Link Breakage Time Prediction Algorithm for Efficient Power and Routing in Unmanned Aerial Vehicle Communication Networks

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***Abstract*—UAV Communication Networks (UAVCN) comes under the umbrella of Ad hoc Network technology. It has the critical differences with existing wireless networks, which are high mobility, high speed, dynamic updates, and changes in topology due to high movement, which creates the problem of link breakages and affects the routing performance. This problem degrades the performance of UAVCN in terms; it decreases throughput and minimizes the packet delivery ratio. In this paper, we have tried to overcome this problem by considering the received signal power strength (RSPS). We have proposed an algorithm which uses the received signal power strength and time and calculates the link breakage time prediction by using the interpolation method. We have implemented the proposed technique by modifying the OLSR protocol. The extended protocol termed EPOLSR, which efficiently using the signal power strength and time and increasing the performance of UAVCN. The extended protocol implemented by using a research tool network simulator (v3). The metrics received rate, no of received packets, throughput, and packet delivery ratio (PDR) is considered for evaluation. We have examined the proposed EPOLSR with existing routing protocols. It has been observed that the modified protocol performs better concerning all existing evaluated routing approaches.**

Keywords—UAV; link breakage; algorithm; power; RSPS; routing

I. Introduction

In this study, we have explored the emerging area of adhoc networks, which is known as UAVCN. These nodes can be deployed for a specific operation; either it belongs to the military or civilian mission. [1,2]. These network nodes have high movement. However, it changes the frequent topology; that's why link breakages issue affects the routing [3]. The coverage increased by minimizing the interference of UAVs' communication [4]. The environment and terrain affect the UAVs' communication, hence to overcome these obstacles, a hybrid mechanism of unicast and geocast routing used to know the trajectory and location [5]. The authors optimized the route by using the neural network concepts and implemented the Dynamic Source Routing (DSR) protocol for evaluation and optimization [6]. The researchers proposed the hybrid protocol which helps in link establishment [7]. In this study, experimental work carried out by comparing the adhoc on demand routing (AODV), DSDV, and OLSR routing protocol [8].

In this paper, we have organized the work into sections. The first section represents the introduction, and the second section provides the information of OLSR working mechanism, the third section contains a modification of OLSR Hello and Topology Messages by updating the reserved field, the fourth section indicates the prediction of route failure and Link breakage prediction. The fifth section presents the proposed algorithm. The sixth section highlights the research methodology. The seventh section describes the Results, and in the Eighth section, we have concluded.

II. The OLSR Working Mechanism

It is the proactive routing approach that operates two nodes by sending Hello Messages. It discovers the neighbors and maintains the neighbors' table. It updates the topology status and updates the topology information and maintains the routing table. Also, share the MID messages. The neighbor discovery process is mentioned as:

Fig. 1 shows the neighbor discovery process through Hello Messages. The X node forwards an empty message Hello. The Y node receives the message and stores information X as an asymmetric neighbor because the Y address is not available in Hello message. Y node then forwards Hello Message by asserting X is an asymmetric neighbor as soon as X obtains this message and gets its information address and then declares Y as neighbor symmetric. In last, X node incorporates Y in the Hello, it forwards, and Y recognize X as neighbor symmetric as receiving Hello message.

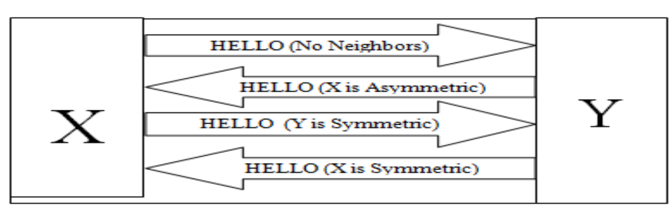

Fig. 1. Neighbor Discovery Process through Hello Messages.

Reserved		Htime	Willingness
Linkcode	Reserved	Link Message service	
Neighbor Interface Address			
Neighbor Interface Address			

Fig. 2. Hello Message Format of OLSR.

The above Fig. 2 shows the Hello Message Format of OLSR. According to RFC 3626, the OLSR furthermore extended or modified by using the reserved field. However, Htime shows the time of the next Hello packet before transmission. The willingness field represents that the willingness of the node when it forwards the traffic. The sender and the neighbor node-link information consists of the link code. It declares the status information of the neighbor node. Link message size provides the total link messages length. The neighbor interface address knows the interface of the neighbor node.

Fig. 3 shows the Topology Control Message Format of OLSR. The Advertised Neighbor Sequence Number (ANSN) shows the incremented sequence number at any time when changes take place in the neighbor set. According to RFC 3626, the OLSR TC packet can furthermore be extended or modified by using the reserved field. The advertised Neighbor Main Address field consists of neighbor node main addresses.

ANSN	Reserved
Advertised Neighbor Main Address	
Advertised Neighbor Main Address	
....	

Fig. 3. Topology Control Message Format of OLSR.

III. Modification of OLSR Hello and Topology Messages

The OLSR hello and topology messages are furthermore extended or modified by using the reserved field. The TC packet also extended or modified by using the reserved field. We have updated these packets by adding the power information in terms of signal strength, which is shown in Fig. 4 and Fig. 5. In this study, the modified OLSR termed as EPOLSR. The objective of EPOLSR design was to improve the routing in unmanned aerial vehicle communication networks. The EPOLSR consists of the Routing Table, which stores the routes information of all reachable destination UAVs.

Power		Htime	Willingness
Link code	Reserved	Link Message service	
Neighbor Interface Address			
Neighbor Interface Address			

Fig. 4. Hello Message Format of EP OLSR.

ANSN	Power
Advertised Neighbor Main Address	
Advertised Neighbor Main Address	
....	

Fig. 5. Topology Control Message Format of EP OLSR.

When a node receives the Hello message, it performs the following operations.

- To populate one-hop neighbors
- To populate two-hop neighbors
- To perform MPR calculation
- To populate MPR selector set

A. *Neighbor Table*

The neighbor table contains the following fields.

- Node Address
- Neighbor address identification
- Power Information (LRSPS and CRSPS)
- Time Information (LRSPST and CRSPST)
- Next Link Breakage Time

Each entry in the routing table has the destination address id, next-hop address, data size in packets, delay, and next route breakage time. Based on this information, one hop table and two-hop table neighbor entries, update the routing table. Compare the topology set and update the routing table.

To improve the performance of routing, a method ought to be introduced to administer the route breakages. Although, mostly routing algorithms are used hello messages for the detection of link breakages. The proposed algorithm operates based on link breakage prediction. It estimates link breakage time based on RSPS (received signal power strength) and, it predicts route breakage time as well.

IV. Link Breakage Prediction Time

The hello messages are used to uphold the prediction of link breakage time. Hence, at each time interval, a hello message is broadcasted to everyone instant neighbor of UAV. On account of RSPS intensity, the cost of subsequently, next link breakage time (y) of the analogous neighbor j, might be enlarged or minimized. While a UAV (x) received a hello message from another UAV (y). Then it evaluates the RSPS with the LRSPS from the same UAV. Furthermore, predicting the new cost of NLBT (x,y) using the interpolation method. The given equation (Eq. 1) computes the value of the next link breakage time NLBT(x,y):

$$\text{NLBPT}(x,y) = \text{Crspst} + \frac{(\text{Crspst} - \text{Lrspst}) * (\text{RxThresh} - \text{Crsps})}{(\text{Crsps} - \text{Lrsps})} \quad (1)$$

V. Link Breakage Time Prediction Algorithm for Efficient Power and Routing

Algorithm :

t_1 = Lrspst(last received signal power strength time)
t_2 = Crspst (current received signal power strength time)
pr_1 = *Lrsps*(last received signal power strength)
pr_2 = *Crsps*(current received signal power strength)
$r_x th$ = RxThresh(signal reception threshold)
T_d= Time_d(time difference)
Pkt = pkt(packet)

Begin

Add signal power strength in the reserved field of Hello_Message and send
Hello_Message with this signal power strength to the receiver, it Receive Hello_Message, and observe the received signal power strength, and extract
the signal pwr strength at receiver UAV.
MaxVal = The extracted signal power strength value from HELLO_Message

Input: R_{hp} (received hello pkt)
x (current UAV)
Rspsi received signal power strength intensity

If (R_{hp}.n_ID is not a neighbor of x)
Add_n(R_{hp}.neighbor_ID);
Lrsps = pr_1 (R_{hp}.n_ID);
Lrspst = t_1 (R_{hp}.n_ID);
Update the *Lrsps* of R_{hp}.N_ID;
Update the Lrspst of R_{hp}.N_ID;
If (*Lrsps* ≠ MaxVal)
Begin
Crsps = pr_2 (R_{hp}.n_ID)
Crspst = t_2 (R_{hp}.n_ID)
If (Crspst < Lrspst) // n_UAV move away
Begin
Time_d= (Crspst – Lrspst) * (RxThresh – *Crsps*) / (Crsps – *Lrsps*)
Next Link Breakage Time(R_{hp}*.n_ID)* = Crspst + Time_d
EndIf
Else *Next Link Breakage Time(* R_{hp}*.n_ID)* = MaxVal;
EndIf
End

VI. Research Methodology

The proposed approach or research methodology which we have used is the experimental method. We have used ns-3 (Network Simulator version 3. It can be used for UAVs networks simulation [9, 10]. Using this tool, we have implemented the EP-OLSR routing protocol and compared it with OLSR, DSDV, AODV, and DSR; by using the IEEE 802.11b environment. After the development of the testbed scenario, the simulation was carried out.

VII. Experimental Work and Simulation Parameters

In this scenario, we have used the ns-3 simulation tool and carried out the experiment. The main characteristics of this scenario are shown in Table I.

TABLE. I. Characteristics of the Testbed Scenario

Parameters	**Values**
Simulation tool	Ns-3.
Adhoc Routing Protocols	EP-OLSR, OLSR, DSDV, AODV, and DSR
Network Scenario Size	1500x400
Number Nodes	25
Data Rate	5 Mbps
Application	Video Streaming
WLAN Physical Characteristics	IEEE 802.11b
Network Protocol	IP
Mobility model	Random Waypoint
Scenario Simulation Time	200 Sec

The scenario has been developed by using 25 nodes — the network scenario based on the area of 1000x400 m2. The WLAN physical characteristics of standard 802.11b are used. The mobility model random waypoint is used. Similarly, the EP OLSR has been developed in C++ and integrated modules in the NS-3 environment. And by using the same wireless LAN physical characteristics standard cross-layer design in the 802.11b environment and the simulation has been run. Similarly, the existing protocols, OLSR, DSDV, AODV, and DSR configured in the scenario, and the simulation has been run. The simulation runs for 200 s. After this experimental setup, the scenario has been accomplished.

VIII. Simulation Results and Discussion

The results show that, in the ns-3 environment, the EP OLSR Receive Rate is 38 Kbps, and on the other hand, we have observed OLSR Receive Rate is 32 Kbps, as depicted in Fig. 6. Overall, the performance of the EP OLSR protocol is found better when compared to that of OLSR.

The results show that, in the ns-3 environment, the EP OLSR Receive Rate is 38 Kbps, and on the other hand, we have observed DSDV Receive Rate is 27 Kbps, as depicted in Fig. 7. Overall, it has been found that the performance of the EP OLSR protocol is better when compared with DSDV.

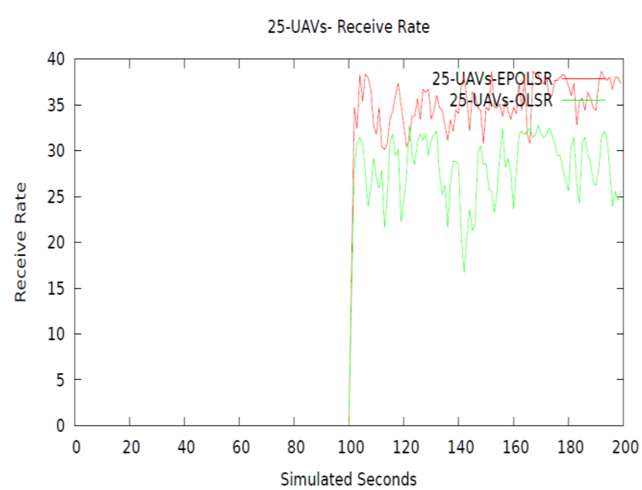

Fig. 6. 25-UAVs- Receive Rate (kbps) using EP OLSR vs. OLSR.

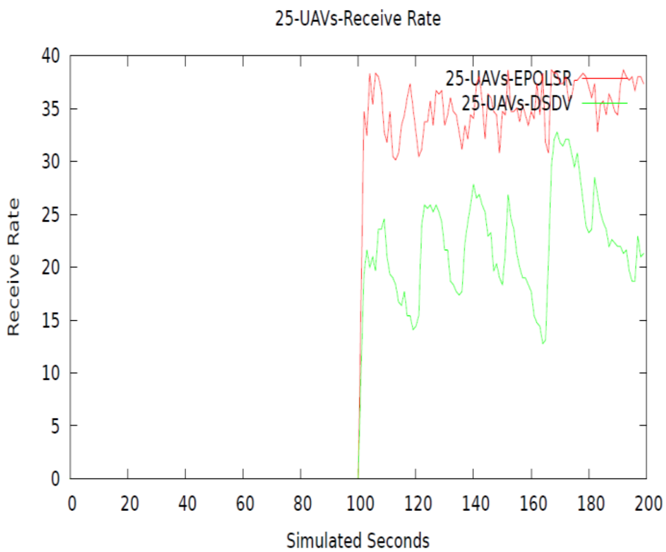

Fig. 7. 25-UAVs- Receive Rate (kbps) using EP OLSR vs. DSDV.

The results show that, in the ns-3 environment, the EP OLSR Receive Rate is 38 Kbps, and on the other hand, we have observed AODV Receive Rate is 28 Kbps, as depicted in Fig. 8. Overall, the performance of the EP OLSR protocol is better when compared with AODV.

The results show that, in the ns-3 environment, the EP OLSR Receive Rate is 38 Kbps, and on the other hand, we have observed DSR Receive Rate is 30 Kbps, as depicted in Fig. 9. Overall, the performance of the EP OLSR protocol is found better when compared to DSR.

The results show that, in the ns-3 environment, the EP OLSR Receive Rate is 38 Kbps, OLSR Receive Rate is 32 Kbps, DSDV Receive Rate is 27 Kbps, AODV No of Packets Received is 28 Kbps, on the other hand, DSR Receive Rate is 30 Kbps, as depicted in Fig. 10. Overall, it has been observed that the performance of the EP OLSR protocol is better when compared to OLSR, DSDV, AODV, and DSR.

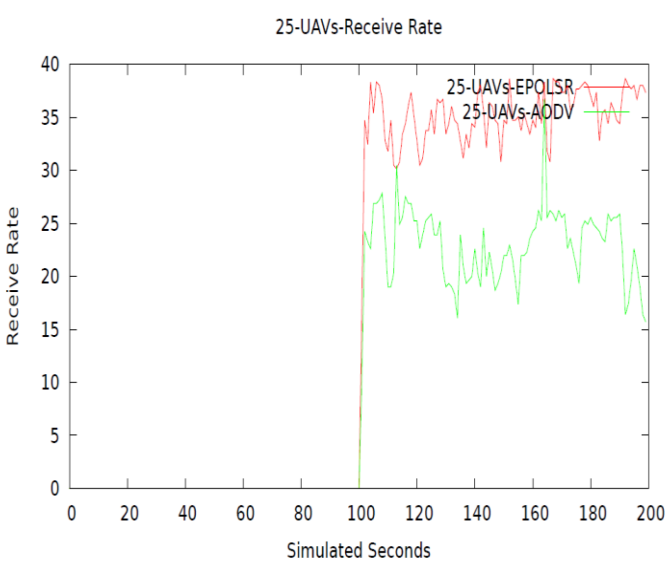

Fig. 8. 25-UAVs- Receive Rate (kbps) using EP OLSR vs. AODV.

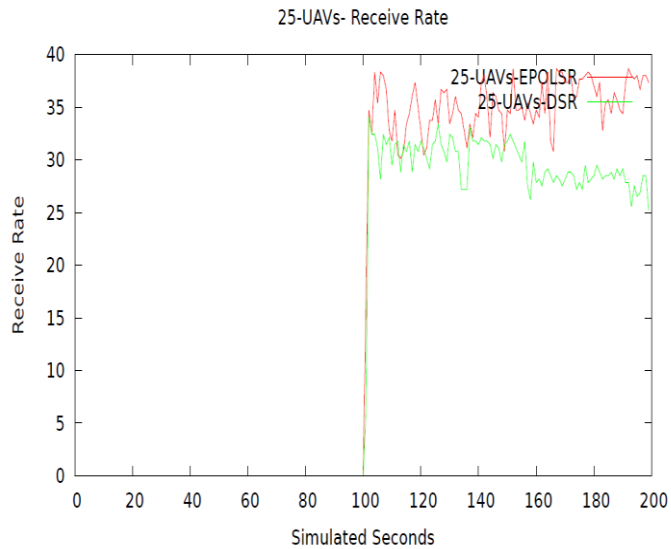

Fig. 9. 5-UAVs- Receive Rate (kbps) using EP OLSR vs. DSR.

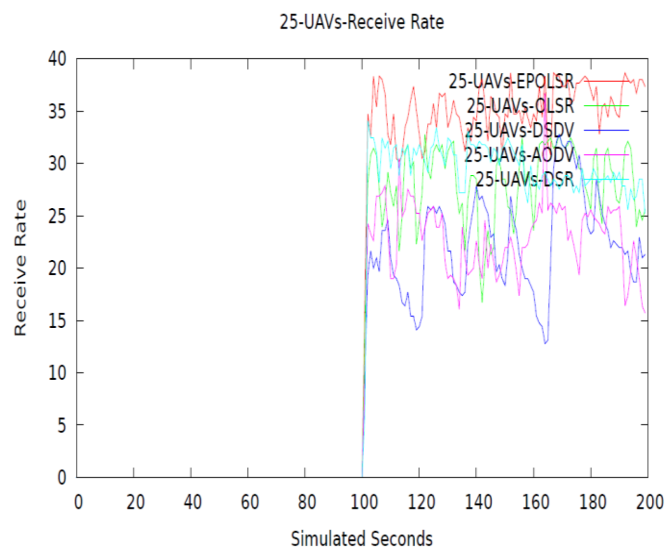

Fig. 10. 25-UAVs- Receive Rate (kbps) using EP OLSR vs. OLSR, DSDV, AODV, and DSR.

The results show that, in the ns-3 environment, the EP OLSR No of Packet Received is 38 Kbps, and on the other hand, we have observed OLSR No of Packet Received is 32 Kbps, as depicted in Fig. 11. Overall, the performance of the EP OLSR protocol is found better when compared with OLSR.

The results show that, in the ns-3 environment, the EP OLSR No of Packet Received is 38 Kbps, and on the other hand, we have observed DSDV No of Packet Received is 26 Kbps, as depicted in Fig. 12. Overall, the performance of the EP OLSR protocol is found better when compared with DSDV.

The results show that, in the ns-3 environment, the EP OLSR No of Packet Received is 38 Kbps, and on the other hand, we have observed AODV No of Packet Received is 26 Kbps, as depicted in Fig. 13. Overall, the performance of the EP OLSR protocol is found better when compared with AODV.

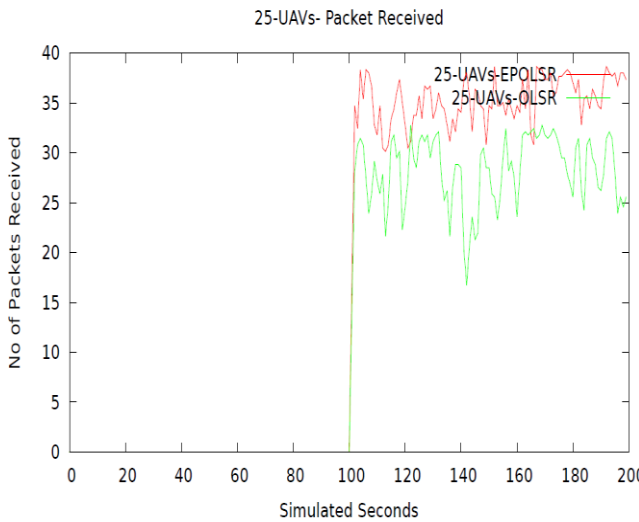

Fig. 11. 25-UAVs- No of Packet Received (kbps) using EP OLSR vs. OLSR.

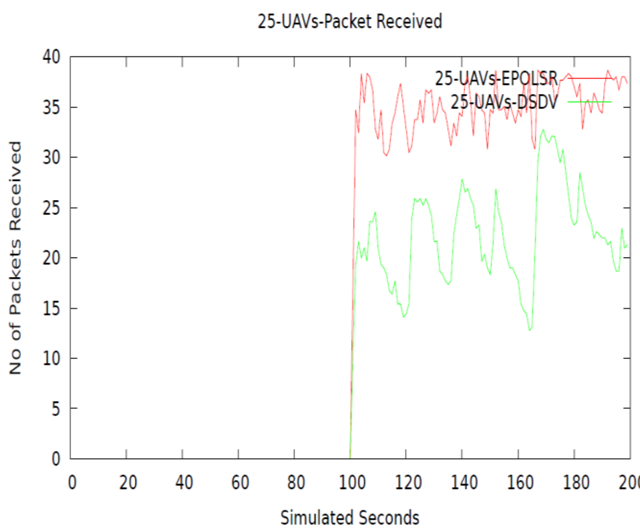

Fig. 12. 25-UAVs- No of Packet Received (kbps) using EP OLSR vs. DSDV.

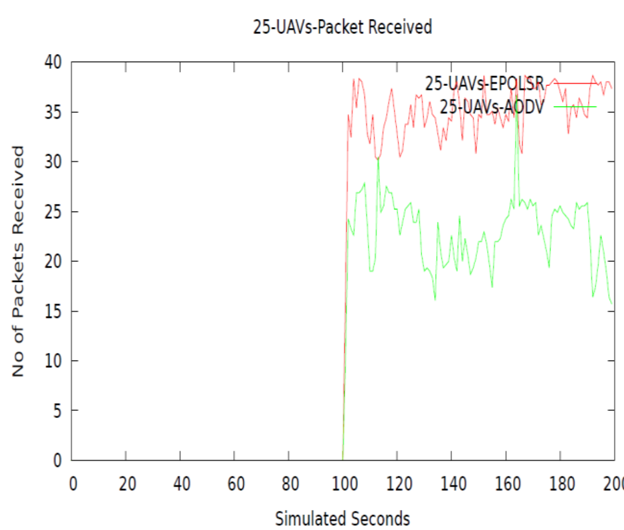

Fig. 13. 25-UAVs- No of Packet Received (kbps) using EP OLSR vs. AODV.

The results show that, in the ns-3 environment, the EP OLSR No of Packet Received is 38 Kbps, and on the other hand, we have observed DSR No of Packet Received is 32 Kbps, as depicted in Fig. 14. Overall, the performance of the EP OLSR protocol is found better when compared with DSR.

The results show that the performance of routing protocols concerning no of the packet received in the ns-3 environment as above depicted Fig. 15. The No of Packets Received in the EP OLSR is 38 Kbps, the No of Packets Received in OLSR is 32 Kbps, the No of Packets Received in DSDV is 25 Kbps, the No of Packets Received in AODV is 26 Kbps, and the No of Packets Received in DSR is 30 Kbps. Overall, it has been observed that the performance of the EP OLSR protocol is better when compared to OLSR, DSDV, AODV, and DSR.

The results show that, in the ns-3 environment, the EP OLSR throughput is 38 Kbps, and on the other hand, we have observed OLSR throughput is 31 Kbps, as depicted in Fig. 16. Overall, the performance of the EP OLSR protocol is found better when compared with OLSR.

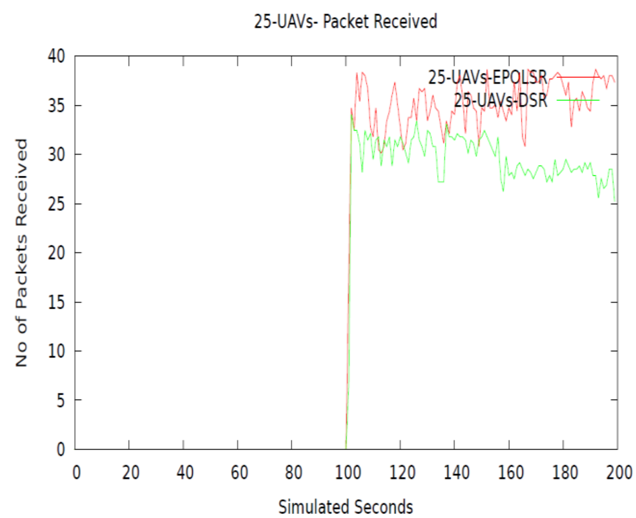

Fig. 14. 25-UAVs- No of Packet Received (kbps) using EP OLSR vs. DSR.

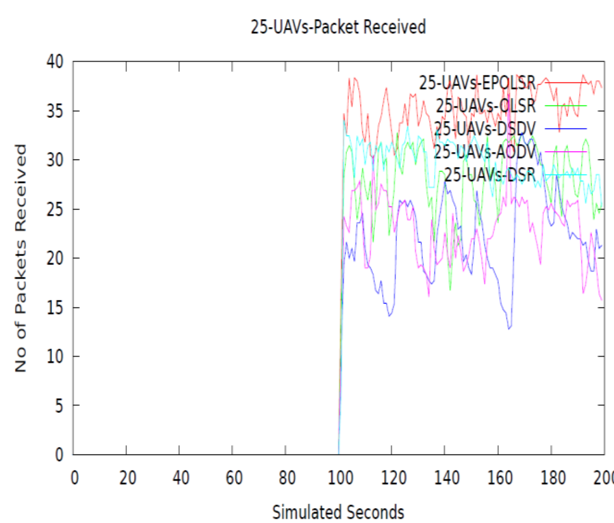

Fig. 15. 25-UAVs- No of Packets Received (kbps) using EP OLSR vs. OLSR, DSDV, AODV, and DSR

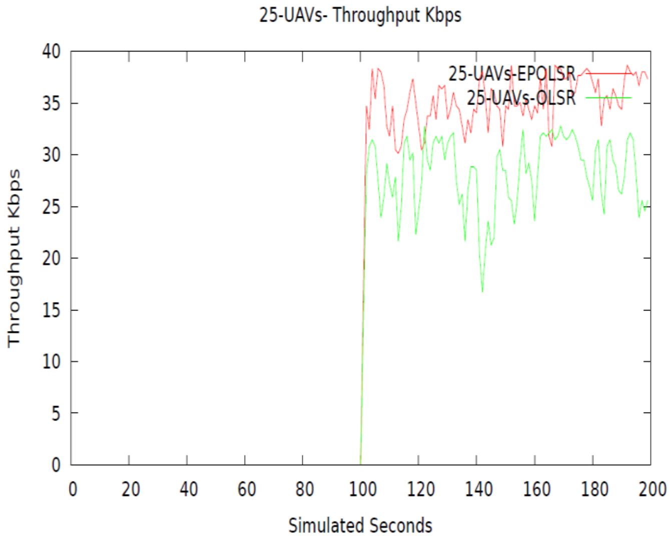

Fig. 16. 25-UAVs- throughput (kbps) using EP OLSR vs. OLSR.

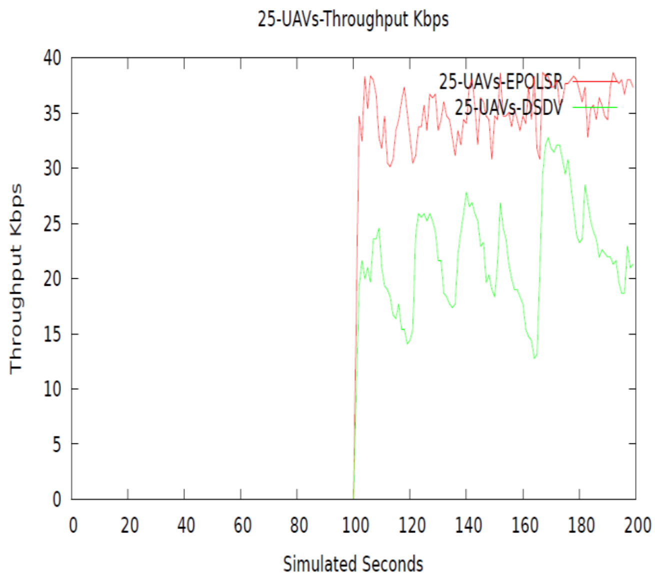

Fig. 17. 25-UAVs- throughput (kbps) using EP OLSR vs. DSDV.

The results show that, in the ns-3 environment, the EP OLSR throughput is 38 Kbps, and on the other hand, we have observed the DSDV throughput is 25 Kbps, as depicted in Fig. 17. Overall, the performance of the EP OLSR protocol is better when compared with DSDV.

The results show that, in the ns-3 environment, the EP OLSR throughput is 38 Kbps, and on the other hand, we have observed AODV throughput is 26 Kbps, as depicted in Fig. 18. Overall, the performance of the EP OLSR protocol is better when compared with AODV.

The results show that, in the ns-3 environment, the EP OLSR throughput is 38 Kbps, and on the other hand, we have observed DSR throughput is 30 Kbps, as depicted in Fig. 19. Overall, the performance of the EP OLSR protocol is better when compared with DSR.

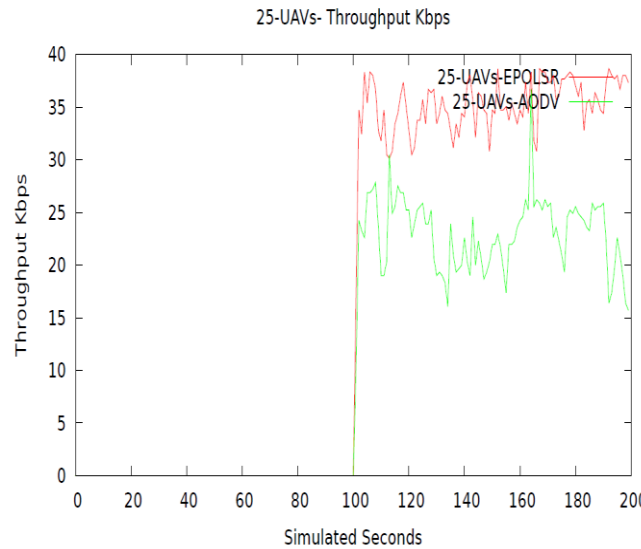

Fig. 18. 25-UAVs- throughput (kbps) using EP OLSR vs. AODV.

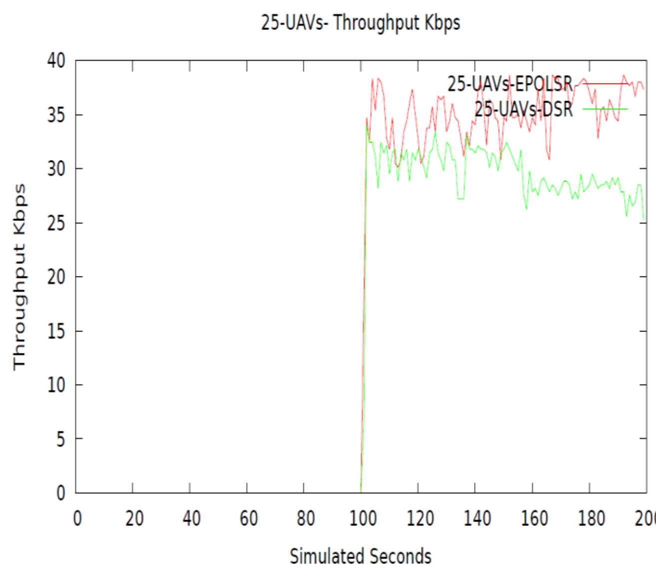

Fig. 19. 25-UAVs- throughput (kbps) using EP OLSR vs. DSR.

The results show that, in the ns-3 environment, the EP OLSR throughput is 38 Kbps, OLSR throughput is 32 Kbps, DSDV throughput is 25 Kbps, AODV throughput is 26 Kbps, on the other hand, DSR throughput is 30 Kbps, as depicted in Fig. 20. Overall, it has been observed that the performance of the EP OLSR protocol is better when compared to OLSR, DSDV, AODV, and DSR.

The results show that, in the ns-3 environment, the EP OLSR Packet Delivery Ratio is 99%, OLSR Packet Delivery Ratio is 96 %, DSDV Packet Delivery Ratio is 83%, AODV Packet Delivery Ratio is 93%, on the other hand, DSR Packet Delivery Ratio is 91 %, as depicted in Fig. 21. Overall, it has been observed that the performance of the EP OLSR protocol is better than OLSR, DSDV, AODV, and DSR.

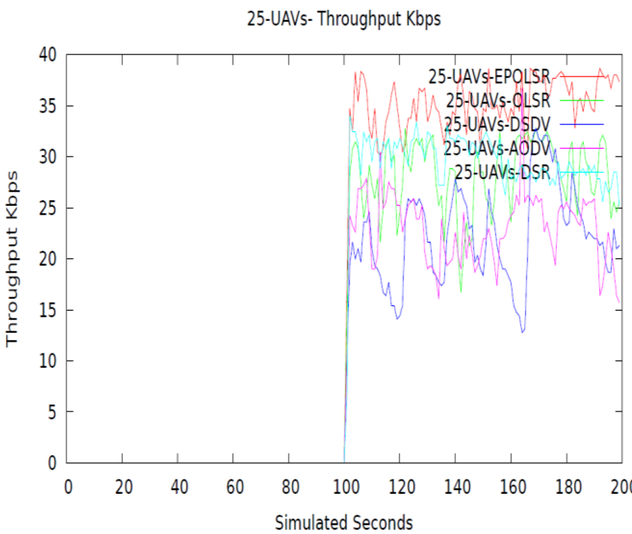

Fig. 20. 25-UAVs- throughput (kbps) *u*sing EP OLSR vs. OLSR, DSDV, AODV, and DSR

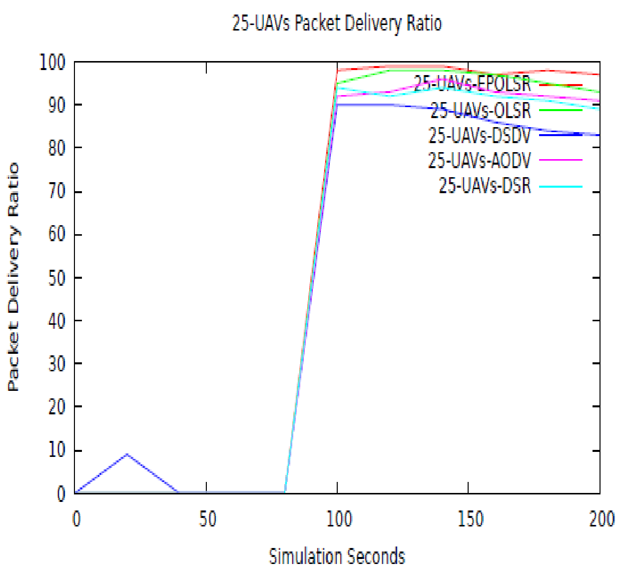

Fig. 21. 25-UAVs- Packet Delivery Ratio *u*sing EP OLSR vs. OLSR, DSDV, AODV, and DSR.

IX. Conclusion

In this research, the UAVCN scenario was developed by using the NS-3. We have simulated 25 UAV nodes and implemented the proposed modified approach of routing, which is termed as EPOLSR. After this, we have evaluated the existing routing protocols with a new approach. In this paper, we have considered and used the received signal power strength (RSPS) by using an algorithm that predicts the link breakage time before route failure. And make the nodes intelligent through hello messages to ensure communication by changing route before failure. However, this method is using the interpolation method and updating the neighbor tables by power information. At the reception node, the signal power strength and time calculated for the next link breakage time by using the interpolation method. We have implemented the proposed technique by modifying the protocol OLSR. The extended protocol termed EPOLSR, which efficiently using the signal power strength and time and increasing the performance of UAVCN. The extended protocol implemented by using the research tool. The metrics received rate, no of received packets, throughput, and packet delivery ratio (PDR) are considered for evaluation. We have examined the proposed EPOLSR with existing routing protocols. It has been observed that the modified protocol performs better concerning all existing evaluated routing approaches.

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