Performance Evaluation and Comparison of AODV, DSR and TORA Routing Protocols in Wireless Mesh Networks

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Abstract-A Wireless Mesh Network (WMN) is a collection of wireless radio nodes dynamically forming a network topology without the use of any existing network infrastructure or centralized administration. Routing is the process which transmitting the data packets from a source node to a given destination. The main classes of routing protocols are Proactive, Reactive and Hybrid. A Reactive (on-demand) routing strategy is a popular routing category for wireless ad hoc routing. In this paper work an attempt has been made to compare the three Reactive (on-demand) routing protocols for WMN: - Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) protocols, Temporally Ordered Routing Algorithm (TORA).

Keywords: WMN, Routing protocol, AODV, DSR, TORA

I. INTRODUCTION

A Wireless Mesh Network (WMN) is a communication network made up of radio nodes organized in a mesh topology. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may, but need not, connect to the Internet. The coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. Access to this mesh cloud is dependent on the radio nodes working in harmony with each other to create a radio network. A mesh network is reliable and offers redundancy. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes.This paper describes a comparative study of Reactive routing protocols AODV, DSR, TORA for ad hoc networks.

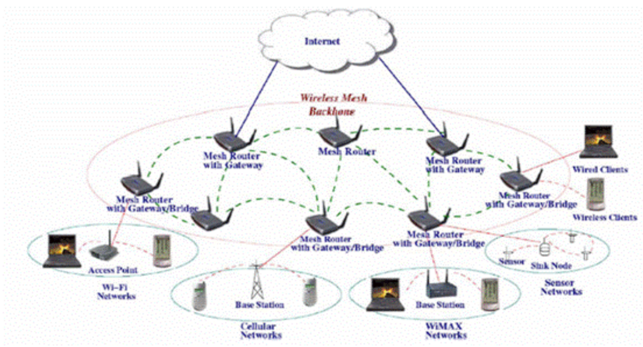

Figure 1.1 Wireless Mesh Network

II. CLASSIFICATIONOF REACTIVE PROTOCOLS

The figure 1 shows the prominent way of classifying WMN routing protocols. The protocols may be categorized into two types, Proactive and Reactive. Other category of WMN routing protocols which is a combination of both proactive and reactive is referred as Hybrid.

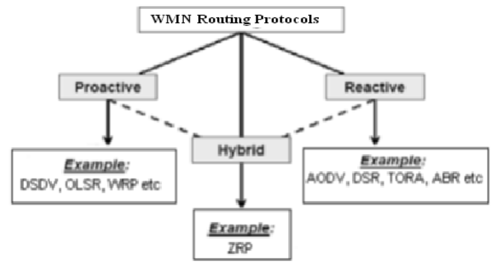

Figure 2.1 Classification of WMN routing protocols

A. Proactive routing (Table- Driven) protocols: Table-driven routing protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. The routing information is kept in a number of different tables and they respond to changes in network topology by propagating updates throughout the network in order to maintain a consistent network view. The areas in which these protocols differ are the way the routing information is updated, detected and the type of information kept at each routing table.

B. Reactive Routing (On-Demand) protocols: On-demand routing protocols were designed to reduce the overheads in Table-Driven protocols by maintaining information for active routes only. 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 route 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. Route discovery usually occurs by flooding a route request packets through the network. When anode with a route to the destination (or the destination itself) is reached a route reply is sent back to the source node usinglink reversal if the route request has traveled through bidirectional links or by piggy-backing the route in a route replypacket via flooding. On-Demand routing protocols can be classified into two categories: source routing and hop-by-hop routing. In Source routed on-demand protocols each data packets carry the complete path from source to destination. Therefore, each intermediate node forwards these packets according to the information in the header of each packet. The major drawback with source routing protocols is that in large networks they do not perform well. This is due to two main reasons; firstly as the number of intermediate nodes in each route grows, then so does the probability of route failure. Secondly, as the number of intermediate nodes in each route grows, then the amount of overhead carried in each header of each data packet will grow as well. In hop-by-hop routing each data packet only carries the destination address and the next hop address. Therefore, each intermediate node in the path to the destination uses its routing table to forward each data packet towards the destination. The advantage of this strategy is that routes are adaptable to the dynamically changing environment of MANETs, since each node can update its routing table when they receiver fresher topology information and hence forward the data packets over fresher and better routes. Using fresher routes also means that fewer route recalculations are required during data transmission. The disadvantage of this strategy is that each intermediate node must store and maintain routing information for each active route and each node may require being aware of their surrounding neighbors through the use of beaconing messages.

C. Hybrid routing protocols: These protocols incorporates the merits of proactive as well as reactive routing protocols. Nodes are grouped into zones based on their geographical locations or distances from each other. Inside a single zone, routing is done using table-driven mechanisms while an on-demand routing is applied for routing beyond the zone boundaries. The routing table size and update packet size are reduced by including in them only art of the network (instead of the whole); thus, control overhead is reduced.

III. DESCRIPTIONOF REACTIVE PROTOCOLS

A.Reactive Routing Protocols

In this protocols, a node initiates a route discovery process throughout the network, only when it wants to send packets to its destination. This process is completed once a route is determined or all possible permutations have been examined. Once a route has been established, it is maintained by a *route maintenance* process until either the destination becomes inaccessible along every path from the source or the route is no longer desired. A route search is needed for every unknown destination. Therefore, theoretically the communication overhead is reduced at expense of delay due to route search. Some reactive protocols are Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA).

B. Ad hoc On-demand Distance Vector Routing (AODV)

Ad hoc On-Demand Distance Vector (AODV) Routing is a routing protocol for mobile ad hoc networks (MANETs) and other wireless ad hoc networks. In AODV, the network is silent until a connection is needed. At that point the network node that needs a connection broadcasts a request for connection. Other AODV nodes forward this message, and record the node that they heard it from, creating an explosion of temporary routes back to the needy node. When a node receives such a message and already has a route to the desired node, it sends a message backwards through a temporary route to the requesting node. The needy node then begins using the route that has the least number of hops through other nodes. Unused entries in the routing tables are recycled after a time. When a link fails, a routing error is passed back to a transmitting node, and the process repeats.Much of the complexity of the protocol is to lower the number of messages to conserve the capacity of the network. For example, each request for a route has a sequence number. Nodes use this sequence number so that they do not repeat route requests that they have already passed on. Another such feature is that the route requests have a "time to live" number that limits how many times they can be retransmitted. Another such feature is that if a route request fails, another route request may not be sent until twice as much time has passed as the timeout of the previous route request. The advantage of AODV is that it creates no extra traffic for communication along existing links. Also, distance vector routing is simple, and doesn't require much memory or calculation. However AODV requires more time to establish a connection, and the initial communication to establish a route is heavier than some other approaches.

1) AODV Route Discovery Process

During a route discovery process, the source node broadcasts a route query packet to its neighbors. If any of the neighbors has a route to the destination, it replies to the query with a route reply packet; otherwise, the neighbors rebroadcast the route query packet. Finally, some query packets reach to the destination. Figure 1 shows the route discovery process from source node1 to destination node 10. At that time, a reply packet is produced and transmitted tracing back the route traversed by the query packet as shown in Figure 3.

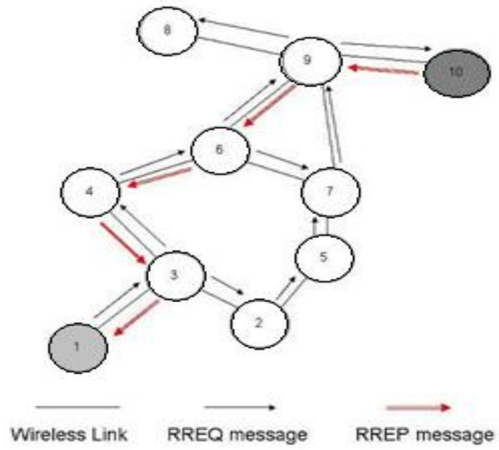

Figure 3.AODV Route Discovery Process

2) AODV Route Message Generation

During the route maintenance process if a link break occurs while the route is active, the node upstream (i.e node 4)of the break propagates a route error (RERR) message to the source node to inform it of the now unreachable destinations. The RERR message eventually ends up in source node 1. After receiving the RERR message, node 1 will generate a new RREQ message (Figure 4).

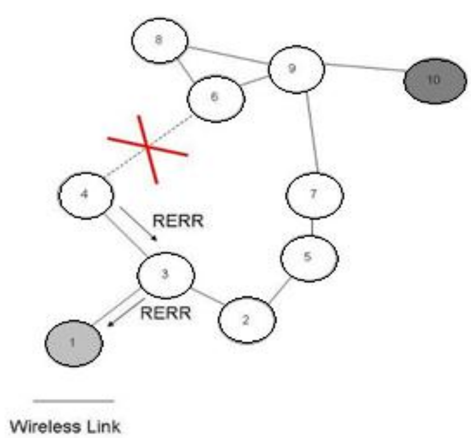

Figure4. AODV Route Message Generation

3) AODV Route Maintenance Process

Finally, if node 2 already has a route to node 10, it will generate a RREP message, as indicated in Figure 4. Otherwise, it will re-broadcast the RREQ from source node 1 to destination node 10 as shown in Figure 5.

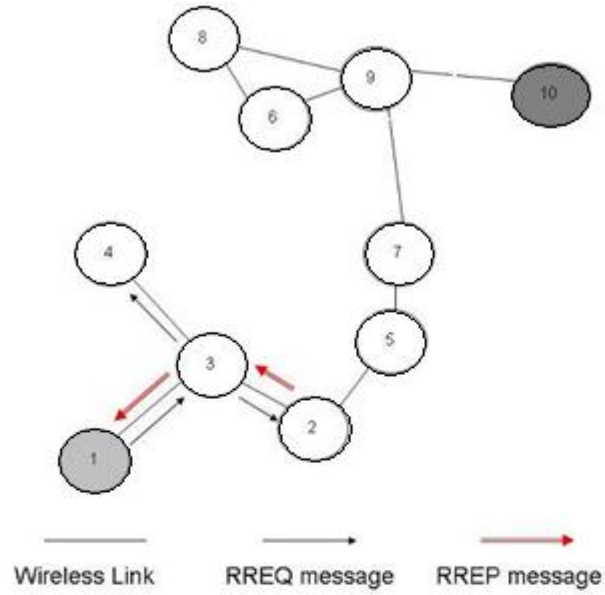

Figure 5. AODV Route Maintenance Process

C. Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) is routing protocol for wireless mesh networks. It is similar to AODV in that it forms a route on-demand when a transmitting computer requests one. However, it uses source routing instead of relying on the routing table at each intermediate device. Determining source routes requires accumulating the address of each device between the source and destination during route discovery. The accumulated path information is cached by nodes processing the route discovery packets. The learned paths are used to route packets. To accomplish source routing, the routed packets contain the address of each device the packet will traverse. This may result in high overhead for long paths or large addresses, like IPv6. To avoid using source routing, DSR optionally defines a flow id option that allows packets to be forwarded on a hop-by-hop basis. This protocol is truly based on source routing whereby all the routing information is maintained (continually updated) at mobile nodes. It has only two major phases, which are Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node (route record which is initially contained in Route Request would be inserted into the Route Reply). To return the Route Reply, the destination node must have a route to the source node. If the route is in the Destination Node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the Route Request message header (this requires that all links are symmetric). In the event of fatal transmission, the Route Maintenance Phase is initiated whereby the Route Error packets are generated at a node. The erroneous hop will be removed from the node's route cache; all routes containing the hop are truncated at that point. Again, the Route Discovery Phase is initiated to determine the most viable route.

Dynamic source routing protocol (DSR) is an on-demand protocol designed to restrict the bandwidth consumed by control packets in ad hoc wireless networks by eliminating the periodic table-update messages required in the table-driven approach. The major difference between this and the other on-demand routing protocols is that it is beacon-less and hence does not require periodic hello packet (beacon) transmissions, which are used by a node to inform its neighbors of its presence. The basic approach of this protocol (and all other on-demand routing protocols) during the route construction phase is to establish a route by flooding RouteRequest packets in the network. The destination node, on receiving a RouteRequest packet, responds by sending a RouteReply packet back to the source, which carries the route traversed by the RouteRequest packet received.

1) Route Discovery

For route discovery, the source node starts by broadcasting a Route Request packet that can be received by all neighbor nodes within its wireless transmission range. The Route Request contains the address of the destination host, referred to as the target of the route discovery, the source's address, a route record field and a unique identification number (Figure 5). At the end, the source node should receive a Route Reply Packet with a list of network nodes through which it should transmit the data packets.

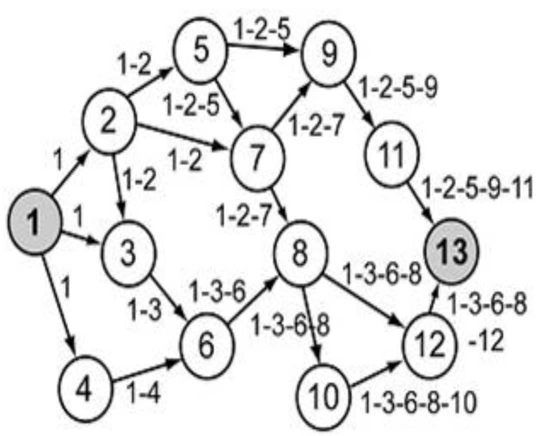

Figure 6. DSR Route Graph

The above Figure Building of the record during route discovery in DSR During the route discovery process, the route record field is used to contain the sequence of hops which already taken. Initially, all senders initiate the route record as a list with a single node containing itself. The next intermediate node attaches itself to the list and so on. Each route request packet also contains a unique identification number called as request_id which is a simple counter increased whenever a new route request packet is being sent by the source node. So each route request packet can be uniquely identified through its initiator's address and request_id. When a node receives a route request packet, it is important to process the request in the following given order. This way we can make sure that no loops will occur during the broadcasting of the packets.

D. Temporally Ordered Routing Algorithm(TORA)

Temporally-Ordered-Routing-Algorithm (TORA) is an algorithm for routing data across Wireless Mesh Networks or Mobile ad hoc networks. The TORA attempts to achieve a high degree of scalability using a "flat", 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 type. TORA builds and maintains a Directed Acyclic GraphDAG rooted at a destination. No two nodes may have the same height. Information may flow from nodes with higher heights to nodes with lower heights. Information can therefore be thought of as a fluid that may only flow downhill. By maintaining a set of totally-ordered heights at all times, TORA achieves loop-free multipath routing, as information cannot 'flow uphill' and so cross back on itself. The key design concept 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. 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 destination. Thereafter links are assigned based on the relative height metric of neighboring nodes. During the times of mobility the DAG is broken and the route maintenance unit comes into picture to reestablish a DAG routed at the destination. Timing is an important factor for TORA because the height metric is dependent on the logical time of the link failure. TORA's route erasure phase is essentially involving flooding a broadcast clear packet (CLR) throughout the network to erase invalid routes.

1) Route Creation

A node which requires a link to a destination because it has no downstream neighbours for it sends a QRY (query) packet and sets its (formerly unset) route-required flag. A QRY packet contains the destination id of the node a route is sought to. The reply to a query is called an update UPD packet. It contains the height quintuple of the neighbour node answering to a query and the destination field which tells for which destination the update was meant for. A node receiving a QRY packet does one of the following:

- If its route required flag is set, this means that it doesn't have to forward the QRY, because it has itself already issued a QRY for the destination, but better discard it to prevent message overhead.
- If the node has no downstream links and the route-required flag was not set, it sets its route-required flag and rebroadcasts the QRY message.

A node receiving an update packet updates the height value of its neighbour in the table and takes one of the following actions:

- If the reflection bit of the neighbours height is not set and its route required flag is set it sets its height for the destination to that of its neighbours but increments d by one. It then deletes the RR flag and sends an UPD message to the neighbours, so they may route through it.
- If the neighbours route is not valid (which is indicated by the reflection bit) or the RR flag was unset, the node only updates the entry of the neighbours node in its table.

2) Route Maintenance

The availability of multiple paths is a result of how TORA models the entire network as a directed acyclic graph (DAG) rooted at the destination. Each node has a height associated with it and links between nodes flow from one with a higher height to one with a lower height. The collection of links formed between nodes forms the DAG and ultimately all nodes will have a route to the destination. For each possible destination required, a separate DAG needs to be constructed. Route maintenance occurs when a node loses all of its outgoing links. When the detection of a link failure causes a node to lose all of its out-going links, the node propagates an update packet which reverses the links to all of its neighbouring nodes. Intermediate nodes that receive the update packet then reverse the links of their neighbouring nodes. Links are reversed only for neighbouring nodes that do not have any out-going links and have not performed link reversal recently. The link reversal needs to be repeated until each node has at least one out-going link. This entire process ensures that the DAG is maintained such that all nodes have routes to the destination.

3) Route Erasure

In the event that a node is in a network partition without a route to the destination, route erasure is initiated. The detection of a network partition is undertaken by the node that first initiated route maintenance. During route maintenance, the node sends out update packets to reverse links to all its neighbouring nodes and attempts to find a route to the destination. It is able to determine the presence of a network partition if a similar update packet is sent back to it by another node. This means that all nodes in the current network partition cannot find a route and are trying to find a route through the original node. Route erasure is then performed by the node by flooding clear packets throughout the network. When a node receives a clear packet, it sets the links to its neighbours as unassigned. Eventually, these clear packets propagate through the network and erase all routes to that unreachable destination.

IV. COMPARISONOF REACTIVE PROTOCOL

Protocol	Update destination	Update period	Unidirectional links	Multiple routes	Advantages	Disadvantages
AODV	Source	Event driven	No	Yes	1.Adaptability to dynamic networks. 2.Reduced overhead. 3.Lowerset up delay.	1.Periodic updates. 2.Inconsistent routes.
DSR	Source	Event driven	Yes	Yes	1.A route is established only when it is required. 2. Reducing load.	1. Route overheads. 2. Higher delay 3. The route maintenance
TORA	Neighbors	Event driven	Yes	Yes	1.Multiple paths created. 2.Communication overhead and bandwidth utilization is minimized.	1.Routing overheads 2.Depends on synchronized clocks among nodes

V. CONCLUSION

In this paper we have provided descriptions of several routing scheme proposed for mobile ad hoc networks. We have provided a classification of these schemes according the routing strategy i.e. table driven and on demand and presented a comparisons of these categories of routing protocols. Reactive protocols were introduced and their core architecture was described. The basic actions related to the routing process were studied in details.

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