# A Survey On Hybrid Routing Protocols In MANETS

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***Abstract*****—**Mobile Ad hoc NETwork (MANET) is a collection of mobile nodes that are arbitrarily located so that the interconnections between nodes are dynamically changing. A routing protocol is used to find routes between mobile nodes to facilitate communication within the network. The main goal of such an ad hoc network routing protocol is to establish correct and efficient route between a pair of mobile nodes. Route should be discovered and maintained with a minimum of overhead and bandwidth consumption. There are number of routing protocols were proposed for ad hoc networks. The objective of this paper is to create a taxonomy of the ad hoc hybrid routing protocols, and to survey and compare each type of hybrid protocols. We try to show the requirements considered by the different hybrid protocols, the resource limitations under which they operate, and the design decisions made by the authors.

***Keywords****-MANET; hybrid routing ; proactive routing; reactive routing*

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## I. INTRODUCTION

Ad hoc networks are mobile wireless networks that have no fixed infrastructure. There are no fixed routers, instead each node acts as a router and forwards traffic from other nodes. Ad hoc networks were first mainly used for military applications. Since then, they have become increasingly more popular within the computing industry. Applications include emergency, search and rescue operations, deployment of sensors, conferences, exhibitions, virtual classrooms and operations in environments where construction of infrastructure is difficult or expensive. Ad hoc networks can be rapidly deployed because of the lack of infrastructure. A MANET (Mobile Ad hoc Network) is a type of ad hoc network with rapidly changing topology. These networks typically have a large span and connect hundreds to thousands of nodes. Correspondingly, the term Reconfigurable Wireless Networks (RWN) refers to large ad hoc networks that can be rapidly deployed without infrastructure and where the nodes are highly mobile. In this paper, we concentrate on routing in large ad hoc networks with high mobility. Since the nodes in a MANET are highly mobile, the topology changes frequently and the nodes are dynamically connected in an arbitrary manner. The rate of change depends on the velocity of the nodes. Moreover, the devices are small and the available transmission power is limited. Consequently, the radio coverage of a node is small. The low transmission power limits the number of neighbor nodes, which further increases the rate of change in the topology as the node moves.

## II. ROUTING IN AD HOC NETWORKS

A number of routing protocols have been suggested for ad hoc networks. These protocols can be classified into three main categories: proactive (table-driven), reactive (source-initiated or demand-driven), hybrid (combination of reactive and proactive). In Figure 1 examples of each type are shown.

### *A. PROACTIVE ROUTING PROTOCOLS*

Proactive routing protocols attempt to keep an up-to- date topological map of the entire network. With this map, the route is known and immediately available when a packet needs to be sent. Proactive protocols are traditionally classified as either distance-vector or link-state protocols. The former are based on the distributed Bellman-Ford (DBP) algorithm, which is known for slow convergence because of the “counting-to-infinity” problem. To address the problem, the Destination-Sequenced Distance-Vector routing (DSDV) protocol was proposed for ad hoc networks. On the other hand, link-state protocols, as represented by OSPF, have become standard in wired IP networks. They converge more rapidly, but require significantly more control traffic. Since ad hoc networks are bandwidth limited and their topology changes often, an Optimized Link-State Protocol (OLSR) has been proposed. While being suitable for small networks, some scalability problems can be seen on larger networks. The need to improve convergence and reduce traffic has led to algorithms that combine features of distance-vector and link-state schemes. Such a protocol is the wireless routing protocol (WRP), which eliminates the counting-to infinity problem and avoids temporary loop without increasing the amount of control traffic [1].

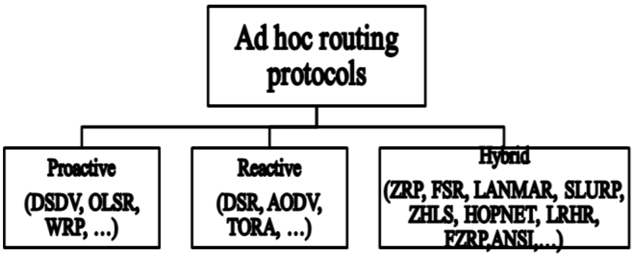


Figure 1. Ad hoc routing protocols

### *B. REACTIVE ROUTING PROTOCOLS*

In contrast to proactive routing, reactive routing does not attempt to continuously determine the network connectivity. Instead, a route determination procedure is invoked on demand when a packet needs to be forwarded. The technique relies on queries that are flooded throughout the network. Reactive route determination is used in the Temporally Ordered Routing Algorithm (TORA), the Dynamic Source Routing (DSR) and the Ad hoc On demand Distance Vector (AODV) protocols. In DSR and AODV, a reply is sent back to the query source along the reverse path that the query traveled. The main difference is that DSR performs source routing with the addresses obtained from the query packet, while AODV uses nexthop information stored in the nodes of the route. In contrast to these protocols, TORA creates directed acyclic graphs rooted at the destination by flooding the route replies in a controlled manner[1].

### *C. HYBRID ROUTING PROTOCOLS*

The hybrid routing schemes combine elements of ondemand and table-driven routing protocols. The general idea is that area where the connections change relatively slowly are more amenable to table driven routing while areas with high mobility are more appropriate for source initiated approaches. By appropriately combining these two approaches the system can achieve a higher overall performance.

## III. HYBRID ROUTING PROTOCOLS

In these section we will introduce every kind of hybrid routing protocols and theirs differences.

### *A. ZONE ROUTING PROTOCOL (ZRP)*

ZRP was the first hybrid routing protocol with both a proactive and a reactive routing component. ZRP is proposed to reduce the control overhead of proactive routing protocols and decrease the latency caused by routing discover in reactive routing protocols. ZRP defines a zone around each node consisting of its ρ-neighborhood (e. g. ρ=2). In ZRP, the distance and a node, all nodes within hop distance from node belong to the routing zone of node. ZRP is formed by two sub-protocols, a proactive routing protocol: Intra-zone Routing Protocol (IARP), is used inside routing zones and a reactive routing protocol: Inter-zone Routing Protocol (IERP), is used between routing zones, respectively. A route to a destination within the local zone can be established from the proactively cached routing table of the source by IARP therefore, if the source and destination is in the same zone, the packet can be delivered immediately. Most of the existing proactive routing algorithms can be used as the IARP for ZRP. For routes beyond the local zone, route discovery happens reactively. The source node sends a route requests to its border nodes, containing its own address, the destination address and a unique sequence number. Border nodes are nodes which are exactly the maximum number of hops to the defined local zone away from the source. The border nodes check their local zone for the destination. If the requested node is not a member of this local zone, the node adds its own address to the route request packet and forwards the packet to its border nodes. If the destination is a member of the local zone of the node, it sends a route reply on the reverse path back to the source. The source node uses the path saved in the route reply packet to send data packets to the destination. Consider the network in Figure 2. The node S has a packet to send to node X. The zone radius is ρ=2. The node uses the routing table provided by IARP to check whether the destination is within its zone. Since it is not found, a route request is issued using IERP. The request is broadcast to the peripheral nodes (gray in the picture). Each of these searches their routing table for the destination [2].

### *B. FISHEYE STATE ROUTING (FSR)*

FSR protocol is a proactive (table driven) ad hoc routing protocol and its mechanisms are based on the Link State Routing protocol used in wired networks. FSR is an implicit hierarchical routing protocol. It reduces the routing update overhead in large networks by using a fisheye technique. Fisheye has the ability to see objects better when they are nearer to its focal point that means each node maintains accurate information about near nodes and not so accurate about far-away nodes. The number of levels and the radius of each scope will depend on the size of the network. Entries corresponding to nodes within the smaller scope are propagated to the neighbors with the highest frequency and the exchanges in smaller scopes are more frequent than in larger. That makes the topology information about near nodes more precise than the information about far away nodes. FSR minimized the consumed bandwidth as the link state update packets that are exchanged only among neighboring nodes and it manages to reduce the message size of the topology information due to removal of topology information concerned far-away nodes. Even if a node doesn't have accurate information about far away nodes, the packets will be routed correctly because the route information becomes more and more accurate as the packet gets closer to the destination. This means that FSR scales well to large mobile ad hoc networks as the overhead is controlled and supports high rates of mobility.

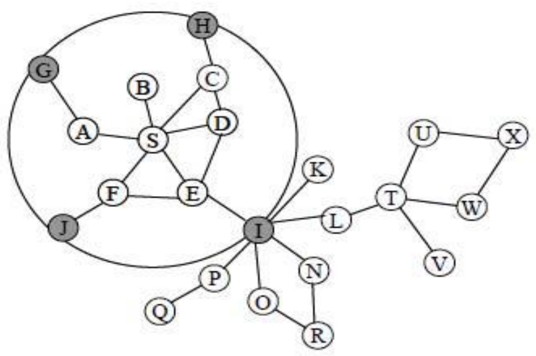


Figure 2. Example routing zone with ρ = 2.

Figure 3 illustrates how the fisheye technique is applied to a MANET. When the size of a network increases, sending update messages may potentially consume the bandwidth. FSR uses the fisheye technique to reduce the size of the update message without affecting routing. In the Figure 3, fisheye scopes are defined with respect to the focal point, node 11[3].

### *C. Landmark ad hoc routing (LANMAR)*

LANMAR which builds subnets of groups of nodes which are likely to move together. A landmark node is elected in each subnet, similar to FSR. The LANMAR routing table consist of only the nodes within the scope and landmark nodes. During the packet forwarding process, the destination is checked if it is within the forwarding node’s neighbor scope. If so, the packet is directly forwarded to the address in the routing table. If a packet on the other hand is destined to a farther node, it is first routed to its nearest landmark node. As the packet gets closer to its destination, it acquires more accurate routing information, thus in some cases it may bypass the landmark node and routed directly to its destination. During the link state update process, the nodes exchange topology updates with their one-hop neighbors. A distance vector, which is calculated based on the number of landmarks, is added to each update packet. As a result of this process, the routing tables entries with smaller sequence numbers are replaced with larger ones [4].

### *D. Scalable location update based routing protocol (SLURP)*

SLURP develops an architecture scalable to large size networks. A location update mechanism maintains location information of the nodes in a decentralized fashion by mapping node IDs to specific geographic sub-regions of the network where any node located in this region is responsible for storing the current location information for all the nodes situated within that region. When a sender wishes to send a packet to a destination, it queries nodes in the same geographic sub-region of the destination to get a rough estimate of its position. It then uses a simple geographic routing protocol to send the data packets. Since the location update cost is dependent on the speed of the nodes, for high speeds, more number of location update messages are generated. By theoretical analysis, it is shown that the routing overhead scales as O($v$) where $v$ is the average node speed, and O($N^{3/2}$) where $N$ is the number of nodes within the network [5].

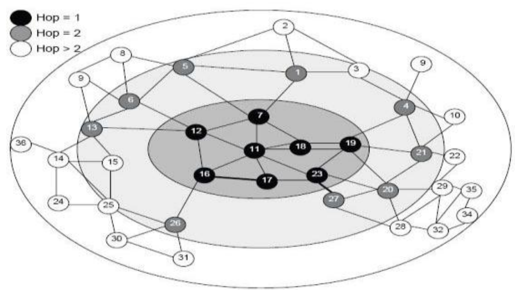


Figure 3. Fisheye routing protocol.

### *E. Zone based hierarchical link state routing protocol (ZHLS)*

ZHLS routing protocol where a hierarchical structure is defined by non-overlapping zones with each node having a node ID and a zone ID. These IDs are calculated using an external location tool such as GPS. The hierarchy is divided into two levels: the node level topology and the zone level topology. There are no cluster heads in ZHLS. When a route is required for a destination located in another zone, the source node broadcasts a zone-level location request to all other zones. Once the destination receives the location request, it replies with the path. In this technique, only the node and zone IDs of a node is required to discover a path. There is no need for updates as long as the node stays within its own region and the location update is required only if the node switches regions. The only drawback of ZHLS is that all nodes should have a preprogrammed static zone map to recognize the zones created in the network. This may not be possible in scenarios where the network boundaries are dynamic in nature. On the other hand, it is suitable for the networks deployed with fixed boundary lines [6].

### *F. Hybrid ant colony optimization (HOPNET)*

HOPNET based on Ant Colony Optimization (ACO) and zone routing. It considers the scenario of ants hopping from one zone to the next with local proactive route discovery within a zone and reactive communication between zones. The algorithm borrows features from ZRP and DSR protocols and combines it with ACO based schemes. The forward ants are sent only to border nodes. These forward ants are then directed towards the destination node by using the nodes’ local routing table. The ants move from one zone to another via border nodes and by using available local routing information. The zone approach achieves the scalability. Link failures are handled within a zone without flooding the network. Inter and intra zone routing tables are always maintained which can efficiently rediscover a new route in case of a link failure [7]. An example scenario is shown in Figure 4.

### *G. Link reliability based hybrid routing (LRHR)*

Frequent topology changes in MANETs may require the dynamic switching of table-driven and on demand routing strategies. The LRHR protocol achieves this switching in a smooth and adaptive fashion. Each node operates in a promiscuous receive mode to overhear any packet transmission in the neighborhood and setup multiple routes from the source to the destination. The LRHR assigns edge weights between links based on the link reliability. The higher value of edge weight has greater reliability. It finally selects the route which has the maximum edge weight sum as the main route. The LRHR primarily operates in the table-driven mode and switches to on demand mode when a source either has no route to a destination or when the time interval between a new route discovery and the previous route discovery phase is larger than the minimum route request interval. The route discovery process in LRHR is similar to DSR. The route maintenance operations are carried out based on the edge weights between the nodes [8].

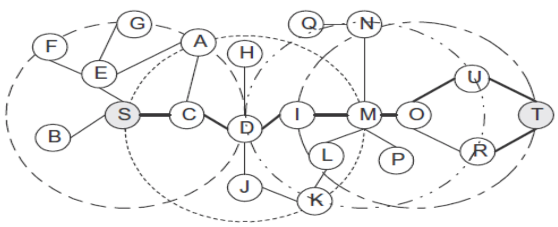


Figure 4. Example of HOPNET

### *H. Fisheye zone routing protocol (FZRP)*

FZRP combine the zone routing protocol with the fisheye state routing mechanism. By using the concept of a fisheye, a multi-level routing zone structure is created where different levels are associated with different link state update rates (see Figure 5). The source node generates a RREQ packet which is bordercast to nodes till the destination is reached. These packets are forwarded along the border of the zone. The nodes at the periphery of the zones forward the RREQ to a different zone if the destination node is not located within the current zone. A time to live (TTL) field is used within the forwarding packets to cover the zone in which the update packets are forwarded. The routing table at each node contains entries for nodes within its own zone and for those in an extended zone. An extended zone is a zone located beyond the inner zone. Extended zone entries are generally not very accurate due to different update frequencies in different zones. Other procedures such as local route repair in case of a broken link are similar to ZRP [9].

### *I. Ad hoc networking with swarm intelligence (ANSI)*

ANSI is a hybrid routing protocol utilizing swarm intelligence (SI) to select good routes in a network. SI allows self-organizing systems and helps maintain state information about the network. ANSI employs a highly flexible cost function which uses information collected from local ant activity. The protocol takes advantage of the basic principles of ant based routing algorithms which allows the maintenance of multiple routes to a destination. In ANSI, the nodes using proactive routing perform stochastic routing to select the best path, while those performing reactive routing use the extra routes in the event of route failure. The pheromone trail concept allows selecting the routes to the destination from every node. Nodes using reactive routing first broadcast a forward reactive ant towards the destination. Once the destination receives the forward ant, it replies with a backward reactive ant which updates routing tables for all nodes in the path. If route failure occurs at an intermediate node, that node buffers the packets which could not be routed and sends a forward ant initiating route discovery. Nodes which are part of a less dynamic, infrastructure network maintains routes proactively by periodic routing updates using proactive ants. Proactive ants are not returned as the reactive ants, rather they help reinforce the path taken by the ant. Local route management is achieved by reinforcement due to movement of data packets and an explicit neighbor discovery mechanism (see Figure 6) [10].

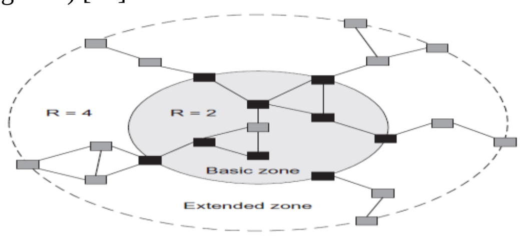


Figure 5. Two level routing zone in FZRP

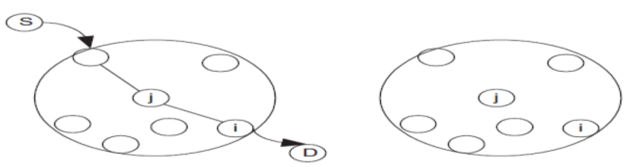


Figure 6. An example scenario of ANSI

HELLO messages are also broadcast periodically through which network state information is easily exchanged.

### *J. Mobility aware protocol synthesis for efficient routing*

In this protocol new stability metric is used to determine the mobility level of nodes in a network. Using this metric, the nodes can be classified into different mobility classes in which they in turn determine the most suitable routing technique for a particular source–destination pair. Stability uses the concept of associativity, which is the total time for which nodes are connected through beacons. With the level of stability defined, a protocol framework is designed, which operates above the network layer on the protocol stack, determines the optimal routing technique. Minimal changes are needed to the original routing protocols to ensure ease of integration [11].

### *K. Load balancing in MANET shortest path routing*

In this protocol load balancing is used to enable efficient routing in MANETs. It has been observed that the load is maximal at the center while it decreases farther from the center of the network. Essentially, the load becomes minimal at the network edges. The authors state that such a load imbalance takes place due to shortest-path routing and propose a new routing metric, the node's centrality, when choosing the best route. Thus, instead of selecting the shortest routes, nodes with longer distances from the center of the network are chosen. A new routing metric is proposed as follows:

$$\text{Minimize } \frac{1}{n}\sum_{1}^{n}\eta(k) \qquad (1)$$

where $n$ is the number of nodes in the network and $\eta(k)$ represents the centrality of node $k$. The $\eta(k)$ value is calculated based on the size of the node's routing table. A greater size denotes closer to the center of the network while a lower size indicate otherwise [12].

### *COMPARISON*

Table 1 summarizes the protocols reviewed in this section and compares some of their features.

TABLE 1. HYBRID ROUTING PROTOCOLS COMPARISON.

| Protocol | MR | Rout metric | Route repository | Route Rebuilding | CC |
|---|---|---|---|---|---|
| **ZRP** | No | SP | IntraZ and InterZ RTs | Start repair at failure point | M |
| **FSR** | No | Scope range | RTs | Notify source | L |
| **LANMAR** | No | SP | RTs at landmark | Notify source | M |
| **RDMAR** | No | SP | RT | New route and notify source | H |
| **SLURP** | Yes | MFR: InterZ, DSR: IntraZ | RC at location | Notify source | H |
| **ZHLS** | Yes | SP | IntraZ and InterZ RTs | Location request sent | M |
| **HOPNET** | No | SP | IntraZ and InterZ RTs | Start repair at failure point | H |
| **LRHR** | Yes | Edge weight | RC, RT | Route discovery | H |
| **FZRP** | No | SP | IntraZ and InterZ RTs | Start repair at failure point | M |
| **ANSI** | Yes | SP | RT | Start repair at failure point | M |

MR =Multiple Routs.

Rout metric: SP =Shortest path; InterZ =Intrazone; IntraZ =Intrazone.

Rout repository: RC =Rout cache; RT =Routing table.

CC =Communication Complexity [High =H; M =Medium; L =Low].

## IV. CONCLUSION

Hybrid approaches are, in general, justified for large networks. If a network is small, we can usually make a clear decision between source driven or table driven approaches.

Similarly, hybrid approaches cover a very wide range of approaches and intellectual ideas. Still we can identify several guiding ideas. First, there is a group of approaches which performs a differential treatment of the network nodes based on either (a) zones or (b) the nodes participation in a backbone. The approaches which classify nodes into zones are usually counting the zones from the perspective of the source node. The zones are usually defined based on hop count in protocols such as ZRP, FSR and although we also have protocols where the zone is based on physical location such as in SLURP and ZHLS. In some cases, the zones might be mobile zones of nodes moving together, as in LANMAR. A separate class of protocols are those which we could call explicit hybridization. In these protocols there are two, clearly separable routing models, which are frequently full featured routing protocols on their own. The main challenge of these protocols, naturally, is the appropriate choice between the two protocols as well as their integration in the systems, the basis of this decision is frequently the defining factor of the protocol. For instance, LRHR takes the decision based on link reliability, while Mobility Aware Protocol makes the decision based on mobility classes. There is also a wide variety among the protocols combined: Zone routing with ant colony optimization in HOPNET, FSR with ZRP in FZRP, reactive ants with proactive ants in ANSI.

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