# A Comparative Study on Reactive or On Demand Routing Protocols in Mobile Ad Hoc Networks

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## ABSTRACT
Mobile Ad hoc network simply MANET is a collection of mobile nodes that are connected together over a wireless medium that do not depend on any fixed infrastructure. Mobile nodes in the MANET are moving arbitrarily hence the topology of network may change rapidly. Nodes may also act as routers in order to forward the packets to other node and also each node in the network depends on other nodes. In order to perform routing among the mobile nodes, routing protocol is needed. The main goal of routing protocol is efficient route establishment between any given pair of nodes. So the message could reach the destination on time and without loss of packets. In this paper we present various Reactive or On Demand routing protocols such as AODV, DSR, and TORA and discussed their route establishment and maintenance and also discusses their advantage and disadvantage. Finally we have done a comparative study on these protocols.

## Keywords
**MANET; Routers; On Demand Routing; AODV; DSR; TORA**

## 1. INTRODUCTION
Mobile Ad Hoc Network (MANET) is one where there is no fixed infrastructure such as base station or mobile switching centers. Mobile nodes that are within each other's radio range communicate directly via wireless means, while those that are far apart rely on other nodes to relay messages as routers. In recent years, MANET has received tremendous attention because of the self configuration and self maintenance [1] capabilities. Node mobility in MANET causes frequent changes in network topology. Although security [2] has long been an active research topic in wire line networks, the unique characteristics of MANETs present a new set of non trivial challenges such as open network architecture, shared wireless medium, stringent resource constraints and highly dynamic network topology. Now the applications of MANET are growing rapidly. Some commercial applications of MANET are Conference, Home Networking, Emergency Services, Personal area network and Blue tooth, Embedded Computing Applications, Sensor Dust and Automotive PC interactions [3]. Typically types of network falls into two categories, first one is traditional network that is wired, another one is wireless. In wired network the nodes are connected over a communication medium such as copper wire, optical cable etc. In MANETs nodes are connected over wireless links such as infrared, radio etc.  It is impossible to set up a network where the emergency situation occurs like military and disaster etc., the wireless network falls into two categories that is wireless with fixed infrastructure another one wireless without Infrastructure (Ad hoc). In the first one mobile nodes are communicating within a radio range of fixed backbone. If the nodes go out off the radio range it may join in another fixed backbone's radio range this situation is called "handoff". Second one is called Mobile Ad hoc network in this mobile nodes are communicating with each other without any fixed infrastructure. In addition to this there are other research avenues in the field of MANET such as Scalability, Quality of Service, Client server model shift, Security, Interoperation with the Internet and Power control [3].

## 2. ROUTING PROTOCOLS
Routing is the process of finding path from any source to any arbitrary destination. Routing is a considerable factor in MANET because of its dynamic topology. In this unstable environment routing of information from one place to another it's a challenging task. We are in situation that our information should be reaching the destination timely as well as without loss of any data. So this task is accomplished by routing protocols. The function of routing protocols is to maintain routing tables that store all available routing information and the purpose is to dynamically maintain a router's routing table. To do this, routers must share information about the valid routes. This sharing is accomplished by the exchange of special packets that are called routing updates. The actual work of routing protocol is not move data from one end to another end; it simply carries information about the best path from router to router [4]. Therefore routing is the process of directing packets from a source node to a destination node on a network. Getting packets to their next hop, a router requires performing two basic activities: path determination and packet switching. Path determination is the process of choosing an optimal route from all the available routes typically from all the routing information stored in the respective routing table. Packet switching involves changing a packet's physical destination address to that of the next hop. Some challenges in routing protocols are, dynamic topology, bandwidth constrained variable capacity link, energy constrained devices, limited physical security and scalability.

## 3. DESIGN GOALS OF ROUTING PROTOCOLS
**Optimality:** A routing protocol should be capable of choosing the optimal route or quickest route from all the several alternative routes.
**Flexibility:** A protocol should have an ability to adapt to constantly changing network conditions.

**Rapid Convergence:** If any change within the network, that change should propagate to all the routers within the minimum amount of time. The time it takes for all routers to be notified of the change is called convergence.
**Robustness:** The protocols continue functioning even if any unpredictable and unusual change occurs.
**Simplicity:** A protocol should be simple to be efficient.

## 4. CLASSIFICATION OF ROUTING PROTOCOLS

Static routing does not reflect any topology change that occurs in the network. But dynamic routing automatically discovers routes and can react to network changes.

Some protocols choose a single path from all available routes, that path information alone is stored in the routing table. In multipath, all available paths are stored in the routing table it causes higher throughput. It also supports multiplexing over multiple lines.

A flat routing protocol considers all routers as peers. In such routing all router would receive the same routing updates from all other routers. But in hierarchical routing protocol there is some classification among routers. They may not receive same information; they only receive routing updates from other routers within their network also it keeps local traffic information. It reduces the bandwidth overhead required by the routing protocol and improves network performance.

In distance vector routing, routing decisions are based on the distance of the remote destination in terms of the number of network layer hops that the packet will have to traverse. In link state routing, routing decisions based on messages received from other routers in the network that give information about the state of the links connected to them [5].

## 5. REACTIVE OR ON DEMAND ROUTING PROTOCOL

In Reactive routing protocol the routes are created only when it is needed. There is no need of periodic updates of Routing tables compared with proactive or table driven protocol. In order to establish a route between source and the destination, it initiates a route discovery process that is used to send data to the destination. After the successful completion of route discovery process, the path is available to send data. In order to maintain consistency of routes between nodes route maintenance process is used. On Demand Routing Protocols are taken up for the discussion here. Some of the protocols are, DSR, AODV and TORA.

### 5.1. AODV (Ad Hoc On-Demand Distance Vector Routing)

AODV creates routes only when it is needed, there is no need to maintain periodic updates of routing information. It is derived from DSDV and DSR and also called descendent of DSDV. From DSDV it inherits the route discovery, route maintenance and hop by hop routing, Sequence number from DSR. It supports both unicast and multicast transmission [6-8].

In AODV each node in the network maintains the following fields in its routing table such as Destination address, Next hop address, Number of hops, Active neighbors, Destination sequence number and Life time. For providing effective and timely packet delivery AODV, uses Route discovery and Route Maintenance Phases.

**Route Discovery Phase**: Typically route discovery is achieved by flooding. To accomplish route discovery process two packets are used one is Route Request (*RREQ*) another one is Route Reply (*RPLY*). When a node wishes to transmit a packet to a particular destination, first it checks the routing table entries. If it has a desired path to the destination, then it will forward the packet to next hop address otherwise it broadcasts route discovery process by *RREQ* packet to all its neighboring nodes. The *RREQ* consist of Source address, Broadcast ID, Source Sequence number, Destination address, Destination Sequence number and the hop count. The combination of Source address and sequence numbers are used to uniquely identify the *RREQ*. Fig.1 illustrates the route discovery and route reply process.

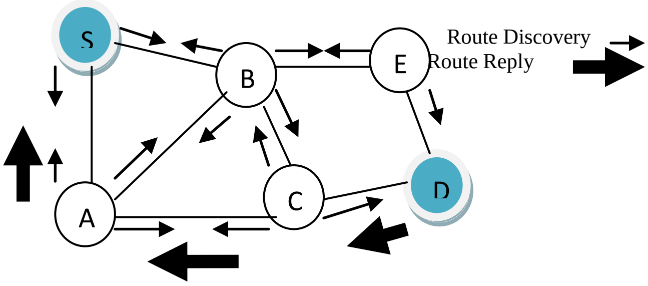


**Fig 1: Route Discovery and Route reply**

Once the intermediate node received the *RREQ* packet, it compares the sequence number which is in the own routing table with *RREQ*'s sequence number. If the sequence number is less than *RREQ*'s sequence number then it rebroadcasts request to next neighboring nodes otherwise it will set up a reverse path and stores the reverse path entry in its routing table. The reverse path entry consist of Source IP address, Source Sequence Number, Number of hops to source node, IP address of node from which *RREQ* is received. Subsequently the reserve path used for sending a *RPLY* to the node which sent *RREQ* previously. Route reply is carried out by unicast routing not flooding. Route Reply is demonstrated in the Fig. 1. Sequences numbers are used to determine the most recent entry in the routing table to avoid the routing loops. Likewise the route discovery process is carried out.

**Route Maintenance Phase:** Route maintenance is achieved by the Route Error (*RERR)* packet and also periodically propagating *HELLO* message to its neighboring nodes. The absence of *HELLO* messages from the receiving node depicts link failure so the source node again reinitiates the route discovery process if the failure route is still in demand. When a node is unable to forward a packet to a particular destination it generates *RERR* to its predecessor node i.e. upstream nodes. So when a node receives *RERR* packet, it marks its own destination table as invalid and also sets the destination entry as infinity and deletes the particular route entry. Hence the source node reinitiates the route discovery process.

**Optimizations in AODV**

**Time to live:** Every *RREQ* packet carries a TTL (Time to Live) field when it sends a packet. It denotes how many hops that this packet should cross to reach the destination. So the value of this field is predefined when it sends initially. Then it will increment each time when retransmission of *RREQ* occurs.

**Ring search Technique*:*** Propagation of route request for large network in AODV is achieved by expanding ring search method. In this technique the source node is at the centered. It expands the search ring by incrementing the TTL value for every *RREQ* retransmission until the node finds the information being searched is found [9].

**Advantage*:*** Each node needs to store routing information only when it is needed and also it stores active routes only, hence minimum space complexity. Maximum utilization of bandwidth is achieved by increasing sequence number by the way we can avoid stale route. It supports unicast and multicast routing though movements of nodes. Also its loop free property is achieved by sequence number. It is scalable to large No of nodes. No additional overhead on data packet compared with DSR. It also supports least congested route instead of shortest route.

**Disadvantages*:*** Increasing amount of network overhead when broadcasting hello message to maintain the local connectivity of the message. It supports only symmetric link between nodes not asymmetric link. Before sending the actual transmission of data packets we in demand to find out route discovery process causes degrade the performance of network. Nodes are required to maintain coordination. The lack of coordination leads to security vulnerabilities.

## 5.2 DSR (Dynamic Source Routing)

It is another On Demand Routing Protocol. It is based on the concept of source routing that is the entire path is explicitly mentioned in the packet header of source. Hence intermediate nodes do not require to keep the routing information also no need of periodic updates like *Hello* message in AODV. It supports both unidirectional and asymmetric links. Route Discovery and Route Maintenance phases are used to achieve reliable routing in DSR [9-12].

**Route Discovery:** Every node in MANET maintains route cache that is used to store all available route information. The main advantages of route cache are used to speed up the route discovery process and reduce the propagation of route request. When a node wants to transmit a packet to another node, first it will check the route for a source to the destination in its route cache. If any route is found to a destination, it forwards the packets otherwise it initiates a route discovery process by propagating *RREQ* packet to its neighbouring nodes. In the mean time of *RREQ*, a node will do some other process like sending and receiving of packets from other nodes in the network. Typically the destination node does not forward any *RREQ* because it is the intended destination. *RREG* packet contains Sender's Address, Destination Address and Unique Request ID determined by the sender. While transmitting each node appends its own identifier to the forwarding node. Duplication of *RREQ* is avoided by <*initiator address and request id* > pair. Fig.2 illustrates route discovery process in DSR.There are two probabilities that will arise when a node receives a *RREG* that is a node may be an intermediate node or it may be a destination node.

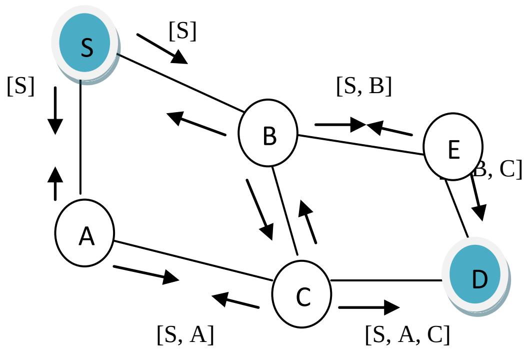


**Fig 2: Route Discovery process**

If it is an intermediate node, the node will perform the following actions, finding of its own address in the *RREQ* packet or if same ID of *RREQ*. In that case a node simple discards the packet otherwise the node appends its own address to the route record of the *RREG* packet and propagating to next hop neighbors. If it is a destination node, it will return a route reply message to the sender with the path where it is stored in its route cache. On receiving *RREP* the sender receives the route in route cache for subsequent uses as well as copy the accumulated route record from *RREQ* into *RPLY* here route reply is done by unicast not by multicast. Once the *RPLY* reaches the source node, the source node the actual data packet along the way to the destination. Fig.3 illustrates route reply process.

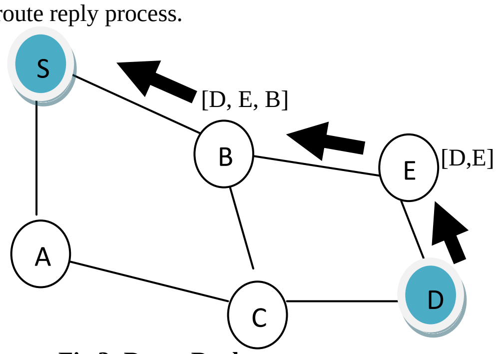


**Fig 3: Route Reply process**

**Send buffer**: when discovering a route, due to lack of route some packets may not be transmitted, those packets will be stored in the send buffer. Each packet which is stored in the send buffer will spend some specific time out period, if the packet not delivered within that time, it will be discarded.

**Route Maintenance**: Route maintenance is achieved by Route Error packet (*RERR*) and acknowledgement from the receiving nodes. When error packet is received from a particular node, the entire routes of the affected node are removed from the route cache of the rest of the nodes. Acknowledgement is achieved by listening to the transmission of active nodes within the network. To ensure this appending a acknowledge bit explicitly is done. If a node fails to receive the bit, it invokes a route discovery process again by sending a route error packet to the sender.

**Optimizations:**

**Route Reply Storms*:*** While discovering a route by *RREQ*, it is possible to receive more than one Route Reply (*RPLY*) to a requested node simultaneously from different nodes, because they have received the *RREQ* at same time. It may cause collision. This problem is called route reply storms. To avoid this, each node should randomly delay sending the route reply.

**Snooping:** At the time of processing, a node may also find some unvisited node. Those nodes' routes also stored in the route cache. This multiple alternative nodes may be used at the time of link failure.

**Salvaging:** when a node finds a route established to a particular destination node is broken hence it generates *RERR* to its upstream node and search if there any alternative routes in its route cache. If found the node modifies the route as per the route cache and forward to next hop node.

**Route Shortening:** Node *S* wants to route a packet to Destination *D* via some intermediate nodes called *A* and *B* hence the path is *S-A-B-D.* In this case node *B* sends a gratuitous massage to Node *S* that has a path to *D.* So instead of using the path *S-A-B-D.* Node S uses *S-B-D* because Node *B* has a route to *D.*

**Spreading of Route Error Messages**: When a node receives a *RERR* message for the *RREQ.* It piggybacks the *RERR* on a new *RREQ* to its neighbouring nodes. It will awake nodes to update their route cache to avoid the stale routes in *RPLY* sent by the neighbours.

**Hop Limits:** Each node has a field called hop limit, it shows the propagation of *RREQ* to the number of hops (i.e.) how many intermediate nodes are allowed to forward the *RREQ*. On receiving this, the node decrements the hop limit by one before forwarding it. When the limit reaches zero the packet will be discarded even if it does not reach the destination.

**Advantages*:*** It is based on the concept of source routing so the intermediate nodes need not to keep the routing information because the entire route information is stored in the packet header, resulting reduce in memory overhead also there is no need of periodic update. Route caching is used to reduce the overhead of route discovery. Discovery of single *RREQ* yields multiple routes to the destination due to multiple replies from the intermediate nodes so it does not affect the propagation even if link failures occur. Reduce in overhead of route maintenance is achieved because route maintenance is done only between nodes that need to communicate.

**Disadvantages*:*** It is not suitable for large networks because if the number of nodes increase, the diameter of the network may also increase due to this the packet header where all the available routing information to reach the destination may also increase hence will consume more bandwidth, also care is needed when collision occurs that is simultaneous replies from intermediate nodes to requested node.

## 5.3 TORA (Temporally Ordered Routing Protocol)

TORA is a highly adaptive on demand routing protocol. It is based on the concept of link reversal. It is a combination of both GB algorithm and LMR algorithm. It derives the *QRY-RPY* mechanism from LMR algorithm and partial link reversal mechanism from GB algorithm. It can find multiple routes from source to the destination node though many topological changes occurs, one route is sufficient. The main feature of TORA is that the control messages are localized to a very small set of nodes near the place of occurrence of a topological change. Because of this reason it is scalable to large network. To achieve this, nodes are always maintaining route information about their adjacent nodes. Each node has a quintuple (*t, oid, r, δ, i*) associated with its height and also exchange their height value with its neighbouring nodes. Timing is one of the considerable factors in TORA because height metrics of any node that depends on the logical link failure (*t*). So every node in TORA has a synchronized clock to achieve this Global Positioning System (GPS). Link is always represented from higher node to a lower node that is the significance of height [13-16]. The height is represents by,

- Logical time of a link failure(*t*)
- The unique ID of the node that defines the new reference level(*oid*)
- A reflection indicator bit(*r*)
- A propagation ordering parameter(*δ*)
- The unique ID of the node(*i*)

From these points, the first three elements represent as reference level. The reference level is defined each time that a node loses its last downstream link due to link failure. Rests of the elements indicate the offset from the reference level. In order to establish the route among the nodes effectively TORA uses three phases, route creation, route maintenance and route erasure

**Route Creation:** To create route from various sources to the destination, first we have to establish a sequences of directed link from each sources to a given destination. For that in this phase nodes use height metrics to establish a Directed Acyclic Graph (DAG) rooted at the destination. *QRY* (Query) and *UPD* (Update) packet is used for building the destination oriented Directed Acyclic Graph (DAG). Initially the height of each node is *NULL* because no information about the neighbours and the height of the destination node is set to *ZERO*. The route creation of TORA is illustrated in the Fig.4.

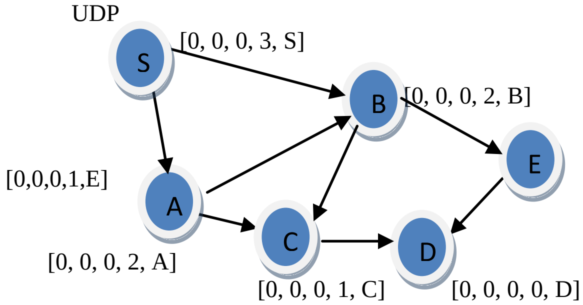


**Fig 4: Route Creation**

If node S wants to create a route to the destination D, it has a *QRY* packet and forwards it to neighbouring nodes. Upon receiving a *QRY* packet each node will perform the following actions,

- If the node itself has no downward link and its route required flag is unset, it forwards *QRY* to its neighboring nodes and sets its route required flag.
- If the node has a download link but its route required flag is set already, in this case it simply discards the *QRY* packet.
- If a node has at least one downward link and also its height is *NULL*, it set the height (-,-,-,-, i) into (t, oid, r, δ+1, i).
- If node has at least one downward link and also its height is Not Null, and if a *UPD* packet has been broadcast since the link over which the *QRY* packet was received became active, it discards the *QRY* packet. Otherwise it broadcasts an *UPD* packet.

The above process will continue until it reaches the destination node. After the successful completion of route creation now the route is available for sending data.

**Route Maintenance:** Due to dynamic nature of the topology, there is a possibility of link failure it causes Directed Acyclic Graph to break down. We are in need of to reconstructing the DAG again. One of the main features of TORA is that when a link fails the control message is propagated only around the point of failure. Unlike other protocols they reinitiate the route discovery process.

**Route Erasure:** This phase will occur when nodes are facing network partition. When a destination node becomes unreachable, it broadcast clear packet (*CLR*) throughout the network in order to erasure the invalid routes.

**Advantages:** TORA is scalable to large network because of propagation of control messages only around the point of failure when link failure occurs and also it causes reduction in bandwidth overhead. TORA is also loop free. TORA support multiple routes from source to the destination. Even if link failure occurs between a pair of nodes, it does not affect the process due to alternative routes are in hand.

**Disadvantage:** Each node in TORA the height depends on the logical time of link failure as it is mentioned earlier. So if a node does not have Global Positioning System [17] or some other external time sources the algorithm will fail. It will affect the entire routing process. Sometimes there is a possibility of temporary loops. Each node in the network expect constant coordination with neighbouring nodes, so in order to detect topology changes and converge it causes high bandwidth and CPU requirements.

# 6. COMPARISON

The following table compares the properties of these three routing protocols [18-21].

| | AODV | DSR | TORA |
|---|---|---|---|
| **Routing Structure** | Flat | Flat | Flat |
| **Loop Free** | Yes | Yes | Yes |
| **Multiple Routes Availability** | No | Yes | Yes |
| **Routing information Maintain** | Route table | Route Cache | Route Table |
| **Route Error** | Delete Route, Intimate to source | Delete Route, Intimate to source | Link reversal, Attempt to route repair |
| **Timing expire** | Yes | No | No |
| **Route Creation** | By source | By source | By source |
| **Throughput** | High | Low | Low |

# 7. CONCLUSION

In this paper the major routing protocols proposed for Mobile Ad hoc Network are discussed. The main goal of routing protocol is efficient and accurate route establishment between pair of nodes. In order to achieve this, every protocol in MANET should meet the design goal of its own. These things are also discussed. We have studied and discussed the three on demand routing protocols**.** Every protocol in MANET has its own set of advantage and disadvantage. Accordingly AODV, DSR and TORA have their own characteristics. Classification of various routing protocols was also discussed. We conclude that the performance of DSR in large network is poor. But AODV routing overhead is high compared to DSR, the performance of AODV is good in all types of networks. At the same time if we compare these two protocols with TORA, it provides better performance because the control message is propagated only around the point of failure. So it is highly adaptive for large networks. In future we would like to study all the routing protocols and analyze their performance through simulation for different types of applications.

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