A Survey: Routing Protocols in MANET

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Abstract
Mobile Ad-Hoc Network (MANET) is a collection of multi-hop wireless mobile nodes that communicate with each other without centralized control or established infrastructure. The wireless links in this network are highly error prone and can go down frequently due to mobility of nodes, interference and less infrastructure. Therefore, routing in MANET is a critical task due to highly dynamic environment. In recent years, several routing protocols have been proposed for mobile ad hoc networks and prominent among them are DSR, AODV and TORA, FSR, ZPR, WRP.

Keywords
MANET, DSR, AODV, TORA, FSR, ZPR, WRP

I. Introduction

The use of wireless networks has become more and more popular. There exist three types of mobile wireless networks: infrastructured networks, ad-hoc networks and hybrid networks which combine infrastructured and ad-hoc aspects.

An infrastructured network (Fig. 1(a)) consists of wireless mobile nodes and one or more bridges, which connect the wireless network to the wired network. These bridges are called base stations. A mobile node within the network searches for the nearest base station (e.g. the one with the best signal strength), connects to it and communicates with it. The important fact is that all communication is taking place between the wireless node and the base station but not between different wireless nodes. While the mobile node is traveling around and all of a sudden gets out of range of the current base station, a handover to a new base station will let the mobile node communicate seamlessly with the new base station.

In infrastructure networks, an ad-hoc network lacks any infrastructure. There are no base stations, no fixed routers and no centralized administration. All nodes may move randomly and are connecting dynamically to each other. Therefore all nodes are operating as routers and need to be capable to discover and maintain routes to every other node in the network and to propagate packets accordingly. Mobile ad-hoc networks may be used in areas with little or no communication infrastructure:

think of emergency searches, rescue operations, or places where people wish to quickly share information, like meetings etc.

A hybrid network combines both aspects described before. It makes use of any available base stations while it also supports infrastructure less communication.

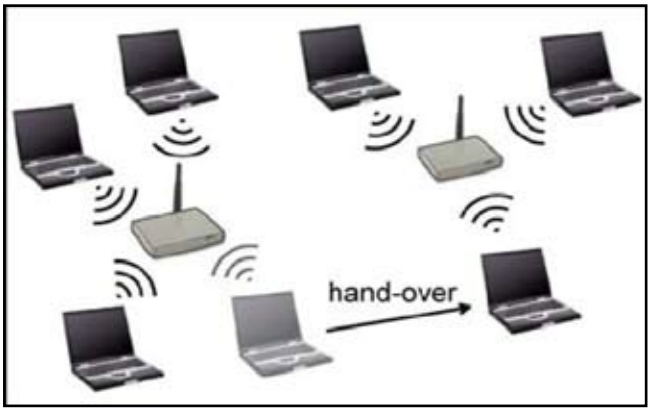


Fig. 1(a): An Infrastructured Network With Two Base Stations

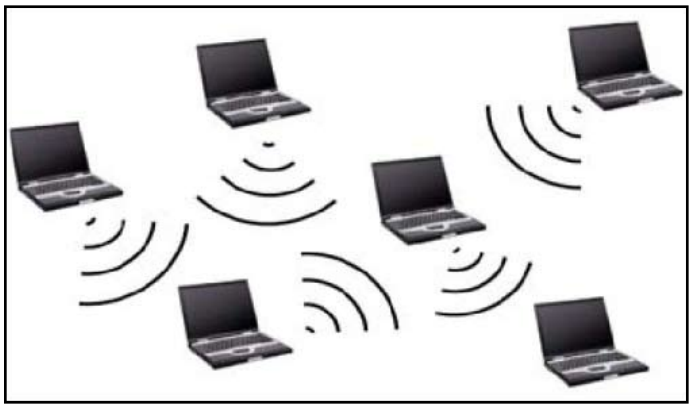


Fig. 1(b): A Mobile Ad-Hoc Network

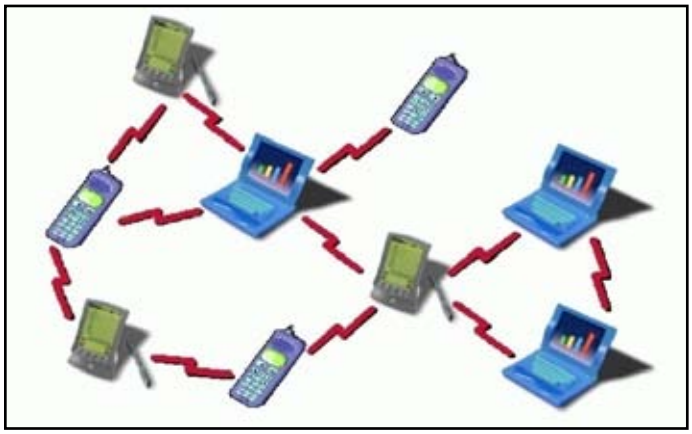


Fig. 1(c): Mobile Network

A. Mobile Ad-Hoc Network (MANET)

A Mobile Ad Hoc Network (MANET) is a collection of wireless mobile nodes forming a temporary/short-lived network without any fixed infrastructure where all nodes are free to move about arbitrarily and where all the nodes configure themselves. In MANET, each node acts both as a router and as a host & even the topology of network may also change rapidly. Some of the challenges in MANET include:

- Unicast routing
- Multicast routing
- Dynamic network topology
- Speed
- Frequency of updates or Network overhead
- Scalability
- Mobile agent based routing
- Quality of Service
- Energy efficient/Power aware routing
- Secure routing

The key challenges faced at different layers of MANET are shown in fig. 2. It represents layered structure and approach to ad hoc networks.

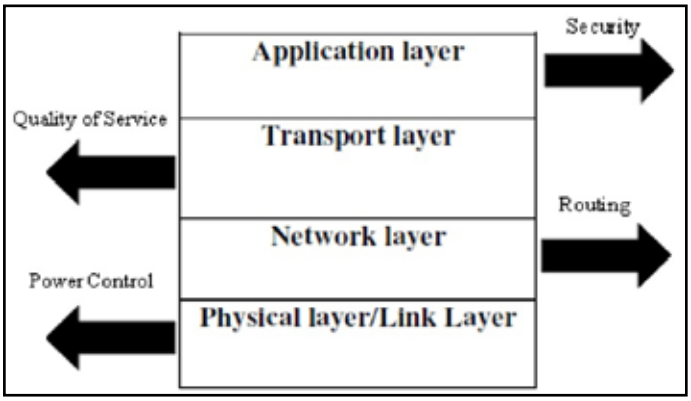


Fig. 2: MANET Challenges

II. Routing Protocols

Routing is the process of finding a path from a source to some arbitrary destination on the network. A routing protocol is needed whenever a packet needs to be transmitted to a destination via number of nodes and numerous routing protocols have been proposed for such kind of ad hoc networks. These protocols find a route for packet delivery and deliver the packet to the correct destination. The studies on various aspects of routing protocols have been an active area of research for many years. Many protocols have been suggested keeping applications and type in view.

MANET routing protocols fall into two general categories:

- Proactive routing protocols
- Reactive routing protocols

Design of efficient routing protocols in such a network is a challenging problem due to its unique characteristics, such as dynamic topology and scare wireless bandwidth.

A. Pro-Active/Table Driven Routing Protocols

Proactive MANET protocols are table-driven and will actively determine the layout of the network. Through a regular exchange of network topology packets between the nodes of the network, a complete picture of the network is maintained at every single node. There is hence minimal delay in determining the route to be taken. Some Proactive MANET Protocols include: DSDV [6], [19], DBF [7], GSR [24], WRP [29], ZRP [28, 30], FSR [29].

B. Reactive/On Demand Routing Protocols

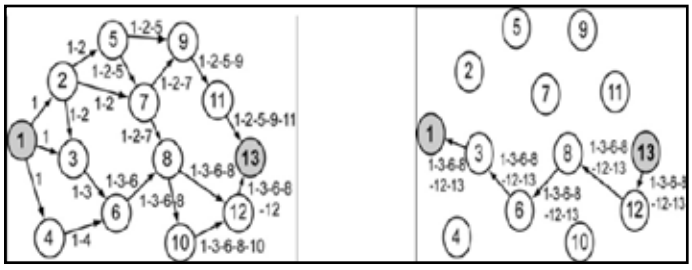
On-demand routing is a popular routing category for wireless ad hoc routing. It is a relatively new routing philosophy that provides a scalable solution to relatively large network topologies. The design follows the idea that each node tries to reduce routing overhead by only sending routing packets when communication is requested. Common for most on-demand routing protocols are the route discovery phase where packets are flooded into the network in search of an optimal path to the destination node in the network. Some Reactive MANET Protocols include: DSR [8] [9], AODV [9], and TORA [26-27].

The emphasis in this paper is concentrated on the comparison of various Proactive and Reactive protocols like DSR, AODV, TORA, FSR, ZRP, WPR.

III. DSR (Dynamic Source Routing)

The Dynamic Source Routing (DSR) protocol is an on-demand routing protocol based on source routing. In the source routing technique, a sender determines the exact sequence of nodes through which to propagate a packet. In DSR, every mobile node in the network needs to maintain a route cache where it caches source routes that it has learned. When a host wants to send a packet to some other host, it first checks its route cache for a source route to the destination. In the case a route is found, the sender uses this route to propagate the packet. Otherwise the source node initiates the route discovery process. Route discovery and route maintenance are the two major parts of the DSR protocol .Every node maintains a cache to store recently discovered paths. When a node desires to send a packet to some node, it first checks its entry in the cache. If it is there, then it uses that path to transmit the packet and also attach its source address on the packet. If it is not there in the cache or the entry in cache is expired (because of long time idle), the sender broadcasts a route request packet to all of its neighbors asking for a path to the destination. The sender will be waiting till the route is discovered. During waiting time, the sender can perform other tasks such as sending/forwarding other packets.

As the route request packet arrives to any of the nodes, they check from their neighbor or from their caches whether the destination asked is known or unknown. If route information is known, they send back a route reply packet to the destination otherwise they broadcast the same route request packet. When the route is discovered, the required packet swill be transmitted by the sender on the discovered route. Also an entry in the cache will be inserted for the future use. The node will also maintain the age information of the entry so as to know whether the cache is fresh or not. When a data packet is received by any intermediate node, it first checks whether the packet is meant for itself or not. If it is meant for itself (i.e. the intermediate node is the destination), the packet path attached on the data packet. Since in Ad hoc network, any link might fail anytime. Therefore, route maintenance process will constantly monitors and will also notify then odes if there is any failure in the path. Consequently, the nodes will change the entries of their route cache is received otherwise the same will be forwarded using the path attached on the data packet .Since in Ad hoc network, any link might fail anytime. Therefore, route maintenance process will constantly monitors and will also notify the nodes will change the entries of their route cache.



(a) Building of the Route Record, (b) Propagation of the Route Reply

Fig. 3: DSR Route Discovery Process

The main benefit of DSR protocol is that there is no need to keep routing table so as to route a given data packet as the entire route is contained in the packet header. The limitations of DSR protocol is that this is not scalable to large networks and even requires significantly more processing resources than most other protocols. Basically, In order to obtain the routing information, each node must spend lot of time to process any control data it receives, even if it is not the intended recipient. The flowchart [17] for DSR Protocol is given below:

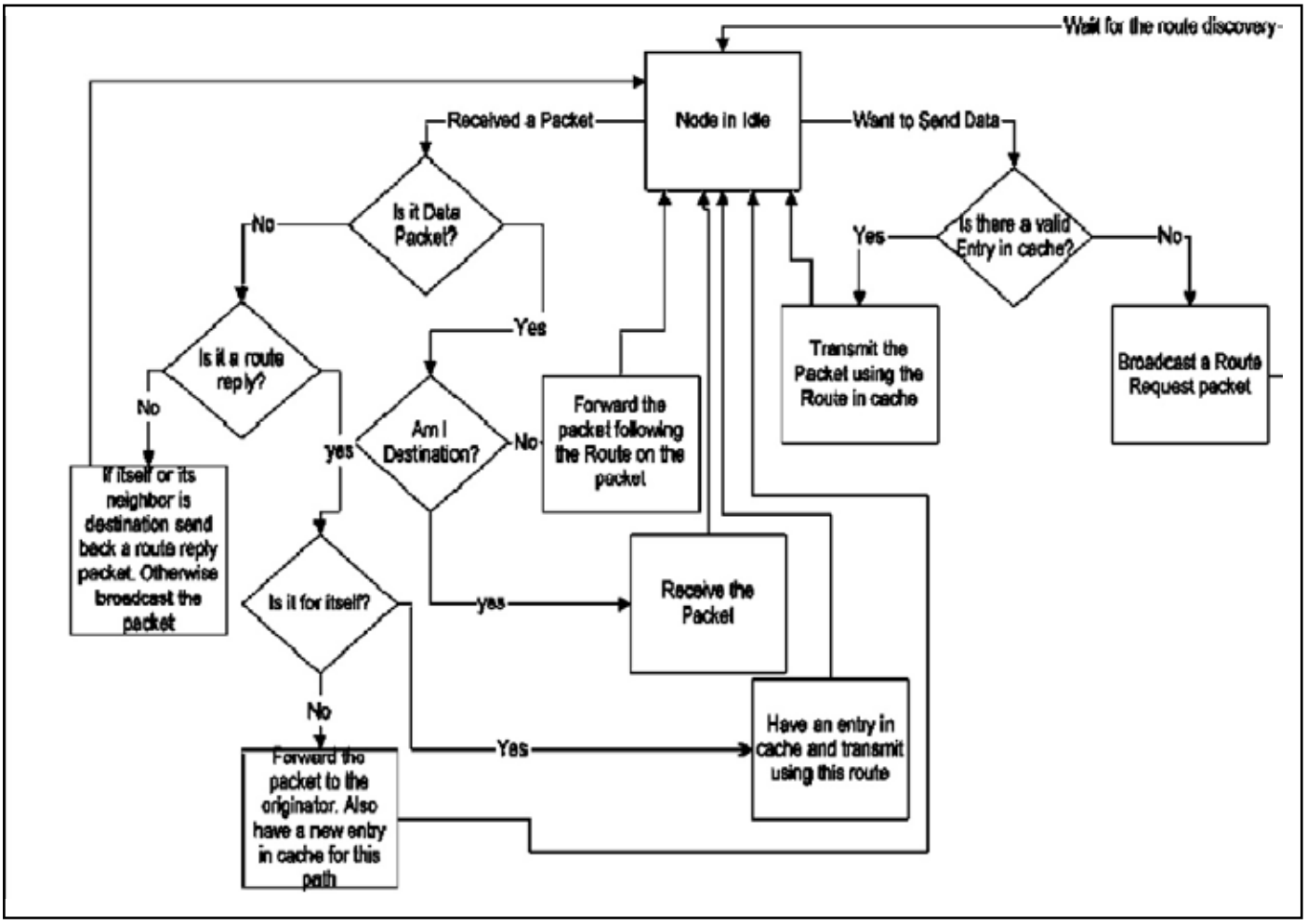


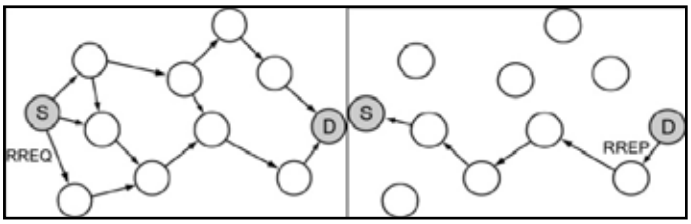
Fig. 4:

IV. AODV (Ad-Hoc on-Demand Distance Vector)

The Ad Hoc On-Demand Distance Vector routing protocol (AODV) is an improvement of the Destination-Sequenced Distance Vector routing protocol (DSDV). DSDV has its efficiency increasing smaller ad-hoc networks. Since it requires periodic advertisement and global dissemination of connectivity information for correct operation, it leads to frequent system-wide broadcasts. Therefore the size of DSDV ad-hoc networks is strongly limited. When using DSDV, every mobile node also needs to maintain a complete list of routes for each destination within the mobile network. The advantage of AODV is that it tries to minimize the number of required broadcasts. It creates the routes on a on-demand basis, as opposed to maintain a complete list of routes for each destination. The steps of the algorithm used by AODV are explained below.

A. Path Discovery Process

When trying to send a message to a destination node without knowing an active route to it, the sending node will initiate a path discovery process. A Route Request Message (RREQ) is broadcasted to all neighbors, which continue to broadcast the message to their neighbors and so on. The forwarding process is continued until the destination node is reached or until a intermediate node knows a route to the destination that is new enough. To ensure loop-free and most recent route information, every node maintains two counters: sequence number and broadcast_id. The broadcast_id and the address of the source node uniquely identify a RREQ message. Broadcast_id is incremented for every RREQ the source node initiates. An intermediate node can receive multiple copies of the same route request broadcast from various neighbors. In this case –if a node has already received a RREQ with the same source address and broadcast_id – it will discard the packet without broadcasting it furthermore. When an intermediate node forwards the RREQ message, it records the address of the neighbor from which it received the first copy of the broadcast packet. This way, the reverse path from all nodes back to the source is being built automatically. The RREQ packet contains two sequence numbers: the source sequence number and the last destination sequence number known to the source. The source sequence number is used to maintain "freshness" information about the reverse route to the source while the destination sequence number specifies what actuality a route to the destination must have before it is accepted by the source. [5] When the route request broadcast reaches the destination or an intermediate node with a fresh enough route, the node responds by sending a unicast route reply packet (RREP) back to the node from which it received the RREQ. So actually the packet is sent back reverse the path built during broadcast forwarding. A route is considered fresh enough, if the intermediate node's route to the destination node has a destination sequence number which is equal or greater than the one contained in the RREQ packet. As the RREP is sent back to the source, every intermediate node along this path adds a forward route entry to its routing table. The forward route is set active for some time indicated by a route timer entry. The default value is 3000 milliseconds, as referred in the AODV RFC [4]. If the route is no longer used, it will be deleted after the specified amount of time. Since the RREP packet is always sent back the reverse path established by the routing request, AODV only supports symmetric links.



(a) Source Node S Initiates the Path Discovery Process. (b) A RREP Packet is Sent Back to the Source
Fig. 5: Explains the AODV Path Discovery Process

B. Maintaining Routes

If the source node moves, it is able to send a new RREQ packet to find a new route to the destination. If an intermediate node along the forward path moves, its upstream neighbor notices the move and sends a link failure notification message to each of its active upstream neighbors to inform them of the erasure of that part of the route (see fig. 6). The link failure notification is forwarded as long as the source node is not reached. After having learned about the failure, the source node may reinitiate the route discovery protocol. Optionally a mobile node may perform local connectivity maintenance by periodically broadcasting hello messages.

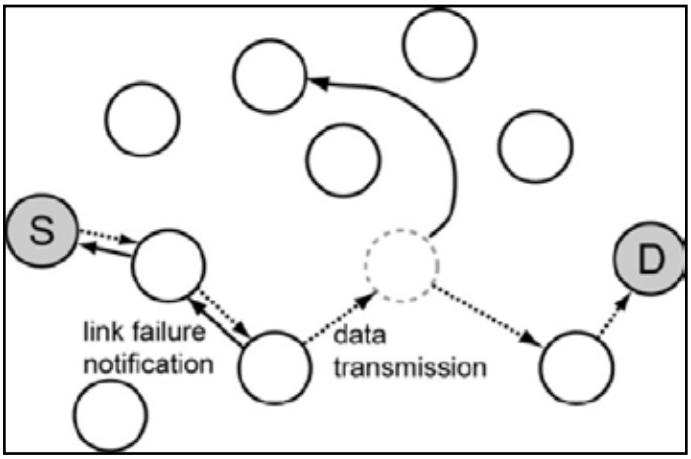


Fig. 6: AODV Route Maintenance by Using Link Failure Notification Message

The benefits of AODV protocol are that it favors the least congested route instead of the shortest route and it also supports both unicast and multicast packet transmissions even for nodes in constant movement. It also responds very quickly to the topological changes that affects the active routes. AODV does not put any additional overheads on data packets as it does not make use of source routing. The limitation of AODV protocol is that it expects/ requires that the nodes in the broadcast medium can detect each others' broadcasts. It is also possible that a valid route is expired and the determination of a reasonable expiry time is difficult. The reason behind this is that the nodes are mobile and their sending rates may differ widely and can change dynamically from node to node. In addition, as the size of network grows, various performance metrics begin decreasing. AODV is vulnerable to various kinds of attacks as it based on the assumption that all nodes must cooperate and without their cooperation no route can be established.

V. TORA (Temporally Ordered Routing Protocols)

The Temporally-Ordered Routing Algorithm (TORA) [26-27] is an adaptive routing protocol for multi-hop networks that possesses the following attributes:

- Distributed execution
- Multipath routing
- The protocol can simultaneously support both source initiated, on-demand routing for some destinations and destination-initiated, proactive routing for other destinations.
- Minimization of communication overhead via localization of algorithmic reaction to topological changes.

TORA is distributed, in that routers need only maintain information about adjacent routers (i.e., one-hop knowledge). Like a distance-vector routing approach, TORA maintains state on a per-destination basis. However; TORA does not continuously execute a shortest-path computation and thus the metric used to establish the routing structure does not represent a distance. The destination-oriented nature of the routing structure in TORA supports a mix of reactive and proactive routing on a per-destination basis. During reactive operation, sources initiate the establishment of routes to a given destination on-demand. This mode of operation may be advantageous in dynamic networks with relatively sparse traffic patterns, since it may not be necessary (or desirable) to maintain routes between every source/destination pair at all times. At the same time, selected destinations can initiate proactive operation, resembling traditional table-driven routing approaches. This allows routes to be proactively maintained to destinations for which routing is consistently or frequently required. TORA is designed to minimize the communication overhead associated with adapting to network topological changes. The scope of TORA's control messaging is typically localized to a very small set of nodes near a topological change.

The benefits of TORA is that the multiple routes between any source destination pair are supported by this protocol. Therefore, failure or removal of any of the nodes is quickly resolved without source intervention by switching to an alternate route. TORA is also not free from limitations. One of them is that it depends on synchronized clocks among nodes in the ad hoc network. The dependence of this protocol on intermediate lower layers for certain functionality presumes that the link status sensing, neighbor discovery, in order packet delivery and address resolution are all readily available. The solution is to run the Internet MANET Encapsulation Protocol at the layer immediately below TORA. This will make the overhead for this protocol difficult to separate from that imposed by the lower layer. The Flow chart [17] for TORA Protocol is given below:

VI. FSR (Fisheye State Routing)

Fisheye State Routing (FSR) is a link state type protocol which maintains a topology map at each node. To reduce the overhead incurred by control packets, FSR modifies the link state algorithm in the following three ways. First, link state packets are not flooded. Instead, only neighboring nodes exchange the link state information. Second, the link state exchange in only time-triggered, not even-triggered. Third, instead of transmitting the entire link state information at each iteration, FSR uses different exchange Intervals for different entries in the table. To be precise, entries corresponding to nodes that are nearby (within a predefined scope) are propagated to the neighbors more frequently than entries of nodes that are far away. These modifications reduce the control packet size and the frequency of transmission.

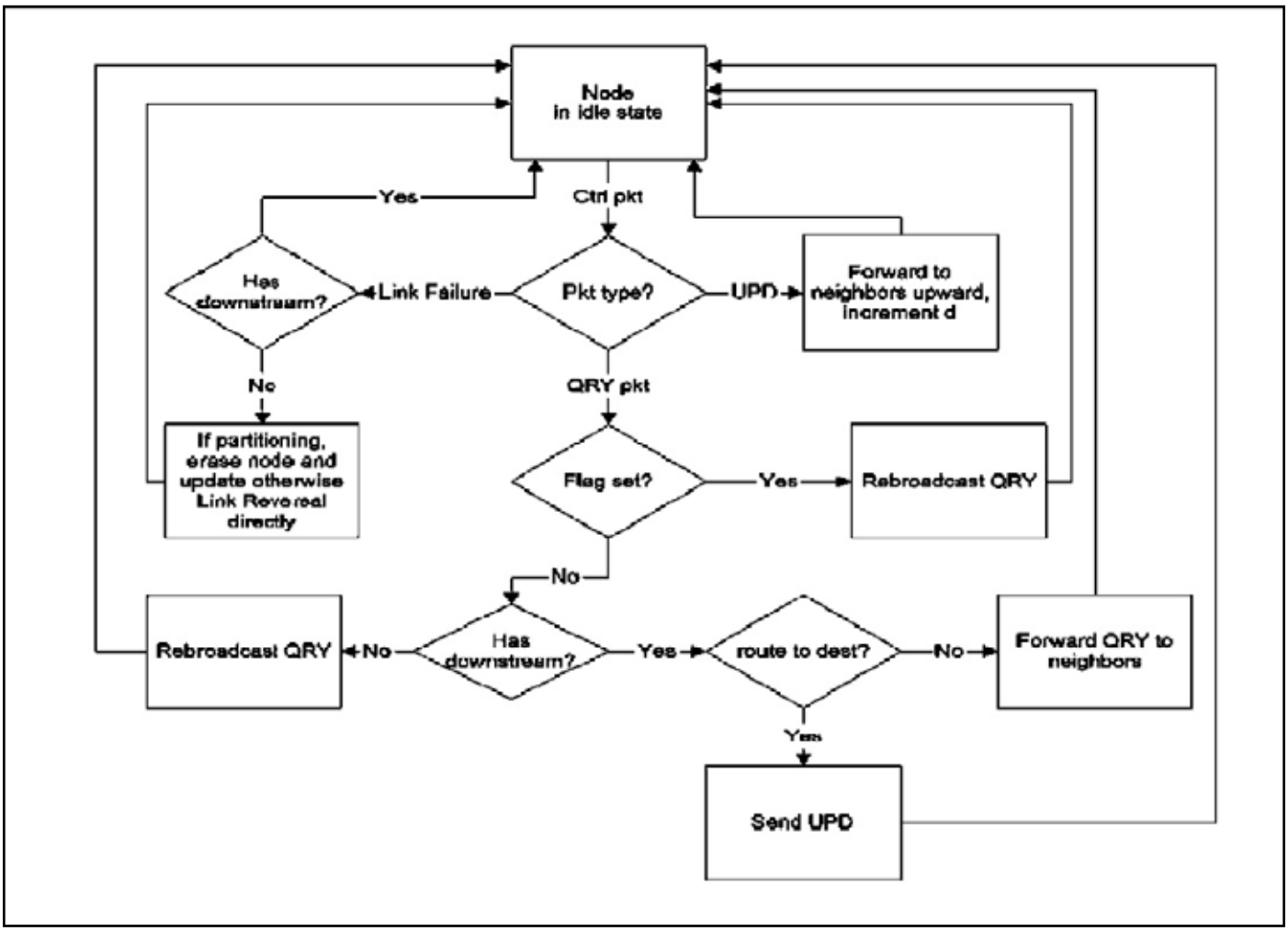


Fig. 7:

VII. ZRP (Zone Routing Protocol)

In a mobile ad-hoc network, it can be assumed that most of the communication takes place between nodes close to each other. The Zone Routing Protocol (ZRP) described in [28] takes advantage of this fact and divides the entire network into overlapping zones of variable size. It uses proactive protocols for finding zone neighbors (instantly sending hello messages) as well as reactive protocols for routing purposes between different zones (a route is only established if needed). Each node may define its own zone size, whereby the zone size is defined as number of hops to the zone perimeter. For instance, the zone size may depend on signal strength, available power, reliability of different nodes etc. While ZRP is not a very distinct protocol, it provides a framework for other protocols [30].

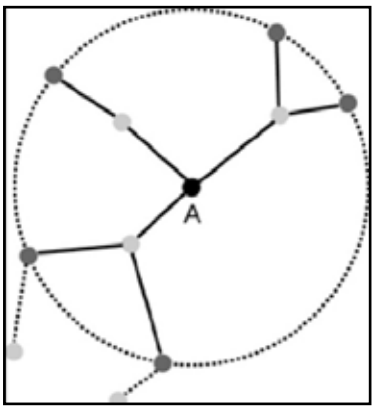


Fig. 8: ZRP - Routing Zone of Node A, $\rho = 2$

First of all, a node needs to discover its neighborhood in order to be able to build a zone and determine the perimeter nodes. In Figure 6, all perimeter nodes are printed in dark gray color – they build the border of A's zone with radius $\rho = 2$. The detection process is usually accomplished by using the Neighbor Discovery Protocol (NDP). Every node periodically sends some hello messages to its neighbors. If it receives an answer, a point-to-point connection to this node exists. Nodes may be selected by different criteria, be it signal strength, radio frequency, delay etc. The discovery messages are repeated from time to time to keep the map of the neighbors updated.

VIII. WRP (Wireless Routing Protocol)

Wireless Routing Protocol (WRP) is a distance vector based protocol designed for ad hoc networks. WRP modifies and enhances distance vector routing in the following three ways. First, when there are no link changes, WRP periodically exchanges a simple HELLO packet rather than exchanging the whole route table. If topology changes are perceived, only the 'path-vector tuples contain the destination, distance, and the predecessor (second-to-last-hop) node ID. Second, to improve reliability in delivering update messages, every neighbor is required to send acknowledgments for update packets received. Retransmissions are sent if no positive acknowledgements are received within the timeout period. Third, the predecessor node ID information allows the protocol to recursively calculate the entire path from source to destination.

IX. Performnace Metrics

There are number of qualitative and quantitative metrics that can be used to compare reactive routing protocols. Most of the existing routing protocols ensure the qualitative metrics. Therefore, the following different quantitative metrics have been considered to make the comparative study of these routing protocols through simulation.

A. Routing Overhead

This metric describes how many routing packets for route discovery and route maintenance need to be sent so as to propagate the data packets.

B. Average Delay

This metric represents average end-to-end delay and indicates how long it took for a packet to travel from the source to the application layer of the destination. It is measured in seconds.

C. Throughput

This metric represents the total number of bits forwarded to higher layers per second. It is measured in bps. It can also be defined as the total amount of data a receiver actually receives from sender divided by the time taken by the receiver to obtain the last packet.

D. Media Access Delay

The time a node takes to access media for starting the packet transmission is called as media access delay. The delay is recorded for each packet when it is sent to the physical layer for the first time.

E. Packet Delivery Ratio

The ratio between the amount of incoming data packets and actually received data packets.

F. Path Optimality

This metric can be defined as the difference between the path actually taken and the best possible path for a packet to reach its destination.

X. Conclusion

In this research paper, an effort has been made to concentrate on the working of various Pro-active and Reactive protocols (DSR, AODV,TORA, FSR, ZPR, WPR). In the last few years, there were several performance examinations of such routing protocols, although the performance was almost always evaluated as a function of mobility rate and speed without considering the network size. As a result of our studies, it can be said that DSR performs very poor in larger networks, as it shows extreme high delays and delivers less than 40% of all packets in a network of 200 nodes. The performance of AODV was very good in all network sizes, even though the routing overhead is higher than in DSR.Control packets are generated only as needed, i.e., there are no control messages which are not utilized. WRP and FSR, especially, were the main beneficiaries of the group movement model. Unfortunately, we cannot take a conclusion for ZRP due to the missing IERP packets. Those results will need to be validated in a future experiment. In summary, there is no single routing strategy that is best for all network situations. Every protocol has its advantages and disadvantages in different scenarios. The choice of a routing protocol should be made carefully after considering every aspect we provided in this section (and possibly more). In future work we must add certain routing protocols with multistrategy and multi-efficient (i.e. highly real time traffic control, less delay in acquiring route, etc.).

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