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DIRECTIONAL ORIENTED FORWARDING PROTOCOL FOR UAANETS

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ABSTRACT

In this paper, we proposed a new routing protocol for Unmanned Aerial Vehicles (UAVs). We named this protocol as Directional Oriented Forwarding Protocol (DOFP). The protocol assumes the structure of the UAANET is 3 dimensional structures. UAVs are flying at different heights. All the UAVs are equipped with directional antenna and GPS system. The UAV communicates with other UAVs, Ground level devices and also with ships. The node uses the position information from GPS system. From the position the node identifies the direction of the receiver. Then the node forwards the data signal through the directional antenna of that direction.

Keywords: unmanned aerial vehicles, unmanned aeronautical ad-hoc networks, routing protocol

INTRODUCTION

In UAANET, UAV is envisioned to participate as a self-aware node and communicates with ground infrastructure and other UAVs. Thus, these networks show different features with typical ad hoc networks in that information becomes available through in-UAV, UAV-to-ground and UAV-to-UAV, UAV-to-ship communications and also sent the signal to army radar. [1] With help of these networks, traffic between UAVs can be distributed and is regarded to have improved reliability as well as scalability. Based on this property, the need of UAV ad hoc networks increases due to an unprecedented increase in air traffic, fuel costs and environmental pollution. [1], [2].

The routing protocol design for UAANETs is challenging one because the UAVs are connected in three dimensional structures.

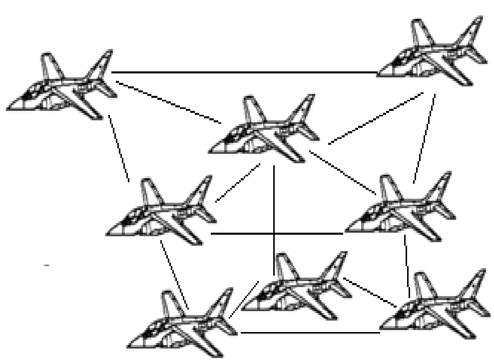

Figure-1. Three dimensional structure of the UAANET.

Some of the UAVs are in one plane; some others are in another plane. They are flying at different heights. So communication between the UAVs is taking place at different levels. The transmission range of the UAV has also to be considered. The routing protocol is an important one for effective communication. The routing protocol should be efficient. The routing protocols are classified into two. Topology-based protocols and position-based protocols. Topology-based protocols are routing protocols where the information about the links in the network is used in order to establish and maintain routes. [3] Among these topology-based protocols, we further distinguish proactive (e.g. Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing Protocol (OLSR) [4], etc.), reactive (e.g. Ad-hoc on-demand Distance Vector (AODV) [5], [6], Dynamic Source Routing (DSR) [7], etc.) and hybrid (e.g. Zone Routing Protocol (ZRP) protocols.

AODV Protocol

AODV is a reactive routing protocol designed for MANETs. It is said to be reactive because routes are not established and maintained in advance of the transmission of eventual data packets. The reactive protocols are not maintaining the routing table. It starts route searching process whenever needed. If one node wants to make communication with another node, it starts route discovery process. After finding the route, it will send the data through the selected path [5]. Hence routing overhead is reduced compared with Proactive routing protocol. It increases the delay. During discovery, the source node floods the request packet to all available neighbors. It reduces the network overhead. It sometimes maintains table to save the recently used routes for further routing. [6]. But it increases the routing overhead.

Greedy Geographic Forwarding

There are several greedy routing strategies. They can be defined in terms of *progress, distance* and *direction* towards the destination. The larger this distance, the more progress the corresponding neighbor can make. For instance, *the Most Forward within Radius* (MFR) scheme is based on this progress notion. In MFR, the packet destined to destination *D* is forwarded to the next neighbor who maximizes the progress towards *D.* This scheme

ARPN Journal of Engineering and Applied Sciences

minimizes the number of hops to reach *D*. Under this category, there is another scheme called *Nearest with Forward Progress* (NFP) [8], which forwards the packet to the nearest neighbor of the sender that is closer to the destination. The main problem with greedy routing is that it does not guarantee delivery to the destination even if there is a path from the source to the destination. This is called a local minimum [8].

The RGR Protocol

The RGR protocol is a routing protocol based on AODV and GGF. RGR works like AODV until a forwarding node faces a broken link. By forwarding node, we mean a node that has received a data packet and is trying to send it to the packet's next hop (in the case of control message packets, we call such nodes Intermediate Nodes). In AODV, when the next hop is unreachable (broken link), we have two options: if local repair is not enabled, the packet is dropped. Otherwise, when local repair is enabled, the FN holds on to the packet and broadcasts an RREQ in order to "repair" the broken link. Eventually, it will send the data packet using the newly re-established or repaired route. In the case of RGR, when the FN faces a broken link, instead of performing local repair like in AODV, it switches to the GGF mode. The GGF mode here works as follows: the FN calculates its own distance to the DN alongside the distance to the same DN of all its current neighbors. If there is a neighbor that is closer to the DN than the FN, the FN forwards the data packet to that neighbour [9].

mpRGR

In mpRGR, mobility prediction (mp) is added [10]. To accomplish this, the speed and the direction of the nodes are piggybacked in the control messages. When a node receives location information of another node in a control packet, it can predict where that node currently is. In fact, the information in the packet is not real-time; there is a timestamp that indicates when that location information was recorded. Based on that timestamp, speed, and direction, the current location can be approximated [10]. These protocols consider the network structure as 2 dimensional structures.

DIRECTIONAL ORIENTED FORWARDING PROTOCOL FOR UAANETS

The protocol assumes that all the UAVs and the ground located communicating nodes are equipped with GPS system. For each and every node the GPS gives Latitude, Longitude and Sea level. These three parameters are used to define the geographic position on the surface of planets such as earth.

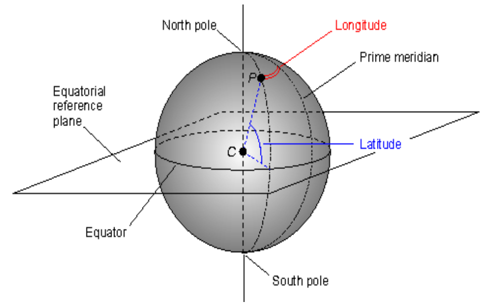

Figure-2. The GPS position calculation diagram.

The equatorial reference plane passes through the center C of the earth sphere. The latitude of a point *P* on the surface is defined as the angle that a straight line, passing through both *P* and *C*, subtends with respect to the equatorial plane. For the points which are above the reference plane the latitude value is positive. The range of the latitude angle is from 0 to +90 degrees. 90 degree represents the North Pole. For the points which are below the reference plane the latitude value is negative. The range of the latitude angle is from 0 to -90 degrees. -90 degree represents the South Pole.

The meridians are half-circles running between North Pole and South Pole. The meridian which passes through Greenwich, England is called the Greenwich meridian. This meridian is used as reference meridian. The longitude of a point P on the surface is defined as the angle between the meridian which contains that point P and the reference meridian. For the planes which are to the east of the reference meridian the longitude value is positive. On east side the longitude value ranges from 0 degree to +180 degree. For the planes which are to the west of the reference meridian the longitude value is negative. On west side the longitude value ranges from 0 degree to -180 degree.

The Sea level defines the height of the position from the earth surface.

The proposed protocol uses these three parameters to find the routing path between the transmitter and receiver.

θ – represents the latitude value

Φ – represents the longitude value.

H- represents the height.

The direction oriented forwarding reduces the routing overhead, saves energy of the nodes. If one UAV want to send data to some other UAV, it first identifies the location of the receiver UAV. Based on the three GPS parameters the location of the receiver can be identified. The UAV are equipped with the set of eight directional antennas. The directional antenna transmits signal in one direction efficiently. The transmission range of the directional antenna is very high; hence it reduces the number of forwarding nodes in the transmission between

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ARPN Journal of Engineering and Applied Sciences

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transmitter and receiver. It transmits in only one direction and not in remaining directions; hence it reduces the interference in those directions. All UAVs are equipped with one omnidirectional antenna and the group of eight directional antennas. It uses omnidirectional antenna for receiving the signal. For data transmission it uses any one of the directional antenna.

This protocol first identifies the position of antenna based the location of the receiver. From that position it identifies the direction of the receiver, then it will transmit data through the directional antenna of that particular direction.

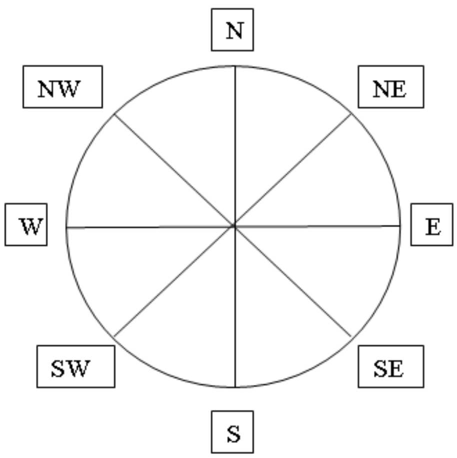
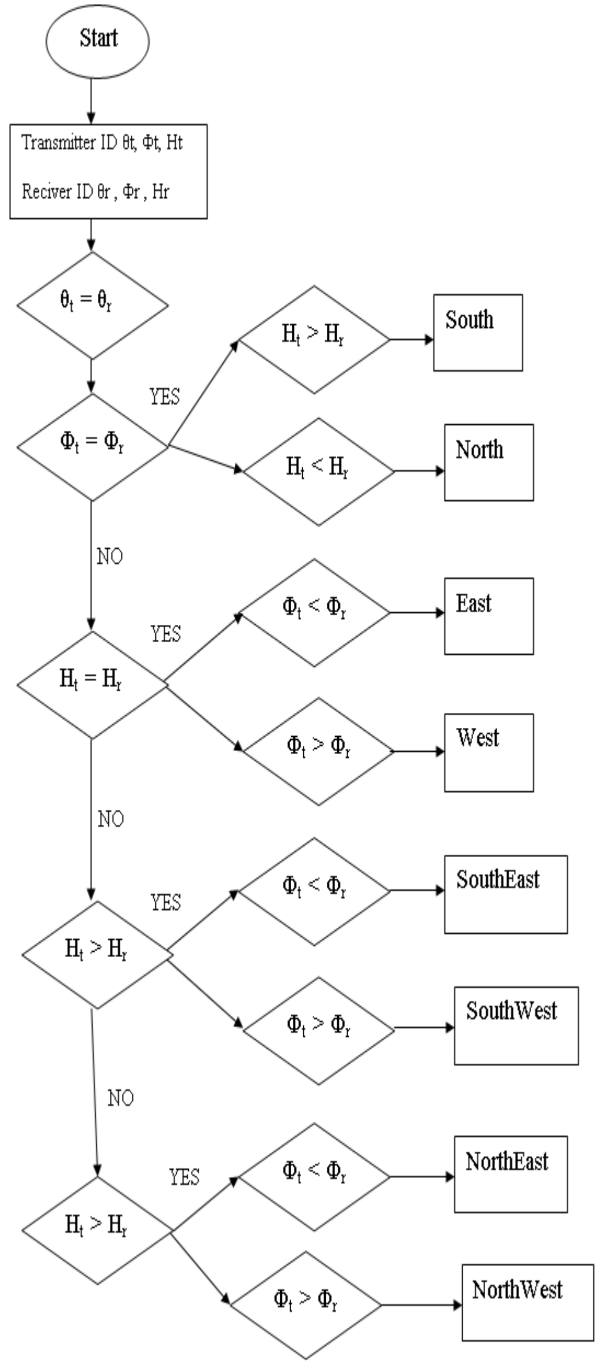


Figure-3. The transmission range is divided into eight directions.

In the diagram the eight directions are mentioned. For each direction one directional antenna is available. The transmitting UAV identifies the direction of the receiving UAV.

The position id of the transmitting UAV is θ_t, Φ_t, H_t
The position id of the receiving UAV is θ_r, Φ_r, H_r
Direction Identification Algorithm



The following diagrams show the transmission range in eight directions.

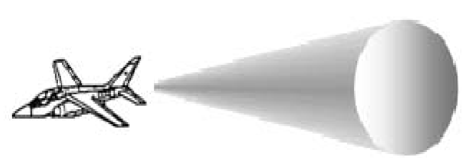


Figure-4. Transmission of signal in East direction.

ARPN Journal of Engineering and Applied Sciences

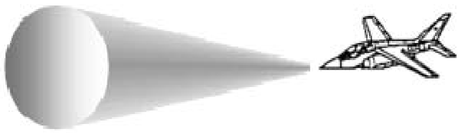


Figure-5. Transmission of signal in West direction.

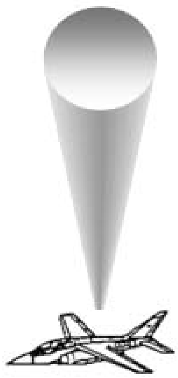


Figure-6. Transmission of signal in North direction.

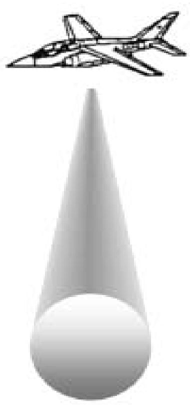


Figure-7. Transmission of signal in South direction.

Figure-8. Transmission of signal in North-East direction.

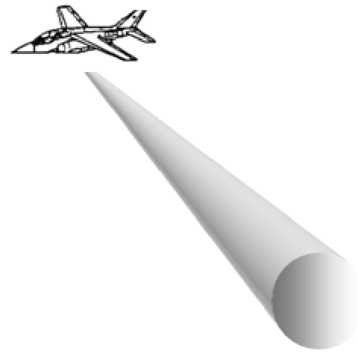


Figure-9. Transmission of signal in South-East direction

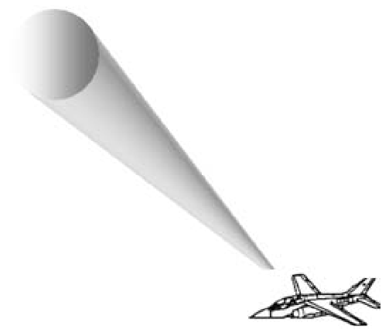


Figure-10. Transmission of signal in North-West direction

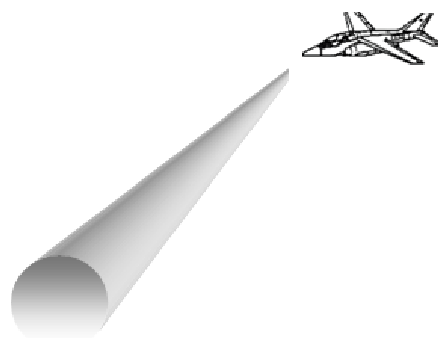


Figure-11. Transmission of signal in South-West direction.

SIMULATION RESULTS

The simulation was done by the Network Simulator 2 (NS2) simulator. The NS2 network simulator is a discrete event simulator, which is used to simulate wired and wireless networks. The NS instructions can be used to define the topology structure of the network and the motion mode of the nodes, to configure the service of the node. Here we used NS2 to analyze the performance of the above mentioned algorithms.

ARPN Journal of Engineering and Applied Sciences

Table-1. Parameters of simulation.

Parameters	
Chanel	**Wireless Channel**
Propagation	TwoRayGround
Phy type	Wireless phy
Mac type	802_11
Queue type	Droptail
Antenna type	Omni directional antenna
Traffic	CBR
Data rate	5 Mb
Max packet in queue	50
Packet size	1000
Topology Range	500 x 500
Transmission Range	250m

In the trace file the third Column records the component in which the operation is performed. The third column is RTR or AGT.

RTR -stands for routing agent, and

AGT- stands for either the source or the sink.

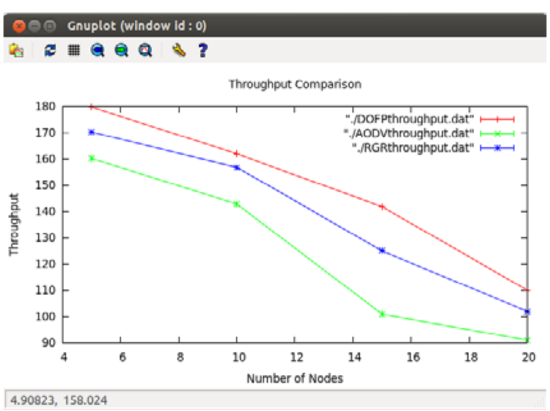
The number of routing agent messages over all messages is calculated for analysis.

Performance Metrics

Here three performance metrics are used to analyze the performance of the proposed protocol.

Throughput

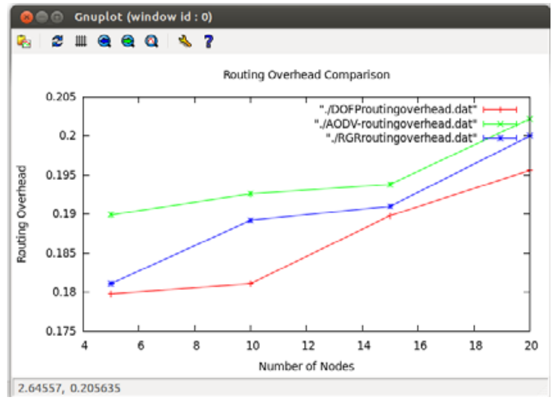
Network throughput is the rate of successful message delivery over a communication channel. The number of successfully received packets in a unit time.



The network throughput is increased in our protocol.

Routing Overhead

The total number of routing packets normalized by the total number of received packets. This proposed protocol has reduced Routing Overhead.



The routing overhead has been reduced in our protocol.

Average Energy Consumption

In trace file the meaning of each item is as follows:

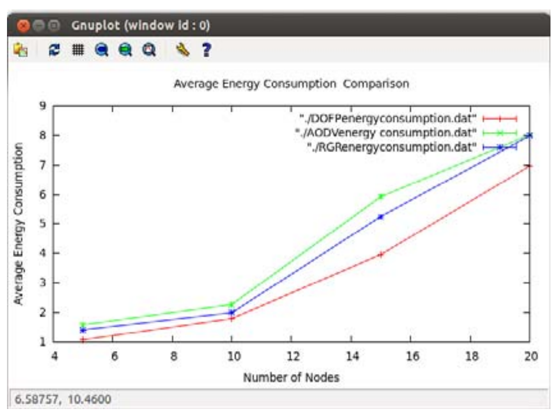
energy: total remaining energy

ei: energy consumption in IDLE state

es: energy consumption in SLEEP state

et: energy consumed in transmitting packets

er: energy consumed in receiving packets



In our protocol the Average Energy Consumption is reduced. The energy consumption is balanced over all nodes in the network. Hence the lifetime of the network is increased

CONCLUSIONS

Here we used DOFP protocol for UAANET. It reduces the routing overhead and the possibility of data loss. The performance of DOFP algorithm is compared with RGR and AODV. In AODV, all the nodes have been involved in the routing process. In RGR, in AODV mode all nodes are involved, then in GRG mode some nodes are involved. The routing overhead is high; hence the energy consumption is also high. But, the DOFP protocol tries to identify the direction in which the receiver is present and selects only one directional antenna for transmission. It has lower routing load. Hence throughput is increased. The average energy consumption is reduced.

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