A performance analysis study of MANETs routing protocols in FANETs networks environments

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Abstract: In this technology driven world, wireless networks take part a key role in helping a society to enhance their life style .Unmanned air vehicles connected in an ad hoc manner been used in various application from civil projects to military applications. Establishing reliable, secure connection among UAV nodes in FANET is bit challenging task due to high node mobility, environmental condition under which it is operated and minimum energy capability of nodes etc. Routing protocols used in such a network should have unique features that overcome the limitation to make reliable and secured connectivity between nodes. There are many viable routing techniques had been discussed by past researchers .In our study we have gone through in detail different routing approach used currently in Ad-hoc network , analyzed their merits and demerits and made performance comparison study among AODV,DSR and DSDV on FANETs using ns-3 simulator. Performance metrics used for comparison are network delay, traffic received, data dropped and throughput. This metrics are evaluated by varying node density and node speed. Our study results reveal that different protocols suits for different FANETs network situations.

Key words: FANET:-Flying Ad-Hoc Network, UAV:-Unmanned Air Vehicles, MANET:-Mobile Ad-Hoc Network, VANET:-Vehicles Ad-Hoc Network, GPS:-Global positioning system

Introduction: Usage of Wireless technology has been increased tremendously in our daily life. The important reason for this is the availability of cheap wireless system components like portable computing devices, Wifi radio interfaces, GPS, Sensors, microcontrollers chip etc. Due to the development of simple and cost effective Unmanned Air Vehicle (UAV) for communication application, Flying Ad Hoc Network (FANET) has become a popular among researchers in recent years. FANETS is used in vast civilian applications as well in military and research field, because of its unique features. FANET is a kind of Mobile Ad-hoc networks where nodes are UAV, which are specially designed, mostly used to accomplish specific mission. Though FANET similar to traditional Ad-hoc network, few characteristics of FANET differentiate from VANET AND MANET .Nodes in FANET moves faster than MANET, VANET, distance between neighboring nodes longer than MANET ,VANET [13, 14] and it is powered by sources such as fuel cell, solar system, battery etc. Whereas in MANETs and VANETs nodes are powered by standalone batteries.UAV Nodes are build with different equipments depends upon the applications in which they used [29]. This days UAVs are used in many real time applications such as real time monitoring, search and rescue operation, wildlife surveys, delivery services, wireless services, and precision agriculture [4]In [2, 16], the researcher has proposed many good communication architecture for multi – UAV system, the most common architecture from his proposal are shown in figure 1.

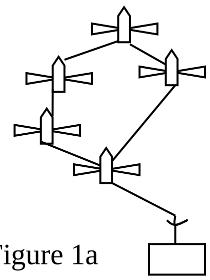


Figure 1a

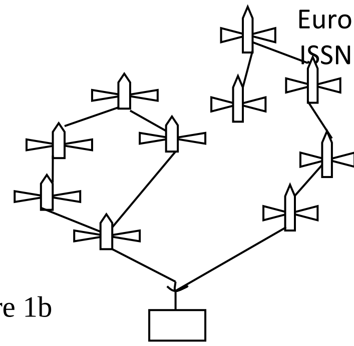


Figure 1b

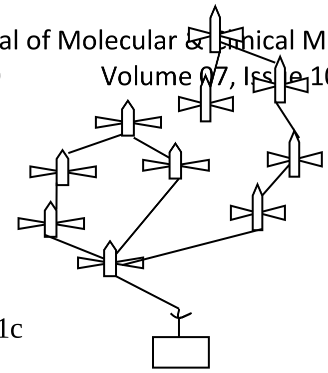


Figure 1c

Simple FANET architecture, In Figure 1a [2, 16] we can see that the backbone UAV node play a part of a gateway to establish communication between base station and other sub-UAVs. Only the Gateway UAV will have high power communication utility, because it needs to communicate with ground station which is very far and to communicate with other UAV nodes it needs only less power because nodes are near to each other. The multi-groups UAV architecture is basically the integration of ad hoc network and centralized network. As shown in Figure 1b [2, 16] for intra group communication it does not need ground station, but for inter group communication it need the support of ground station. Figure 1c [2, 16] represents the multi-layers UAV communication architecture where the communication system consists of many groups. The information transfer among groups does not require the help of the ground station; this greatly reduces the communication load and other computing burden of the ground station.

Routing is the process of finding a communication path from a source to destination .It uses suitable metrics and algorithms to find a optimal path that helps to build high performance communication networks.. Since the advent of DARPA in 1970s numerous protocols have been developed for wireless mobile network [3]. Such protocols must deal with the typical limitations of wireless mobile ad hoc networks, like minimum power availability, low bandwidth and high error rates, high packet dropout, less network life time etc.

The performance of FANETs greatly influenced by the routing mechanisms employed, hence design of suitable routing protocol for FANET is an important issues and research problems .At present there is no specific routing protocols available for FANET, hence the existing protocols used in MANET environment can be chosen depends upon FANETs network conditions and requirements [1].In this paper we discussed and analyzed the various routing protocols that are in use in ad-hoc networks currently and performed performance comparison on three main routing protocols namely AODV,DSR AND DSDV on FANETs.

The remainder of this paper is organized as follows .Section two introduces the concept of routing, routing method in MANETs, AODV, DSR, and DSDV Pocket routing principle. Section three presents about simulation parameter and metrics used. And in section four simulation results are analyzed and compared for the aforementioned protocols .Finally conclusion presented in section five.

2.Standard Routing Protocols :Developing a specific routing protocols for mobile ad hoc network is vital, because of its unique communication environment.There are mainely three types of routing mechanisms used in MANET.
1.Table-driven(Proactive) 2.On-demand (Reactive) 3. Hybrid (combination of both)[32]

Table –driven protocols: Each nodes finds the routing path for all destinations and store collected routing information in its own routing table .To learn the current network topology nodes frequently exchanges routing information to the neigbouring nodes .

Proactive strategy alwayes keeps valid path to all source and destinations pairs even if the path are not currently used.Main advantage of this approach is ,it can forward packet immediately as ready made route is available for each source and destination pairs.However,the draw back is control packet overhead ,which consumes sigificant amount of network bandwidth as well as node energy [33,34].].Two important proactive protocols are 1.Optimized link state routing (OLSR)[35] 2. Destination Sequenced Distance Vector (DSDV) [12]

On demand routing protocols: Unlike reactive approach this 'on demand protocols' using route discovery mechanisum it finds the path on demand .When there is a need for a path between two nodes it establishes the routes.It uses route request packet(RREQ) and route reply packet in route discovery process to find the routes between given pairs of nodes.After establishing route it retains this routing information until receiving node not reachable or established route is no more required by source.During packet transmission sometime DLL link may breakdown, due to that packet could not reach the destination, in such a situation route maintenance procedure will be intiated to find the active alternative routes.Main advantage of reactive protocols compared to proactive is, it needs minimum control packet overhead which leads to low bandwitdh consumption , less power utilization and minimum network congestion. Most common on 'demand routing protocols' are 1.Ad hoc on-demand(AODV)[9], 2.Dynamic Source Routing (DSR) [10]

Hybrid routing: The features of both reactive and proactive protocols are combined to form a Hybrid protocols**.** Here the big network is divided into groups called Zones, for communication between nodes inside a zone proactive protocols are used for routing and to communicate between nodes which are in different zones reactive protocols used. Two main protocols which come under hybrid routing are 1.Zone-based routing protocol (ZRP) [36] 2.Sharp hybrid adaptive routing protocol (SHARP) [37].

In our study we use Ad hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR) from reactive routing protocols and Destination Sequenced Distance Vector Routing (DSDV) from the proactive one. We have chosen these three MANET routing protocols because MANETs working group or Internet Engineering Task Force (IETF) constituted these protocols as a reference for other multi hop ad hoc networks routing protocols [8].

2.1. Ad Hoc On-demand Distance Vector (AODV). It is one of the reactive kind of protocol, here when a node want to send a packet to other node ,it checks it is own routing table information,if route exists then it uses that route and transmit the packets .If the routing table has no valid route information then it initiates route discovery process using RREQ broadcast messsage[9].In case multiple route exists between two pairs of nodes ,then it selects shortest path among them.

AODV is verymuch suitable in a network envirnment where there is scarcity of network resources like bandwitdh & power. The main limitation of wireless networks are bandwitdh and power ,so for such a networks environments AODV can be a better choice.It establishes route in two phases namely route discovery phase and route maintenance phase.

Route Discovery process :

Route discovery process is initiated by source node, when it does not have valid path information to its intended destination.Discovery process generates RREQ packet and it broadcast to neigboring nodes which in turn re forward to thier neighbors and it goes on, until RREQ reaches an intermediate node that has a valid route to required destination or it reaches destination node.

Table 2.1: RREQ Packet field

TYPE	FLAG
Source IP	Destination IP
Source Sequence Number	Destination Sequence Numbers
Broadcast ID	Hop Count

Broadcast ID along with source IP used to uniquely identify the each RREQ initiated by source nodes.when a source node initiate new RREQ ,it is old broadcast id will be incremented by one.Sequence number is used by intermediate node to make sure loop free condition and to find the freshness of the available route information .

When RREQ packet arrives at a intermediate node ,before it reforward to its neighbours, it builds the reverse route to the sender node by noting in its routing table, the address of the adjustant node from which the first copy of RREQ received.The intermediate nodes which has fresh route to destination or destination nodes after

receiving RREQ,generates the RREP packet and send it to source node via the reverse route that is established during route discovery process.
How reverse path established during RREQ transmission , same way RREP packet are used by each intermediate in the reverse path,notes the path in routing table while the RREP traverses along the reverse route.So when RREP reaches source node, forward and reverse path are established between source and destination pairs.More importantly after this each intermediate node need to remember only the next hop to the destination.

Route Maintenance: After finding the route to destination by route discovery process, the source node forward packets via established route using multi hop mode transmission to its destination.Frequent link failure at DLL may happen in ad hoc networks becuase of the high mobilty nature and stand alone battery drainage issues.Intermediate nodes reqularly exchanges hello packet to neighbours to say they are active ,using this message intermediate node can validate the routing information stored in its table.At the time of invalid path detection ,it delete the routing information from the table and send route error message using RERR PACKET in the reverse direction to the source nodes.After receiving RERR,Source node initiate the route discovery process with new broascasting id.[9]

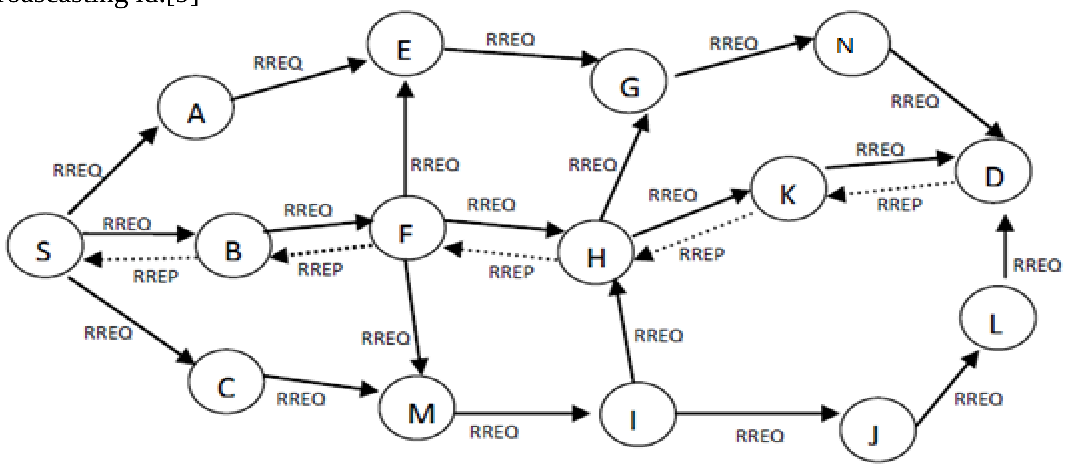


Fig2.1(a) :Route discovery process

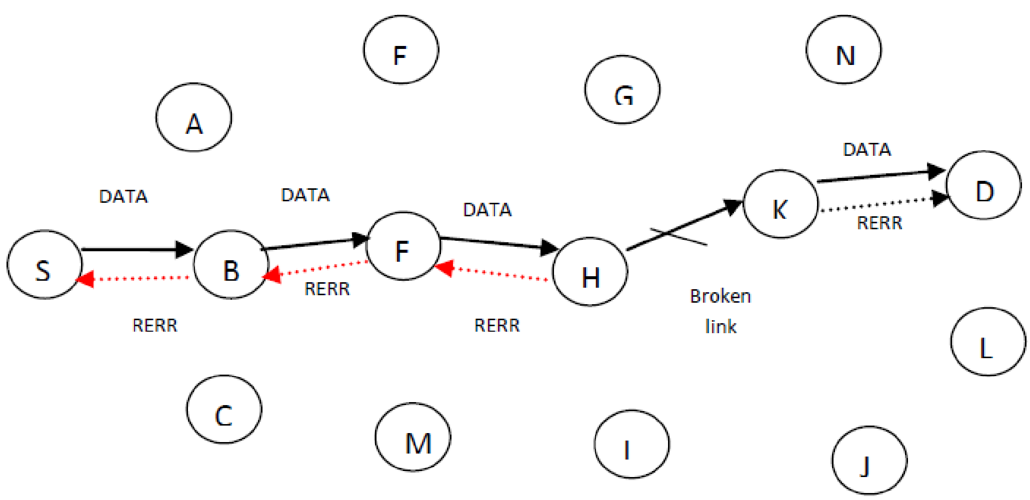


Fig 2.1 (b) Route maintenance process

Figure 2.1: AODV Route discovery and route maintenance
Figure 2.1(a) illustrate the route discover process,where it is assumed that network consists of 15 mobile nodes.Node S which need to transmit packet to destination node 'D',initially start the route discovery process by

generating RREQ packet and broadcast the RREQ in the network.The neigbouring nodes of ‘S’ are ‘A’,’B’ & ‘C’.They receive the RREQ packet request ,first examines the replication of packets, if its new,then they record ‘S’ on the routing information table as a reverse path to node S. Next all nodes check their routing information table for valid path entry for destination nodes,they rebroadcast the route discovery packet, if they do not have valid route entry.The intermediate nodes which has valid route entry in the routing table will reply RREP packet via reverse path towards source node.In the figure 2.1(a) it is assumed that none of the intermediate node has valid route,so RREQ packets reaches the destination via multiple routes.Finaly the destination nodes generates RREP packet and send via shortest reverse path(minimum hop count) towards source node S.Destination nodes send RREP packet via D-K-H-F-B-S as it is the shortest path among three the available path.

TABLE:2.2: RREP Packet field

TYPE	FLAG
Source IP	Destination IP
Source Sequence Number	Destination Sequence Numbers
Broadcast ID	Hop Count
Life time	

Figure 2.1 (b) illustrates the maintenance process for DLL link failure. In case of link failures the intermediate nodes informs the source and destination nodes using RERR packet. In figure 2.1(b) the link between intermediate node H & K broken, so H & K, Generate RERR packets and transmits to source and destination respectively. Nodes in the forward and reverse path, before forwarding the RERR to the neighboring nodes, deletes their route entry after seeing the RERR packet as this route is no more available. Source nodes when it receives the RERR packet it initiate new route discovery process with new broadcast ID.

2.2. Dynamic Source Routing (DSR)[10]: It is one of the classic reactive routing protocols different from others by source routing process.In DSR routing packets contains all the routing information ,that is each packet contains address of the all nodes between source to destination through which packet travels. So intermediate nodes need not have routing information for each destination and it does not need periodic hello packet exchanges between the neigbouring nodes.The main advantages of DSR compared to AODV is reduced bandwitdh requirements,less power consumption but network delay is high as it chooses the path without considering path distance and more processing burden at the intermediate node.Two phases of DSR are route discovery and route maintenance**.**

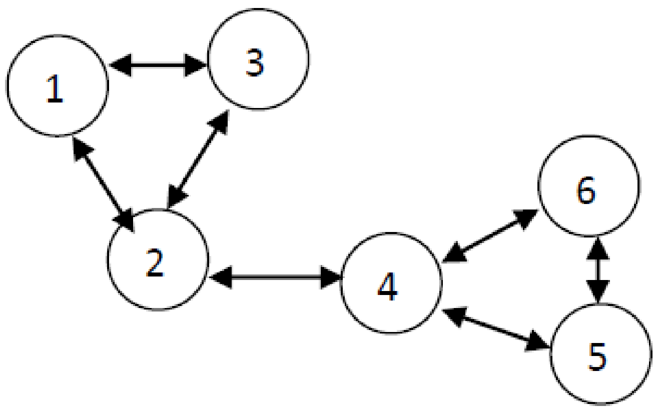
DSR route discovery :In DSR Routing, node having a packet to send to a destination, checks its routing table for routing information, if not found, intiates route discovery process by generating RREQ packet and floods in the networks.Upon receiving the RREQ packet intermediate nodes reforward the RREQ to its neighbours after adding its address in path record field , if the following listed conditions are meets.1.Not a destination node 2.RREQ is fresh 3.No routing information in its cache.This process will continue until RREQ reaches the intermediate node which has route information to the destination or RREQ received by destination node.In both scenario node will generate RREP packets, which contains the route record consists of the address of all nodes through which RREQ travelled .RREP packets transmitted back to source by unicast transmission using the path information available in RREQ record.

DSR Route Maintenance Process: DSR uses acknowledgments based link failure detection system for finding disconnected DLL link.when a node sends packet, it waits for a acknowledgments from the receiving nodes,if acknowledgments is not received in prescribed time interval , RERR packet is transmitted back to source node.Nodes which receives the RERR packet removes the route entries in the cache. Source node re initiate the route discovery process after seeing RERR packet.

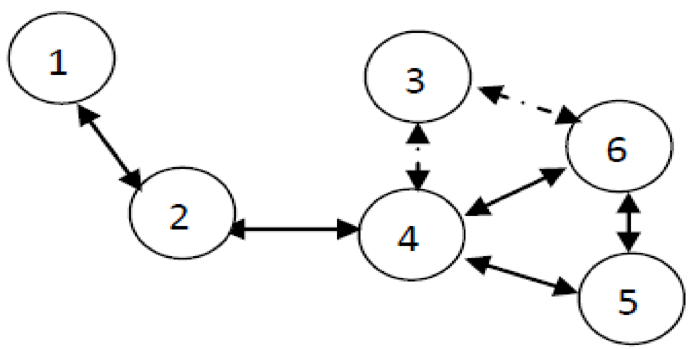
2.3. Destination Sequenced Distance Vector Routing (DSDV)[12] :It is a kind of proactive routing protocols of enhanced version of distributed bellman-ford algorithum with loop free routes implementation by sequence number. In DSDV each node maintains routing tables which contains the following information 1.List of destinations 2.Next hop to each destinations. 3.Destination sequence number 4.Total number of hops to each destination.Routing information available at each nodes are shared periodically to neighbouring nodes using broadcast DSDV packet .

In DSDV nodes uses the sequence number to check the freshness of the route information,if it is new then nodes updates its entries than forward the updated information to all neighbours. For exampel if a node ‘B’ receives broadcast packet from node ‘A’,then node ‘B’ check its routing table with the received one,if the sequence number entry is new then it update entries and forward the packet.When this packet is received by another node ‘C’,which is not a neighbour to ‘A’ ,its checks own routing entry to check the node ‘A’ entry is new,if it is new then node ‘C’ updates its entry relative to node ‘A’.For node ‘C’,node ‘B’ acts as next hop to reach ‘A’

Example : Figure 2.2 shows network with 6 nodes in two different topology ,figure 2.2(a) depicts initial topology of the network and table 2.2(a) shows its corresponding routing table entry at node 2. Figure 2.2(b) shows the new network topology after the movement of node 3 and table 2.2(b) shows updated version of the node 2 routing table entry after topology change.



a) Topology before node 3 movement



b) Topology after node 3 movement

Figure 2.2: Examples of routing table updates in DSDV

Table 2.3: Initial routing table entry of node 2

Destination	Next hop	Metric	Sequence
1	1	1	SQN602-1
2	2	0	SQN88-2
3	3	1	SQN210-3
4	4	1	SQN446-4
5	4	2	SQN342-5
6	4	2	SQN746-6

Table 2.4: Updated node 2 routing table after movement of node 3

Destination	Next hop	Metric	Sequence
1	1	1	SQN602-1
2	2	0	SQN88-2
3	4	3	SQN234-3
4	4	1	SQN446-4
5	4	2	SQN342-5
6	4	2	SQN746-6

Network delay in DSDV compared DSR and AODV is very low, One major problem in DSDV is "count-to-infinity" problem, requires more time to detect node or link failure, for example when total number of node in networks is 'N' , it take 'N' iterations approximately to detect node failure [17]. Other drawback is control packet overhead due to periodic routing information updates between neighbors.

3.Simulation environments and metrics

Table 3.1. Simulation Environment

Simulation area	5000 m x 5000m
Maximum UAV speed	20 m/s
Minimum UAV spedd	10m/s
Maximum number of UAV nodes	30
Minimum number of UAV nodes	15
Total simulation period	1000 sec
CBR	512 Bytes
Mobilty models	Random waypoint mobility
Altitude	400 m
DLL protocol	802.11 b

The evaluation metrics used for performance comparison among the aforementioned MANETs routing protocols are throughput, packet dropped, network delay and traffic received.
Network delay (sec): It represents the end to end delay of the each transmitted packets between source nodes to destination nodes. Network delay is important issues for live stream data. Significant delay in network leads to poor network performance.
Traffic received: The total amount of traffic received (bits/sec) by each destination in the entire network.
Data dropped: The total number of data (bits/sec) dropped due to network failure .Data are lost or dropped due to link failure in MAC layer, coverage area issues ,battery failure or due to bandwidth ,corrupted received bits, and buffer overflow in the intermediate node in multi hop link.
Throughput : It is the measures of how many packets or bits arrive at destination successfully measured in packet /sec or bits/sec.

4. Performance evaluation of existing Ad hoc network protocols in FANETs .

This section presents detail simulations results of one proactive routing protocol (DSDV) and two reactive ad hoc routing protocols (AODV, DSR) by means of NS-3 simulator [18]. The aim of the simulation is to evaluate the relative performance among there important existing routing protocols and to suggest , appropriate routing protocol for FANET in different network condition . Moreover, it provides a response to one of the important researcher question *"Which conventional routing protocol of MANETs is suitable for FANET Environments?*

Network delay analysis*:* *Graph in* Fig.4.1 depicts the average network delays of DSR,AODV, & DSDV for different nodes density and different UAV nodes speed. By comparing the Fig. 4.1(a) and Fig. 4.1(b), we can find that when node density is less,the network delay of DSDV protocol not much influenced by increse of node speed. But, the network delay of AODV and DSR routing increases notably with the increase in node speed.

Observing the Fig. 4.1(c) and Fig. 4.1(d), we can find that when the node density is high, the network delay is not severely affected by the node speed. Observing Fig. 4.1(a) and Fig. 4.1(c), we can understand that when the node speed is minimum,there is a very little variation in network delay on DSDV for node density variations.But for AODV& DSR delay increases notably with the increase of node density. By comparing Fig. 4.1(b) and Fig. 4.1(d),we find that, when the node speed is increased , the network delay of DSDV has very small amount of variation with respect to the node density variations, but the network delay of AODV and DSR increases greately with the increase of node density. From the above comparison result ,we can conclude that DSDV Routing protocols has minimum network delayin all four network conditions.AODV network delay is very less compared to DSR,and similar to DSDV when network size and speed is low.

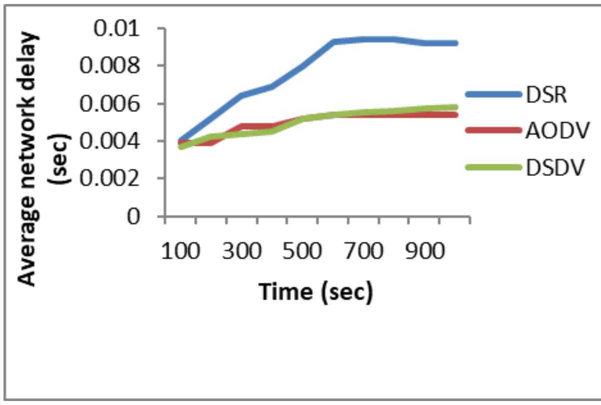


Fig4.1 (a)

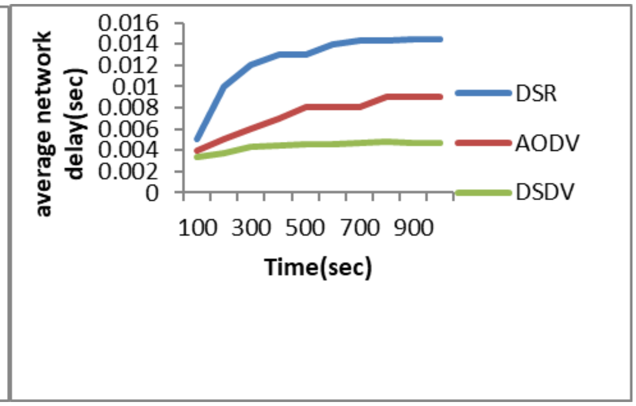


Fig4.1 (b)

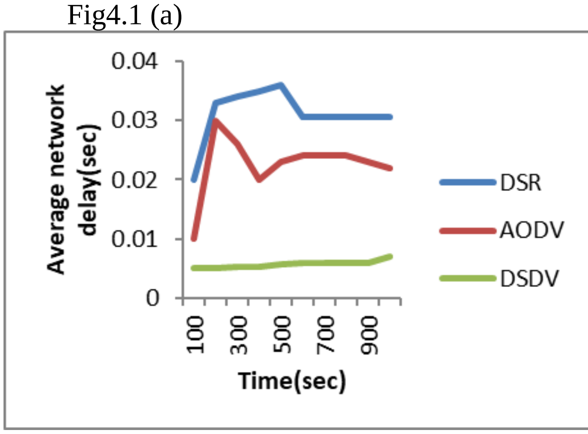


Fig4.1 (c)

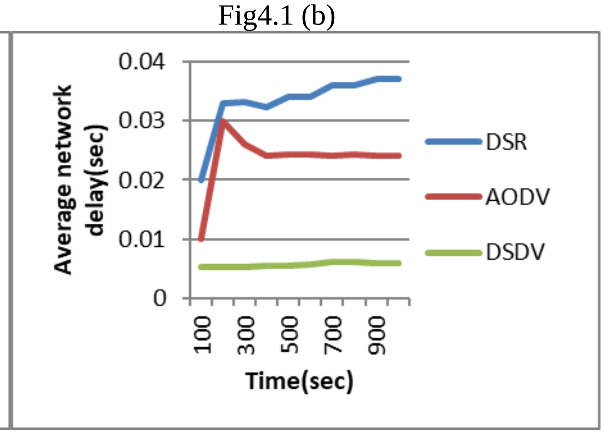


Fig4.1 (d)

FIGURE 4.1. Average network delay 4.1 (a) nodes density 15, nodes speed 10m/s. (b) node density 15, node speed 20m/s. (c) nodes density 30, node speed 10m/s. (d) nodes density 30, node speed 20m/s.

Traffic received analysis: Graph *in* Fig.4.2 depicts the average traffic received of DSR, AODV, & DSDV for different nodes density and different UAV nodes speed. By comparing the Fig. 4.2(a) and Fig. 4.2(b), we can find that when node density is less, the average traffic received by AODV & DSDV protocols are not severely affected by the node speed. But, the average traffic received by the DSR protocols increases notably with the increase of the node speed. Observing the Fig. 4.2(c) and Fig. 4.2(d), we can find that when the node density is high, the average traffic received in all three protocols severely affected by the node speed. Observing Fig. 4.2(a) and Fig. 4.2(c), we can understand that when the node speed is minimum, for all three protocols average traffic received increases considerably with the increase in node density. By comparing Fig. 4.2(b) and Fig. 4.2(d), we can say that, when the node speed is increased, average traffic received also increases with increase in node density for all three protocols. But for DSDV it is minimum & AODV and DSR increases greatly with the increase of node density. From the above comparison result, we can conclude that DSR has better traffic received performance in all four network condition. AODV traffic received performance is good when node density is high. DSDV has very poor network traffic received performance in all four network condition.

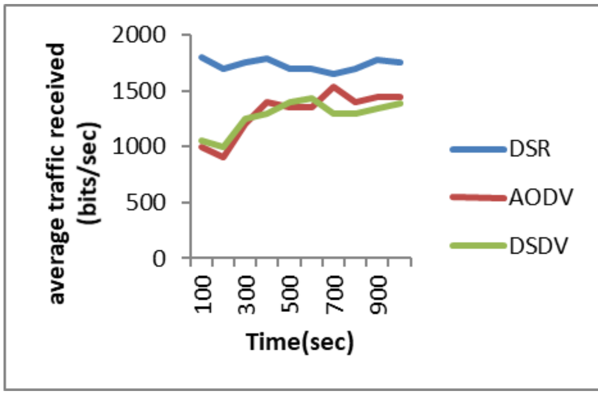


Fig4.2 (a)

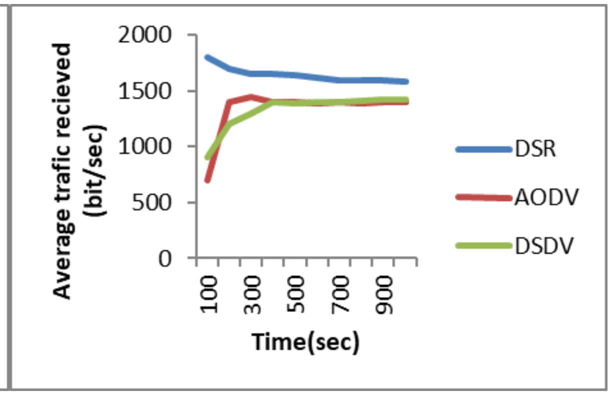


Fig4.2 (b)

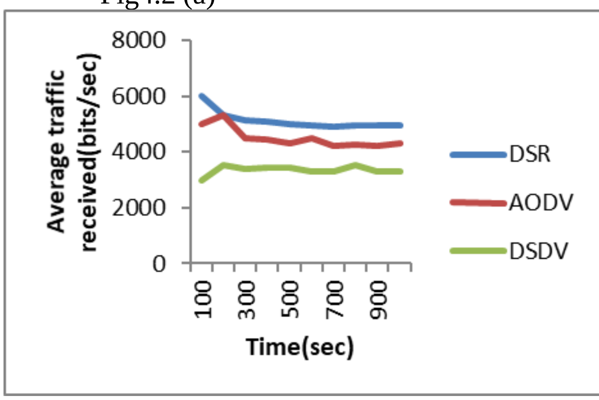


Fig 4.2(c)

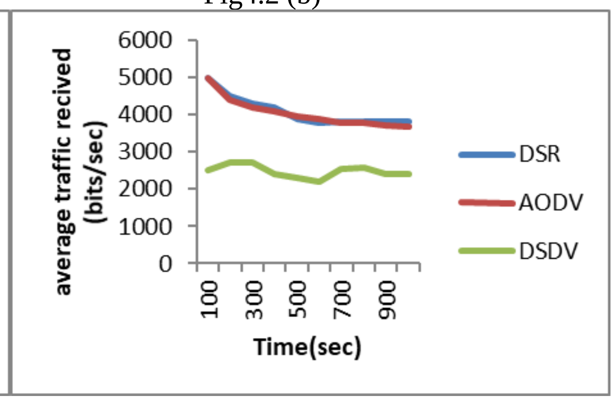


Fig 4.2(d)

FIGURE 4.2. Average traffic received (a) node density 15, node speed 10m/s. (b) node density 15, node speed 20m/s. (c) node density 30, node speed 10m/s. (d) nodes density 30, node speed 20m/s.

Data dropped analysis: *Graph in* Fig.4.3 depicts the average data dropped of DSR, AODV, & DSDV for different nodes density and different UAV nodes speed. By comparing the Fig. 4.3(a) and Fig. 4.3(b), we can find that when node density is less, the average data dropped by all three protocols increases considerably with the increase in node speed. Observing the Fig. 4.2(c) and Fig. 4.2(d), we can find that when the node density is high, average data dropped by DSR protocols increases considerably with the increase in node speed. Observing Fig. 4.2(a) and Fig. 4.2(c), we can understand that when the node speed is minimum, for all three protocols average data dropped are not much influenced by the increase in node density. By comparing Fig. 4.2(b) and Fig. 4.2(d), we can say that, when the node speed is increased, average data dropped also increases with increase in node density for all three protocols. As a conclusion we find that AODV perform better than other protocols in all four network conditions.DSR performance is very poor compared to other two protocols when the node speed is high. DSDV and AODV have similar performance when network size and speed is high.

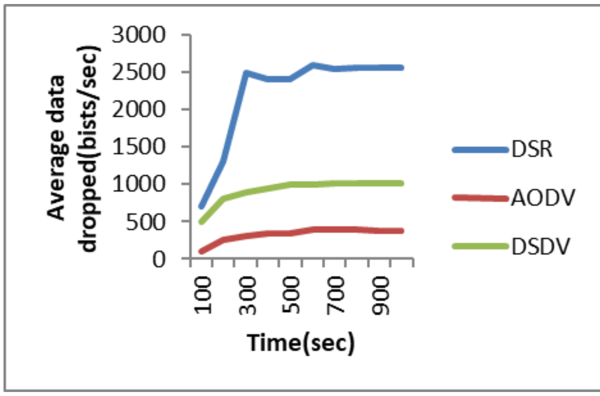


Fig 4.3(a)

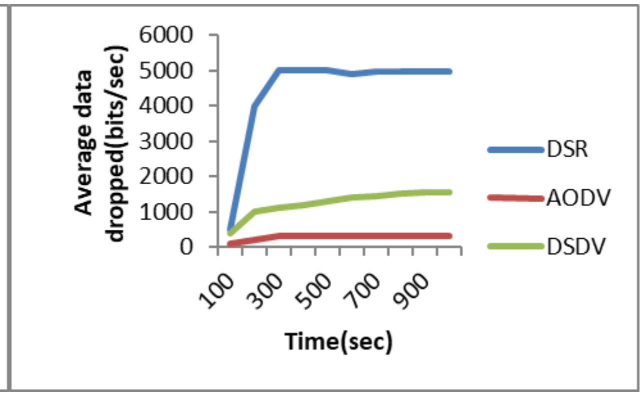


Fig 4.3(b)

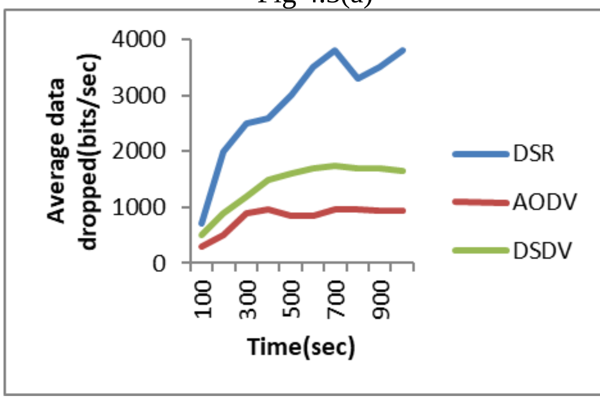


Fig 4.3(c)

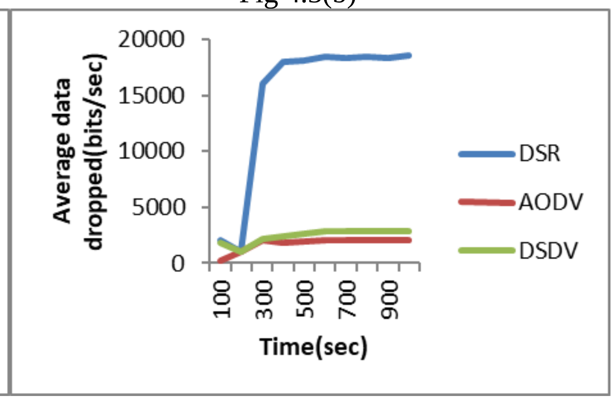
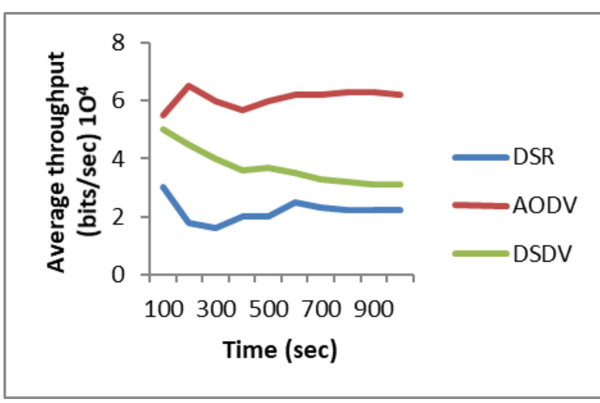


Fig 4.3(d)

FIGURE 4.3. Average data dropped (a) node density 15, node speed 10m/s. (b) nodes density 15, node speed 20m/s. (c) node density 30, no speed 10m/s. (d) nodes density 30, node speed 20m/s.

Throughput analysis: *Graph in* Fig.4.4 depicts the average throughput of DSR, AODV, & DSDV for different nodes density and different UAV nodes speed. By comparing the Fig. 4.4(a) and Fig. 4.4(b), we can find that when node density is less, no much variation in the average throughput by all three protocols for the increase in node speed. Observing the Fig. 4.4(c) and Fig. 4.4(d), we can find that when the node density is high, no much variation in average throughput with the increase in node speeds. Observing Fig. 4.4(a) and Fig. 4.4(c), we can understand that when the node speed is minimum, for all three protocols average throughput increases considerably with the increase in node density. By comparing Fig. 4.4(b) and Fig. 4.4(d), we can say that, when the node speed is increased, average throughput also increases with increase in node density for all three protocols. Compared other two protocols AODV throughput performance is good in all four network situations.



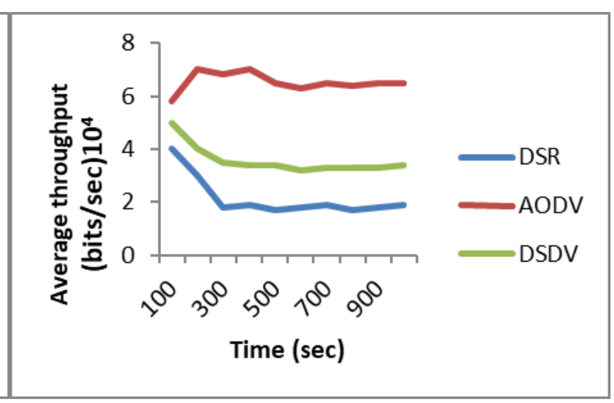


Fig 4.4(a) Fig 4.4(b)

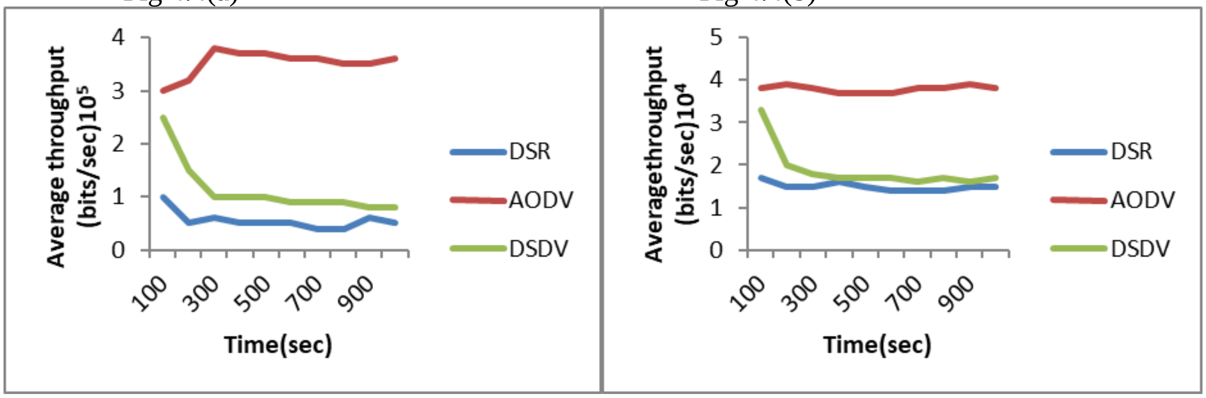


Fig 4.4(c) Fig 4.4(d)

FIGURE 4.4. Average throughput (a) node density 15, node speed 10m/s. (b) nodes density 15, node speed 20m/s. (c) node density 30, node speed 10m/s. (d) nodes density 30, node speed 20m/s.

Conclusion: As we all aware that FANET is one of the growing network environment used in many emergency relief operational field such as in natural calamity situation, medical help during pandemic in remote places, in military coordination during war, and other civilian and research applications. MANETs is popular among us for such a networks needs. Although FANET and MANET have many similar features, in some network environment FANET is more preferable than MANET because of its unique features such as Long distance coverage, fuel based power supply ,remote are coverage ,fast deployment . As such now there is no specific routing algorithm available for FANET, we can choose among standard existing MANET protocols for FANET application. In our work we analyzed three important MANET protocols [AODV, DSDV, DSR] for their adaptability in FANET environments. Performance evaluation under four different network condition [(Minimum network size, Minimum node speed),(Minimum network size, Maximum node speed), (Minimum network size, Minimum node speed) and (Maximum network size, Minimum node speed)]is performed .The following are the key findings of our research work. DSDV routing method is very good choice for network delay sensitive application in FANETs, because compared to other two protocols network delay for DSDV is very minimum in all four tested condition. AODV is most preferable among all three ,when the application is sensitive to throughput, because compared to all other two protocols AODV has good throughput and less packet dropout for all four tested condition and in addition when network size and speed minimum it has minimum network delay. DSR provides good traffic received performance compared to other two protocols for all four tested network condition .DSR has poor throughput and high data dropout in all network condition.

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