled replication will produce a little delay and Maximum throughput compared to available protocols in the literature. The protocols outperform the already available protocol epidemic in the case of throughput, delay and packet drop ratio. The work is further extended to monitor the traffic of the DDMUAV network to analyse the network for further issues.

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