RO-AODV: Route Optimized Ad-hoc On-demand Distance Vector Routing Protocol

Dinesh Shetty
Information Security Consultant
dinesh.shetty@live.com

***Abstract*-- Wireless ad-hoc networks are characterized by the lack of infrastructure, use of wireless links with limited bandwidth and frequent topological changes. Enhancing route request broadcasting protocols constitutes a substantial part of recent research in Mobile Adhoc Network (MANET) routing.**
Ad-hoc On Demand Distance Vector Routing (AODV), is a novel algorithm for the operation of such Ad-hoc networks. Previous studies have shown limitations of Ad-hoc On Demand Vector (AODV) protocols in certain network scenario.
We suggest a novel approach to constrain route request broadcast which by means of route optimization using cache mechanism. The performance of AODV has been modified by using route optimizing technique and thus called Route Optimised AODV (RO-AODV). This protocol optimizes AODV to perform effectively in terms of routing overhead, power consumption and delay during high load.
Network Simulator2 (Ns2) can been used as the platform for the simulation environment to show how this optimized source route affects the performance of AODV routing protocol.

***Keywords*-- AODV, DSR, network simulations, performance evalutation, Routing Protocol, route cache.**

I. INTRODUCTION

Wireless communication between mobile users is becoming more popular than ever before due to recent technological advances in laptop computers and wireless data communication devices, such as wireless modems and wireless LANs. This has lead to lower prices and higher data rates, which are the two main reasons why mobile computing continues to enjoy rapid growth.

There are two distinct approaches for enabling wireless communication between two hosts. The first approach is to let the existing cellular network infrastructure carry data as well as voice. The major problems include the problem of handoff, which tries to handle the situation when a connection should be smoothly handed over from one base station to another base station without noticeable delay or packet loss. Another problem is that networks based on the cellular infrastructure are limited to places where there exists such a cellular network infrastructure. The second approach is to form an ad-hoc network among all users wanting to communicate with each other. All users participating in the ad-hoc network must be willing to forward data packets to make sure that the packets are delivered from source to destination. Networking of this form is limited in range by the individual nodes transmission ranges and is typically smaller compared to the range of cellular systems. But it does not mean that the cellular approach is better than the ad-hoc approach.

Ad-hoc networks have several advantages compared to traditional cellular systems.Ad-hoc networks do not rely on any pre-established infrastructure and can therefore be deployed in places with no infrastructure. Disaster recovery situations and places with no existing or damaged communication infrastructure where rapid deployment of a communication network is needed becomes a useful application of Ad-hoc networks. Ad-hoc networks can also be useful on conferences where people participating in the conference can form a temporary network without engaging the services of any pre-existing network. Because nodes are forwarding packets for each other, some sort of routing protocol is necessary to make the routing decisions.
Currently there does not exist, any standard protocol for routing to meet all the demands of ad-hoc networks.The routing algorithms in Ad-hoc networks can be classified either as proactive or reactive. Proactive protocols attempt to continuously evaluate the routes within the network, so that when a packet needs to be forwarded, the route is already known and can be immediately used. The family of Distance-Vector protocols is an example of a proactive scheme. Reactive protocols, on the other hand, invoke a route determination procedure on demand only. Thus, when a route is needed, some sort of global search procedure is employed. The family of classical flooding algorithms belongs to the reactive group. Proactive schemes have the advantage that when a route is needed, the delay before actual packets can be sent is very small. On the other side proactive schemes needs time to converge to a steady state. This can cause problems if the topology is changing frequently.

II. RELATED WORK

Routing, being a fundamental issue of wired and wireless networks so a range of protocols have been proposed. Some of the existing protocols have been discussed in the following section. The conventional wired networks are usually based upon either distance vector or link state routing algorithms. Both these algorithms require periodic advertisement broadcasts. In Distance Vector Routing, each router broadcasts to its neighboring routers its view of the distance to all the other nodes, the neighboring routers then computes the shortest path to each node. In Link State Routing each router broadcasts to its neighboring nodes its view of status of each of its adjacent links; the neighboring routers then compute the shortest distance to each node depending upon the topology of the network. The conventional routing algorithms are not efficient for the dynamic changes that occur in an ad hoc network. In an environment with mobile nodes, the changing topology will not only trigger frequent re-computation of routes but the overall convergence to stable routes may be infeasible due to high level of mobility. Routing protocols in MANET are classified into two main categories Proactive and On-Demand.

The Proactive or Table driven routing protocols attempt to maintain consistent up-to-date routing information 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. Destination Sequenced Distance Vector (DSDV) a Proactive protocol based on the Bellman Ford algorithm maintains shortest distance to each node in their routing table. These routing tables are updated periodically or if there is a significant change in the topology. The second category is of On-demand routing protocols that are designed to reduce the overheads in Table Driven protocols by maintaining information for active route only. When a node requires a route to a destination it initiates a route discovery process within the network. Once a route is established it is maintained by a route maintenance procedure until either the destination becomes inaccessible along every path from source or until route is no longer desired.

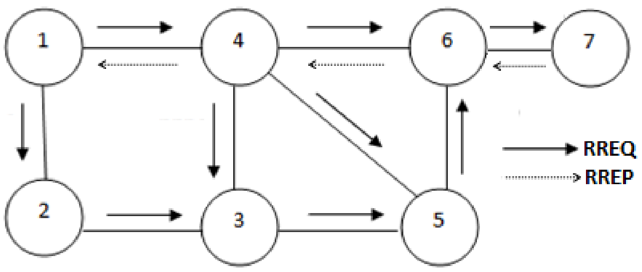
On-Demand routing protocols are classified into two categories: source and hop-by-hop routing. In source routed on-demand protocols each data packet carry the complete path from source to destination. Therefore each intermediate node forwards the packet according to the information in the header of each packet. The major drawback of source routing protocol is in case of a large network where as the number of intermediate nodes grow 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 dynamic changing environment of MANET, since each node can update its routing table when they receive fresh topology information and hence forward the packets over fresh and better routes. The detailed studies on their performance comparison are performed which has revealed that in the presence of node mobility, the On-demand approaches perform better than Proactive ones. This is mainly due to their low routing overheads. The Ad hoc On Demand Distance Vector (AODV) due to its moderate overheads and its route convergence performance has become one of the promising protocols that are currently available for the mobile ad hoc network.

A. AODV

AODV is one of the protocols designed to address a number of important performance related issues. It is an improvement over DSDV and DSR protocols. It retains the desirable feature of DSR in that the routes are discovered on demand by flooding the network with route request broadcast (RREQ) packets. The route requests (RREQ) are forwarded in a manner similar to DSR. Each node receiving an RREQ rebroadcasts it, unless it is the destination or it has a route to the destination in its route cache. Such a node replies to the RREQ with a route reply (RREP) packet that is routed back to the original source.

However, AODV adopts a very different mechanism from DSR to maintain routing information. It uses traditional routing tables, one entry per destination. This is in contrast to DSR, which can maintain multiple route cache entries for each destination. AODV reduces the need for the system wide broadcasts by localizing the propagation of change in the network. If the link status does not affect the ongoing communication, no broadcast occurs.

Only when a distant source tries to use path with broken links, nonlocal changes occur. The nodes using the route with broken links are informed. The routes which are not used, get expired and discarded. Thus, it removes the stale and unused routes. Like the DSDV, it uses sequence number to avoid the loop formation.



Dest.	Seq. No.	Hop Count	Next Hop	Expiration Timeout

Figure 1. Working and Routing Table of AODV

B. Effects of maintaining Route Cache.

In AODV protocol, an intermediate node can reply to the route request only when the destination sequence number for the entry is greater than the destination sequence number of the route requests. However, this is a very conservative approach restricting some of the possible optimizations for improving the performance of the protocol.

The RREQ packets is very much similar to that of plain AODV. RREQ packets are flooded in the network by the intermediate nodes forwarding the requests to the neighbor nodes. RREQ forwarding operation is controlled by the expanding ring search method. When the destination gets the route request, it unicasts the route reply back to the source. The route reply packet accumulates the nodes on the route. The nodes receiving the route reply, copy the source route in the routing table corresponding to the entry for the destination, and before forwarding the reply, it appends its own address in the route reply packet.

On subsequent requests, an intermediate node checks for the availability of route to the intended destination of any route cached in its routing table. If the entry is found, the data packet is forwarded to the next hop. Otherwise, the route discovery is initiated.

The extra packet overhead is proportional to the number of the nodes on the route. The addresses of the node are not long, for example in case of IP addresses are 4 bytes long. The number of the nodes on the route is limited with the network diameter. For example, in case of 30 hop network, 4 byte addresses will result maximum of 30*4 = 120 bytes of overhead with the route reply. Average lengths of paths will be far less than the network diameter. Hence, the overhead due to source route is not high. The memory requirements are more in case of the nodes that are close to the source. Again the extra memory requirements will be limited with the number of the nodes on the route. However, it will require more computational time. The search time is dependent upon the number of connections currently going through the node and the number of nodes in each path down the stream upto the destinations. In case of failed search, it will have to go through the complete routing tables. However, as the number of the active route going through a node may not be large, it is not expected to incur large overhead.

III. MOTIVATION

In AODV, a source that has a packet to a destination needs first to discover a route to this destination. If the source has no route already in its routing table to that destination, it sends a route request (RREQ) which is flooded to the whole network. When the destination or a node that has a route to the destination receives this RREQ, it replies back with a RREP. When the source receives the RREP it can start sending data packets along the route from which the RREP arrived. Intermediate nodes receiving the RREQ create entries in their routing table to the source, similarly nodes receiving the RREP create entries to the destination. The routing table entry contains the next-hop to the corresponding node. Accordingly, a route between a source and a destination is constructed hop-by-hop along the path taken by the RREP and data packets do not need to contain the whole route.

One of the disadvantages of this protocol is that intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries. Also multiple RouteReply packets in response to a single RouteRequest packet can lead to heavy control overhead. Another disadvantage of AODV is that the periodic beaconing leads to unnecessary bandwidth consumption.

However when compared with DSR routing protocol, it is observed that, due to the presence of route cache, the overheads are comparatively lower than AODV. Thus, incorporating this route cache in AODV would provide a higher probability of routes being present in the routing table, since the routing table is being populated during subsequent route requests. This decreases the number of route discovery cycles as compared to basic AODV and thus increase the efficiency of AODV.

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IV. PROPOSED SOLUTION

The proposed protocol will make the following changes to the existing AODV protocol:

- Reduce routing load.
- Improve packet delivery fraction.
- Reduce end-to-end delay.

The idea of our route optimization is to allow nodes receiving and forwarding control packets to record their identity in the packet and eventually learn about other nodes in the path between the source and destination. Each RREQ and RREP contains a source route for the nodes along the path, so that each node can have a routing table entry to the rest of the nodes. The RREP message is unicast back to the source, each intermediate node forwards the RREP packet by adding its address in the packet. Hence, at any point the RREP packet contains all the previously visited nodes. Similar to the RREQ, the routing table is updated for each intermediate node visited by the RREP in addition to the destination node. Following the guidelines of AODV, entries are also created in the precursor lists by a node forwarding a route reply back to the source. If an entry is updated to any intermediate nodes, any pending packets to that node are sent.

Consider five nodes A, B, C, D and E as shown in figure 2.. Node A wants to send data to node E. Node A does not have a route for E in its routing table, it broadcasts a route request. B receives the route request, updates its routing table for the reverse route to A, and forwards the request since it also has no route to E. Before forwarding, it appends its own address to the request. When C receives the RREQ, it updates its routing table for both node A and B and appends its address to the request. When D receives the request it updates its routing table for nodes A, B and C, while E learns about nodes A, B, C and D.

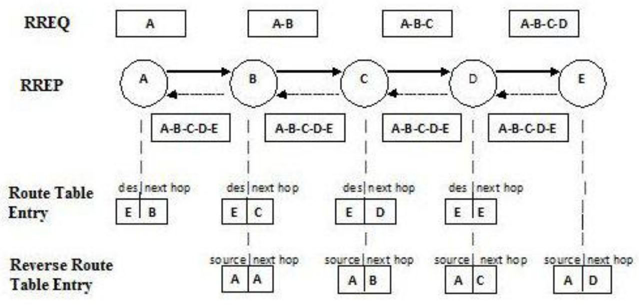

Figure 2. Route Discovery with and without Route Optimization

The main benefit of obtaining the additional routing entries is to reduce the route discovery overhead by eliminating some of the RREQs that would be required to discover these nodes. Since RREQs are the major source of control overhead due to flooding the whole network, any reduction in RREQs is expected to improve the performance significantly. The tradeoff is that the RREQ and RREP packet header will become larger to accommodate the source route.

V. IMPLEMENTATION

In RO-AODV, AODV is enhanced with an optimization to its route cache (RO) with which the path from either the routing table or the control packet may be used to route the RREP message back to the requesting node during route establishment. It provides an added advantage especially for nodes with very limited resource since they can opt not to record the route during RREQ flooding. Instead, route information can be obtained directly from the control packets. In addition, the RO feature enables wider dissemination of route information in route discovery. Whenever a node receives an RREQ, it might update its route table for every path node listed in Accumulation Path List (APL). Consequently, the number of broadcast messages is decreased. The quantity of the broadcast messages is critical when the traffic internal to the MANET is high.Our Route Optimization feature is the preliminary attempt to converge AODV with DSR routing protocol before standardizing the ad hoc routing protocol.

The exact steps would be, First the source broadcasts the route request message (RREQ) to find the most suitable route to get through to the destination. Intermediate nodes appends its own address although they do not have the route, if there is a route to destination it will appends the address and updating the route table and broadcast to other intermediate nodes until reach to destination. After RREQ have reach the destination, it also do the same things, appends it own address and do route reply message (RREP) to the source with all the addresses of intermediate nodes which have the routes establish from source to destination.

VI. RESULTS

The proposed protocol RO-AODV has been proved to outperform AODV and AODV. The performances of all the three protocols have been evaluated and compared using Network Simulator (ns-2).

The three important metrics on which AODV, DSR and the proposed protocol RO-AODV are evaluated is explained below:

1) **Packet Delivery Ratio**: This is defined as the ratio of the number of data packets received by the destinations to those sent by the CBR sources.

2) **Normalized routing load -** This is defined as the number of routing packets transmitted per data packet delivered at the destination. Normalized routing load gives a measure of the efficiency of the protocol.

3) **End-to-end delay of data packets -** This is defined as the delay between the time at which the data packet was originated at the source and the time it reaches the destination. Data packets that get lost en route are not considered. Delays due to route discovery, queuing and retransmissions are included in the delay metric.

A) Packet Delivery Ratio

The packet delivery ratio of RO-AODV is similar to AODV under all conditions. The protocol suffers a little at fewer connections and low velocities. At low velocities, packets are dropped in AODV and RO-AODV due to packet collisions. The number of collisions increases in RO-AODV because of additional pending data packets sent by the intermediate routes during route discovery. The additional packets are sent when intermediate nodes gather routing information due to path accumulation. Because DSR does not use expiry timers, the number of stale routes increases with increase in connections and high mobility. The number of stale routes further increases with the number of nodes in the network. As a result, the packet delivery ratio of DSR decreases in these scenarios.

B) Route Load

RO-AODV reduces the routing load as compared to AODV, particularly under high load scenarios. RO-AODV uses aggressive accumulation of the routes during its route discovery process. This increased knowledge of the network reduces the number of route discoveries in RO-AODV, which leads to a decrease in the routing load. However, the routing load of RO-AODV is not as small as DSR.

Even though RO-AODV uses a similar accumulation of routes as DSR, it differs in a subtle but very important manner. RO-AODV utilizes a more conservative approach than DSR by making use of expiry timers for its routing table entries. It attempts to keep the routes fresh and invalidate the stale routes. DSR does not use any timers and invalidates its routing table entries only on a link break. This helps in improving the performance of RO-AODV for application oriented metrics such as delay and packet delivery ratio by using only valid and current routes. Because stale entries may linger in DSR's cache, these routes are likely to be selected after a link break.

C) Delay

RO-AODV has less delay than both AODV and DSR under almost all possible scenarios. The difference is magnified under high load and moderate mobility conditions. The primary reason is that the number of route discoveries is reduced in RO-AODV as compared to that in AODV. RO-AODV performs considerably better than DSR, because DSR focuses on routes with the fewest hops, while RO-AODV and AODV tend to choose the least congested route. Also, when utilizing promiscuous listening DSR has to spend time processing any control packet it receives, even if it is not the intended recipient. For 100 nodes, the average hop-count decreases with increase in the number of connections. As a result the delay curves taper-off.

VII. CONCLUSION

This paper proposes a new protocol that modifies AODV to improve its performance. The protocol, RO-AODV, incorporates the route optimization during the route discovery process in AODV to attain extra routing information.

The route optimization feature of , RO-AODV provides broader dissemination of route information compared to AODV. Higher route dissemination reduces the number of route discovery, leading to lower routing load in MANET and lower processing power consumptionIt is evident from the results that RO-AODV improves the performance of AODV under conditions of high load and moderate to high mobility.

RO-AODV also scales better than AODV in large networks. Under most conditions, RO-AODV has a higher packet delivery ratio and lower delay than DSR, though the routing load of DSR is slightly less than that of RO-AODV The difference in the routing load of RO-AODV and DSR decreases with an increase in the load. RO-AODV can be used either as an alternative to AODV or as an optimization under moderate to high load scenarios. RO-AODV could also be suitable either if overall routing load or if application oriented metrics such as delay and packet delivery ratio are important for the Ad hoc network application.

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