An Epigrammatic Study on Ad-Hoc on-Demand Distance Vector Routing Protocol And Its Variants

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Abstract- *Mobile Ad-hoc Networks (MANET) is one of the current research areas in the field of wireless networks. Ad-hoc On-Demand Distance Vector Routing Protocol (AODV), one of the prominent protocols in MANET is under study for its applications and flexibility. The current paper gives a concise study on the various procedures involved in the working of AODV and the current research on AODV.*

Keywords- AODV, MANET, ESR, Route Discovery, Route Maintenance

I. INTRODUCTION

An Ad Hoc On-Demand Distance Vector (AODV) is a Reactive routing protocol designed for wireless and Mobile Ad-hoc Networks. This protocol discovers routes to destinations when required and are maintained only as long as they are required. It supports both unicast and multicast routing. AODV is a variation of Destination-Sequenced Distance Vector (DSDV) routing protocol. It offers fast habituation to changing link conditions, low processing and low memory overhead.

II. WORKING OF AODV ROUTING PROTOCOL

AODV nodes communicate using two procedures Route Discovery and Route Maintenance. AODV nodes maintain a routing table in which next hop routing information for destination nodes is stored. The data structures/ fields in the routing table are Destination IP Address, Destination Sequence Number, Interface, Hop Count (number of hops needed to reach destination), Last Hop Count, Next Hop, List of Precursors, Lifetime (expiration or deletion time of the route) and Routing Flags.[1][2].

Whenever there is a request for an AODV router for message to be sent, it checks its routing table to see if there exist a current route to that destination node. If it exists, the data packet is forwarded to the convenient next hop towards the destination node else the **Route Discovery process** is initiated.

A. Route Discovery Process:

In the AODV routing protocol, each node in the network can join or leave at any time due to the dynamic nature of network topology. Hence the nodes have to frequently monitor their neighbors. The HELLO message is broadcasted to provide link connectivity information periodically. Whenever a node receives a HELLO message from the neighbor node, it ensures that there is a valid route with the neighbor node. A new route is to be created if there is none.

If a route already occurs, the lifetime of the route should be increased and the hello message packet must contain the latest destination sequence number of the node[13]. This route can be utilized to transfer packets. The source node creates a RREQ packet and floods the network by broadcasting it to its neighboring nodes, which broadcast the message further.The broadcast ID in RREQ is incremented each time the source node instigates RREQ.

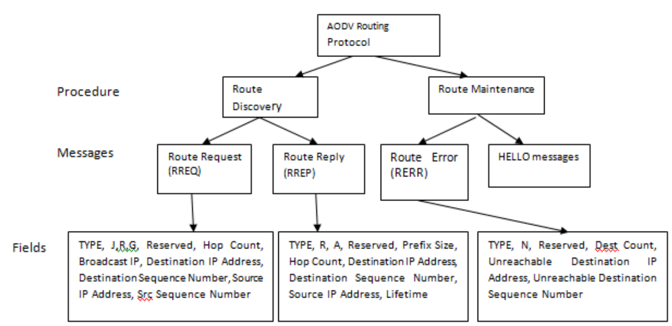

Figure 1: Working Parameters of an AODV Routing Protocol

The sequence numbers are used to determine the logical time of each data packet and each request is identified uniquely by the broadcast ID and the IP address in the RREQ. Sequence numbers are used to ensure that nodes only refresh routes with latest ones. Loop freedom is ensured as RREQ messages include the Source sequence number, and its latest known destination sequence number. If the node receives same RREQ message through another path, it picks the route with the smaller hop count. To reply to a Route Request , node's destination sequence number is compared with maximum destination sequence number of all nodes through which the RREQ message has passed. If so then a RREP is sent back to the Source through this route [3]. The node sets up a reverse route entry for the source node in its routing table. If a destination node or a transitional node, which has a route to the destination receives the RREQ, it initiates the RREP and Unicast's it towards the source node through the node from which RREQ was received as the next hop.

When RREP is routed back along the reverse path and received by an intermediate node, it sets up a forward path entry to the destination in its routing table. When the RREP reaches the source node, it means a route from source to the destination has been established and the source node can begin the data transmission.

To control the flooding and network wide broadcast of RREQ for large networks, the source node uses an E**xpanding Ring Search Technique (ESR)**[3].

A. Expanding Ring Search Technique (ERS)

- In this technique, the source node sets the Time to Live (TTL) value of the RREQ to an initial start value which determines the maximum number of nodes that the RREQ message can go through.
- If there is no reply within the discovery period, the next RREQ is broadcasted with a TTL value increased by an increment value which can be specified value [4], a fixed value of 1 [5] or 2 [6], or a random value [7]. TTL determines the order of flooding .
- The process of incrementing TTL value continues until a threshold value is reached, after which the RREQ is broadcasted in a ring across the entire network. .

ERS reduces overhead and utilizes energy efficiently for networks in which the destination node is at a small distance from source node. But if the destination node is at a larger distance from source node then source node has to rebroadcast RREQ several times. The intermediate nodes have to receive and process the messages repeatedly. Indirectly increases routing and energy overhead for large networks. To overcome this drawback many researchers have proposed variants of ERS.

Duy Ngoc Pham et. al.[8] proposed a variation of ERS in which Local network information that has been collected during the first search at the nodes is used by the next search by the nodes in first ring. But with TTL value lesser than 2 , neighbors will not be able to forward RREQ . Hence the border nodes will not be able to forward RREQ again.

D.N.Pham et. al.[9] proposed a modification to ERS to handle the nodes whose TTL value is less than 2. This approach not only provided an energy efficient routing, but also handles the overhead occurring due to mobility between nodes. It was observed that energy efficiency is obtained by making some nodes silent on the basis of information received in the RREQ. In this approach the initial states for relaying the message is activated only when value is greater than 2 else initially set to "false". But node whose TTL value is less than 2 might be processed before due to mobility, thus it will not participate in the second search.

Shweta Mishra et. al. [10] proposed a Modified Expanding Ring Search Algorithm (MERS), in which the node relay a RREQ with TTL value greater than 1, its both relay and forward value becomes "false" which are initially made true. When a node receives a duplicate RREQ the node will match its own address with the predecessor address (address of node which sends message to sender). If it matches it will set the relay value to "true" and drop RREQ.

B. Route Maintenance

A route discovered between a source node and destination node is sustained as long as it is desired by the source node. Due to mobility in MANET and the movement of source node during an on-going session, route discovery mechanism can be reinitiated to discover a new route to the destination. If the destination node or a transitional node moves, a link break in an active route is detected and a Route Error (RERR) message is initiated by the node upstream of the break to the affected active neighbor nodes. Consequently, these nodes propagate the RERR to their neighbor nodes till the source node is reached. RERR is used to convey other nodes that the loss of a link has occurred and hence which destinations are now unreachable.

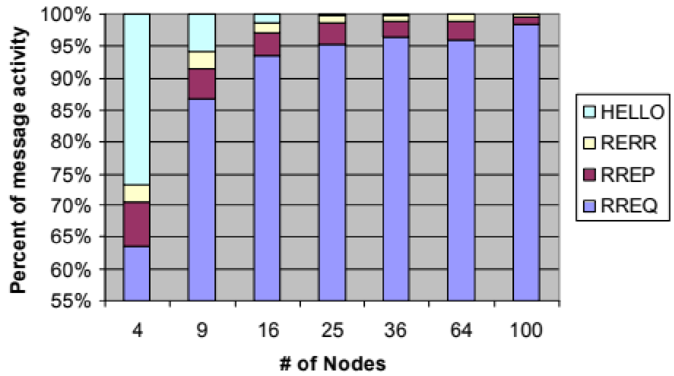

Figure 2: Breakdown of AODV Messages

Figure 2 illustrates that maximum ratio of messages (HELLO,RREQ,RREP,RERR) passed through the AODV network is that of RREQ whose proportion increases with the number of nodes. This is because, upon each route request RREQ messages are flooded through the network. In contrast, RREP, RERR, and HELLO messages are always sent to specific neighbors nodes.

III. RESEARCH IN AODV

Since AODV gives an alternative route instead of an optimized one, Yang Hua et.al [13] implemented continuous Hopfield Neural Networks to optimize the AODV route and to find an optimal route, to improve the functionality and sustainability of MANET. The simulation results indicate that CHNN-AODV as more effective and advantageous than AODV in the measurement of packet receiving rate, end-to-end average delay and routing recovery frequency, but energy consumption is higher.

MANETs are vulnerable to a number of security issues. One among them is wormhole attack in which intruder node tunnels packet to the other intruder nodes and results in a fake route. Jamali S et.al. [14] designed an AODV-based routing protocol which employs fuzzy logic and artificial immune system technique which is robust against wormhole attacks. The fuzzy logic system is used to distinguish the secure routes from the others by considering node's residue energy, path's hop count. To recognize and bypass the wormhole attackers, the artificial immune system was employed without affecting the overall efficiency of the network.

Energy efficiency is a very important factor of research in MANETs as nodes are battery operated. Wireless communication links generally deteriorate due to the characteristics of realistic physical layer, hence Faouzi, Hassan et. al. [15] used a realistic physical layer by modeling transmission errors by the Gilbert-Elliot model. They took into account a metric based on energy consumption during route discovery, thereby increasing the network lifetime, packet delivery ratio and decreasing load of control packets. Praneeth Paranavithana et. al.[16] presented a modified AODV routing protocol in which a node calculates its residual energy and selects the best path based on the existing matrices and the total energy of the path. Each node adds its remaining energy during RREQ packet exchange which is copied to RREP packet and sent to source node in reverse path. The route with highest energy value gets priority over other routes.

Sung-Ju Lee et. al. [11] proposed a scheme to improve existing AODV protocol by forming a mesh and providing various alternate routes. The proposed algorithm (AODV-Backup Routing) creates mesh and multipath without transferring any extra control messages. This improves the performance of AODV in terms of throughput. As the mobility increases the performance gain by alternate routes becomes more important. When link breakage occurs, AODV-BR uses longer equivalent paths to transfer packets which would have been dropped in AODV Routing Protocol. Another drawback is the creation of redundancy due to multiple alternate paths which in turn increases the number of data packet transmissions.

Meeta Singh, et. al. [17] designed a Secure and efficient AODV routing protocol (SE-AODV). The route maintenance is based on the proactive procedure by applying, link state prediction algorithm to predict the link breakage beforehand. Data packets are discovered and diverted through multiple disjoint routes without sending a warning message with secure transmission to the source node which the occurrence of link failure is reduced. C. Perkins et.al.[6] proposed an extension of AODV, called AOMDV, a multipath routing protocol which can discover multiple paths between the source node and the destination node. AOMDV reduces packet loss and delay, and improves the process of route discovery.

Dipika Sarkar et.al.[18] proposed the finest route for data delivery using pheromone value of the path. The pheromone value is calculated based on end to end reliability, congestion, number of hops. The path with highest pheromone value is selected for transmission of data packet.
Anouar Boudhir et.al. [19] proposed Dicho AODV which aims to reduce the number of messages RREQ during route discovery process. Dichotomic algorithm focuses on finding the target nodes following a request RREQ. It consists of a probabilistic search for RREP (Route REPlay) from

destination node, in the right field, before the left one, of the node by minimizing the number of queries initiated by the node.

IV. DRAWBACKS OF AODV PROTOCOL

- A large number of control packets are generated when a line breakage occurs. These control packets increase the congestion in the active route.
- Route discovery mechanism based on simple flooding method. Mobile node massively rebroadcasts received Route REQuest (RREQ) packets until a route to destination is established. This can cause more retransmissions and thus excessive energy consumption.
- It has a high processing demand and consumes a large share of bandwidth.
- AODV is based on the assumption that all nodes must cooperate and without their cooperation no route can be established. Hence AODV is vulnerable to various kinds of attacks.
- Does not consider remaining energy of nodes and no guarantee for long network lifetime.
- It is possible that a valid route may have expired and the determination of a reasonable expiry time is difficult due to high mobility of nodes.
- As the size of network grows various performance metrics begin decreasing.
- Considers hop count as metric hence quick diminution of battery power of nodes.

V. VARIANTS OF AODV PROTOCOL

Table 1: Types of AODV and their drawbacks

Sl. No	Name of the variant	Objective	Methodology	Drawback
1.	AODV-ROE (AODV Reduction Overhead and Energy)	To reduce the number of control messages and to balance energy consumption among all nodes in networks	• Allows each destination to receive a request packet only when all intermediate nodes along the route have good levels of energy, and consequently, the first message received by the destination is considered taking a route reasonably powerful, and essentially with an energy sufficient enough. • Each node determines from its residual energy,a decision based on threshold value.	Inadequate for ad-hoc networks of high mobility.
2.	EAODV	To establish a reliable and energy saving transmission path in Ad hoc networks and improves the routing interrupt update strategy of the original AODV protocol.	• It proposes a dynamic routing algorithm, which defines a rule that if the energy of nodes are overused or not and represents them with a mark of 0 and 1.[15] • When a neighbor node receives a message with a tagged message, it reads the information of the mark, and selects a suitable route selection algorithm from the proposed minimum energy consumption routing algorithm and the energy balanced routing algorithm according to the mark bit, and establishes the route.[15]	Efficiency decreases as number of nodes in a network increases.
3.	Dicho_AODV (Dichotomic AODV)	Aims to reduce the number of messages RREQ, by a new probabilistic and dichotomic protocol for the discovery of destination.[19]	• The concept of Dichotomic algorithm focuses on finding the target nodes following a request RREQ • It consists of a probabilistic search for RREP (Route REPlay) from destination node, in the right field, before the left one, of the node by minimizing the number of queries initiated by the node. [19]	Energy consumption increases very fast when the speed of nodes exceed 20m/s.
4.	stability and Energy Aware Reverse Adhoc On demand Distance	It provides energy and route stability metric	• Uses the path with high RF value as the primary path to route the data packets where as secondary paths are used based on the descending order of their RF values. [22] • It uses a new make-before break route maintenance mechanism. [22]	When the mobility increases, the environment becomes much more dynamic

	Vector (SEAR-AODV)			and unstable
5.	Reverse AODV (R-AODV)	Decreases both communication delay and power consumption as well as increase in packet delivery ratio.	• Uses reverse route discovery procedure. • When the destination node receives first route request message, it generates so called reverse request (R-RREQ) message and broadcasts it to neighbor nodes within transmission range like the RREQ of source node does.[12] • When broadcasted R-RREQ message arrives to intermediate node, it will check for redundancy. If it already received the same message, the message is dropped, otherwise forwards to next nodes.[12]	Causes a lot of control packet overhead as R-AODV floods route reply message
6.	Enhanced ANT-AODV	To construct an optimal route from source to destination	• Pheromone value of route is calculated based on end to end reliability of path, congestion, number of hops and residual energy of nodes along the path.[18] • The path which has highest pheromone value will be selected for transmission of the data packet.[18]	No alternate path if route error occurs
7.	Multi-Route AODV Ant routing	To reduce end to end delay during data packet delivery.	• AODV discovers routes on demand and ACO creates routes between nodes irrespective of the demand. • It uses alternate paths for data delivery.	Storing and maintaining backup routes is an overhead.
8.	Node Residual Energy Adhoc On Demand Distance Vector (NREAODV)	Increase the life time of network and fairly distribute an energy consumption of hosts in MANET.	• In NRE-AODV, when all nodes in some possible routes between a source-destination pair have large remaining energy than the threshold then a route having maximum of the difference of average sum of residual energy and threshold among the possible routes is selected. [21] • Otherwise the maximum difference of the average minimum residual energy and threshold among the routes is selected.[21]	Performance degrades as network becomes dense.
9.	Modified-AODV (M-AODV)	To increase the performance when the underlying system has routes that have high throughput and hop count.	• Modified the minimum hop count routing metric to consider the effect of route throughput, in route discovery process.[20] • The value of the throughput field in the RREQ packet is compared with the link throughput, when forwarding the RREQ packet. [20] • If the throughput of the link is less than the throughput field value in the RREQ packet, then the throughput field value is replaced by the throughput of the link and vice versa. The hop count is also incremented by one while forwarding the RREQ packet.[20]	Packet loss rate is high if interval between packets is reduced.

VI. CONCLUSION

There is a vast scope for enhancement in features and working of AODV routing Protocol. Still research can be carried out for the security against various type of attacks. Also energy efficiency for large networks as size of network grows, is a concern for future research. Concepts of applied mathematics like game theory and enhancements in Ant colony Optimization (ACO) can be utilized for further enhancement in terms of security and energy efficiency of AODV.

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