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Sivaranjani.V
PG Scholar, Dept of CSE
Sri Krishna College of technology Coimbatore, India

Madhavan.P
Assistant Professor, Dept of CSE Sri Krishna College of technology Coimbatore, India

Correspondence:
Sivaranjani.V
PG Scholar, Dept of CSE
Sri Krishna College of technology Coimbatore, India

RPSM- Routing protocols survey in MANET

Sivaranjani.V, Madhavan.P

Abstract
A mobile ad hoc network (MANET) is a continuously self-configuring and infrastructure less network of mobile devices. Each device in a MANET is free to move independently in any direction, so it will change its links frequently. Each device can act as both host and router respectively. Hence, routing is the challenging issue in MANET. The objective of this paper is to provide the observations of various routing protocols in MANET, in order to adapt the suitable routing protocol based on their routing characteristics for the efficient routing process.

Keywords: MANET, Routing Protocols, Proactive, Reactive, Hybrid

1. Introduction

The two types of wireless network are infrastructure and infrastructure less network. In infrastructure wireless network, base stations are fixed. Nodes moves randomly in the wireless environment and node communication takes place with the help of base station. It acts as the central controller, which controls the network functions effectively. Examples of infrastructure wireless network are cellular phone and paging systems. It can efficiently utilize the network resources for controlling the activities like transmission scheduling, dynamic resource allocation and power control. But, it is more expensive or simply not feasible or practical to deploy infrastructure.

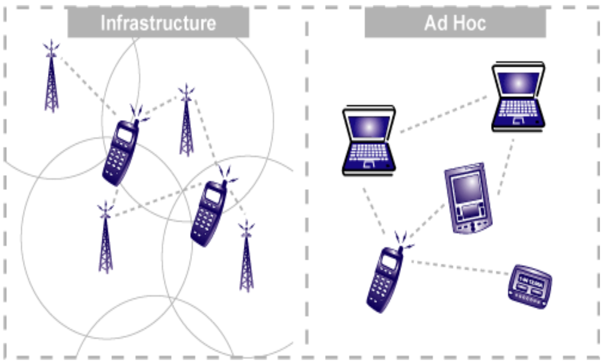


Fig 1: Infrastructure and Infrastructure less Networks

Infrastructure less wireless networks is also called Adhoc wireless networks in which nodes can communicate directly with each other without help of base station as in infrastructure networks. Manet is an adhoc networks that can change location and configure itself because Manets are mobile they use wireless connections to various networks. The Manet characteristics are distributed operation, Multi-hop routing, Autonomous and light weight terminals, dynamic topology and Shared physical medium. Manet challenges are Routing overhead, Hidden terminal problem, Battery constraints, Security threats and Mobility induced route changes. Applications of Manet are Military field, Bluetooth and Education. A Manet advantages includes the following:

- They provide access to information and services regardless of geographic position and network can be formed at any place and time.
- Independent and Self-configuring network, nodes are also acted as routers. Less expensive as compared to wired network.

- Scalable, accommodates the addition of more nodes.
- Improved Flexibility.
- Robust due to decentralized

Broadcasting approaches in Manet

In MANET, a number of broadcasting approaches on the basis of cardinality of destination set:

1) **Unicasting:** Sending a message from a source to a single destination.
2) **Multicasting:** Sending a message from a source to a set of destinations.
3) **Broadcasting:** Flooding of messages from a source to all other nodes in the specified network.
4) **Geocasting:** Sending message from source to all other nodes inside geographical region.

2. Routing Protocols

Ad-Hoc network routing protocols are commonly divided into three main classes; Proactive, reactive and hybrid protocols as shown in figure 1.1

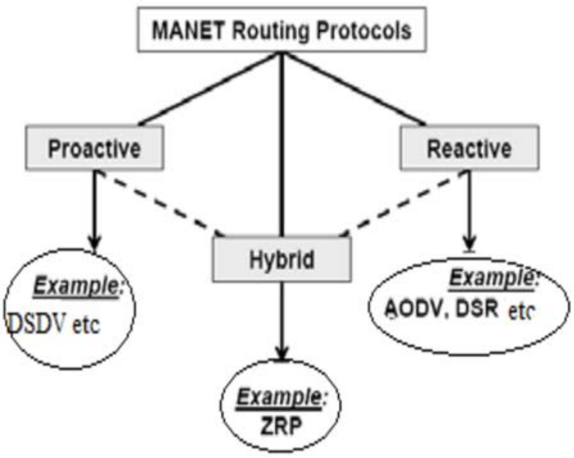


Fig 2: Classification of MANET routing protocols

It is the mechanism of forwarding packet towards its destination using most efficient path. Routing mechanism in Mobile Ad Hoc Network is as follows: Routes are mainly multi hop, due to limited radio propagation range and frequent topology changes, because each network host moves randomly. Hence, routing is considered as an integral part of ad hoc communications. Routing helps in finding and maintaining the routes between nodes in a dynamic topology, by using minimum resources with possibly uni-directional links.

The routing protocol should have the qualities such as: Distributed operation, Loop-freedom, Demand-based operation, Proactive operation, Security, "Sleep" period operation, unidirectional link support.

1) Proactive Protocols: Proactive or table-driven routing protocols. Each node has to maintain one or more tables to store routing information, and changes in the network topology need to be updated throughout the network in order to maintain a consistent network view.

2) Reactive Protocols: It is also known as on-demand routing protocol since they do not maintain routing information.

3) Hybrid Protocols: They introduce a hybrid model that combines reactive and proactive routing protocols. The Zone Routing Protocol (ZRP) is a hybrid routing protocol that divides the network into zones. It provides the hierarchical architecture, where each node has to maintain the additional topological information, which occupies extra memory.

Proactive (Global/Table Driven): Route determination at startup, Maintain using periodic update.

Reactive (On-demand): Route determination as needed, Route discovery process.

Hybrid**:** Combination of proactive and reactive

Proactive Protocols

- Table driven.
- Continuously evaluate routes.
- No latency in route discovery.
- Large network capacity to keep current information.
- Most routing information may never be used.

Reactive Protocols

- On Demand.
- Route discovery by some global search.
- Bottleneck due to delay in route discovery.
- May not be helpful for real time communication.

Manet Protocol Considerations

- Simple, Reliable and Efficient.
- Distributed but lightweight in nature.
- Should be adaptable to changes in topology and traffic pattern.
- Changes in topology should result in minimal control overhead.
- Bandwidth efficient.
- Mobility Management includes user location management and Hand-off management.

2.1. Proactive Protocols

- OLSR
- DSDV
- WRP
- GSR

Optimized Link State Routing (OLSR)

Optimized Link State Protocol is a proactive routing protocol, so the routes are available when needed. OLSR is a pure link state protocol; hence the topological changes cause the flooding of the topological information to all available hosts in the network. To minimize the overhead in the network protocol, Multipoint Relays are used. The idea of MPR is to reduce flooding of broadcasts by reducing the same broadcast in the network. Finally, it provides the shortest path. Two kinds of the control messages are used such as, Hello and Topology Control. Hello messages are used to find the information about link status and the host's neighbors. The Multipoint Relay Selector set is constructed based on the hello messages, in which neighbor to be chosen to act as MPR and from this, the host can calculate its own set of the MPRs. The TC messages are broadcasted throughout the entire network whereas the Hello messages were sent only one hop away. TC messages are used to broadcast the information about own advertised neighbors. The TC messages were broadcasted periodically and only the MPR hosts can forward the TC messages.

Routing

Neighbor Sensing, Multipoint Relays, Multipoint Relays Selection, Topology Information, Routing Table Calculations.

Advantages

1) OLSR does not need any central administrative system which is a flat routing protocol, to handle its routing process. It provides the routing information to all participated hosts in the network. Each host should periodically send the updated topology information throughout the entire network, hence the bandwidth usage of the protocol increases. The flooding can be minimized by the usage of MPRs, which are allowed only to forward the topological messages.
2) The reactiveness to the topological changes can be controlled by changing the time interval for broadcasting the Hello messages. It does not require that the link is reliable for the control messages, because the messages are sent periodically and the delivery does not have to be sequential.
3) Due to its simplicity, it is easy to integrate the routing protocol in the existing operating systems, without changing the format of header of the IP messages. Hence, the protocol only interacts with the host's Routing table.
4) It is well suited for the applications, which does not allow the long delays in the transmission of the data packets. The working environment considered for OLSR protocol is a dense network, in which communication is concentrated between a large numbers of nodes.
5) OLSR allow the hosts to have multiple OLSR interface addresses and provides the external routing information, which gives the possibility for routing to the external addresses. Therefore, hosts in the ad hoc network which can act as gateways to another possible network.

Destination Sequenced Distance Vector (DSDV)

All mobile station maintains a routing table which lists all available destinations, the number of hops and sequence number assigned by the destination node. The sequence number is used to differentiate the stale routes from new ones and thus avoid the formation of loops. Periodically, it transmits their routing tables to immediate neighbors and also transmits its routing table if a significant change has occurred in its table from the last update sent. Hence, the update is both time-driven and event-driven. The routing table updates can be in two ways, a "full dump" or an incremental update. A full dump transfers the full routing table to the neighbors whereas in an incremental update only those entries from the routing table are transferred. If there is space in the incremental update packet then those entries may be included sequence number which has been changed. When the network is relatively stable, incremental updates are transferred to avoid traffic (or) collision but full dump are relatively infrequent. In a frequently-changing network, incremental packets can grow in size, so full dumps will be more frequent. Each route updates packet, in addition to the routing table information and also contains a unique sequence number assigned by the transmitter. The route labeled with the highest (most recent) sequence number is used. The shortest route is found out; if two routes have the same sequence number.

Advantages

- Simple (almost like Distance Vector)
- Loop free through destination sequence numbers
- No latency caused by route discovery

Disadvantages

- No sleeping nodes
- Process overhead

The Wireless Routing Protocol (WRP)

It belongs to a general class of algorithms called Path Finding Algorithms (PFA) and uses information with respect to the "length of" and the second-to-last-hop on the shortest path.

Path Finding Algorithm

Each node maintains the shortest path spanning tree maintained by each of its neighbors. By using this, it creates its own shortest path spanning tree. Shortest path denotes Shortest Weighted Path. Periodically, each node broadcasts an update that reports updates to its spanning tree. Each update contains the destination address, Distance to that destination**,** an identifier of the node that is at the second-to-last-hop on the shortest path to that destination. It uses the generic ideas in PFA and reduces the number of "temporary" routing loops. The second-to-last-hop node is considered as the predecessor node. When a node receives an update from a neighbor it checks the consistency of the predecessor information reported by all its neighbors. The spanning tree also gives information with regards to the next hop neighbor towards that destination. The next hop neighbor is called as the successor node.WRP is a table-based distance-vector routing protocol. All nodes in the network maintain a Distance table, a Routing table, a Link-Cost table and a Message Retransmission list.

Distance Table

Let us consider a particular node A. In this table, for each destination K, node A maintains the distance to K via each of its neighbors (say B) D^{A}_{KB}, and the predecessor node P^{A}_{KB}, along that path. This table is used in the construction of the minimum spanning tree.

Routing Table

For each destination Node K, it contains the address and distance of Node, The successor on the shortest path to Node K, The predecessor on this path to Node K, May also contain a flag to indicate whether the path is correct, or erroneous (no path to destination).

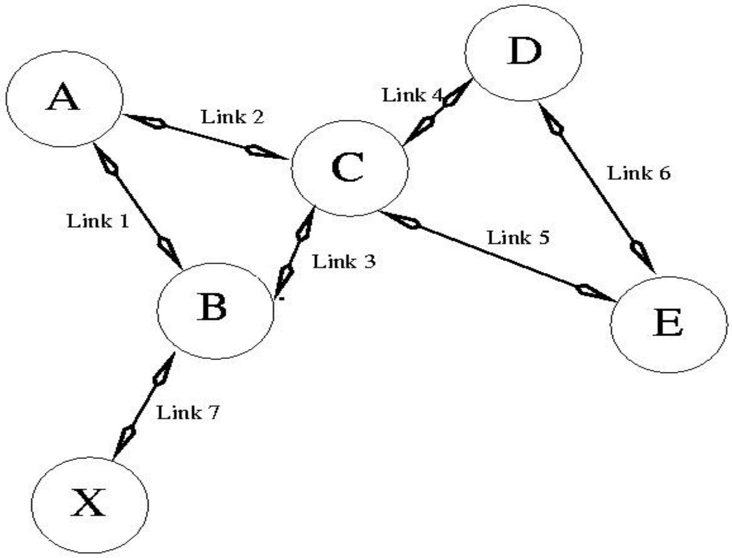
Link-Cost Table

It tabulates the cost of transmitting through each neighbor. Cost depends on link characteristics – need not be hop count.

Message Re-transmission List

It contains information with regards to each transmitted update by the node (say node A). Each update message has a sequence number that is tabulated in this table. Also contains a retransmission counter and ACK required flag vector. The flag vector indicates the neighbors that responded to the update which helps to eliminate redundant update transmissions.

Example:



Let cost of Link 2 is '10'.

Fig 3: Node with Links

Table 1: Routing table at A

Dest	Cost	Pred	Succ
A	0	A	A
B	1	A	B
C	2	B	B
D	3	C	B
E	3	C	B
X	2	B	B

Now Let Link 1 fails. Node A will notice this failure. Let us consider a single destination – say Node X. Node A will set the distance to X to infinity and its predecessor and successor values to "null". This is broadcast to Node C. Node C computes the alternate route to A which is by means of Link 2. This information is then transmitted to A. A then realizes (by means of C's new spanning tree) that it can reach other nodes via C.

Node A's new routing table would now look like:

Table 2: Routing table at A (1)

Dest	Cost	Pred	Succ
A	0	A	A
B	11	C	C
C	10	A	C
D	11	C	C
E	11	C	C
X	12	B	C

Advantages:

- No Loops
- Lower number of updates upon link failure – reports sent only to neighbors.
- Overhead grows as O (n) – n is the number of nodes.

Disadvantages

- Messages may be large.
- Maintenance of four tables
- Hello packets required
- Cannot go into sleep mode
- Overhead issue
- Scalability still an issue

Global State Routing (GSR)

Link State routing (to re-iterate) requires that an update be sent to every node in the network upon the change of the state of a link. Flooding may have to be used. This is very expensive in a bandwidth starved wireless network.GSR is similar to the other link state routing protocols. It attempts to provide the benefits of link-state routing but with the simplicity of distance vector protocols. Avoid flooding the network with link-state updates. Instead maintain a link-state table based on up to date information received from neighboring nodes. Periodically exchange collected link-state information with its neighbors. Source uses sequence numbers to ensure that the link state table is up to date. The entries with older sequence numbers are replaced with updates with later sequence numbers. A source rooted minimum cost tree is computed based on the collected link-state and is used to route packets to any destination.

Advantages:

- Avoids Flooding for disconnects/reconnects
- Updates are time triggered than event triggered
- Greatly reduces control overhead
- Can provide loop free paths that are optimal
- Can be used to support Quality of Service

Disadvantages:

- Hogs bandwidth since entire topology table is broadcast with each update
- Link state latency depends on update interval
- Most inadequacies of link-state routing protocols remain
- Link layer reliability is still required
- If updates are frequent which results in high overhead
- Not very scalable

2.2. Reactive protocols

- AODV
- DSR

Ad hoc On-demand Distance Vector routing (AODV)

It is pure on-demand protocol. Node does not need to maintain knowledge of another node unless it communicates with it. Broadcast discovery packets only when necessary. To disseminate Information about changes in local connectivity to those neighboring nodes that is likely to need it. Initiated whenever nodes want to communicate. Route Request packets are broadcasted. Steps involved in AODV are:

- Path Discovery
- Reverse Path Setup
- Forward Path Setup
- Route Table Management
- Path Maintenance
- Local Connectivity Management

RREQ format: < source_addr, source_sequence-#, broadcast_id, dest_addr, dest_sequence_#, hop_cnt >

RREQ uniquely identified by <source_addr, broadcast_id>. Broadcast id incremented with every RREQ. Neighboring nodes satisfy RREQ by sending RREP or broadcast RREQ after incrementing hop_cnt. Each intermediate node keeps following information- Destination Address, Source Address, Broadcast_id, Expiration time for reverse path entry, Source node's sequence number. Source sequence number is used to maintain freshness about reverse route to source. Destination number specified for freshness of route before accepted by source. Reverse path setup by having link to neighbor. Node processing on reception of RREQ: It Checks if the route is current by comparing dest_seq#. If route is current node unicasts RREP back to neighbor from which it received the RREQ. RREP contains <source_addr, dest_addr, dest_sequence_#, hop_cnt, life time>. Node propagates RREP back to source. Updates information on reception of subsequent RREPs. Route Request Expiration Timer for purging reverse paths which do not lie on source-destination route. Route Caching Timeout for time after which the route is considered invalid. Active_timeout Period used to determine if neighboring node is active. Route Table entry contains Destination, Next Hop, Number of hops (metric), Sequence numbers of Destination, Active Neighbors for this route, Expiration time for the route table entry. When destination node or intermediate node moves a special RREP is sent. When next hop become unreachable the upstream node sends propagates RREP with fresh sequence number and hop count. Restart route discovery process from source on receipt of RREP.

Example:

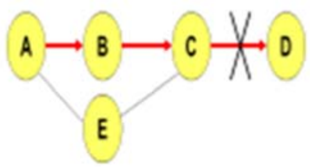


Fig 4: AODV: Routing Loops

Assume, link C-D fails, and node A does not know about it (route error packet from C is lost). C performs a route discovery for D. Node A receives the route request (via path C-E-A). Node A replies, since A knows a route to D via node B. The results in a loop: C-E-A-B-C

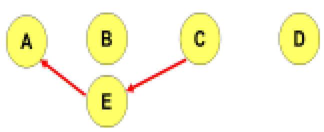


Fig 5: AODV: Link failure

Assume, the link C-D fails, and node A does not know about it (route error packet from C is lost). C performs a route discovery for D. Node A receives the route request (via path C-E-A).Node A replies, since A knows a route to D via node B. The Results in a loop: C-E-A-B-C

AODV: Use Sequence Numbers

Each node X maintains a sequence number which acts as a time stamp and incremented every time X sends any message. Each route to X (at any node Y) also has X's sequence number associated with it, which is Y's latest knowledge of X's sequence number. Sequence number signifies 'freshness' of the route – higher the number, more up to date is the route. Loop freedom: Intermediate node replies with a route (instead of forwarding request) only if it has a route with a higher associated sequence number.

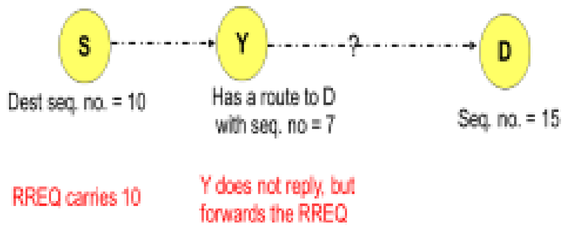


Fig 6: Sequence Numbers in AODV

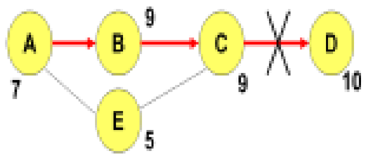


Fig 7: Avoidance of Loop

By using Destination Sequence Number (DSN).The Link failure increments the DSN at C (now is 10).If C needs route to D; RREQ carries the DSN (10). A does not reply as its own DSN is less than 10. Path Maintenance includes, if source moves, reinitiate route discovery, when destination or intermediate node moves results in upstream node of break broadcasts Route Error (RERR), RERR contains list of all destinations no longer reachable due to link break, RERR propagated until node with no precursors for destination is reached.

Summary: AODV

At most one route per destination maintained at each node. After link break, all routes using the failed link are erased. Expiration based on timeouts and use of sequence numbers to prevent loops

Dynamic Source Routing (DSR)

It constructs a source route in packet header. Each host maintains a route cache. Route discovery used for routes not in cache. It contains Route Request Packet, Route Reply Packet, Route Record, Unique Request id. Possible scenarios on receipt of route request packet: Discard packet if <initiator address, request id> already seen, If host already listed then discard packet, If target address is same as host address then obtain reverse route from route record and send route reply, Add host address in case of none of the above. Route error packet sent on detection of break containing addresses on both sides of error, the host that detected the error and the host to which it was trying to send the packet. All upstream node then deletes routes with that particular hop

Optimizations

Full Use of Route Cache, Piggy Backing on Route Discoveries, Reflecting Shorter Routes, Improved Handling of errors, Each forwarding host can add route information to cache , Nodes can operate in promiscuous mode and add information to cache from any packets that they hear, Each intermediate node having a route can send a route reply packet, Data is piggybacked on Route Request Packet and Route Reply Packet (like SYN for TCP), While piggybacking on Route Request and intermediate node send Route Reply propagate Route Request with data , In scenario when network becomes partitioned buffer packets and use exponential back off , Use promiscuous mode to remove entries.

Performance Comparison of AODV and DSR

- DSR has access to significantly greater amount of routing information than AODV by virtue of source routing and promiscuous listening.
- DSR replies to all requests reaching a destination from a single request cycle whereas AODV only replies once thereby learning only one route.
- In DSR, no particular mechanism to delete stale routes unlike AODV.
- In AODV the route deletion causes all the nodes using that link to delete it, but in DSR only the nodes on that particular part are deleted.
- Both protocols do not perform any load balancing.
- Routing load in DSR is less than AODV but in terms of bits the difference is less.
- In AODV the path discovery is mostly due to RREQ (but in RREP & RERR's but in terms of network load both of them are nearly the same).
- Both protocols use hop-wise determination of routes.

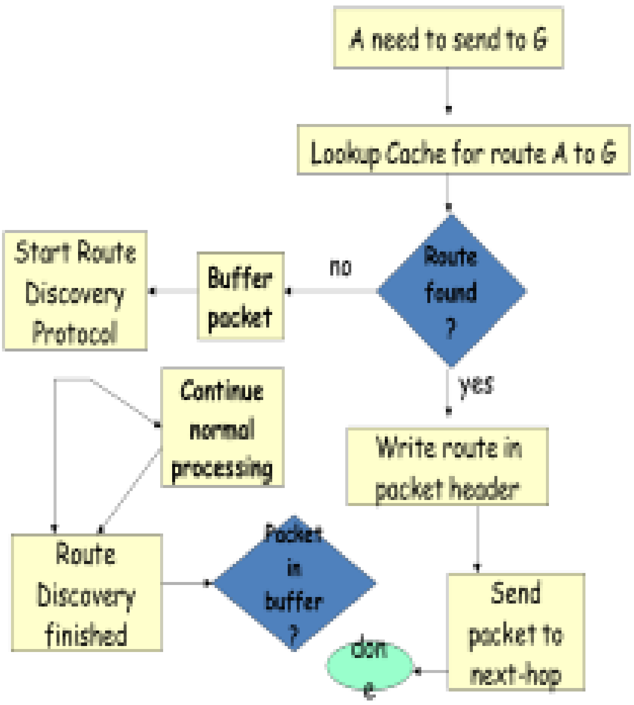


Fig 8: Route Discovery: At source A

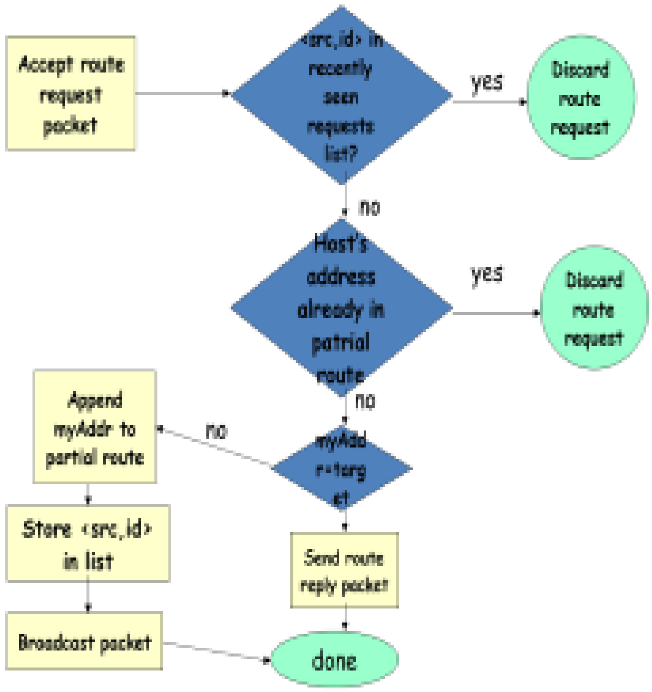


Fig 9: Route Discovery: At an intermediate node

Summary of DSR

Entirely on-demand, potentially zero control messages overhead. Trivially loop-free with source routing. Conceptually supports unidirectional links as well as bidirectional links. High packet delays/jitters associated with on-demand routing. Space overhead in packets and route caches. Promiscuous mode operations consume excessive amount of power.

2.3. Hybrid (Combination of both On-demand and Proactive)

ZRP has three sub-protocols

- Intrazone Routing Protocol (IARP)
- Interzone Routing Protocol (IERP)
- Border cast Resolution Protocol (BRP)

Zone Routing Protocol (ZRP)

A Hybrid Routing Protocol in which zone is defined for each node. The proactive maintenance of topology within a zone (IARP) and reactive query/reply mechanism between zones (IERP). It Uses 'Border cast' instead of neighbor broadcast. Neighbor Discovery/Maintenance (NMD) and Border Resolution Protocol (BRP) used for query control, route accumulation etc. Routing Zone and Intra zone Routing Protocol: Zone Radius may be based on hop count; Identity the distance of each Node within the Zone is proactively maintained. The Inter zone Routing Protocol: Check if destination is within the routing zone, Border cast route query to all peripheral nodes, Peripheral nodes execute the same algorithm. Route Accumulation: It Provides reverse path from discovery node to source node. It may employ global caching to reduce query packet length. Query Detection/Control: Terminate Query thread in previously queried regions, Intermediate nodes update a Detected Queries Table [Query Source, ID]. Route Maintenance may be reactive or proactive

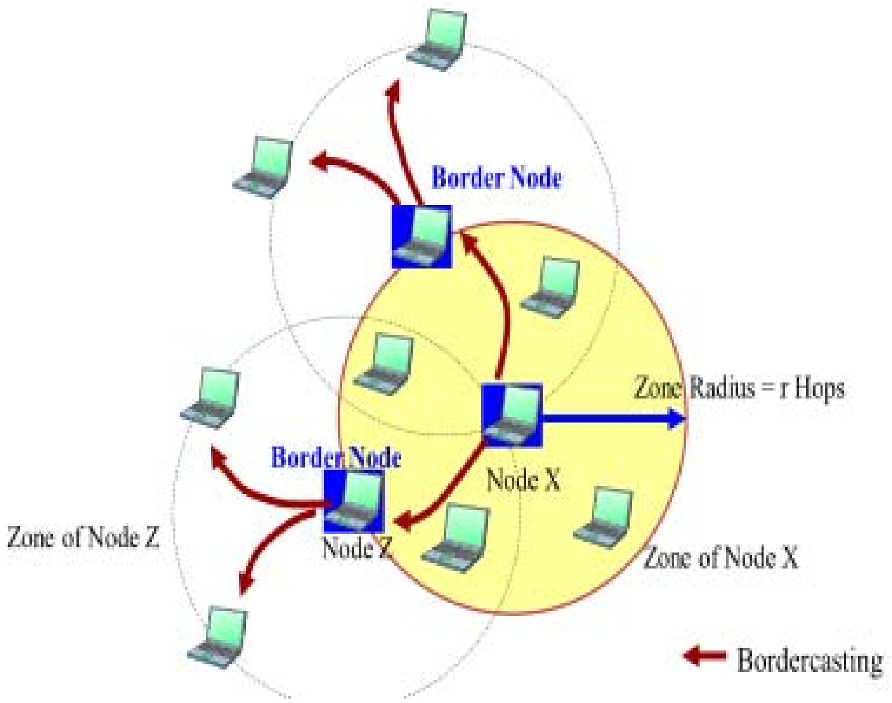


Fig 9: ZRP

3. Protocol Comparison

Quality of Service (QoS) is the performance level of a service offered by the network to the user. Most of the multimedia applications have stringent QoS requirements that must be satisfied. The goal of QoS provisioning is to achieve a more deterministic network behavior, so that information carried by the network can be better delivered and network resources can be better utilized. However, there still remains a significant challenge to provide QoS solutions and maintain end-to-end QoS with user mobility. QoS consists of a set of characteristics or constraints between the source and the destination that a connection must guarantee during the communication in order to meet the requirements of an application. To judge the merit of a routing protocol, one needs metrics both qualitative and quantitative, with which to measure its suitability and performance. Generally, there are four main metrics presented in as parameters of QoS which are probability of packet loss (or packet delivery ratio), delay (route latency), jitter (delay variance), and bandwidth. Some of the metrics in are applied to compare the proactive and reactive and hybrid routing protocols in terms of overhead, scalability, and loop-freedom.

Manet Routing Protocols Performance Metrics:
Quantitative metrics End-to-End Delay**,** Throughput Route**,** Overhead**,** Packet Delivery Ratio Mobility

Qualitative metrics Loop-freedom, Stability, On-demand, Proactive, Scalability, Reliability.

Table 3: Comparison between proactive and reactive protocols

Qualitative Metrics	Proactive		Reactive	
	OLSR	DSDV	AODV	DSR
Security	No	No	No	No
Loop Freedom	Yes	Yes	Yes	Yes
Sleep Mode	Yes	No	No	No
Unidirectional link support	Yes	No	No	Yes
Multicasting	No	No	Yes	No

S.NO	Properties	DSDV	AODV	DSR	ZRP
1	Route discovery	Periodic	On demand	On demand	Both proactive(local Zone) and Reactive(outside Zone)
2	Hello Message	Yes	Yes	No	Yes
3	Distributed	Yes	Yes	Yes	Yes
4	Periodic broadcasts	Yes	Yes	No	Yes
5	Power Conservation	No	No	No	No
6	Route Mechanism	Route table with next hop	Route table with next hop	Complete Route cached	A routing zone is defined for each node separately, and the zones of neighboring nodes overlap
7	Network overhead	High	Medium	Low	High
8	Node overhead	Medium	Medium	High	High
9	Network Support	Less number of nodes	Highly Dynamic	Up to 200 nodes	Many number of nodes
10	Packet size	Uniform	Uniform	Non Uniform	Uniform

11	Routing overhead	Medium	High	Low	High
12	Route maintenance	No	Yes	Yes	Yes
13	Routing Structure	Flat and hierarchical structure	Flat	Flat	Hierarchical
14	Control overhead	High	Low	Medium	Medium
15	Communication overhead	High	Low	Medium	Medium
16	Route acquisition delay	Lower	Higher	Higher	Lower for Intra-zone; Higher for Inter-zone
17	Bandwidth requirement	High	Low	Low	Medium

4. Conclusion
In this survey paper, the comparative study and performance analysis of various routing protocols (DSR, AODV, DSDV and ZRP) are done on the basis of above mentioned performance metrics. The results indicate that a reactive protocol performs better when compared to the proactive protocols. In reactive protocol, AODV performs better with minimal overhead. It provides the shortest route for the transmission of data packets. It outperforms better in the dynamic network environment by providing routes on demand.

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