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International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 2 Issue 3 March 2013 Page No. 707-718

Comparative study of reactive routing protocol (AODV, DSR, ABR and TORA) in MANET

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Abstract *A mobile ad hoc network (MANET) is a collection of wireless mobile 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 four Reactive (on-demand) routing protocols for MANETs: - Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) protocols, Temporally Ordered Routing Algorithm (TORA) a*nd Associativity Based Routing (ABR) protocol.

Keywords: Manet, Routing protocol, AODV, DSR, TORA, ABR

1.Introduction

Mobile ad hoc network is an autonomous system of mobile nodes connected by wireless links; each node operates as an end system and a router for all other nodes in the network. Nodes can freely and dynamically self-organize and co-operate into arbitrary and temporary network topologies, allowing peoples and devices to communicate without any pre-existing communication architecture. Existing protocols of MANET may be classified into two distinct categories. One category of protocols is based on minimum-power routing algorithms. It selects a path which minimizes the total energy consumption from source to destination. The disadvantage of this category is that always it selects least power cost routes which tends to "die" rapidly.

A second category is based on increasing the network lifetime. It attempts to distribute the forwarding load over multiple paths. This is performed by reducing a set of nodes needed for the forwarding duties and allowing subset of nodes to sleep over different periods of time. In this way, they balance the traffic inside the MANET and increase the overall useful life of the network. A number of different reactive routing protocols have been proposed to increase the performance of Manet. This paper describes a comparative study of an Reactive routing protocol AODV, DSR, TORA and ABR for ad hoc networks.

Section 2 describes about classification of reactive protocols. Section 3 describes Description of reactive protocols. Section 4 describes comparison of reactive protocol followed by conclusion in the section 5.

2. Classification of reactive protocols

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

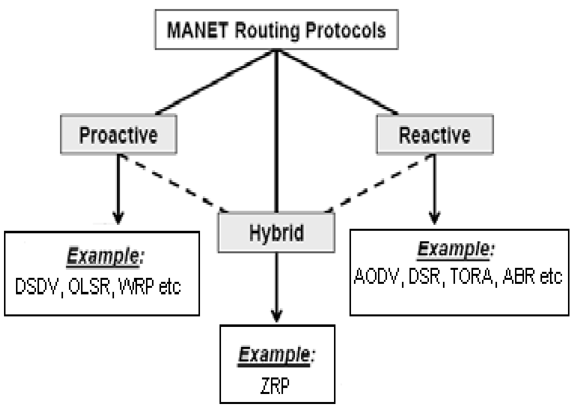

Figure 1 Classification of MANET routing protocols

Proactive routing (Table- Driven) protocols: In this protocol, all the nodes continuously search for routing information with in a network, Every node maintains one or more tables representing the entire topology of the network. These tables are updated regularly so that when a route is needed, the route is already known. If any node wants to send any information to another node, path is known, therefore, latency is low. However, when there is a lot of node movement then the cost of maintaining all topology information is very high.

Reactive Routing (On-Demand) protocols: Routing information is collected only when it is needed, and route determination depends on sending route queries throughout the network. That is whenever there is a need of a path from any source to destination then a type of query reply dialog does the work. Therefore, the latency is high; however, no unnecessary control messages are required.

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.

3. Description of reactive protocols

3.1 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), Associativity-Based Routing (ABR),

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

AODV belongs to the class of Distance Vector Routing Protocols (DV). In a DV every node knows its neighbours and the costs to reach them.

Ad hoc On Demand Distance Vector (AODV) is a reactive routing protocol which initiates a route discovery process only when it has data packets to transmit and it does not have any route path towards the destination node, that is, route discovery in AODV is called as on-demand. AODV is composed of three mechanisms: Route Discovery process, Route message generation and Route maintenance

The significant feature of AODV is whenever a route is available from source to destination, it does not add any overhead to the packets. However, route discovery process is only initiated when routes are not used and/or they expired and consequently discarded. This strategy reduces the effects of stale routes as well as the need for route maintenance for unused routes. Another distinguishing feature of AODV is the ability to provide unicast, multicast and broadcast communication. AODV uses a broadcast route discovery algorithm and then the unicast route reply message.

3.2.1. 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 2.

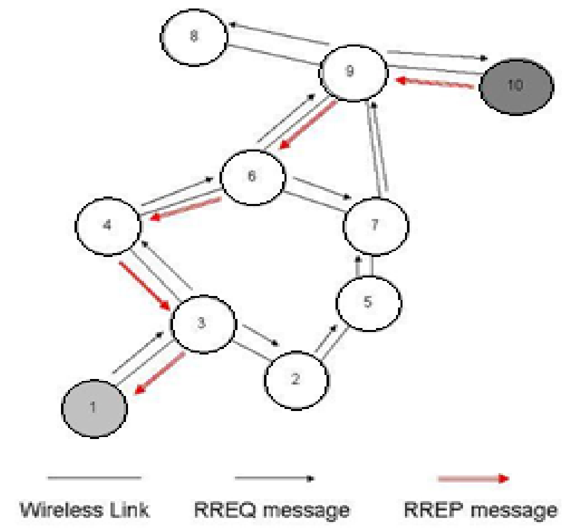

Figure 2. AODV Route Discovery Process

3.2.2. 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 3).

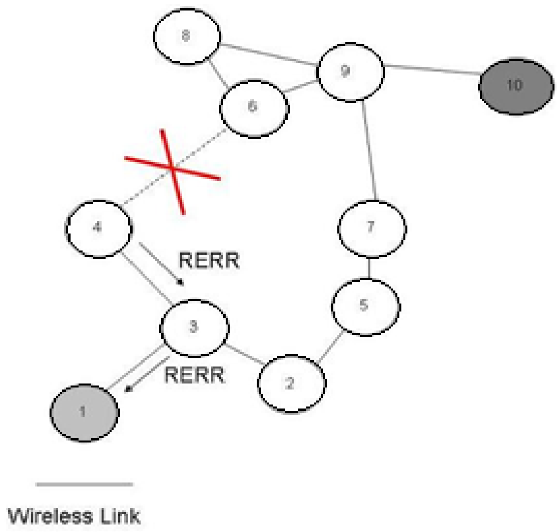

Figure 3. AODV Route Error message generation

3.2.3 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 3.

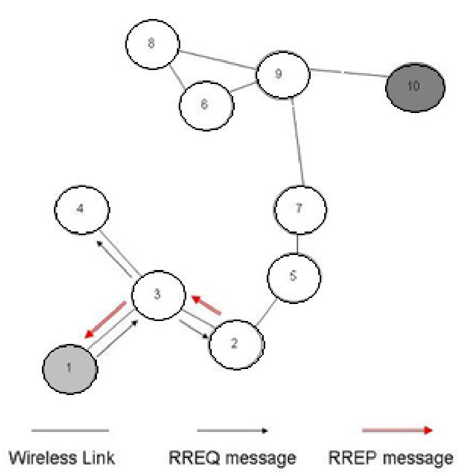

Figure 4. AODV Route Maintenance Process

3.3 Dynamic Source Routing (DSR)

The Dynamic Source Routing (DSR) is one of the purest examples of an on-demand routing protocol that is based on the concept of source routing. It is designed specially for use in multihop ad hoc networks of mobile nodes. It allows the network to be completely selforganizing and self-configuring and does not need any existing network infrastructure or administration. 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. DSR has a unique advantage by virtue of source routing. As the route is part of the packet itself, routing loops, either short – lived or long – lived, cannot be formed as they can be immediately detected and eliminated. This property opens up the protocol to a variety of useful optimizations.

3.3.1. 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

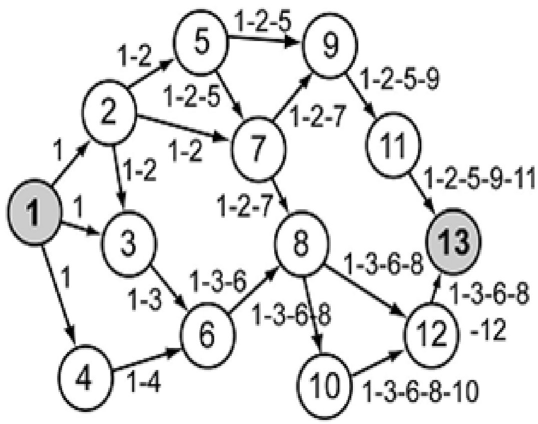

Figure 5. Building of the record during route discovery in DSR

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.

- If the pair < source node address, request_id > is found in the list of recent route requests, the packet is discarded.
- If the host's address is already listed in the request's route record, the packet is also discarded. This indicates removal of same request that arrive by using a loop.
- If the destination address in the route request matches the host's address, the route record field contains the route by which the request reached this host from the source node. A route reply packet is sent back to the source node with a copy of this route.
- Otherwise, add this node's address to the route record field and re-broadcast this packet.

A route reply is sent back either if the request packet reaches the destination node itself, or if the request reaches an intermediate node which has an active route4 to the destination in its route cache. The route record field in the request packet indicates the sequence of hops which was considered. If the destination node generating the route reply, it just takes the route record field of the route request and puts it into the route reply. If the responding node is an intermediate node, it attaches the cached route to the route record and then generates the route reply (Figure 6).

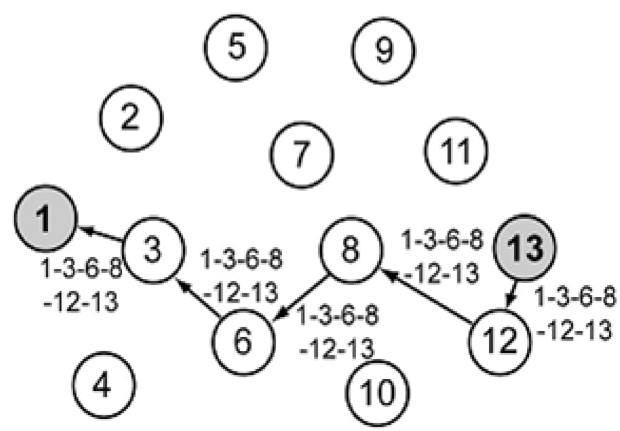

Figure 6. Propagation of the route reply in DSR

Sending back route replies can be processed with two different ways: DSR may use symmetric links. In the case of symmetric links, the node generating the route reply just uses the reverse route of the route record. When using asymmetric links, the node needs to initiate its own route discovery process and back the route reply on the new route request.

3.3.2. Route Maintenance

Route maintenance can be accomplished by two different processes:

- Hop-by-hop acknowledgement at the data link layer
- End-to-end acknowledgements

Hop-by-hop acknowledgement is the process at the data link layer which allows an early detection and re-transmission of lost packets. If the data link layer determines a fatal transmission error, a route error packet is being sent back to the sender of the packet. The route error packet contains the information about the address of the node detecting the error and the host's address which was trying to transmit the packet. Whenever a node receives a route error packet, the hop is removed from the route cache and all routes containing this hop are truncated at that point.

When wireless transmission between two hosts does not process equally well in both directions, end-to-end acknowledgement may be used. As long as a route exists, the two end nodes are able to communicate and route maintenance is possible. In this case, acknowledgements or replies on the transport layer used to indicate the status of the route from one host to the another. However, with end-to-end acknowledgement it is not possible to find out the hop which has been in error.

3.4 Temporally Ordered Routing Algorithm (TORA)

The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive, efficient and scalable distributed routing algorithm based on the concept of link reversal. TORA is proposed for highly dynamic mobile, multi-hop wireless networks. It is a source-initiated on-demand routing protocol. It has a unique feature of maintaining multiple routes to the destination so that topological changes do not require any reaction at all. The protocol reacts only when all routes to the destination are lost. In the event of network partitions the protocol is able to detect the partition and erase all invalid routes. The protocol has three basic functions: *Route creation*, *Route maintenance* and *Route erasure*.

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3.4.1 Route Creation

Initially, all nodes start off with a null height and links between the nodes are unassigned. When a node requires a route to a destination, it initiates route creation where *query* packets are flooded out to search for possible routes to the destination. Eventually, a *query* packet reaches either a node that has a route or the destination itself, and the node replies with an *update* packet. When a node receives an *update* packet, it sets its link as directed from itself to the sender of the *update* packet. This setting of directional links eventually reaches the node which requires the route and provides it with at least a route to the destination.

3.4.2 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.

The route maintenance function of TORA is the main problem as this function produces a large amount of routing overhead. It causes the network to be congested thus preventing data packets from reaching their destinations.

3.4.3 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.

3.5 Associativity-Based Routing (ABR)

ABR is a *source initiated on-demand routing protocol*. It is free from loops, deadlock and packet duplicates. It only maintain routes for sources that actually desire routes. However, ABR does not employ route re-construction based on alternate route information stored in intermediate nodes (thereby avoiding stale routes). In addition, routing decisions are performed at the destination and only the best route will be selected and used while all other possible routes remain passive. Its distinct feature is the use of associativity ticks which is required to only form routes based on the stability of nodes, under the fact that there is no use to form a route using a node which will be moving out of the topology and thus making the route to be broken. ABR has three modes of operation namely route discovery phase, route reconstruction phase and route deletion.

3.5.1 ABR Route Discovery Phase

The route discovery phase uses *broadcast query* BQ messages and an *await reply* BQ_REPLY messages. Each BQ message has a uniquely identifier. A source node desiring a route to destination broadcasts the network with BQ messages. An intermediate node that receives the query first checks if they have processed the packet: if yes query packet will be discarded, otherwise check if the node is the destination. If not the intermediate nodes appends the following information before broadcasting the BQ message:

□□□ its address
□□□ the associativity ticks with its neighbors
□□□ the route relaying load,
□□□ the link propagation delay
□□□ the hop counts information.

The next intermediate node will then erase its upstream neighbor's associativity ticks and retain only those concerns with itself and its upstream neighbor. In this manner, the query packet reaching the destination will only contain:

-the intermediate mobile hosts address
-mobile host's associativity ticks
-mobile host's relaying loads
-route forwarding delay
-hop count.

After receiving first BQ packet the destination node will choose the best route based on stability and quality-of service QoS. Given a set of possible routes from source to destination node, if a route consists of mobile hosts having high associativity ticks then that route will be chosen by the destination in favor of other existing shorter-hop routes. The selected route is likely to be long-lived due to the propriety of associativity. The destination node responds by sending a BQ_REPLY message back to source node via the route selected. Intermediate nodes that receive the BQ_REPLY message validate their routes. Other routes are marked as inactive. This mechanism prevents duplication of messages.

3.5.2 Route reconstruction phase

When one of the source, destination or intermediate nodes moves the route reconstruction operation start.

Route reconstruction phase includes

- Partial route discovery
- Invalid route deletion
- Valid route updates
- New route discovery

Intermediate nodes moves

When an intermediate node along an existing route moves out of range, the immediate downstream node sends a *route notification* RN message toward the destination. Nodes along the path to destination that receive a route notification message RN delete this route entry. The immediate upstream node initiates a *localquery* LQ to discover a new, partial route as is shown in figure 7

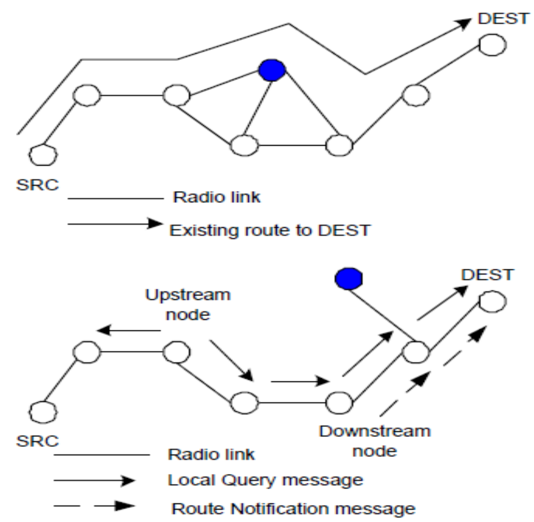

Figure 7: Route maintenance when intermediate nodes move

LQ messages are similar to BQ messages but use a hope count field to limit their range of action.

Once the destination receives several LQ messages it chooses the best route based on stability and QoS and responds by sending an LQ_REPLY. If the upstream node does not receive an LQ_REPLY after a certain amount of time LQ_TIMEOUT, it responds by sending its own RN message to its immediate upstream node. The new upstream node removes the invalid route and initiates anew LQ messages process.

The LQ process continues till it reaches halfway point to the source node then is aborted and a new BQ message is initiated.

Source node moves

When source node moves, it will cause a route reconstruction similar with route initialization that is BQ and BQ-REPLAY messages. Concurrent node movements may generate route reconstruction conflicts. ABR resolves the multiple route reconstruction messages by assuring that only one ultimately succeeds. Each LQ process is tagged with a sequence number so that earlier LQ process is terminated when a new one is invoked. For example if a node processing LQ messages hears a new BQ for the same connection then the LQ process is terminated.

Destination node moves

When the destination node moves, its immediate upstream node (known as the pivoting node) will erase his route. It then sends a localized query LQ[H] messages to localize the destination node. H is the hop count from the upstream node to the destination node. If the destination node receives LQs messages it will select the best route and send a LQ_REPLAY. If LQ_TIMEOUT period is reached and the destination node hasn't received LQ, the next upstream will became the pivoting node. The backtrack process continues until the new pivoting node will be half away from the destination. If no partial route is found the pivoting route will send a route notification RN back to the source. The source will initiate a new route discovery process BQ that is the worst situation.

3.5.3 ABR Route deletion phase

Route deletion phase is used when a source no longer requires a route and it consists of a route delete RD broadcast from source node to all intermediate nodes. The full broadcast is used because the source may be not aware about new routes after many reconstruction phases.

4. Comparison of 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.Lowersetup 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

					3. Loop-free routing.	mechanism is poor.
ABR	Source	periodically	No	No	1. Avoids packet duplicates. 2. No route reconstructions.	1. Operation complexity 2.Communication complexity.
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

5. 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. Also the advantages and disadvantages of the protocols based on their routing processes were given in the end of the chapters.

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