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Comparative Study of Routing Protocols in Wireless Mobile Ad Hoc Networks

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***Abstract*- A mobile ad hoc network (MANET) is a collection of wireless mobile nodes that are self organizing and self configuring multi hop wireless networks and the topology of network changes dynamically. This is mainly due to mobility of nodes. There are several routing protocols have been proposed for mobile ad hoc network and prominent among them are AODV, DSR, DSDV, TORA, and ZRP. This research paper provides these protocols by presenting their characteristics, functionality, benefits and limitation and then makes their comparative analysis to analyze their performance. The main objective is to make observations how the performances of the protocols can be improved**.

Index keywords- MANET, AODV, DSR, DSDV, TORA, ZRP

1. Introduction

A mobile ad hoc Network [MANETs] is a technology which involves the communication of various hosts which are themselves act as routers and has capability to establish networks at any time. These are mainly classified into two categories: Infrastructure and infrastructure less. In infrastructure wireless networks, while communication the mobility of nodes occurs but the base stations are centralized and fixed. It contains the centralized routing as the nodes goes out of the range of the base station, it enters into the range of another base station. As shown below, in Fig.1. In infrastructure less or Ad hoc wireless network, while communication the mobility of nodes occurs but there are no fixed centralized base stations and all the nodes are act as a router. The mobile nodes dynamically establish their route as the path break or path change occurs. As shown in Fig. 2. Nowadays a lot of research effort focuses on the Mobile Ad hoc networks.

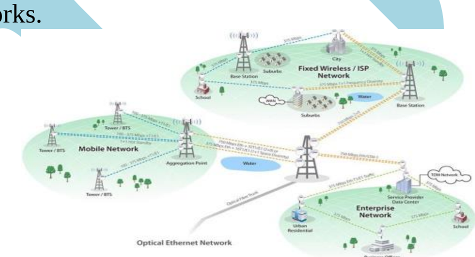

fig. 1 Infrastructure Wireless network

MANETs have a dynamic topology where links are formed and broken with time. These links can be unidirectional or bi-directional. It has high level of dynamic, reliable, fast and energy efficient routing of data packets from the source to the destination. Routing in MANETs involves designing a protocol which helps using routing data packets from source to destination with minimum possible hops and minimum battery power consumption of nodes.

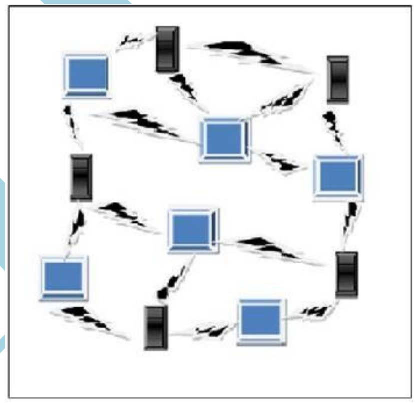

Fig 2. Ad hoc wireless network

2. Routing Protocols

Since the ad hoc wireless network consist of a set of mobile nodes (hosts) that are connected by wireless links, the network topology in such a network may keep changing randomly. Hence a variety of routing protocols for ad hoc wireless network has been proposed.

Basically, routing protocol can be broadly divided classified into three types as (a) Table driven protocols or Proactive Protocols (b) On-demand protocols or Reactive Protocols and (c) Hybrid Protocols.

A. **Table Driven or Proactive Protocols**, in which each node maintains one or more tables containing routing information to every other node in the network [1]. DSDV [4], [7], WRP [20] and ZRP [26], [27]. It runs an appropriate path-finding algorithm on the topology information it maintains.
B. **On Demand or Reactive Protocols**, protocols that fall under this category do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. Hence these protocols do not

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exchange routing information periodically [5]. DSR [6], [8], AODV [14], [28] and TORA [21], [22].

C. **Hybrid Protocols**, it is best feature of combination of Proactive and Reactive Protocols (as discussed above), for routing within a Zone, a table driven approach is used and nodes which are located beyond this zone are used on-demand approach.

The emphasis in this research paper is concentrated on the survey and comparison of various On Demand/Reactive Protocols and Hybrid protocols such as DSR, AODV and TORA, DSDV and ZRP as these are best suited for Ad Hoc Networks. The next sub-section describes the basic features of these protocols.

3. Destination Sequenced Distance –Vector Routing Protocol(DSDV)

DSDV is the enhanced version of distributed Bellman-Ford Algorithm where each node maintains the table that contains the shortest distance and the first node on the shortest path to every other node in the network. As each node maintains a routing table that lists the available destinations, the number of hops to reach the destination and the sequence number assigned by destination node table.

The tables are exchanged between neighbors at regular interval to keep up-to-date view of the network topology. Table updates are initiated by a destination with a new sequence number in which is always greater than the previous one.

The sequence number is used to distinguish old routes from New ones and thus avoid the formation of loops. Consistent Routing tables are maintained by updating them periodically. The stations periodically transmit routing tables to their immediate neighbors. A station also transmits its routing table if a significant change has occurred in its table from the last update sent. So, the update is both time-driven and event-driven. The routing table updates can be sent in two ways a full dump or an incremental update. A full dump sends the full routing table to the neighbors and could span many packets whereas in an incremental update only those entries from the routing table are sent that have a metric change since the last update. If there is space in the incremental update packet then those entries may be included whose sequence number has changed. When the network is relatively stable, incremental updates are sent to avoid extra traffic and full dump are relatively less frequent. In the dynamic network, incremental packets can grow big so full dumps will be more frequent.

The advantage of DSDV is less delay is involved in the route setup process. And updates are propagated throughout the network in order to maintain the up-to-date network topology at all nodes.

4. Dynamic Source Routing(DSR)

Dynamic Source Routing is an Ad Hoc routing Protocol which is based on the theory of source- based Routing rather than table based. It is beacon-less and does not required periodic hello packet Transmission. The Basic Approach is to establish a route by flooding RouteRequest Packets in the network. Then the Destination node respond to route request by sending a Route Reply packet to the source. During the process of transmission of packets each RouteRequest carries a Sequence number generated by the source node and the path it has traversed. The node checks this sequence number before forwarding it. It examined that the RouteRequest should not be duplicate before forwarding it further.

The Sequence number on the packet is used to prevent from loop formations and to avoid multiple transmissions. The source node chooses the best and shortest route and uses that for sending Packets. Each data Packet carries the complete path to the destination. In case if any path brake occurs then the source node initiate the route discovery process.

One of 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.

5. Ad Hoc On Demand Distance Vector(AODV)

AODV is a variation of Destination-Sequenced Distance-Vector (DSDV) routing protocol which is based on DSDV and DSR. It aims to minimize the requirement of system-wide broadcasts to its extreme. It does not maintain routes from every node to every other node in the network rather they are discovered as and when needed & are maintained only as long as they are required. The key steps of algorithm used by AODV for establishment of unicast routes are explained below.

A. Route Establishment

When a node wants to send a data packet to a destination node, the entries in route table are checked to ensure whether there is a current route to that destination node or not. If it is there, the data packet is forwarded to the appropriate next hop toward the destination. If it is not there, the route discovery process is initiated. AODV initiates a route discovery process using Route Request (RREQ) and Route Reply (RREP). The source node will create a RREQ packet containing its IP address, its current sequence number, the destination's IP address, the destination's last sequence number and broadcast ID. The broadcast ID is incremented each time the source node initiates RREQ. Basically, the sequence numbers are used to determine the timeliness of each data packet and the broadcast ID & the IP address together form a unique identifier for RREQ so as to uniquely identify each request. The requests are sent using RREQ message and the information in connection with creation of a route is sent back in RREP message. The source node broadcasts the RREQ packet to its neighbors and then sets a timer to wait for a reply.

To process the RREQ, the node sets up a reverse route entry for the source node in its route table. This helps to know how to forward a RREP to the source. Basically a lifetime is associated with the reverse route entry and if this entry is not used within this lifetime, the route information is deleted. If the RREQ is lost during transmission, the source node is allowed to broadcast again using route discovery mechanism.

B. Expanding Ring Search Technique

The source node broadcasts the RREQ packet to its neighbors which in turn forwards the same to their neighbors and so forth. Especially, in case of large network, there is a need to control network-wide broadcasts of RREQ and to control the same; the source node uses an expanding ring search technique. In this technique, the source node sets the Time to Live (TTL) value of the RREQ to an initial start value. If there is no reply within the discovery period, the next RREQ is broadcasted with a TTL value increased by an increment value. The process of incrementing TTL value continues until a threshold value is reached, after which the RREQ is broadcasted across the entire network. When the destination node or an intermediate node with a route to the destination receives the RREQ, it creates the RREP and unicast the same towards the source node using the node from which it received the RREQ as the next hop. When RREP is routed back along the reverse path and received by an intermediate node, it sets up a forward path entry to the destination in its routing table. When the RREP reaches the source node, it means a route from source to the destination has been established and the source node can begin the data transmission.

C. Route Maintenance

A route discovered between a source node and destination node is maintained as long as needed by the source node. Since there is movement of nodes in mobile ad hoc network and if the source node moves during an active session, it can reinitiate route discovery mechanism to establish a new route to destination. Conversely, if the destination node or some intermediate node moves, the node upstream of the break initiates Route Error (RERR) message to the affected active upstream neighbors/nodes. Consequently, these nodes propagate the RERR to their predecessor nodes. This process continues until the source node is reached. When RERR is received by the source node, it can either stop sending the data or reinitiate the route discovery mechanism by sending a new RREQ message if the route is still required.

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.

6. Temporary Ordered Routing Protocol(TORA)

TORA is a Source-Initiated on-demand routing protocol. It basically used the link reversal algorithm. It attempts to achieve a high degree of scalability used a non-hierarchical routing algorithm. In its operation the algorithm attempts to suppress, to the greatest extent possible, the generation of far-reaching control message propagation. In order to achieve this, the TORA does not use a shortest path solution, an approach which is unusual for routing algorithms of this protocol.

The key design concepts of TORA is 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 the routing information about adjacent (one hop) nodes.

TORA basically has three main functions:

1. Route establishing
2. Route maintaining
3. Erasing routes.

The route establishment function is performed only when a node requires a path to a destination but does not have any directed link. This process establishes a destination-oriented directed acyclic graph using a query/update mechanism. Once the path to the destination is obtained, it is considered to exist as long as the path is available, irrespective of the path length changes due to the re-configurations that may take place during the course of data transfer session. If the node detects a partition, it originated a clear message, which erases the existing path information in that partition related to the destination

TORA metric is quintuple comprising five elements namely:

1. Logical time of link failure
2. Unique ID of the node that defined the new reference level.
3. Replication indicator bit
4. Propagation ordering parameter
5. Unique ID of the nodes

The first three elements collectively represent the reference level. A new reference level is defined each node loses its last downstream link due to a link failure. Finally erasure phase essentially involves the flooding a broadcast "clear packet". Throughout the network to erase invalid routes.

It mainly incurs the less control overheads and detects the concurrent partitions. Failure or removal of any of the nodes is quickly resolved without source intervention by switching to an alternate route. But 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

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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.

7. Zone Routing Protocol(ZRP)

It effectively combines the best features of both Proactive and Reactive routing protocols. It uses Proactive scheme within a limited zone in the r-hop neighborhood of every node and use reactive routing scheme for nodes beyond the zone. An Intra-Zone Routing Protocol (IARP) is used in the zone where a particular node employs proactive routing and Reactive Routing used beyond his zone is referred as Inter-Zone Routing Protocol (IERP).

Route establishment, when a node has packets to be sent to a destination node, it first to check whether the destination node is in Zone or not. If it finds the node in its own zone then it directly send the packets to the destination node, otherwise broadcast the RouteRequest to its peripheral nodes. If any peripheral node finds destination node to be located within its routing zone, it sends a RouteReply back to node which indicating the path; otherwise, the node rebordercasts the RouteRequest packet to the peripheral nodes. This process continues until destination node is located. During RouteRequest propagation, every node that forwards the RouteRequest appends its address to it. This information is used for delivering the RouteReply packet back to the source. The criteria for selecting the best path may be the shortest path, least delay path etc.When an intermediate node in an active path detects a broken link in the path, it performs a local path reconfiguration in which the broken link is bypassed by means of a short alternate path connecting the ends of the broken link. A path update message is then sent to the sender node .This results in sub-optimal path between two end points.

8. Performance Metrics & Analysis

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.

Performance / constraints	PROTOCOLS				
	DSDV	AODV	DSR	TORA	ZRP
Category	Table-driven or proactive	On-Demand or Reactive	On-Demand or Reactive	On-Demand or Reactive	Hybrid
Protocol Type	Link State	Distance Vector	Source Routing	Link Reversal	Link Reversal
Loop Freedom	Yes	Yes	Yes	No	Yes
Multiple Routes	No	No	Yes	No	Yes
Route Mechanism	Flat	Flat	Flat	Flat	Flat
Multicast	Yes	Yes	No	No	No
Requires Sequence Data	No	Yes	No	Yes	Yes
Route Maintenance	Route Table	Route Table	Route Cache	Route Table	Route Cache
Method	Unicast	Unicast	Unicast	Broadcast	Broadcast
Message Overhead	Minimum	Moderate	Moderate	Moderate	Moderate
Routing Metrics	Shotest Path	Shortest Path	Shortest Path	Shortest Path	Shortest Path
Update Period	Table-Driven	Event-Driven	Event-Driven	Table-Driven	Event-Driven
Summary	Control Message for Link Sensing, Neighbor(MPR) Detection, Multiple Interface Detection, Route calculation	Route Discovery, Expanding Ring Search, Setting Forward Path	Route Discovery, Expanding Ring Search, Setting Forward Path	Route Update Packets	Link Reversal,Route Discovery, Route Pakets

Table 1: Comparison of different routing protocols

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.

1) **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.
2) **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.
3) **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.
4) **Packet Delivery Ratio:** The ratio between the amount of incoming data packets and actually received data packets.
5) **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.

Given table evaluates that TORA and ZRP performs better than other cases. AODV is still performs better in route updating and route maintenance process.

9. Conclusions

It has been observed that the performance of all protocols studied was almost stable and in sparse medium with low traffic ZRP finds much better in packet delivery owing to selection of better routes with less control overheads. The analysis indicates the AODV keeps on improving with denser medium and at faster speed.

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It has been further concluded that due to the dynamically changing topology and infrastructure less, decentralized characteristic is hard to achieve in mobile ad hoc networks. The focus of the study is on these issues in our future research work and effort will be made to propose a solution for routing in Ad Hoc networks by tackling these core issues of security.

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