Advancements in AODV Routing Protocol - A Review

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ABSTRACT

Mobile Ad-hoc Network (MANET) is a collection of mobile nodes forming short lived or temporary networks without having any centralized infrastructure. Due to high mobility of the nodes the topology of the Ad-hoc network is highly dynamic. MANET is expected to be very useful for the deployment of temporary networks in military environments and emergency situations such as fire, safety, search and rescue operations, meetings or conventions in which people wish to quickly share information. Nodes are the only resource available, which also acts as router to forward packets. Among many, the main challenge of MANET is that of discovering the connections/routes between the mobile nodes within the continuously changing network topology. Thus routing protocols must be adaptive and fast enough to maintain routes in spite of the changing network topology and available low bandwidth. In this paper we have studied Ad-hoc On-Demand Distance Vector (AODV), a popular on demand reactive routing protocol for wireless networks. During recent years many enhancements have been suggested to improve the working of AODV like AODVUU, MAODV, etc.

Keywords

AODV, RREQ, RREP, RERR, Mobile Ad-hoc Network.

1. INTRODUCTION

Mobile ad hoc networks (MANET) are collection of mobile nodes which can be characterized as self-configurable, self-organizable and self maintainable. These mobile nodes communicate with each other through wireless channels with no centralized control. The inherently infrastructure-less, inexpensive and quick-to deploy nature of MANETs is providing a promise for its use in diverse domains.

To establish a communicating path between any two nodes routing protocol is required by the nodes. As there is no fixed infrastructure available, nodes act as source, destinations and intermediate packet routing devices. Many routing protocols have been suggested for MANETs during last few years. These routing protocols can be classified into two broad categories, based on their working. Proactive routing protocols attempt to maintain consistent and upto-date routing information tables on each node to every possible destination in the network by periodically exchanging routing table information. On the other hand, in reactive routing protocols routes are only discovered when needed. Each node maintains a route for a destination without periodic routing table exchanges or full network topological view. Additionally, there is hybrid routing protocols that combines the good features of both types of the routing protocols.

In MANET the topology keeps on changing due to mobility of the nodes, which leads to frequent link failures and reestablishment of the path. Also due to inherent challenges of wireless technology the communication over wireless links are enabled with low bandwidth and high probability to packet drop. These situations require a routing protocol to be able to provide stable, less congested path with ability to withstand the link failure problems.

Rest of the paper is organized as, second section classifies the two types of routing protocols, third section gives an overview of AODV [1] routing protocol, fourth section covers the literature covering earlier advancements of AODV and in last sections discussion and references are provided.

2. ROUTING PROTOCOLS

The routing protocols in Mobile Ad-hoc networks can be broadly classified into two categories, namely proactive routing protocols and reactive routing protocols.

2.1 Proactive Routing Protocols

These are also called as table-driven routing protocols as they use routing table, built at every node before starting any communication between any two nodes. DSDV [3] and OLSR are examples of this category. In these, all nodes make requests to their neighbors (if any) in order to figure out the network topology, and then, build the routing table. These requests are sent after a constant time interval and tables are updated in order to be ready when data has to be sent. This type of protocol is close to wired networks where the same mechanisms are used in order to take routing decisions. These mechanisms are used for finding the shortest path across the network topology; it can be the Link state" method or the Distance Vector" method. With the Link State" method, each node has its own view of the network, including the states of its own channels. When an event on the channel occurs, the node floods the network topology with its own new view of the topology. Other nodes which receive this information use algorithms to reflect changes on the network table.

With the Distance Vector" routing approach, each node transmits to its nearby nodes, its vision of the distance which separates it from all the hosts of the network. Based on the information received by the neighborhood, each node performs a calculation in order to define routing tables with the shortest path to all destinations available in the network.

2.2 Reactive Routing Protocols

Reactive protocols are more specific to Ad Hoc networks. Contrary to the proactive algorithms, they ask their neighbors for a route when they have data to send. AODV and DSR [4] falls under this category. If the neighbors do not have any known route, they broadcast the route request messages. Reactive protocols define a best path through the topology for every available node. This route is saved even if not used. Permanently saving routes cause a high traffic control on the topology, in particular in networks with a high number of nodes.

Reactive protocols are the most advanced design proposed for routing on Ad Hoc networks. They define and maintain routes depending on needs. There are different approaches for that, but most are using a backward learning mechanism or a source routing mechanism.

3. OVERVIEW OF AODV

Ad hoc On Demand Distance Vector (AODV) [2] is designed for use in ad-hoc mobile networks. AODV is a reactive routing protocol, it initiates the route discovery process only when it has data packets to send and it cannot find a route to the destination node. AODV uses sequence numbers to ensure avoidance of routing loops.

3.1 AODV Route Discovery

Route discovery process allows any node in the ad hoc network to dynamically discover a route to other node in the network, either directly within the radio transmission range, or through one or more intermediate nodes. In AODV protocol, the source node broadcasts a RREQ (Route REQuest) packet to its neighbors. If any of the neighbors has a route to the destination, it replies to the request with a RREP (Route REPly) packet; otherwise, the neighbors rebroadcast the RREQ packet. Finally, some RREQ packets reach the destination. At that time, a RREP packet is produced and transmitted tracing back the route traversed by the RREQ packet.

3.2 Route Maintenance

To handle the case in which a route does not exist or RREQ or RREP packets are lost, the source node rebroadcasts the route request packet if no reply is received by the source after a time-out. A route maintenance process is used by AODV to monitor the operation of a route in use and informs the sender of any routing errors. If a source node receives Route Error (RERR) notification of a broken link, it can re-launch the route discovery processes to find a new route to the destination. If a destination or an intermediate node detects a broken route or broken link, it sends RRER message to the originator of the data packet.

Every routing protocol have its own features and some disadvantages also. Likewise AODV also have some challenges to face under some specific situations, like:

1) Routing overhead incurred by control packets.
2) Repeated route establishment under high mobility of nodes.
3) High initial path setup time.
4) Very less information gathering about position of nodes.
5) Flooding of entire network by RREQ packets.
6) No alternate availability in case of link break.
7) No provision of avoiding congested links.
8) No QoS provisions.

4. EARLIER ADVANCEMENTS

With the popularity of wireless networks many researchers have tried to overcome the challenges faced in real life implementation of wireless technologies. Apart from other issues a lot of works have been contributed to improve the routing protocols in the ad-hoc networks. Addressing to the issues mentioned in earlier section many enhancements have been suggested to optimize the performance of the AODV routing protocol.

In our research we have reviewed many such enhancements of AODV, which are provided in this section.

The proposed cross layer approach in [5] finds the channel security at link layer to AODV routing protocol to improve the communication in vehicles for safety purpose. It also proposes a mechanism, AODV_BD, to improve the local repair during link break. In this data packets are sent instead of RREQ packets to find alternate path to the destination. The data packets are treated alike RREQ by intermediate and destination node. The packet header in data packet is used to find the reverse path. When this data packet has reached the destination, a RREP packet is sent to the source. In this way data is delivered and route is also established.

Though this approach reduces some control over head, but by sending data packet a lot of bandwidth is consumed.

In [6] AODV-BR is proposed keeping in view the higher extent of mobility of nodes in ad-hoc networks. In this paper a node overhears the RREP packet promiscuously to obtain alternate path and become part of mesh. The overhearing node records the neighbor as the next to the destination. When RREP reaches source, the path is used as primary path. When this primary path is broken, the packets are one hop broadcast to neighbors. Upon receiving this, neighbor node looks for alternate path in table and unicast the packet to their next hop node. Also a RERR is sent to source to find a new optimized path.

This new AODV have longer delays, it delivers more packets. It improves hop-wise data transmission per data delivery to the destination.

The author in [7] has proposed to enhance the network performance of AODV, when frequent link failure in network occurs due to mobility of the nodes in the network. In this work, during a transmission, when the promised data rate is not satisfied by any link, than traffic is stopped to avoid dropping and new route is found by sending RREQ.

The packet delivery fraction and end to end delay is increased, packet drop is improved. Un-intentionally it implements QoS in route establishment and in route maintenance.

In [8] a weight based packet scheduling is used for AODV. Weighted-hop scheduling gives higher weight to data packets that have fewer remaining hops to traverse in the network. For fewer hops a packet needs to traverse to reach its destination quickly and incurs less queuing in the network. For the scheduling algorithms that give high priority to control packets, it uses different drop policies for data packets and control packets when the buffer is full. In given queue, if incoming packet is a control packet, node drop the last en-queued data packet, if any exists in the buffer, to make space for the control packet. If all queued packets are control packets, node drop the incoming control packet.

Proposed scheduling algorithms that give higher weight to data packets with smaller numbers of hops or shorter geographic distances to their destinations, reduces average delay significantly without any additional control packet exchange. The weighted-hop scheduling algorithm show considerably smaller delay than the other scheduling algorithms.

A new node-disjoint AODV [9] is implemented to find different routes. For this, seen table is updated by adding seen flag, and RREP is updated by adding a field broadcasting id. Both these new field help in establishing actually node-disjoint paths by following the proposed algorithms. Here only one RREQ packet is used to develop all the available multiple paths. For data transmission first path is selected and decided numbers of backup path are kept in table. New path with less hop count is updated in table. Other backup route are found concurrently, with data transmission using first route. Researchers also proposes three route maintenance methods, in first backup route is used when primary route is broken, reducing RREQ., in second method route discovery is started when no backup path is left in table, availing at least a backup path in table. in third method intermediate nodes also backup alternate path for neighbor nodes, reducing the RERR propagation.

Use of one RREQ reduces routing over head, suitable for low and moderate mobility. First route maintenance method gives higher packet delivery ratio and end to end delay.

The packet dropout problem[10] during link failure is addressed in this paper. This SaP protocol helps to catch the packets during the packet drop at link breaks or path failure. In this new AODV when links break is about take place. Link strength is determined by using the battery power and energy level of node as metric. When link is about to fail the packets are sent for retransmission purpose to the neighbor node of successor to transmit them to the next node when that link fails. This protocol transfers the data from the failed node and delivers it to the node next of the failed node in the route through an alternate node.

The time required to perform the data/ packet transmission was far less than AODV. It increases the packet delivery ratio with less energy consumption and with less flooding of requests to the neighboring nodes at the time of delay. Shortest path is preserved during link failure.

Performance of AODV and DSR under mobility and terrain size is studied in [11]. Due to change in mobility link between neighbor nodes can break a number of times as a result of which the performance of a network may be hampered. Different terrain sizes and number of nodes may lead to varied node density in network.

In low terrain area both protocols PDF is near to 100%. In medium and In medium area with low and medium mobility AODV is better than DSR. In large area performance of both is decreased due low node density and high link failure, but still AODV is better. AODV is better than other reactive routing protocols for large areas and areas with high mobility.

In [12] paper, an Efficient Flooding Algorithm has been proposed that makes use of the nodes' position to rebroadcast the packets and efficiently spread the control traffic in the network. It is assumed that Geographical position of nodes is known. In this the radio range of a node is partitioned in four sectors, one candidate neighbor (farthest from that node, not far than 80% of radio range) is selected to rebroadcast the RREQ. This process until the destination is located. CNRR IP field is added in RREQ packet format.

This new AODV performs better for packet delivery fraction, data drop, total overhead and total throughput parameters, due to the huge saving of preventing the unnecessary RREQs, thus better bandwidth usage and reduced congestion. Thus knowing the geographical position of the mobile nodes can assist the protocol to reduce the number of retransmissions, therefore enhancing the protocol performance. In this approach there is a possibility of missing the destination node by not finding a route to that because of some possible node positions.

Least congested path does not guarantee the most stable path [13]. This new WAODV is based on stable path, it uses HELLO packets of intermediate nodes to find the most stable neighbors, and thus the most stable path. Higher the number of HELLO messages received from a node means more it stays in the coverage area of a node. In WAODV before requesting a route to a destination all nodes listen for some predefined time intervals. Then divide the number of HELLO messages by listen period to find a Reliability Factor(RF). Every node attaches its RF to RREQ before broadcasting. Finally destination performs a division on sum of all RFs by hop count of the path and selects the path with Maximum average value.

Impact of jammer leads to link breakage. Due to selected stable path, route rediscoveries are reduced, which saves bandwidth and node power. Suitable for multimedia transmission, can be adapted to network having different node velocities, best suited for military conditions. As a drawback to this we can assume that wait time before sending RREQ adds to the End to End Delay.

Aim of research in [14] is to reduce routing overhead caused by HELLO and RREQ in wireless networks. E-AODV routing protocol has been proposed in this paper which merges the Blocking Expanding Ring Search (BERS) & Routing packets as HELLO packets techniques to reduce routing overhead. Blocking Expanding Ring Search (B-ERS) reduces the search area during route discovery process using Stop packets. Use of routing packet as hello packets for determination of link connectivity. Stop packet reduces unnecessary broadcast of RREQ after destination is reached. RREQ and RERR can be used as HELLO message with efficient use of Control_ Timer and Hello_Timer. More the RREQ & RERR are forwarded, less HELLO packets will be used to transmit link availability information, which in turns decreases the overall Hello load.

Routing overhead is much improved in EAODV as compared to conventional AODV when the network size and the mobility of nodes is increased. Generating a STOP packet every time a destination is found is as bad as generating overhead due to RREQ packet.

The endeavor of work in [15] is to design a routing protocol that offers lesser packet drop and more end-to-end throughput. The proposed protocol selects route on the basis of traffic load on the node and resets path as the topology changes. Instead of transmitting entire data through one route, new efficient paths are discovered from time to time during transmission. Performance can be increased by selection of less congested and smaller path. In this when a neighbor receive RREQ packet it will calculate the number of packets in the queue and divide it with the size of the queue and add the value in the reserved field of the RREQ. At the destination average Load ratio is calculated by dividing the reserved field value with the number of hop count. The destination selects path with least ratio, thus selecting lowest congested path. If a new stable path is available at later stage of time, it will be selected.

Sharing of load decreases the network congestion which directly leads to the decrease of overflowing of queuing buffer and packet loss. Hence packet delivery ratio increases and throughput is increased. Proposed protocol is efficient for a transmission that requires a link for longer period of time.

ELRAODV [16] makes mobile nodes more aware of the local connectivity by extending original HELLO to NHELLO message in AODV. That extra information of the local neighbors allows ELRAODV to repair a route by sending a unicast request rather than broadcast as in original AODV. The aim is to perform local repair efficiently using local info only and adding lesser overhead. RREP packet is extended by adding next to next node field. A new packet is made, called NHELLO, which is used to gather information of all neighbors of a node. A new Local RREQ (LRREQ) packet is also designed Now if a link breaks, a new LRREQ packet is unicast to a neighbor to find path to next to next hop. The details of Next to Next hop is gathered from modified RREP packet This neighbor should have broken next node in its neighbor list. This scheme can also be applied to link break close to source node.

Major improvement of ELRAODV is in terms of routing overhead, which is lower than classic AODV. Packet delivery ratio and end to end delay for ELRAODV is also better than LRAODV as it is able to repair more number of routes. Extra packets are created which may add to overhead increase, even if HELLO packet is used lesser number of times.

To enhance the QoS features like network stability, packet delivery ratio and network life time [17] using the three different parameters viz. stable routing, battery power and signal strength. In this work the concept of backbone nodes is used in the AODV routing protocol. Backbone nodes are selected on the basis of availability of nodes, battery power and signal strength. These nodes help in fast reconstruction of broken links. Details of backbone nodes is kept in routing table by every node. During link break the backbone node selected should be at one hop distance. In route establishment phase the RREP packet is overheard by the nodes not in route promiscuously and store that neighbor as next hop to the destination in backup route table. When a route break occurs it just starts from these nodes only. In route maintenance phase the node detecting the link break performs one hop broadcast of the data packet informing its neighbors of link break and the node with good power status and signal strength is selected to find alternate route. In local repair also the backbone nodes are selected, even if they provide long route. Thus improving the stability and packet delivery ratio.

The research work carried out in [18] is simply fine tuning the various timers and other parameters of AODV to optimize the energy consumption during the routing of the packets in wireless sensor networks. In WSN the maximum energy consumption is at the transceiver, the routing protocol in use must perform reliable data transfer using less amount of energy. Use of HELLO message decreases the throughput. With HELLO message the end to end delay is improved as due to periodic beaconing. The packet delivery ratio also reduces with the use HELLO messages

Max - hop or the diameter of a network [19] is used to adjust the parameters of AODV routing protocol to enhance the performance. AODV have many timers and counters and the default value set to them may not be efficient to get best performance of the network itself. To prevent the unnecessary broadcasting of RREQ TTL_START, TTL_INCREMENT are set equal to the NET_DIAMETER value. The NET_DIAMETER describes the maximum distance between any two nodes in the network. To measure the max hop value RREQ and RREP packet formats are updated. Also a NET_DIAMETER filed is added to the routing table. When the routing table entries are updated it is assured that every entry equals max hop value. HELLO packets can also be used to calculate the max hop value when there is no RREQ to broadcast. Finally the max hop value is assigned to the NETWORK_DIAMETER parameter of the AODV routing protocol. DA_AODV enhance the performance by reducing the overhead and improving the overall throughput.

Directional AODV (D-AODV) [20] routing protocol proposed a concept of hop count to a gateway. In the route discovery to a gateway, D-AODV can reduce the number of broadcasting route request (RREQ) packets by using a restricted directional flooding technique. Simulation results showed that D-AODV could significantly reduce routing overhead by RREQ packets and enhance overall throughput performance.

AODV-NC [21] is used to limit route request broadcast which are based on node caching. The intuition behind this approach is that the nodes involved in recent data packet forwarding have more reliable information about its neighbors and posses better locations than other nodes. Nodes which have been recently involved in data packet forwarding are cached and used to forward route request. Dropping a route request from forwarding the other node considerably reduces routing overhead.

In [22], authors present a node-disjoint multipath extension for AODV referred as MP-AODV. MP-AODV discovers two routes for each source-destination pair, a main route and a back-up route. The routes are discovered using two RREQ messages, each for one route. Whenever one route is broken, the other is used for data transmission and a RREQ is flooded to replace the broken route. This approach has two drawbacks: (i) MP-AODV has higher overhead than the traditional AODV because it requires one RREQ flooding for one path and additional RREPs for node-disjoint path and, (ii) the proposed approach is not able to find all the available node-disjoint paths between a source and destination pair.

Authors in [23] propose a scheme to find all node-disjoint paths from source to destination. NDM-AODV also considers the residual energy of nodes while selecting the routes. The routing overheads to find multiple paths are kept minimum by using Destination Source Routing (DSR) protocol like source routing in route discovery process. Periodic HELLO messages are used to maintain local connectivity for all active routes during the route maintenance phase. The main disadvantage of the proposed approach is that as the size of the network increases, the size of the RREQ and RREP messages also increases due to path accumulation function. Furthermore, the size of routing table at destination node also increases due to the storage required to store multiple paths.

In [24] author proposed two methods to reduce the number of rebroadcasts: the probabilistic scheme and the counter-based scheme. The probabilistic scheme is similar to the simple flooding, except that the nodes rebroadcast the RREQ with a predetermined probability p. In the counter-based scheme, upon receiving a previously unseen broadcast message, the mobile node initializes a counter with a value of one and set a random defer time. During this deferring time; the counter is incremented by one for each redundant message received. If the counter is less than a predetermined threshold, when the deferring time expires, the message will be relayed. Otherwise, it is simply discarded. The probability-based and the counter-based methods are simple, but their performance depends on the variation of network density. This is due to the values of the probability and the counter threshold that are defined regardless of the variation on the network environment.

EFPA [25], the author proposed an efficient flooding algorithm, which generates a small number of packet transmissions during a short time. EFPA allocates a priority of packet transmission or a waiting time to every node considering the distance from a sender node and the direction of packet transmission, so every node in a network can receive packets rapidly.

The status adoptive routing protocol [26] combine the shortest route selection criteria of AODV with real network status including link quality, the remaining power capacity and traffic load. The traffic load status is defined as a ratio of maximum length of queue and number of buffered packets. The paper contributed by giving status adoptive routing which improves network life and delivery ratio.

For heterogeneous MANET a protocol [27] is proposed. That used congestion aware routing which employ combined weight value as routing metric based on data rate, queuing delay, link quality and MAC overhead. A cost factor is calculated and among the discovered routes, the route with minimum cost is chosen. Load status is calculated by sending Dummy RREP those are stored in the node to destination to estimate delay. Route with delay within the bound of application requirement is selected.

In [28] classic AODV is optimized by proposing a new routing metric for Wireless Mesh Networks. Support for mobility and network dynamics makes AODV as a candidate for routing in WMN. AODV uses hop count as a metric for selection of path but this path may be having high congestion, low throughput and low bandwidth, which may lead to poor performance of the WMN. Thus using some existing metrics like hop count, per-hop round trip time, per-hop packet pair delay and expected transmission cost the author has suggested a new metric for AODV to be used in WMN. The reserved 11 bits of RREQ packet are used for this purpose. Every node calculate the value of expected transmission count and add to the previous value in RREQ packet. When this RREQ reaches the destination, it performs final metric value by multiplying the hop count. The path with least cost is selected as optimal path and a RREP is unicast back to source. Using this cost metric enables AODV to select the optimal path with low packet loss ratio, load balanced path and with high bandwidth. The drawback of this scheme is that it will take more time to calculate the optimal path and extra calculations as overhead but once the path is established, the throughput is increased.

Enhancement of Fault Tolerance AODV (ENFAT AODV) [29] is designed to handle the problem of fault tolerance in Wireless Sensor Networks. In this a backup route is created and is used when primary route fails, to reduce number of packet dropped. RREQ and RREP packets are updated with BACKUP flag, UPDATE flag DistanceToDest flag. It also uses a new routing table for storing backup path, called Backup Route Table. Some of feature like HELLO, Gratuitus RREP and RREP-ACK are removed in this version. The main route is discovered by same process as in classic AODV. The backup route establishment goes with RREP phase of main route. The nodes which receive RREP along main path creates a backup path by broadcasting a backup RREQ with TTL value set to three. This is again processed as similar. The intermediate nodes take consideration of DistanceToDest flag to ensure loop freedom. The path so discovered is stored in Backup Route Table and is used under any link failure. This approach provides reliable packet delivery with increased throughput and improved end to end delay. However, it is also calculated that this scheme increases the control packet load in the network for backup route establishment and updating that consumes more network energy. The ENFAT-AODV performs well only in the static or very low movement scenarios.

AODV-I [30] is an improved AODV which enables congestion control processing and routing repair mechanisms to the RREQ packet. In route establishment process, in this work it is assumed that by analyzing the size of buffer queue, any intermediate node can judge its busyness and accordingly decide how to deal with RREQ and RREP. If the node is idle it will allow these packets to go through else these control packets have to wait. If other nodes are busier than this node than the path will eventually be established through this node. For route repair while a RREP was in transit, the node facing the link error will cache the RREP and broadcast RREQ-r with TTL set to 1. As every node records the reverse path to source during route discovery, the node receiving this RREQ-r having path back to the source will reply with RREP-r. This replying node can also take in consideration its busyness also, to reply immediately or wait for some time. The node performing the route repair will update its routing table based on first RREP-r and earlier received RREP and then the final RREP is sent along the path. After this the route repairing node will send a RREP-u packet to nodes towards destination helping them to update their routing table with new updated path and its sequence number. These improvements to the classic AODV not only reduce the packet loss rate and end to end delay but also enhance the utilization of the network resources.

5. CONCLUSION/ DISCUSSION

With the progress of time the wireless technology is finding interest from many sectors. Much work is being done to improve it for practical implementation in real life scenarios. Routing protocols play an important and pivotal role in success to practical implementation and thus it has become the prime area of research in MANETs since some time..

From the previous work done, it is observed that reactive routing protocols are the best choice for Ad-hoc Networks, as they are fast to establish routes with exchange of fewer packets thus incurring low routing overhead. Among others much of the work has been done to improve the state of art Ad-hoc On-Demand Distance Vector (AODV) routing protocol. In this paper we have observed major research work concentrates on new route establishing phase, route failure phase, energy efficiency, providing QoS, finding a stable long lived path, congestion control and minimizing routing overhead under mobility and heavy traffic.

With the knowledge gained and some scope of improving this reactive routing protocol, in future we will be working to add some advancement to AODV to find more stable routes for sender nodes in MANET scenarios.

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