



## Routing Protocols in Wireless Ad-hoc Networks

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**Abstract:** *Due to recent advancement in wireless ad-hoc networks, various routing protocols have emerged. This paper presents the review of the existing routing protocols in wireless ad-hoc networks.*

**Keywords:** *Ad-hoc networks, DSDV, WRP, CGSR, STAR, ABR, TORA, DSR, AODV, CBRP,*

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### I. INTRODUCTION

An ad-hoc network[6] is a self-configuring network of wireless links connecting mobile nodes. These nodes may be routers and/or hosts. The mobile nodes communicate directly with each other and without the aid of access points, and therefore have no fixed infrastructure. They form an arbitrary topology, where the routers are free to move randomly and arrange themselves as required. In a wireless world, dominated by Wi-Fi, architectures which mix mesh networking and ad-hoc connections are the beginning of a technology revolution based on their simplicity. They were developed by the Defense Forces, to comply with a military framework. The aim was to rapidly deploy a robust, mobile and reactive network, under any circumstances. These networks then proved useful in commercial and industrial fields, first aid operations and exploration missions. Ad hoc networks, also called peer-to-peer networks

### II. ROUTING PROTOCOLS

Routing protocols between any pair of nodes within an ad hoc network can be difficult because the nodes can move randomly and can also join or leave the network[1]. This means that an optimal route at a certain time may not work seconds later. Discussed below are three categories that existing ad-hoc network routing protocols fall into:

1. Table Driven Protocols
2. On Demand Protocols
3. Hybrid Protocols

#### Table Driven Routing Protocols

It is also known as Proactive Protocols; work out routes in the background independent of traffic demands. Each node uses routing information to store the location information of other nodes in the network and this information is then used to move data among different nodes in the network. This type of protocol is slow to converge and may be prone to routing loops. These protocols keep a constant overview of the network and this can be a disadvantage as they may react to change in the network topology even if no traffic is affected by the topology modification which could create unnecessary overhead. Even in a network with little data traffic, Table Driven Protocols will use limited resources such as power and link bandwidth therefore they might not be considered an effective routing solution for Ad-hoc Networks. Fisheye State Routing is an example of a Table Driven Protocol.

#### DSDV - Destination Sequenced Distance Vector Routing Protocol

This protocol is the result to adapt an existing distance vector routing algorithm (Distributed Bellman Ford), as used in RIP, to an adhoc networking environment. This is a proactive protocol, which updates routing information on a regular basis. To avoid routing loops, destination sequence numbers have been introduced. DSDV is one of the first attempts to adapt an established routing mechanism to work with mobile ad hoc networks. Each routing table lists all destinations with their current hop count and a sequence number. Routing information is broadcast or multicast. Each node transmits its routing table to its neighbors. Routes with more recent sequence numbers obsolete older routes. This mechanism provides loop freedom and prevents stale routes. The routing information is transmitted every time a change in the topology has been detected (i.e. a change in the set of neighbors of a node). DSDV works only with bidirectional links.

#### WRP - Wireless Routing Protocol

WRP is related to the DBF algorithm. Routing update messages are only sent locally to the neighbor set. They contain all the routing information the originating node knows of. Of course not the whole routing table is sent in each update. Only changes are transmitted, either by receiving an update from another node, or of a link in the neighborhood have changed. WRP is a proactive routing protocol, since routes are maintained all the time and no special route requests by source nodes need to be performed.

### **CGSR - Clusterhead Gateway Switch Routing**

Clusterhead Gateway Switch Routing is proposed. It consists of a clustering method, called Least Cluster Change which is combined with either “lowest id”, or “maximum links”, to form clusters and elect clusterheads. The method focuses on cluster stability. CGSR explicitly specifies requirements on the link layer and medium access method:

Inter-cluster communication requires a CDMA system, such that each cluster is assigned a different code (spatial reuse of codes is utilized, though).

Within each cluster, TDMA is used. The allocation of time slots is done by a token passing method.

Gateway nodes are nodes that are within more than one cluster, and therefore need to communicate in different codes. The protocol uses a sequence number method (as developed in DSDV) to gain loopfree routes and avoid stale routing entries. In CGSR, a packet is routed alternating between clusterheads and gateways

### **STAR - Source Tree Adaptive Routing**

The simulations have been done without stating the simulation software used. Comparison was against a so called “simple routing protocol”, which always chooses the shortest path. It is unclear if this should be regarded as an optimal routing algorithm. The result shows some advantages (fewer route repairs need to be done), but also drawbacks (longer routes on average, since not all links can be used, and a short distance between hops is encouraged due to the stability criteria). Overall performance measures like routing overhead, throughput or packet latency have not been considered. So it is very unclear, if there is any benefit at all, or if the advantage of fewer repairs and reduced broadcast is consumed by the longer pathlength or multiple route requests.

### **On Demand Routing Protocols**

It is also known as Reactive Protocols, establish routes between nodes only when they are required to route data packets. There is no updating of every possible route in the network instead it focuses on routes that are being used or being set up. When a route is required by a source node to a destination for which it does not have route information, it starts a route discovery process which goes from one node to the other until it arrives at the destination or a node in-between has a route to the destination. On Demand protocols are generally considered efficient when the route discovery is less frequent than the data transfer because the network traffic caused by the route discovery step is low compared to the total communication bandwidth. This makes On Demand Protocols more suited to large networks with light traffic and low mobility. An example of an On Demand Protocol is Dynamic Source Routing[3].

### **ABR - Associatively Based Routing**

ABR is an on-demand routing protocol: Routes are discovered with a Broadcast Query request. From these requests, the destination learns all possible routes, and replies along a selected route to the source. If a route breaks, several route reconstruction methods can be applied, depending if the source, the destination or an intermediate node moves out of reach. Further, ABR maintains a “degree of associativity” in form of associativity ticks. These are not clearly defined, but from context it appears that every node maintains a tick-value for every one of his neighbors. Every time interval a link-layer hello message from that neighbor is received and the tick value is increased. If the

neighbor moves out of reach, the value is reset to zero. A tick level above a certain threshold indicates a stable association between those two nodes.

### **DSR - Dynamic Source Routing**

DSR is an on-demand protocol, which uses source routing. In this case, this means, that each packet carries the complete route to its destination in its header (which introduces some overhead). It was first described in [2]. Since DSR works on demand, a route must be discovered through a Route Discovery Mechanism before use. Discovered routes may be cached and routes may be overheard by a node (by parsing the source route information of packets that are relayed). If broken links are detected, a corresponding Route Error message is transmitted through the network and a route maintenance mechanism takes over to fix the broken routes, if possible. To further reduce unnecessary traffic, a node may reply to a route request with a locally cached route, even if it is not the destination node. Delays in these replies with promiscuous observation (overhearing) of other routing traffic prevent multiple nodes replying with a cached entry all at once. The DSR protocol not only learns about the destination, but on how to get to each individual node along the route. Likewise, every node on the route learns how to get to every other node on the route and stores the route in its route cache.

### **TORA - Temporally Ordered Routing Algorithm**

TORA is a link reversal routing (LRR) algorithm and was introduced by Park and Corson. It evolved from LMR and combines also features from Gafni-Bertsekas in a unique single-pass strategy. In this context “single pass” means, that by processing a single event, all route maintenance tasks (erroneous route deletion, search and establishment of new routes) can be combined. As in LRR algorithms in general, for each destination a destination-rooted DAG is constructed. A height gets associated with each node and thus upstream and downstream links can be identified to route traffic to the destination.

### **AODV - Ad Hoc on Demand Distance Vector Routing Protocol**

This is one of the most discussed and most advanced routing protocols [4]. It is an important part of the work of the MANET IETF working group. The draft was recently accepted as experimental RFC 3561. So this is probably the most

mature suggestion for an ad hoc routing protocol. Its main developers are Charles E. Perkins (Nokia Research) Elizabeth Belding-Royer (UCSB) and Samir Das (University of Cincinnati). AODV is discussed in lots of studies and is often used as a reference to compare other routing protocols. AODV was derived from C. Perkins earlier work, DSDV Compared to DSDV, AODV no longer needs to exchange periodic messages proactively, but works in an on-demand fashion, instead. If a route to a destination is unknown, a route discovery process is initiated. This consists of broadcasting a Route Request (RREQ) packet throughout the network. To limit the impact of a net-wide broadcast, this request should be sent with an expanding ring search technique: the TTL of the packets starts with a small value; if no route has been found, the TTL will be increased and the request will be resent. Each node that rebroadcasts this request, adds its address into a list in the packet. If the destination sees the request, it will reply with a unicast Route Reply (RREP) to the source. Each intermediate node may cache the learned routes. The routing table entries consist of a destination, the next hop toward this destination and a sequence number. Routes are only updated if the sequence number of the updating message is larger than the existing one. Thus routing loops and updates with stale information are prevented. The sequence number technique was already used in DSDV and was adopted by a variety of other routing protocol developers. The amount of information, which needs to be present at each node, is rather limited:

The node is aware of its neighbors (via link-layer-notification, or explicit HELLO messages).

The node knows route destinations and the next hop.

The node has a "precursor list" for each destination. This list consists of all nodes, which use the current node as a relay for the destination. In case of a route failure to this destination, the node knows exactly which other nodes to notify. Each routing entry also has a lifetime.

These are a direct result of the protocols HELLO messages. HELLO messages are sent to established routes neighbouring nodes, periodically. If no response is received within a certain time, the link is considered redundant. AODV thus uses these RERR messages effectively to let all the nodes that use the route, that there has been a link breakage. As specified, this is achieved by notifying all surrounding nodes, the neighbours to the broken link that use that next link, that the link is broken. All nodes connected to these neighbors, and effectively every node that used the route to the destination, eventually gets a RERR message notifying of a break in the route.

### **CBRP - Cluster Based Routing Protocol**

CBRP maintains clusters of two hops diameter, with an elected clusterhead for each cluster. Clusters may be overlapping, but each node must be part of at least one cluster. Clusterheads are not allowed to be direct neighbors, except for a short period (called "contention period"). Nodes maintain a neighbor table which also includes the link type. Also a cluster adjacency table is kept in each node. Source routing is used, with the route in the CBRP header. This allows a limited local repair mechanism and a route cache to be used.

### **Hybrid Routing Protocols**

It combines Table Based Routing Protocols with On Demand Routing Protocols. They use distance-vectors for more precise metrics to establish the best paths to destination networks, and report routing information only when there is a change in the topology of the network. Each node in the network has its own routing zone, the size of which is defined by a zone radius, which is defined by a metric

### **ZRP - Zone Routing Protocol**

The Zone Routing Protocol by Zygmunt Haas was first introduced. It is a hybrid protocol, which combines reactive and proactive strategies. Since the advantages of either approach depend on the characteristics of the network (like the degree of mobility), it could be beneficial to combine them. ZRP introduces the notion of a routing zone, which is a set of nodes within the local neighborhood. In practice the zone is defined by the maximum number of hops, a node within the zone may be distant from the zone's center node. Each node maintains routing information actively within its zone. The algorithm used is called Intrazone Routing Protocol, IARP. A basic link state algorithm is used for this purpose. To discover a route outside the local routing zone, a reactive protocol, the Interzone Routing Protocol, IERP is used. For this purpose a bordercast of a request message is used. Bordercast means, the request is forwarded to the peripheral nodes of the zone, which in turn can check if the target is within their own zone, or continue to broadcast. The broadcast process must take care, not to bordercast requests back into regions already covered. To achieve this, queries must be recorded for some time by the relaying nodes. ZRP uses a special technique for this, called Advanced Query Detection and Early Termination. Route caching and local repair is also possible.

## **III. ROUTING COMPARISON**

It is seeing from the basic information given above on how each of these routing protocols work, that there could be a good deal of significant performance differences depending on how dynamic the network was, the physical and virtual size of a network, the bandwidth available and so on. The usage and performance issues of the two main protocols highlights in [5], DSR and AODV, and provides more tests and analytical results on why these are the best solution for routing in ad-hoc networks. The paper covers important performance metrics including packet delivery and received throughput. It also outlines other important metrics, such as routing loads and MAC overheads, and includes performance analysis for networks with different nodes and sources, providing detailed test results on which routing protocols are more favourable. Other important information regarding testing includes: test models; testing environment variables; and associated assumptions. It once again covers the very important performance of the mobility of nodes on the network.

Overall, the recommendation is that AODV is better than DSR as it has improved mobility and can handle more network traffic. Although, it should also be noted that DSR is regarded as suitable for smaller networks with less mobility, as the way that DSR finds and maintains routes is more advantageous than AODV, and that AODV is more suitable for stressful situations where there is more load on the network and a higher mobility value.

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