A Review of On-Demand Routing Protocols for Mobile Ad-Hoc Networks

*Vivek Sharma, *Sujit Jhare, **Divakar Singh
*School of Computer Science, BUIT, Bhopal
**HOD, School of Computer Science, BUIT, Bhopal
*vivek.rgtu@gmail.com, *sujit.jhare@gmail.com, **divakar_singh@rediffmail.com

Abstract: ***Wireless ad-hoc networks have gained a lot of importance in wireless communications. Wireless communication is established by nodes acting as routers and transferring packets from one to another in ad-hoc networks. Routing in these networks is highly complex due to moving nodes and hence many protocols have been developed. Mobile ad hoc networks are networks without fixed infrastructure. The mobile nodes perform both as a host and a router forwarding packets to other nodes. Due to the special nature of ad hoc networks, there are special demands for ad hoc routing protocols. Performance is also an interesting issue for different protocols. This paper describes some special characteristics of ad hoc on-demand routing protocols like DSR, AODV, DYMO, LAR and TORA, with their performance measurements and study of working of these protocols.***

Keywords: ***Ad Hoc Networks, routing protocol, DYMO, DSR, AODV, TORA, LAR.***

I. Introduction

A mobile ad-hoc network (MANET) [1] is a collection of nodes, which are able to connect on a wireless medium forming an arbitrary and dynamic network. Implicit in this definition of a network is the fact that links, due to node mobility and other factors, may appear and disappear at any time. This in a MANET implies that the topology may be dynamic - and that routing of traffic through a multi-hop path is necessary if all nodes are to be able to communicate.

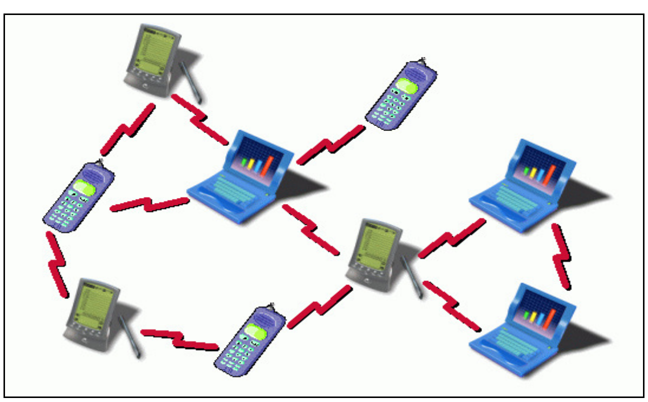


Figure 1: Ad-hoc Network

A key issue in MANETs is the necessity that the routing protocols must be able to respond rapidly to topological changes in the network. At the same time, due to the limited bandwidth available through mobile radio interfaces, it is imperative that the amount of control traffic, generated by the routing protocols is kept at a minimum.

On-demand routing protocols were designed with the aim of reducing control overhead, thus increasing bandwidth and conserving power at the mobile stations. These protocols limit the amount of bandwidth consumed by maintaining routes to only those destinations for which a source has data traffic. Therefore, the routing is source-initiated as opposed to table-driven routing protocols that are destination initiated.

In recent years, several wireless routing protocols are designed to provide communication in wireless environment, such as AODV [4], OLSR [1], DSDV [3], ZRP [10], LAR [11], DYMO [8] etc. Comparative study among some set of routing protocols are already performed by the researchers such as among DSDV, DSR, AODV, and TORA [2] , among DSR and AODV [4], among LAR, AODV and DSR [2], among DSR, TORA and AODV [2] , among DSDV, DYMO and AODV [8] and many more. These comparative are carried out on ad hoc networks. Therefore, evaluating the performance of reactive routing protocols in wireless network environment is still an active research area and in this paper, study of on-demand routing protocol will be presented and describe the protocol, as well as expose some of the protocol's basic characteristics and parameters through tabular study.

The rest of this paper is organized as follows. Section II briefly describes the ad-hoc routing protocols. Section III discusses the most important on-demand routing protocols. Section IV presents a comparative study of various protocols. Section V represents a conclusion of the paper.

II. Ad-Hoc Routing Protocols

In an ad-hoc network, mobile nodes communicate with each other using multihop wireless links. There is no stationary infrastructure; for instance, there are no base stations. Each node in the network also acts as a router, forwarding data packets for other nodes. A central challenge in the design of ad hoc networks is the development of dynamic routing protocols that can efficiently find routes between two communicating nodes. The routing protocol must be able to keep up with the high degree of node mobility that often changes the network topology drastically and unpredictably. Several routing protocols have been developed for ad hoc mobile networks [2]. Such protocols must deal with typical limitations of these networks which include high power consumption, low bandwidth and high error rates. As figure 1 shows the categorization of these routing protocols.

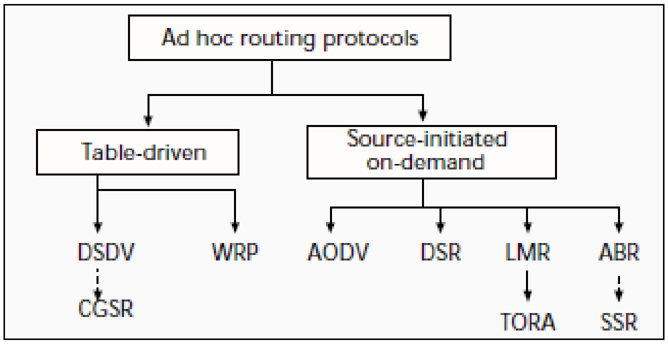


Figure 2: Categorization of ad-hoc routing protocol

A) Table-Driven Routing Protocols

Table-driven routing protocol [5] attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. These protocols require each node to maintain one or more tables to store routing information, and they respond to changes in network topology by propagating updates routes through out the network in order to maintain a consistent network view.

B) On Demand-Driven Routing Protocols

A different approach from table-driven routing is on-demand routing [5] [6]. This type of routing creates routes only when desired by source node. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible routes permutations have been examined. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes inaccessible along every path from the source or until the route is no longer desired.

C) Hybrid Routing Protocols

Based on combination of both table and demand driven routing protocols, some hybrid routing protocols are proposed to combine advantage of both proactive and reactive protocols. The most typical hybrid one is zone routing protocol [10].
As to the major division of routing protocols, Table 1 gives a comparison of table-driven, demand-driven and hybrid Routing Protocol.

Characteristics	Table-Driven	Demand-Driven	Hybrid
Network Organization	Flat Hierarchical	Flat	Hierarchical
Topology Dissemination	Periodical	On-Demand	Both
Route Latency	Always Available	Available when needed	Both
Mobility Handling	Periodical Updates	Route Maintenance	Both
Communication Overhead	High	Low	Medium

Table 1: Comparison of Routing

III. On-demand Routing Protocols

A) Ad hoc On-demand Distance Vector (AODV):

AODV [4] [6] [9] shares DSR on-demand characteristics, discovers routes on an as needed basis via a similar route discovery process. Ad hoc On-demand distance vector (AODV) is another variant of classic distance vector routing algorithm, based on DSDV and DSR. However, AODV adopts traditional routing tables; one entry per destination which is in contrast to DSR that preserves multiple route cache entries for each destination. The early design of AODV is undertaken after the experience with DSDV routing algorithm. Like DSDV, AODV provides loop free routes in case of link breakage but unlike DSDV, it doesn't need global periodic routing advertisement. AODV uses a broadcast route discovery algorithm and then the unicast route reply massage. There are two mechanism used in AODV, first is route discovery and second is route maintenance.
When a node wants to send a packet to some destination and does not have a valid route in its routing table for that destination, initiates a route discovery. Source node broadcasts a route request (RREQ) packet to its neighbors, which then forwards the request to their neighbors and so on. To control network-wide broadcasts of RREQ packets, the source node use an expanding ring search technique.

a) Source node S initiates the path discovery process
b) A RREP packet is sent back to the source

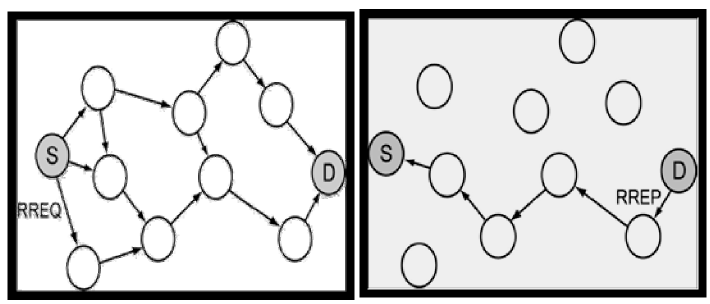


Figure 3: AODV Path Discovery Process

In this technique, source node starts searching the destination using some initial time to live (TTL) value. If no reply is received within the discovery period, TTL value incremented by an increment value. This process will continue until the threshold value is reached. When an intermediate node forwards the RREQ, it records the address of the neighbor from which first packet of the broadcast is received, thereby establishing a reverse path. When the RREQ reaches a node that is either the destination node or an intermediate node with a fresh enough route to the destination, replies by unicasting the route reply (RREP) towards the source node. As the RREP is routed back along the reverse path, intermediate nodes along this path set up forward path entries to the destination in its route table and when the RREP reaches the source node, a route from source to the destination establish.

In route maintenance, a route established between source and destination pair is maintained as long as needed by the source. If the source node moves during an active session, it can reinitiate route discovery to find out a new route to destination. However, if the destination or some intermediate node moves, the node upstream of the break remove the routing entry and send route error (RERR) message to the affected active upstream neighbors. These nodes in turn propagate the RERR to their precursor nodes, and so on until the source node is reached. The affected source node may then choose to either stop sending data or reinitiate route discovery for that destination by sending out a new RREQ message.

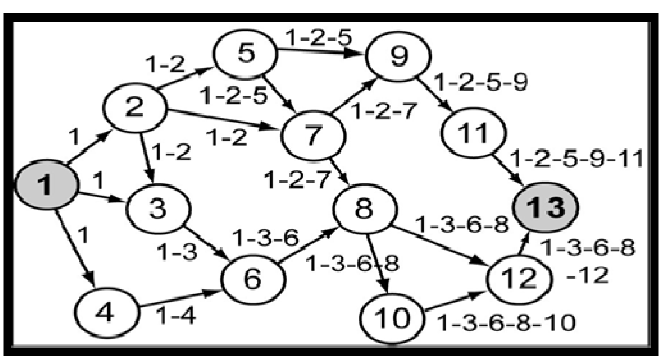
B) Dynamic Source Routing (DSR):

The Dynamic Source Routing (DSR) [6] [7] is one of the purest examples of an on-demand routing protocol that is based on the idea of source routing. It is designed specially for use in multihop ad hoc networks for mobile nodes. It allows the network to be completely self-organizing and self-configuring and does not need any existing network infrastructure or administration. DSR uses no periodic routing messages like AODV, thereby reduces network bandwidth overhead, conserves battery power and avoids large routing updates. Instead DSR needs support from the MAC layer to identify link failure. DSR is composed of the two mechanisms of Route Discovery and Route Maintenance, which work together to allow nodes to discover and maintain source routes to arbitrary destinations in the network.

The Dynamic Source Routing protocol also allows mobile sources to dynamically discover paths towards any desired destination. Every data packet includes a complete list of nodes, which the packet must pass before it reaches the destination. Hence, all nodes that forward or overhear these packets may store routing information for future use. DSR can support fast network topology changes and service even asymmetric links; it can successfully find paths and forward packets in unidirectional link environments. Moreover, like AODV, it has a mechanism for on-demand route maintenance, so there are no periodic topology update packets. When link failures occur, only nodes that forward packets through those links must receive proper routing advertisements. In addition, DSR allows source nodes to receive and store more than one path towards a specific destination. Intermediate nodes have the opportunity to select another cached route as soon as they are informed about a link failure.

A source that desires to send data to a particular destination, first checks to verify that it has a route in its cache for that destination. If it does, it will use that route by placing (in the data packet header) the sequence of hops that the packet must follow to reach the destination. If there is no such route stored in the local cache, then the source will initiate a new path discovery process, by broadcasting a Route Request to its neighborhood.

(a) Building of the route record.
(b) Propagation of the route reply



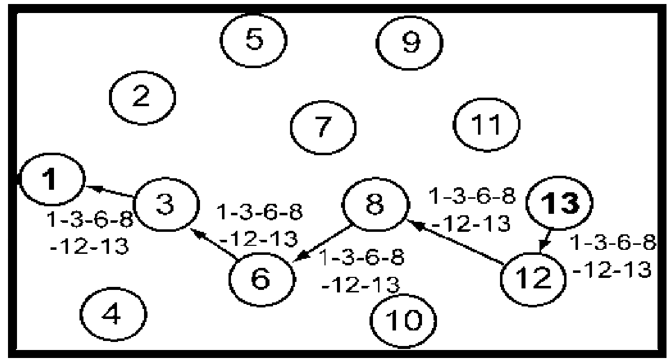


Figure 4: DSR Route Discovery Process

This message contains the source and destination addresses, a request ID and an ordered intermediate node address list, through which this message has passed. This node list is initially blank when the message leaves the source node (it has not yet visited any other node). Thereafter, every other node that receives this request message parses it to see if it is the intended destination. If it is, it will reply with a Route Reply back to the source, after attaching the list with all intermediate nodes through which the request message passed. If it is not and has already received a similar request with the same ID from the same source, it will discard this request message. If it is not and it sees that its own address is included in the message list, it will discard this request message. Else it will append its own address in this list and then it will further broadcast it to its neighbors.

C) The Dynamic MANET On-demand (DYMO):

The Dynamic MANET On-demand (DYMO) [8] [2] routing protocol is a simple and fast routing protocol for multihop networks. It discovers unicast routes among DYMO routers within the network in an on-demand fashion, offering improved convergence in dynamic topologies. To ensure the correctness of this protocol, digital signatures and hash chains are used [14]. The basic operations of the DYMO protocol are route discovery and route management. The following sections explain these mechanisms in more details.

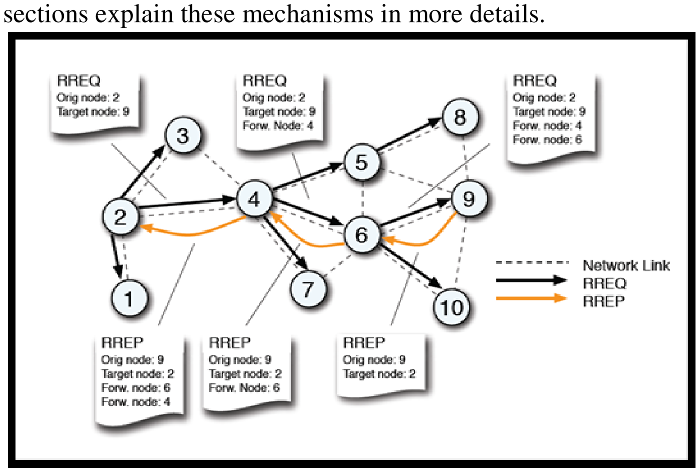


Figure 5: DYMO Route discovery

When a source needs to send a data packet, it sends an RREQ to discover a route to that particular destination. After issuing an RREQ, the origin DYMO router waits for a route to be discovered. If a route is not obtained within RREQ waiting time, it may again try to discover a route by issuing another RREQ. To reduce congestion in a network, repeated attempts at route discovery for a particular target node should utilize an exponential backoff. Data packets awaiting a route should be buffered by the source's DYMO router. This buffer should have a fixed limited size and older data packets should be discarded first. Buffering of data packets can have both positive and negative effects, and therefore buffer settings should be administratively configurable or intelligently controlled. If a route discovery has been attempted maximum times without receiving a route to the target node, all data packets intended for the corresponding target node are dropped from the buffer and a Destination Unreachable ICMP message is delivered to the source. When a data packet is to be forwarded and it can not be delivered to the next-hop because no forwarding route for the IP Destination Address exists; an RERR is issued. Based on this condition, an ICMP Destination Unreachable message must not be generated unless this router is responsible for the IP Destination Address and that IP Destination Address is known to be unreachable. Moreover, an RERR should be issued after detecting a broken link of a forwarding route and quickly notify DYMO routers that a link break occurred and that certain routes are no longer available. If the route with the broken link has not been used recently, the RERR should not be generated.

D) Temporally ordered routing algorithm (TORA)

The TORA [3] [7] routing protocol is based on the LMR protocol. The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive loop-free distributed routing algorithm based on the concept of link reversal. TORA is proposed to operate in a highly dynamic mobile networking environment. It is source-initiated and provides multiple routes for any desired source/destination pair. The key design concept of TORA is the localization of control messages to a very small set of nodes near the occurrence of a topological change. To accomplish this, nodes need to maintain routing information about adjacent (one-hop) nodes. The protocol performs three basic functions:

- Route creation
- Route maintenance
- Route erasure

During the route creation and maintenance phases, nodes use a “height” metric to establish a directed acyclic graph (DAG) rooted at the destination. Thereafter, links are assigned a direction (upstream or downstream) based on the relative height metric of neighboring nodes, as shown in Figure 6. This process of establishing a DAG is similar to the query/reply process proposed in Lightweight Mobile Routing (LMR). In times of node mobility the DAG route is broken, and route maintenance is necessary to reestablish a DAG rooted at the same destination. As shown in Fig. 5b, upon failure of the last downstream link a node generates a new reference level which results in the propagation of that reference level by neighboring nodes, effectively coordinating a structured reaction to the failure. Links are reversed to reflect the change in adapting to the new reference level.

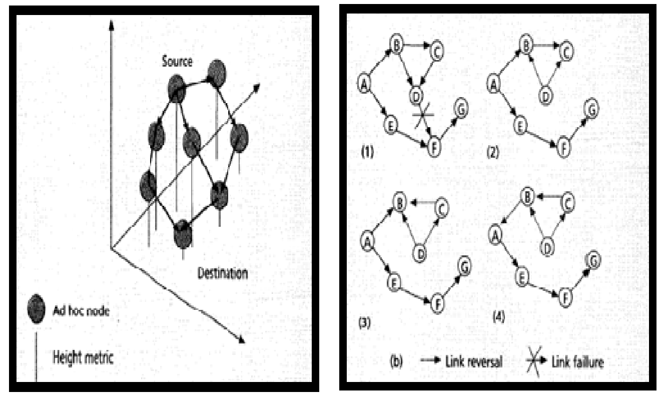


Figure 6: TORA (Temporary Ordered Routing Algorithm)

Timing is an important factor for TORA because the “height” metric is dependent on the logical time of a link failure; TORA assumes that all nodes have synchronized clocks (accomplished via an external time source such as the Global Positioning System). TORA’s metric is a quintuple comprising five elements, namely:

- Logical time of a link failure
- The unique ID of the node that defined the new reference level
- A reflection indicator bit
- A propagation ordering parameter
- The unique ID of the node

E) Location Aided Routing (LAR)

Routing overhead can be decreased, by giving location information to the mobile terminals, with use of the Global Positioning System (GPS) for route discovery. Two Location-Aided Routing algorithms that use location information have been proposed [11] [3], showing how a route discovery protocol, based on flooding, can be improved. If a node S wants to send data to a node D, for which it knows the previous location L at time t0 and node D’s speed u, then S expects that D will be located within an “expected zone” at time t1, a circular area of radius u(t1- t0) and center L. If node S does not know the previous location L, then the “expected zone” for node D will be considered as the whole network geographical region and the algorithm will follow the basic flooding as in the DSR algorithm.

The two LAR algorithms in [11] [3] use flooding with one modification; the source node S defines a “request zone” for the route request. An intermediate node will forward the request message, only if it is located within the request zone. If the request zone includes the expected zone, the probability of finding node D will be increased. The request zone may also include other neighboring request zones. The two schemes give terminals the capability of determining whether they belong to a requested zone or not, so as to know if they should forward certain route request messages. The interested reader may find more details in [11], wherein both schemes are simulated and evaluated.

IV. Comparative Study of Protocols

Performance Constraint	AODV	DSR	TORA
Routing Philosophy	Flat	Flat	**Flat**
Loop Free	Yes	Yes	**Yes**
Route Maintained in	Route Table	Route Cache	**Route Table**
Multicast Capability	Yes	No	**No**
Route reconfiguration methodology	Erase Route notify Source	Erase Route notify Source	**Link reversal route repair**
Multiple Route Possible	No	Yes	**Yes**
Beaconing Requirements	**No**	**No**	**No**

Table 2: Comparison of on- demand Routing Protocols

V. Quantitative Metrics for Performance Evaluation

The following is a list of quantitative metrics that can be used to assess the performance of any routing protocol.

1) ***End–to-End throughput and delay [2]:*** Statistical measures of data routing performance (e.g. means, variances, distributions) are important. These are the measure of routing policy's effectiveness how well it does its jobs as measured from the external perspective of other policies that make use of routing.
2) ***Routing Acquisition Time [1]:*** A particular form of external End-to-End delay measurement of particular concern with "on demand" routing algorithms is the time required to establish the route when requested.
3) ***Percentage out of order Delivery [6]*:** An external measure of connectionless routing performance of particular interest to transport layer protocols such as TCP which prefer in order delivery.
4) ***Packet Delivery Ratio [4]:*** Packet delivery ratio is calculated by dividing the number of packets received by the destination through the number of packets originated by the application layer of the source (i.e. CBR source). It specifies the packet loss rate, which limits the maximum throughput of the network. The better the delivery ratio, the more complete and correct is the routing protocol.
5) ***Energy Consumption [5] :*** Energy consumption, is used to rate the energy used by the routing protocol, how much energy have consumed by the routing, we will analyze and compared with these two protocol algorithm with effects and changes in transmission interval of time.
6) ***Efficiency [1]:*** If data routing effectiveness is the external measure of a policy's performance, efficiency is the internal measure of its effectiveness. To achieve a given level of data routing performance, two different polices can expand differing amounts of overhead, depending on their internal efficiency. Protocol efficiency may or may not directly affect data routing performance. If control and data traffic must share the same channel, and the channel capacity is limited, then excessive control traffic often impacts data routing performance.

VI. Conclusion

This paper presents a brief description of several routing protocols which are proposed for ad-hoc mobile networks and also provides a classification of these protocols according to the routing strategy (i.e. table driven, on-demand and hybrid routing protocol). It has also presented a comparison of currently on-demand routing protocol, and reveals their features, differences and characteristics. The field of ad-hoc mobile networks is rapidly growing and changing and while it is not clear that any particular algorithm or class of algorithm is the best for all environment , each protocol has definite advantages and disadvantages , and is well suited for certain situations.

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