# Mobility Based Study of Routing Protocols in Mobile Ad Hoc Network


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## ABSTRACT

Mobile Ad Hoc network (MANET) can be seen as a collection of intelligent mobile nodes, which form a dynamic and autonomous system. These nodes communicate wirelessly in a self-organized, self-configured and self-administered manner. Since mobile nodes move arbitrary on the fly, they cause frequents link failure which impact network performances and data traffic delivery. Therefore, the task of finding and maintaining an appropriate route between a pair of nodes constitute the main issue in designing routing protocols for MANET. In addition to network topology changes, another intrinsic limitations of MANET, such as limited bandwidth, limited power and processing capabilities of mobile nodes, make routing process more complex and challenging. Several routing protocols have been proposed and developed. Each routing protocol have shown better performances under specific network conditions, such as mobility level, traffic pattern and network size. In this paper we studied routing operations of common MANET routing protocols and we discussed how far are those routing protocols efficient in high dynamic context.



## CCS Concepts

• Networks. Network protocols. Network layer protocols. Routing protocols**.**

## KEYWORDS

Mobile Ad Hoc Networks (MANET); Routing Protocols; Mobility.


**ACM Reference format**[*]




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## 1. INTRODUCTION

Nowadays, the development of mobile technology applications such as web browsing, online banking, online gaming and social media, has stimulated the wide spread usage of wireless network. Therefore, wireless networks have become almost a necessity and a vital component of our daily life.

Wireless networks use radio transmission techniques to connect mobile users and satisfy their need in term of online services. Wireless networks can be split into two categories, as shown in figure.1. Infrastructure based wireless networks, which use fixed access points as gateways between wired and wireless area. For example: cellular networks, Wi-Fi (IEEE 802.11) and Wi-Max (IEEE 802.16). On the other hand, infrastructure less networks, broadly known as Ad Hoc networks, does not rely on any pre-established infrastructure. Ad Hoc networks form a self-organized, self-configured and self-administered system. Furthermore, Ad Hoc Networks are single-hop like Bluetooth or multi-hop like Wireless Sensor Networks (WSN) and Mobile Ad Hoc Network (MANET) [1][24].

Ad Hoc networking is a multi-level issue because of its autonomous operations; Hence network layer should adapt its routing operations to several network constraints, such as node's mobility, node's Energy, scarce bandwidth and network size to establish efficient routes for data communication. In this context, several routing protocols has been designed in order to address those limitations and guarantee the quality of service required by mobile Ad Hoc applications [2].

In the flowing, we will present Mobile Ad Hoc Network characteristics, applications and challenges. In section 3, we are going to present routing protocol operations and their efficiency in high dynamic network. In section 4, we are going to compare and discuss the main virtues and drawbacks of presented routing protocols

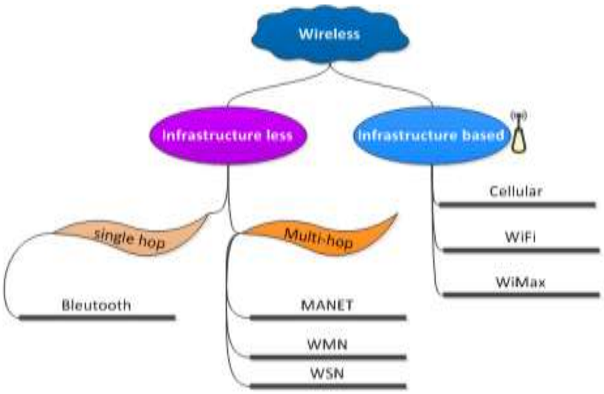


**Figure 1. Wireless network categories**

# 2. MOBILE AD HOC NETWORKS

## 2.1 Characteristics

The main features of MANETs that distinct them from other infrastructure-based network are the lack of central infrastructure like base station in cellular network, and autonomous networking operations. Each Mobile node keeps sensing their neighboring to acquire and maintains routing information in order to coordinate data communication. Moreover, there are some additional features that are inherent to wireless communication technologies such as Bandwidth constraints, variable links capacity, limited physical security, multi-hop routing and others features inherent to mobile nodes such as dynamic network topology, device heterogeneity and limited energy [3][19].

## 2.2 Challenges

The intrinsic characteristics of MANET impose many challenges to network protocol designs on all layers. The physical layer should address the rapid changes in radio link characteristics. The media access control (MAC) layer must solve hidden and exposed terminal problems and permit a fair channel allocation to minimize packet collisions. At the network layer, nodes should cooperate in a distributed manner to establish route between nodes. Established routes are generally multi-hop due to limited transmission range of mobile nodes, so routing protocols must be capable to route data packet through intermediate nodes until reaching targeted destination [3][4].

There are many issues that have to be addressed In MANET environment such as nodes mobility, bandwidth-constrained, energy-constrained, and limited security shared in order to design efficient routing protocols. In our study we are focusing on network topology that can change due to mobility. This issue should be handled without generating excessive control traffic overhead or overusing of restricted nodes processing. Moreover, in high dynamic environment the process of routing become more complex, because an optimal path at time t1 may become useless at time t2, which lead to continuous exploration of new optimal path. If routing protocol does not incorporate efficient route discovery and maintenance procedures, the global network performances might be affected [3][5][19].

## 2.3 Application

Mobile ad hoc networks offer numerous opportunities to develop mobile applications and networking facilities in the areas where a fixed infrastructure is not available, too expensive or there is no time to deploy this infrastructure.

The first Ad Hoc network applications have been developed for military purposes such as Packet Radio Network (PRNET) in 1972 and lately Survival Adaptive Radio Networks (SURAN) in 1980. Since 1990, the development of commercial applications become possible due to the wide spread of smart mobile devices like laptops, notebooks, PDAs and Software development [1][2]. Nowadays many applications have been emerged such as:

- Military communication and operations in battlefield.
- Emergency services: Search and rescue operations, Disaster recovery.
- Commercial and civilian environments like electronic payments anytime and anywhere.
- Home and enterprise networking like smart home, conferences and meeting rooms' facilities.
- Entertainment like P2P networking and multi-users gaming.

# 3. ROUTING PROTOCOLS

Routing protocols constitute the main building bloc in Ad Hoc networking because they are responsible of establishing and maintaining appropriate route between a source node and a destination node. Moreover, due to the unreliable characteristics of lower layers in wireless communication, routing protocols have to be aware of radio transmission and medium access control deficiencies and adapt their mechanisms to overcome such issues. Due to multiple challenges in networking process, researchers have been proposing several routing schemes that meet required functionalities related to a specific application flied. As a result, there is no routing protocol that could fit to all Ad Hoc networking contexts [7][8]. In the following paragraphs, we study routing protocols based on their scheduling model as discussed in our previous paper [6][20]. Hence routing protocol could be proactive, reactive or hybrid.

## 3.1 Proactive Routing Protocols

In proactive or table-driven protocols, each node keeps up to date routing information in routing table. Routing information is updated periodically and when topology changes occur. Following are some ccommon proactive routing protocols.

### *3.1.1 Destination-Sequence Distance Vector (DSDV)*

DSDV is a unicast, flat, proactive and distance victor routing protocol. It uses Bellman–Ford algorithm for short path calculation. A destination sequence number is created to identifies fresh path and avoid route loops. The DSDV protocol requires each node to broadcast its routing table to its current neighbors. This procedure must be accomplished each time a mobile node changes its position in order to maintain a global vision of the network. DSDV introduce very low latency during route discovery operation but it generates a high volume of overhead in large network and high mobility context [1][2].

### *3.1.2 Fisheye state routing (FSR)*

The FSR protocol is a unicast, implicit hierarchical, proactive and link state protocol. It uses the fisheye technique of Kleinrock and Stevens to maintain accurate distance and path quality information about the immediate neighborhood of a node, with progressively less detail as the distance increases. The FSR uses multi-level scopes, as presented in figure 2, which contribute in optimizing the bandwidth consumed by traditional link state update process. Thus, FSR is quite suitable for large topology. Its performances in different mobility rate depend essentially of the number of hops associated with each scope level; consequently scope level should be carefully defined [9].

### *3.1.3 Optimized link-state routing protocol (OLSR)*

The OLSR is a unicast, flat and proactive routing protocol. It employs multipoint relaying (MPR) technique to advertise link stat routing information through the network. Each node chooses a set of neighbor nodes called multipoint relays (MPR), which retransmits its packets. In contrast to the conventional flooding mechanism where every node broadcasts the messages and generates a lot of overhead traffic, nodes that are not in its MPR set can only read and process packets [fig.4]. Thus, MPR process reduces traffic overhead and the number of links that are used for link state packets forwarding. OLSR has several advantages that make it better than other proactive protocols. It reduces the routing overhead associated with table-driven routing and reduces the number of broadcasts operations. Hence OLSR has the advantages of low connection setup time and reduced control overhead. In addition OLSR is highly recommended for low mobility context in contrast high mobility impact significantly the protocol performances due to frequent traffic control associated to MPR reselection process and topology changes advertising [10][11].

### *3.1.4 Distance Routing Effect Algorithm For Mobility (DREAM)*

The DREAM is a unicast, flat and Proactive routing protocol. It uses location and mobility rate information, obtained through GPS, to update routing table stored at each node in the network. Routing overhead is reduced because message update dissemination is proportional to mobility and the distance effect. When node A wants to send a message to node B, it uses the location information for B to obtain B's direction, and then transmits to all its one-hop neighbors in the direction of B. Each neighbor repeats the same procedure, until reaching B [12].

## 3.2 Reactive Routing Protocols

In reactive or on-demand protocols, route is established only when a node has data to send to a given destination and routing information are maintained as long as data are being transmitted

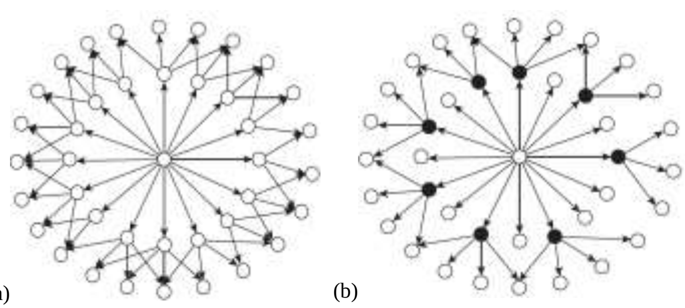
(a) (b)

**Figure 3. OLSR pure flooding (a) vs. MPR operation (b)**

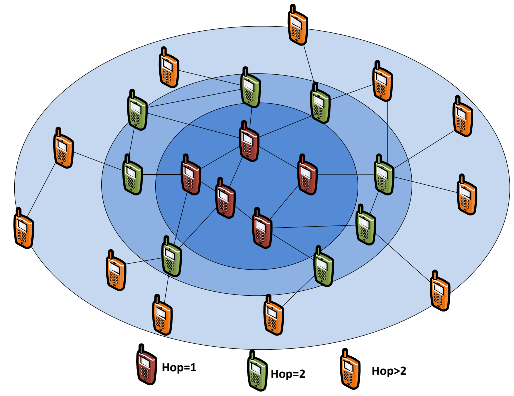


**Figure 2. Fisheye scoop**

over active path. Following are some common reactive routing protocols

### *3.2.1 Ad Hoc On Demand Distance Victor (AODV)*

The AODV is a unicast, flat and reactive routing protocol. It uses on- demand approach to establish routes. Instead of DSDV, Destination sequence number is used to identify the freshest path to the destination node. AODV does not require nodes to maintain routes to destinations that are not evolved in active route. When a source node needs to send Data to a destination, a route request (RREQ) packet is flooded hop by hop through the networks until reaching the destination, then reverse path is established using route response (RREP) packet. When links break, adjacent nodes initiate route error (RERR) packets to inform their neighbors about the link break. The end nodes delete the corresponding entries from their table and source node reinitiate new query to find alternate path. The main advantages of this protocol are reduced control overhead and adaptability to high mobility context. However, route discovery process might introduce large delay until successful route establishment procedure. Link failure introduces in its turn an extra delay consumes more bandwidth [12][13][21][22].

### *3.2.2 Dynamic source routing protocol (DSR)*

The DSR is a unicast, flat and reactive routing protocol. It uses source routing approach. Thus the source knows the complete hop-by-hop route to the destination. Routes are stored in a route cache and carried by data packet in the packet header. This protocol has two major operations: The first is route discovery, where the source initiates flooding process with RREQ packets. When the destination node receives RREQ packet it responds by sending back an RREP packet through the same route. The second phase is route maintenance, which manages links failure due to topology changes. If any link on an active route is broken, the source node is notified through an RERR packet then the source removes any route using this link from its cache and initiate a new discovery process if the source still having data to send along this route. The advantage of this protocol is the reduction of overhead on route maintenance due to multipath capabilities that result of using route cache. However, packet header size grows with the route length due to source routing and RREQ flooding which consume most of the bandwidth in highly dynamic and large networks [14].

*3.2.3 Location-Aided Routing (LAR)*

The LAR is a reactive location based routing protocol. It uses the location information, which can be learned from the Global Positioning System (GPS), to reduce flooding area and thus minimize the routing overhead. Two different schemes were proposed in [15] to determine the forwarding zone of a route request packet. The first scheme calculates a request zone where the route request packets can travel to reach the required destination. The second scheme stores the coordinates of the destination in the route request packets. These packets can only travel in the direction where the relative distance to the destination becomes smaller as they travel from one hop to another. Limited searching area during route discovery process minimizes control overhead and bandwidth consumption. In high mobility context, LAR protocol might flood the whole network due to the high probability that defined request zone doesn't include destination node [1][2].

*3.2.4 Ant Colony-Based Routing Algorithm (ARA)*

The ARA is a Nature-inspired algorithm, also referred to as bio-inspired algorithm, that learn and emulate the features of insect swarms to solve complexes and distributed problems, such as routing algorithms design. The foraging of ants colonies show distributed, adaptive and cooperative behavior, which is directly applicable into algorithms optimization leading to the ant colony optimization (ACO). ACO-based routing algorithm referred to as ARA uses both forward and backward ants for route discovery and setup. When ants search for food they start from their nest and walk towards the food as shown in figure 4, while leaving behind a transient trail called pheromone. This indicated the path that has been taken by the ant and allows others to follow, until the pheromone disappears. To maintain routes, each time a data packet travels between intermediate nodes the pheromone value is increased. Otherwise the pheromone value is decreased overtime until it expires. To repair a broken link, the nodes firstly check their routing table, if no route is found they inform their neighbors for an alternate route. If the neighbors do have a route they inform their neighbors by backtracking. If the source node is reached and no route is found, a new route discovery process is initiated. This strategy has the advantage of minimizing control overhead due to smaller forward and backward packets. However, could not scale very well due to flooding mechanism used in route discovery process [16][17].

## 3.3 Hybrid Routing Protocols

In hybrid routing protocols, both proactive and reactive procedures are combined to improve routing efficiency. Following are some common hybrid routing protocols.

*3.3.1 Ant-HocNet*

AntHocNet is a multipath, hybrid and ACO routing algorithm based. It uses reactive forward and backward ants to discover new routes. When a forward ant reaches the destination, it will be converted into a backward ant and follow the same route in the reverse direction by updating the pheromone table in each visited node. The pheromone update is proportional to the number of hops in the path, traffic congestion and signal to noise ratio. During active communication, AntHocNet tries to find new paths to the destination using proactive path maintenance and path exploration mechanisms [18].

*3.3.2 Zone Routing Protocol (ZRP)*

The ZRP is a hybrid, zone-based, hierarchical and link-state routing protocol. It uses both proactive and reactive mechanisms to accomplish routing process. Around each node, ZRP defines a zone where the radius is measured in hops, see figure 5. Each node uses proactive routing within its zone and reactive routing outside its zone. When a node needs to send data to a given destination, it lookup its routing then if the destination node is within the zone, a route will exist in the route table; Otherwise, the node will set up a route request for that specific destination to establish the path. ZRP is suitable for a wide variety of MANETs, especially with a large network span and diverse mobility patterns.

# 4. COMPARISON AND DISCUSSION

Many routing protocols have been proposed for mobile ad hoc networks, which are different in the approach used for the routing discovery mechanism, maintaining the existing route when link failure occurs or the node moves away from the existing networks. In the next paragraphs we are going to compare, in table 1, those proposed routing protocols according to their efficiency in high mobility context and the impact of link failure management on routing performances such as routing overhead, memory overhead, bandwidth consumption and scalability [23][25][26].

In general, hierarchical routing protocols have been designed to solve scalability issue, which is the main limitation of most of flat routing protocols. However, Cluster formation and maintenance process introduce in case of high mobility a huge amount of extra processing and overheads packets. These unnecessary overheads lead to an overuse of scarce available bandwidth and thus poor quality of service will be delivered to user's application such high latency and high packet loss ratio.

In the following paragraphs, we are going to focus on flat routing because they outperform hierarchical routing in high mobility. First, most proactive flat routing protocols do not scale very well because of their periodic updating procedure. This procedure consumes big amount of scarce bandwidth. Hence, several optimizations have been introduced to improve scalability. For

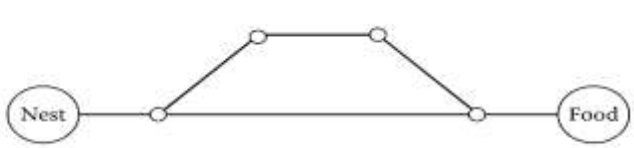


**Figure 4. Ant food searching**

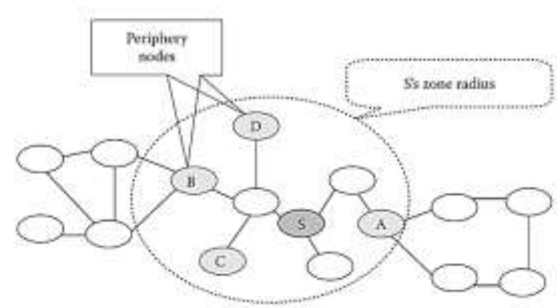


**Figure 5. ZRP radius**

example OLSR may scale the best between all proactive protocols discussed above. Scalability enhancement is achieved by reducing the number of rebroadcasting nodes through the use of multipoint relaying technique, which elects only a number of highly connected neighboring nodes to rebroadcast routing information update. This clearly has the advantage of reducing, channel contention and the number of control packet travelling through the network when compared to strategies that use pure flooding technique. OLSR shows good performance in low mobility, however high mobility impact the performances of the network. This limitation might be the purpose of future work in order to propose an adaptive behavior in high mobility. The DREAM is another flat, proactive protocol that has scalability potential since it has significantly reduced the amount of overhead transmitted through the network, by exchanging location information rather than complete link state information. The DREAM is quite adapted to mobility but its performance depends on the accuracy of location information provided by localization systems such GPS. FSR in its turn has the potential to perform, well in large and highly dynamic topology, due to its implicit hierarchical structure but good performance depend on how scope level is defined. Finally, DSDV could not fit to high dynamicity because of heavy path maintenance process. Second, on-demand routing protocols outperform proactive routing due to their simple route discovery and maintenance procedure. These protocols might experience more latency during route establishment when there is no previous communication between the source and the destination or route recovery due to links breakage. Some protocols take advantage of their multipath capabilities to bypass frequent route recovery procedure. For Example: DSR and ARA can reroute immediately data being transmitted through alternate path without initiating a new route discovery task. DSR performances' decrease significantly in large and high topology change due to packet header size that consumes most of the bandwidth. AODV outperforms all other reactive protocols due to low overhead, low bandwidth consumption and local links failure management. Therefore, AODV has been subject of several thesis and thus, multiple subset of AODV have been proposed such as Multipath AODV, Multicast AODV, Ant AODV…

Third, hybrid routing protocols demonstrated high potential to provide higher scalability in large network than on-demand or proactive routing protocols. This is because they attempt to reduce broadcasting area by dividing the network into several zones. For example, ZRP defines a zone whose radius is measured in terms of hops. Each node utilizes proactive routing within its zone and on-demand routing outside of its zone. Another hybrid routing is AntHocNet, which is adaptable to topology changes because of proactive searching procedure of alternate path.

**Table 1. Comparison**

| | **Scheduling** | **State of Informtion** | **Type of Path** | **Route establishment** | **Routig Metric** | **Mobility** | **Advantages** | **Disadvantages** |
|---|---|---|---|---|---|---|---|---|
| DSDV | Proactive | Distance victor | Single | Hop by hop | Shortest Path | Bad | Routes always available | High overhead |
| OLSR | Proactive | Link state | Single | Hop by hop | Shortest Path | Moderate | Reduced overhead | |
| FSR | Proactive | Link state | Multipath | Hop by hop | Shortest Path | Moderate | Reduced BW consumption | Reduced accuracy |
| DREAM | Proactive | Distance victor | Single | Hop by hop | Shortest Path | Moderate | Low overhead and memory | GPS accuracy |
| DSR | Reactive | Distance victor | Multipath | Source | Shortest Path | Moderate | Route cach, reduced overhaed | Scalability, latency |
| AODV | Reactive | Distance victor | Single | Hop by hop | Shortest Path | Good | Adaptable to high dynamicity | Scalability, latency |
| LAR | Reactive | Distance victor | Multipath | | Shortest Path | M | Low overhead | GPS accuracy |
| ARA | Reactive | - | Multipath | Hop by hop | Shortest Path | Good | Low overhead, small control packet | - |
| AntHocNet | Hybrid | - | Single | Hop by hop | Shortest Path | Good | Latency, PDR | - |
| ZRP | Hybrid | - | Single | Hop by hop | Shortest Path | Good | Reduce rebroudcasting | Zones Overlapping |

## 5. CONCLUSION

In this paper, we highlighted different challenges that researchers are facing in designing Mobile Ad Hoc routing protocols, such as high node mobility and hence dynamic topology, restricted bandwidth and limited energy. Mobility of nodes in MANETs has a negative impact on network performances. Hence, network overhead and traffic control messages increase with mobility level as a results the QoS metrics such end to end delay, path throughput and packet delivery ratio become lower at the point where the application might not work properly. In this context, we studied the common routing protocols and then we compared and discussed their advantages and disadvantages in a highly dynamic network. This comparison shows that reactive and flat protocols have the potential to deliver good performances in a highly dynamic network. However, protocol operations should be optimized to fit with nowadays mobile application and users behavior. In next step of our work, we are going to study in details AODV routing protocol and different optimization schemes that have been proposed to address routing performance in dynamic context.

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