

# A Review of Routing Protocols for Airborne Networks

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**ABSTRACT** - Airborne network is an emerging field in the wireless networks. Efficient routing is a major concern for many researchers in this field. Therefore, to design an efficient routing protocol in an airborne network, various parameters to be considered are discussed in this paper. Review of routing protocols based on performance, routing model, network structure, methodology is further discussed.

**Keywords:** Airborne Networks, Routing Protocols, Wireless Networks, MANETs, Ad Hoc Networks.

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## 1. INTRODUCTION

Wireless networks provide flexible link between users in different locations. Moreover, the network can be extended to any place or building without the requirement for a wired connection. Wireless networks are categorized into two types; infrastructure networks and ad hoc networks.

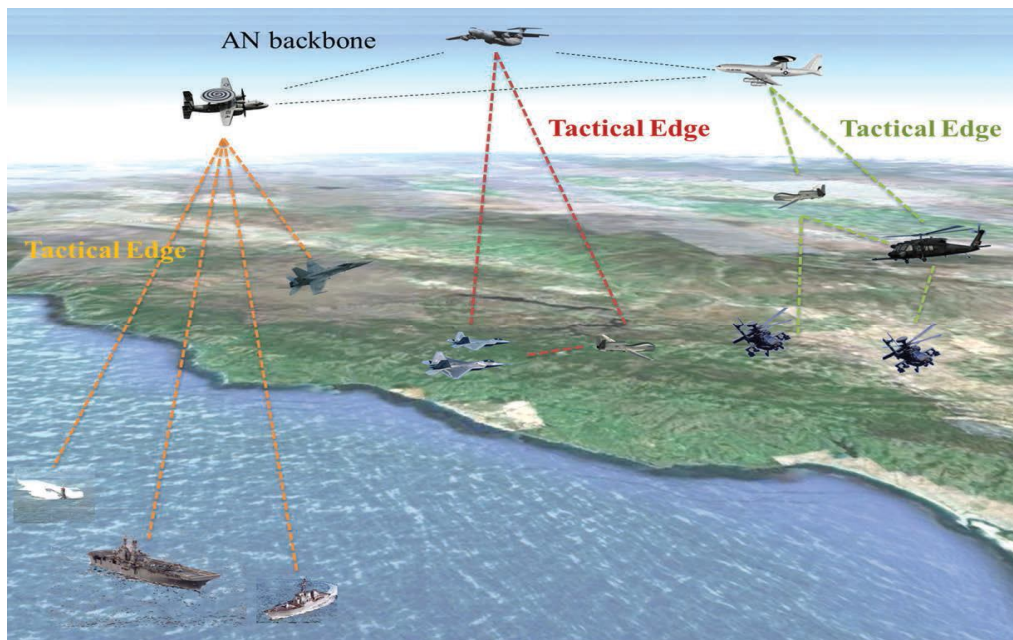
**1.1. Infrastructure networks** An Access Point (AP) is a central coordinator for all nodes. Any node can be linked to the network through AP. It also manages the link between the Basic Set Services (BSSs) so that the route is ready when it is needed. However, one disadvantage of using an infrastructure network is the large overhead of maintaining the routing tables.

**1.2. Ad Hoc networks** A wireless ad hoc network is a distributed type of wireless network. The network is ad hoc because it does not depend on a pre-existing infrastructure, like routers as in wired networks or access points in infrastructure networks [1]. These ad hoc networks do not have a guaranteed topology or a central coordination access point. Hence, sending and receiving packets are more complex than infrastructure networks [2].

Wireless ad hoc networks with a supportive mobility in Mobile Ad Hoc Networks (MANETs) are a collection of mobile nodes which share a wireless channel without any centralized and coordinating control or conventional communication backbone. MANET has a changing topology and each mobile node has limited resources such as battery, processing power and on-board memory [3].

An Airborne Network (AN) is a MANET infrastructure that provides communication services through at least one node that is on a platform capable of flight [4]. Airborne networks are communication networks consisting of both ground nodes and airborne assets. Owing to the limited dependence on current infrastructure, they can be considered a special kind of ad hoc networks; they can also be ordered as “opportunistic networks.”[3] The network is intended for use in aeronautics Communications, Navigation, and Surveillance (CNS) and are also useful to private Internet users, businesses, and government agencies, especially the military. At least three different ways are proposed for placing communication nodes aloft. The first way is the manned aircraft, the second way uses unmanned aircraft, and the third way uses blimps. The nodes may provide surface-to-air, air-to-air, and surface-to-surface communications. The flight nodes or blimps can hover at altitudes of around 10 mi (16 km), and can cover regions of about 40 mi (64 km) in radius [5].

Airborne networks incline to show high heterogeneity. For example, combat planes and interceptors show high mobility and aircraft movements may cause contacts to spasmodically go down due to antenna misalignment. Airborne networks are often categorized by the presence of such *intermittent links*. Such kind of aircraft in the network will effect in dramatic changes in topology and temporary connection failures. Aircraft which have much lower speed, like Unmanned Aerial Vehicles (UAVs) and helicopters, can hover around a particular region. Handheld radios which are used as ground assets have less mobility, and are inhibited by restricted battery life. Although traditional ad hoc routing protocols are intended for mobile nodes, they may not be certainly suitable for airborne nodes because of high-speed motion and recurrent connection interruptions. An operative and capable routing protocol for airborne networks must adjust to heavy motion, ever changing topology and diverse routing abilities [3].



*Figure 1: Airborne Network Architecture [6]*

We discuss various routing protocols used for airborne network in next Section 2. In Section 3, we compare various routing protocols used for airborne networks considering the different parameters that govern the routing protocols. Section 4 gives concluding remarks.

## 2. OVERVIEW OF AIRBORNE ROUTING PROTOCOLS

In [7], authors compare Optimized Link State Routing (OLSR) and Open Shortest Path First with MANET Designated Routers, (OSPF-MDR).

### i. OLSR

In OLSR, there are two leading message types: Hello and Topology Control (TC). Each node every so often sends a hello message to all of its next direct (one-hop) neighbors. In a hello message, a node lists all of its one-hop neighbors; subsequently, a node getting a hello message is able to learn about all of the nodes in its two-hop neighborhood. Topology control messages hold a node's view of the link statuses for the whole network. These messages are flooded to entire network, letting nodes to proactively form an end-to-end path to any other node. Periodically *Hello* and TC messages are sent, with a defaulting periodicity of 2 and 5 seconds, respectively. Every node retransmits every TC message making the bandwidth usage inefficient. This will quickly devastate a wireless network if the number of nodes grows too large. So in OLSR, a node chooses a subset of its neighbors to relay the TC messages, which decreases the total bandwidth used to circulate topology information. The nodes nominated to retransmit a TC message are identified as Multi-Point Relays (MPRs). Each node independently chooses its own set of MPR nodes based on the algorithm specified in paper [7].

### ii. OSPF-MDR

OSPF-MDR has three key message types: *Hello*, *Link State* and *Advertisement (LSA)*, and database description (DD). Parallel to OLSR, nodes learn about their two-hop neighborhood by means of *hello* messages, *hellos* being sent every 2 seconds. A main difference from OLSR is that OSPF-MDR uses incremental *hellos*: changes from the last *hello* only are reported, otherwise an empty *hello* is sent. The LSA message comprises a node's vision of the network topology, and it is similar to OLSR's TC message. To decrease the number of topology messages communicated, LSAs are only produced if a topology change is detected; unlike the *hello* message, empty LSAs are not sent. In a highly dynamic environment, in order not to send too many LSAs, there is a minimum interim between LSA transmissions, with the default value being 5 seconds. To be further bandwidth efficient, OSPF-MDR also chooses a subset of a node's neighbors to relay topology information.

OSPF-MDR presents a new algorithm where nodes coordinate among themselves such that they choose a set of backbone nodes to form a Connected Dominating Set (CDS). This is the difference between OLSR's MPR algorithm, where each node independently chooses its own set of MPR nodes. The nodes that are picked to be part of the CDS are called MANET Designated Routers (MDRs).

Also, OLSR needs that every two-hop neighbor of a node should be able to be reached through an MPR node; OSPF-MDR has no such condition for MDR nodes. OSPF-MDR also has the choice to minimize bandwidth usage by sending LSAs for the whole topology or just part of it. LSAs can comprise only the MDR nodes, which will cause all routes to traverse the set of backbone nodes. Whenever an MDR node forms a new adjacency with another node the database description message is transmitted, and is used to synchronize both nodes' databases of link states.

Authors considered the following metrics in evaluation: routing overhead, packet delivery ratio, and convergence time. For routing overhead, OSPF-MDR produced less control traffic than OLSR. Under lower mobility and denser networks, OSPF-MDR produced an order of magnitude less overhead.

This effect is due to the essential differences between how the two protocols choose nodes to transmit topology information throughout the network, OLSR picks a lot more than OSPF-MDR does. As OLSR picks many relay nodes, it has redundancy in control traffic; therefore, it becomes slightly more robust than OSPF-MDR against topology changes due to mobility. For convergence time, authors found that OLSR had a fairly constant convergence time of about 10 seconds with respect to network size and packet failure rate. OSPF-MDR performance was same without packet losses, but packet losses caused in significantly lengthier convergence times for bigger networks due to certain loss events that disallowed one or two nodes from converging [7].

### iii. MARP/MDP

In [1], the authors propose Mobility Aware Routing Protocol (MARP)/ Mobility Dissemination Protocol (MDP). The crucial idea behind the (MARP) is to utilize the information of the scheduled planned node trajectories of the AN backbone. This information can be used to foresee the network topology changes a priori. However, it can be probable that few airborne platforms may not keep to the pre-decided flight plans. The reasons for this could be changes in weather and revised mission objectives etc. The (MDP) is used to notify the airborne network nodes of disagreements between foreseen topology and the link state facts collected by each node in run time. MARP/MDP essentially falls under the proactive family of ad hoc network routing protocols that maintain a local view of the global topology. MARP uses node mobility data, transmit power and the free space propagation model (airborne network operates in free space) to foresee the network topology during initialization. For every topology entry, MARP computes Dijkstra's shortest paths for every sender-receiver pair and stores this information in a T-time routing table. T-time routing table is unlike from the conventional routing table in the sense that it is time indexed. For a given destination the next hop put in storage at a particular node is a function of time. Therefore, MARP needs to know the current time instant in addition to the destination IP address for a successful route lookup.

MDP transmits "Hello" messages to its neighborhood at every "HELLO\_INTERVAL." To determine condition status of foreseen links and to speculatively realize new neighbors, MDP counts the number of "Hello" messages that it receives from its neighbors in every "CHECK\_NEIGHBOR\_INTERVAL." Matching this count against pre-set thresholds, MDP decides if a link is UP or DOWN. MARP/MDP exploits the mission and mobility knowledge of the airborne nodes to foresee AN topology changes in advances. Authors through simulations show that MARP/MDP overtakes the traditional proactive and reactive ad hoc network routing protocols for representative airborne network deployment scenarios.

### iv. ADS-B

In [10], authors present Topology Aware Routing Protocol based ADS-B System. Airborne ADS-B (Automatic Dependent Surveillance-Broadcast) system can give much more rich and precise flight data/information and integrated with geographic routing system, the scheme uses the location and mobility information provided by ADS-B system to create neighbor table and select next hop. This eliminates the routing beaconing scheme and can effectually cut the routing overhead, increase the packet delivery ratio. Authors perform simulations and the results verify that the proposed protocol has better performance: 1) it can effectively decrease the routing overhead as the number of nodes increases, 2) it can offer better packet delivery ratio while facing frequent topology changes and 3) the enhanced protocol can be accomplished directly and effortlessly without large change of existing equipment.

### v. AODV

The routing protocols are built upon Ad hoc On-Demand Distance Vector (AODV), a reactive hop-by-hop routing protocol. AODV has a flat structure and has the potential to support dynamic networks. In this routing protocol, the route discovery flooding of AODV is only implemented inside a cluster. Route discovery to other clusters generally goes through the link between mesh routers. The advantage here is that duplicate route requests are limited to a certain range instead of flooding the entire network. Moreover, since mesh routers usually hover around a certain area, their locations are relatively stable. The rapid topology changes can be mitigated by using these mesh points.

#### vi. BGP-MX

In [8], authors present a new approach for exterior gateway routing called Border Gateway Protocol with Mobility Extensions (BGP-MX). The BGP-MX approach relies on extending BGP with mechanisms that enable BGP to function correctly and efficiently in mobile networks that are part of the airborne network environment while interoperating with an unmodified BGP infrastructure within the Global Information Grid (GIG). The BGP-MX software enables BGP to automate the process of discovering peers in adjacent Autonomous Systems (AS) and the process of establishing connections between them. Also, the extensions enable BGP speakers that belong to an AS to discover each other and to maintain internal connections between them. Lastly, the BGP-MX software enhances BGP routing mechanisms with new techniques that enable BGP to adapt quickly to link disconnections due to topology changes within the AN environment. The BGP-MX software extensions are BGP compatible. Thus BGP-MX capable nodes can coexist and communicate with BGP nodes that do not support the BGP-MX software extensions. Also, BGP-MX software extensions can be easily integrated with commercial routers. Thus BGP-MX can be utilized by existing networks without requiring major changes to existing communication infrastructures.

#### vii. Aero RP

Aeronautical Routing Protocol (AeroRP) is designed for dynamic airborne networks. Route is discovered by using node's current geolocation or predicted geolocation. Neighbor discovery is a proactive approach in the network. Routing decision are made HOP to route data packets. Routing is not based on end-to-end because node is moving at high speed and there is a chance of link breakage whereas in MANET routing end-to-end path is determined. It uses flat structure and uses single hop and produces a single path as output. It uses multi-modal approach wherein any node can be used to discover neighbor. It shows an improved performance compared to other routing protocols in different mobility models.

#### viii. DSR

Dynamic Source Routing (DSR) is similar to AODV protocol except that it uses source routing method. DSR does not rely on routing table. It is a reactive routing protocol where route is discovered on demand. The source path is determined with the help of cache and time to live options in the network. If the length of the path is more, then the overhead increases in maintaining the source route. Therefore, it is suitable for smaller networks and shorter paths. In DSR approach, routing table is maintained with a single entry for destination. A single route is stored and gives a single path to the destination. Each time, when a packet is routed, single hop is considered. DSR uses a flat structure in the network. This protocol is not suitable for large sized networks. The performance of the protocol is studied in different mobility models.

### 3. COMPARISON OF AIRBORNE ROUTING PROTOCOLS

High mobility is a major concern in designing routing protocols for airborne networks. Therefore, current location, trajectory information of a node is highly needed in calculating the future location. Generally, the trajectory information is given by Low Earth Orbiting (LEO) satellites and racetrack-path Unpiloted Aerial Vehicles (UAVs). Routing algorithms discussed in the literature are plenty to mention here. The literature shows the different approaches in designing routing protocols. The principle in the design of routing protocol is same by using strategy called "neighbor discovery". The protocols are differed in the way it discovers the neighbor. The neighbor discovery is needed to establish the route between source and destination. Based on this approach, the routing protocols are classified as proactive protocols and reactive protocols. Proactive routing protocol discover the routes in advance whereas reactive protocols discover the routes only if it is needed.

The routing protocols differ by considering some of the assumed parameters like known source, known destination, known path etc. Some protocols return single route while some others return multiple routes. The operational characteristics differ in different protocols which include minimize / maximize number of hops, flat/ hierarchy structure, number of nodes, packet delivery ratio. Simulator used to test and study the routing protocols play a vital role in its performance. Mobility models also have an impact in the performance of the routing protocols.

**Table 1: Comparison of Routing Protocols**

S.No.	Parameters	Aero RP	OLSR	DSR	AODV	OSPF-MDR	MARP/MDP	ADS-B	BGP-MX
1	Neighbour discovery	Using multimodal approach where any node can be used	Using HelLo and topology control messages	Multi Hop route discovery	Mesh routers on clusters	Using hello messages in every 2 sec. Only changes are reported.	Node mobility data using time function	Surveillance broadcast	Autonomous system
2	Type of protocol (reactive and proactive)	Proactive	Proactive	Reactive	Reactive	Reactive	Proactive	Proactive	Proactive
3	Assumptions used	Nil	Nil	Designated source Routing table contains one entry for destination	Routing table contains one entry for destination	Nil	Shortest path using Dijkstra's Algorithm		BGP –extension
4	Output (single / multiple routes)	Single	Single	Single	Multiple	Multiple	multiple	Multiple routes	Multiple routes
5	Number of hops	2 hops/single	Single	Single	Single	2 hops	Single	Single	Single/multiple
6	Structure	Flat	Hierarchical---- Multipoint relay system	Flat	Flat	Hierarchical	Flat	Flat	Hierarchical
7	(Number of nodes) Node density	Supports more number of nodes	Few number of nodes	Fails to cope up with more number of nodes	Supports few number of nodes	Fails to cope up with more number of nodes	Supports few number of nodes	Supports moderate to more number of nodes	Supports few number of nodes
8	Packet Delivery ratio(PDR)	PDR is high as number of nodes are increased	Less than MARP/MDP	Less than AeroRP	Improved on static routing protocols	Better than OLSR	Overtakes all proactive and reactive protocols	Improved to MANET protocols	Moderate
9	Simulator	NS-2, NS-3	NS-2, NS-3	NS2	NS-3	NS-2, NS-3	NS-2, NS-3	NS-2, NS-3	NS-3
10	Routing model	3D Gauss-Markov	Random Walk Path, Gauss Markov	3D Gauss-Markov	Random Way Point	Random Way Point	Random Walk Path, Gauss Markov	Random Walk Path, Gauss Markov	
11	Bandwidth utilization	Efficient	Inefficient because of redundant message	Inefficient	Moderate	Efficient because of relevant message	Efficient	Moderate	Moderate
12	Topology update	Only if topology is updated	Every 2 sec	Using router	Cluster based updates using mesh router	every 5 sec only if there is a change	Using Time functions	Geographic routing system and mobility updates	Speaker nodes and Autonomous systems

#### 4. CONCLUSIONS

AeroRP is suitable for larger sized networks. Proactive routing protocols are giving better performance than reactive routing protocols. A simulator used to test the routing protocol is also important factor in deciding the performance of routing protocol. Routing model used is used to decide the performance of the routing protocol under different models. Methodology used in each routing protocols like the discovery of neighbors is different for different protocols. Also, performance of the routing protocol is varied depending upon the density of the nodes in the network. The performance criteria like packet delivery ratio and time to respond to the neighbors is different for different protocols. Structure of the network like flat or hierarchical is dependent on packet delivery ratio and time to respond to the neighbors. Therefore, these parameters are considered for evaluating the routing protocols.

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