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Survey on Energy Efficient Algorithms for AODV

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Abstract: **Wireless technology have gained popularity these days because of its portability and other features. Ad-hoc networks are being used in many sectors. Basically AODV is a flat based routing protocol for ad-hoc networks. As AODV is ad-hoc in nature, hence the routes are created on demand. As in ad-hoc networks battery powered nodes are used. During the communication between nodes, the battery of the nodes may exhaust leading to link failure. So we need to increase the lifetime of the nodes to avoid the link failures in the network. In general, energy and security issues arise in AODV routing protocol. Energy efficiency is the major challenge of this routing protocol. Energy efficiency can be achieved by enhancing the lifetime of the nodes. So, various algorithms have been developed to make the AODV routing protocol energy efficient. We have done a survey on the algorithms, which are developed to make the AODV routing protocol efficient.**

Keywords*: *AODV, flat based routing, hierarichal, blackhole, grayhole, node disjoint paths, flower pollination algorithm.

I. INTRODUCTION

AODV is a flat based routing protocol [1,2] and as in flat based routing the routers or nodes are placed without any hierarchical manner, so it is known as ad-hoc protocol. AODV routing protocol is mainly used for wireless sensor networks which are ad-hoc in nature such as MANETS i.e. mobile ad-hoc networks. Basically in AODV, the network remains still until the transmission or link is needed. When a node needs a route or path to transmit data, it sends the request for the path in the whole network. The nodes present in the network, receive the request and send the replies in the form of temporary routes. The node which is waiting for the connection, checks for the temporary paths and selects the path to the destination node. The path selected by the source node is reliable and contains less number of hops. After the data has been transmitted, the path is terminated. In AODV protocol, the route is created whenever needed, so the energy can be saved and network becomes efficient. When there is a failure in the network, a routing error message is circulated in the whole network[3]. The source node receives the routing error message and repeats the process for creating a new route.

In AODV, the temporary route requests sent by the nodes are having a unique sequence number so that the routes are not repeated again and again[4]. Every route request has a certain lifetime, so that they are not retransmitted after their lifetime ends. But due to this feature, when a link fails, the new route request takes time to be sent because it takes time twice to lifetime to retransmit the same route request. AODV routing protocol decreases the traffic during communication and is simple and hence no complex computation is required for it.

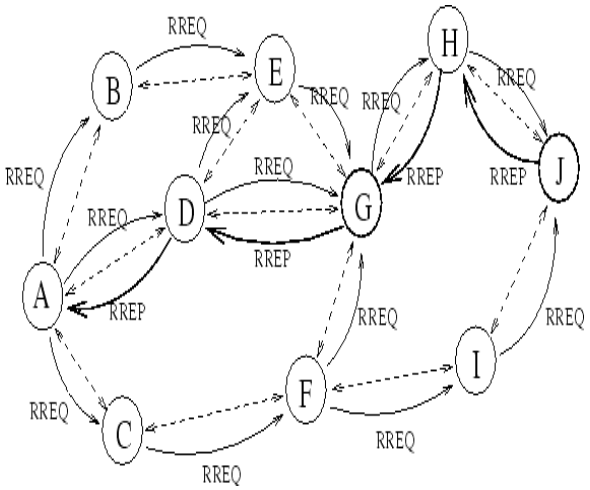

Figure1. Routing in AODV

In AODV routing protocol, the mechanism for path discovery is followed by three messages which are broadcasted in the network: RREQ(route request),RREP(route reply),RERR(route error). These messages are circulated during the discovery and termination of the routes. RREQ stands for route request. Whenever a node present in the network needs to send the data or information, it needs a route for it. As we know in AODV[5] as the name suggests, the route is created whenever the data is to be sent. So the source node sends the route request message i.e. RREQ message in the whole network. When the RREQ message is broadcasted in the network, the destination as well as the intermediate nodes sends the route replies i.e. RREP message to the source node. The source node receives the RREP message from the nodes. Each route reply message consists of a sequence number. The source node selects a path with less intermediate hopes and hence the connection is established. If there occurs a path failure, the intermediate node will send the RERR message i.e. route error message to the

source and the process of detection and termination of the path will be repeated again.[6]

In AODV, hence RREQ, RREP and RERR messages are broadcasted in the whole network for path discovery and path maintenance processes as shown in figure.

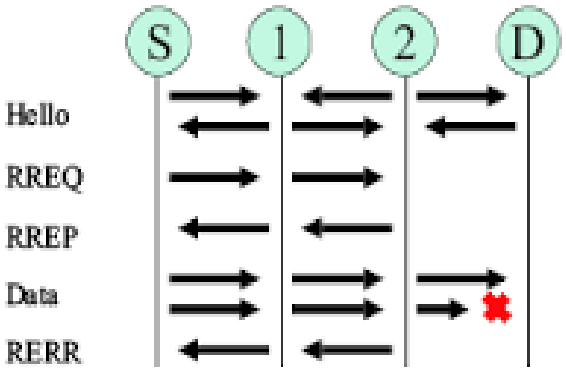

Figure2. Broadcasting of messages in AODV

In AODV routing protocol shortest as well as reliable path is selected for communication. So the two main issues that arise during path selection in AODV routing protocol are security and energy efficiency. To overcome security and energy efficiency issues in AODV routing protocol, various algorithms have been developed. So in AODV path selection is a very crucial process.

II. ISSUES IN AODV:

Two main issues that arise in AODV are security and energy issues which degrade the performance of the AODV algorithm. In the next section we will have a brief discussion about these issues.

Security issues in AODV: It is one of the critical issues that arise in AODV. It occurs due to presence of malicious nodes present in the network. These malicious nodes are responsible for denial of service. Hence the packet dropping takes place. To avoid malicious attacks detection and bye-passing of malicious nodes is done. Cryptography approach is used to detect and bye-pass the malicious nodes present in the network.[7] Hence various encryption algorithms can be used to make the AODV routing protocol more secure. Mainly two procedures, detection of malicious nodes present in the network and bye-passing the malicious nodes, are used to make the Ad-hoc network secure. Ad-hoc networks are established in military or disaster relief areas which are insecure networks. Hence secure network is required for communication. Hence enhancement of AODV routing protocol is needed in terms of security. Security attacks in AODV are Grayhole attack[8], wormhole attack and blackhole attack[9].

Energy issues in AODV: In ad-hoc network, nodes are placed without any hierarchy. And the routes are created as per requirement. Whenever the sender wants to send the packets, it broadcasts the route request message in the network and the nodes present in the network send the route reply messages with their unique sequence numbers. Hence the route with less hop count is selected. Now as the ad-hoc networks are established in remote areas, so nodes which are deployed in the network must have longer lifetime i.e. longer battery life. [3]

In AODV routing protocol, the path with less hop count is selected for transmission of packets. So if this path is selected as shortest path again and again for faster transmission, the nodes present in the path may exhaust faster, creating a network failure. Hence the network will be disconnected and communication will be stopped. Hence an energy efficient network is required to make the communication more reliable. Battery lifetime time should be maximized to increase the lifetime of the network.[4]

To enhance the AODV routing protocol in terms of energy, various algorithms have been developed. With the help of these algorithms, researchers enhanced the lifetime of the Ad-hoc networks. We will discuss these algorithms in this paper.

III. ENERGY EFFICIENT ALGORITHMS FOR AODV IN AD-HOC NETWORKS:

As AODV routing protocol must be energy efficient to have longer lifetime. So researchers have developed various enhancements in AODV to make it energy efficient. These algorithms are discussed below:

A. *EE-AODV:* As the ad-hoc network is a battery operated network, energy is an important perspective for efficient communication. So shortest path is not optimal path for communication. So the algorithms which are created to make the routes energy efficient are known as minimum energy routing[10]. Energy efficient AODV[5] protocol is the enhanced version of AODV. In this protocol every node is provided with an threshold energy level. If the energy of the node decreases than the level provided, the node is not considered as next hop or intermediate hop. During the route discovery, after the RREQ message is broadcasted in the network, the nodes send REPEL message in addition to RREP message. REPEL stands for reply energy level. Hence we know about the energy of the node and determine if the node is having required energy level with respect to threshold energy or not. If the node is having less energy than the threshold level, an alternative route will be selected. [11]

B. *MEL-AODV:* In maximum energy level-AODV routing algorithm, the route selection is done on the basis of overall remaining energy present in the nodes. Hence maximum energy path is selected. Selection of path depends upon highest combined energy of all the hops present in the

route. MEL-AODV is based upon few assumptions which are:

1. In ad-hoc networks, the hops or nodes are having randomly distributed energy levels.
2. Signal attenuation remains same during the communication or transmission between two hops.
3. Power information may be provided to the network layer.[4]

On the basis of these assumptions, we can get information about the energy level of the hops. Most of the algorithms take into account loss ratio, delay etc. while neglect the energy level of the nodes. Due to which link failure takes place. So the MEL-AODV protocol is proposed to select optimal path for communication. Hence we can find the effective energy efficient path for transmission, thereby balancing load on the hops (nodes).[12]

C. *RSEA-AODV***:** As we know AODV[5] is on demand routing protocol. Hence path is created as per requirement. We must avoid the path in which the intermediate nodes are having less residual energy. The energy aware routing protocols[13] basically increase the lifetime of the nodes thereby reducing the power consumption in the nodes. The cost of the battery must be low. In RSEA-AODV route discovery is done by sending RREQ message which consists of accumulated path stability(APS), accumulated energy metric(AEM) and required energy(REQe) as well. Hence required energy as well as residual energy can also be calculated. Hence by sending RREQ message throughout in the network, we can calculate the residual energy of the hops and can compare with the required energy. If the residual energy of the node meets the requirement, path is selected.
RSEA-AODV has a feature i.e. known as make-before-break route maintenance feature. In RSEA-AODV if during communication, any intermediate node reaches to low energy level, it broadcasts HLP message to its neighboring hops. Neighboring hops find the new route with the help of the routing table and communication takes place through the new route. Hence the packet loss can be avoided. If by any chance the destination is the node having low battery level, it sends the intimation to source node to stop the transmission. Hence wastage of resources can be prevented. Route change request messages are sent by the node with low battery level to the source node if there is no next hop present. Hence re-route discovery takes place [14]

D. *EC-AODV:* In AODV, the maximization of lifetime of the batteries of nodes ia a critical issue.[15]. So energy efficient protocols are developed by researchers. In EC-AODV, the optimal path for communication between source and destination hop depends upon two parameters that are energy factor and lifetime of the node. In this routing protocol a threshold energy level is set for nodes. If any node is having energy less than the threshold level, it is not considered as next hop during route discovery process.
During the route discovery process, nodes first check their energy level. If it is higher than the provided threshold level, the node will check its routing table if the path is available or not. If available, communication starts. But if the path is not available in the routing table, route discovery process is initiated. In EC-AODV, with RREQ message, energy factor(EF) and node lifetime(NLT) are also attached to calculate the residual energy and lifetime of the node. As we know, a threshold level is set for the nodes. Hence when RREQ message is broadcasted in the ad-hoc network, the nodes check for their energy level. If the energy level of the hop is less than threshold level, it discards the RREQ message. But if the energy level is higher than the threshold level, nodes calculate their EF and NLT, and update the routing table with current values, sending RREP message to the source. Hence best path is selected on the basis of hop count, EF and NLT.[16]
In EC-AODV, the nodes keep sending HELLO messages to their neighboring nodes to detect if the nodes are exhausted or not. If the packet drop is detected by neighboring nodes, the nodes send the RERR message to the source node. Hence communication is stopped, and routing tables are updated by deletion of failed nodes and re-route discovery takes place.

E. *NDj-AODV:* It is Node disjoint routing technique. As the name suggests, this algorithm creates node disjoint routes to the destination and this algorithm balances the load and provides energy efficient path. The cocept of overhearing is used in NDj-AODV. This concept was first proposed in AODVM(Ad-hoc on demand distance vector multipath routing)[17]

In NDj-AODV, multiple paths are created from source to destination. These paths are node disjoint i.e. they are independent of each other and do not have any node in common and are less in number than link disjoint paths[18]. In NDj-AODV, each node is having its cache in which it stores source address, broadcast id, previous node address and hop count of the previous node. During the route discovery process, when RREQ message is broadcasted, each node checks its cache if empty it stores the information as described above. But if the cache is not empty and the RREQ message was not sent from sibling node, it is rejected. When the destination hop receives the RREQ message, it sends RREP

message and intermediate nodes forward the RREP message to the source node through reverse route using the routing table. Routing tables are checked, if any two paths are sharing same intermediate nodes, one path is deled from the table. If there arise any link breakage in the paths, the paths are discarded immediately on receiving RERR message. Hence by using various disjoint node paths for communication. Energy can be saved and lifetime of nodes can be increased.[19]

F. *EASR:* Energy aware source routing. In this algorithm, various paths are created which do not overlap each other. Hence they are not aware of packet transmission on other paths. Hence overhearing energy waste can be avoided by using EASR algorithm. EASR is implemented to enhance the lifetime of the nodes present in the AODV network. Hence, the transmission of the packets between source and destination takes place through a path which is energy efficient. In this algorithm, we must take care of two parameters. One is the total summed energy of all the nodes present in the path and the other is the residual energy left in the nodes present in the ad-hoc network.

In EASR, in RREQ message, a parameter accumulated battery indicator is added which indicates the battery level or energy level of the node. Hence, when the source node wants to send the message, it broadcasts RREQ message in the whole network and the intermediate nodes also broadcast the RREQ message in the whole network and intermediate nodes also broadcast the RREQ message. The destination node waits for some time, so that all the RREQ messages are broadcasted in the network. Destination node then selects an energy efficient path with the help of accumulated battery indicator present in RREQ message. It selects the path with maximum energy level. The route reply message consists of two parameters (Locx,Locy) which help to find location of the node. Hence, the distance between any two adjacent nodes in the network can be calculated by using friis transmission equation infree space based on the distance[20]. With the help of this distance minimum power required for transmission can be calculated and hence can be kept constant to make the batteries energy efficient.[21]

G. *Energy optimized routing algorithm*: As we know nodes are battery powered in ad-hoc networks. So to increase the lifetime of the nodes various energy efficient protocols[22] are developed. Hence main issue that arises in AODV is energy consumption. This algorithm finds an energy efficient path by indicating the battery level of the nodes. Battery level is indicated by a low battery alert mechanism. As in AODV routing algorithm, shortest path is selected for communication but selected shortest path may not be the optimized path. Hence energy aware routing must be done. There may exist multiple paths between source node and destination node. Hence path must be selected such that low transmission power is required. Hence less energy consumption.

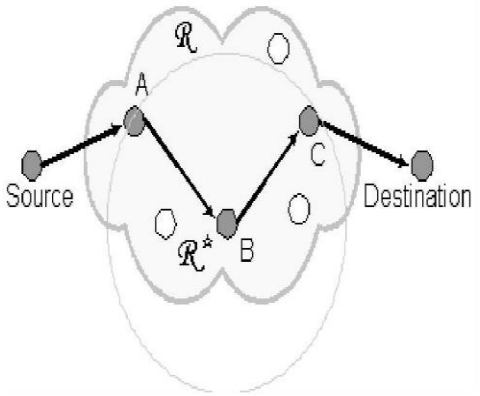

Figure3. An ad-hoc network where R is set of relay nodes and R* is set of neighboring nodes of B

Hence in AODV, while route discovery process takes place, a RREQ message is broadcasted with TTL (pre-defined lifetime). Hence with respect to this TTL, a path is selected. When RREQ message reaches to destination node, it sends RREP message through the reverse route. Hence energy optimized path is formed. But if any intermediate node is already having a path to destination, it sends G-RREP (Gratuitous route reply message to the destination node and RREP message to the source node. Hence a bi-directional energy optimized path is formed.[23]

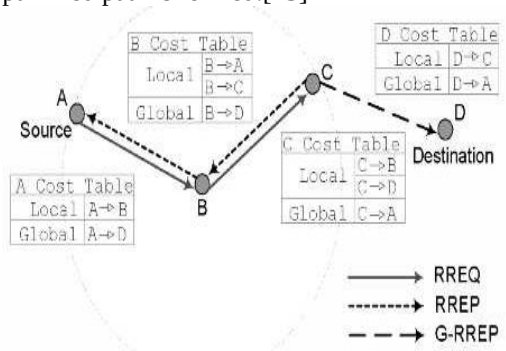

Figure4. Route discovery process in energy optimized AODV

H. *EM-AODV*: In EM-AODV, instead of selecting one optimized path for transmission, multiple paths are formed from source to destination. Hence data transmission takes place through new path every time. Hence depletion of battery life of nodes present in the single optimized path can be avoided. Hence, in EM-AODV load balancing is done. In this algorithm three parameters are taken into account which is bandwidth along the paths affinity and battery life of the node. In EM-AODV, the route discovery process of AODV is

enhanced and multiple node disjoint paths are created for source hop[24].
In EM-AODV, route discovery process is initiated by source node. It broadcasts the RREQ message in the whole network. The RREQ message from the source hop contains the address information of the immediate next hop to the source node through which the RREQ message has been passed. Multiple routes from source to destination are stored in the routing tables of the nodes. The battery level of the nodes is checked if it is less than threshold level, the node discards the RREQ message. If there exist multiple routes between source and destination as per routing tables, the data is split into parts and sent through multiple paths. If there is no route present in the routing table, route discovery process is initiated.
During route discovery process, when destination node gets the RREQ message from multiple optimized paths, it sends RREP message through multiple routes. These route replies are dependent on R-max value i.e. R-max determines how many route replies will be accepted by source node to avoid overhead. Two more tables in addition to routing table are managed: SNR average table and Bandwidth table. With the help of SNR average table, we can calculate affinity. Hence during path selection affinity and bandwidth must be kept minimum and energy must be kept maximum. Hence the best paths are selected for communication. Transmission of data by parts through multiple paths helps to balance the load.[25]

I. *EA-AODV*: For an energy efficient Ad-hoc network, the energy consumption at nodes during transmission of data, route discovery and route maintenance, must be kept low. The consumption of energy is an important factor for QoS in ad-hoc networks[26]. Hence enhancement in AODV is done to make it energy efficient. In Energy aware-AODV, whenever the source node demands for a path, it first broadcasts a RREQ message in the network. The latest sequence number of the destination is broadcasted as well. The intermediate hops keep forwarding the route request message in the network and also keep the record of the reverse route to the source hop. Hence energy efficient path is created.
The link quality between any two adjacent hops is dependent upon signal to interference ratio(SIR). If the SIR ratio between any two nodes decreases the pre-defined threshold value, the link is broken. This information is sent to the source hop by route reply message. Hence re-route discovery process takes place. Instead of sending periodic HELLO messages to maintain a link, in EA-AODV, the neighboring nodes check whether the link is available or not. The link availability is checked on the basis of SIR ratio. Physical layer detects the link breakage using SIR ratio and informs to the network layer by a message indication. Due to this protocol, we can save energy of nodes as periodic transmission of HELLO messages is not required.[27]

J. *C-AODV:* AODV is on demand routing protocol. Routes are selected on the basis of shortest path. Sequence numbers are assigned to the messages sent by the source nodes during path discovery. A path with higher sequence number is a fresh route. But in AODV[5] energy consumption is the major issue. Battery of the nodes may exhaust if same path is used again and again. Hence C-AODV is enhanced routing protocol which provides energy efficiency. C-AODV is derived from two protocols MPCR and CASNCP[29]It is a cooperative routing algorithm in which data sharing is done to avoid congestion and to balance the load. C-AODV is an enhancement to AODV routing protocol. In C-AODV, tttwo phases are there: route discovery and route maintenance[28]. During route discovery process, when RREQ messages are broadcasted by the source node, the intermediate nodes on receiving RREQ message from source node rebroadcast it. When the destination node gets the RREQ message, RREP message is sent. Hence intermediate nodes may receive more than one RREP message. But instead of storing the path with fresh RREP message in the routing table of node, all the paths are stored. The nodes keep on sending HELLO messages during communication to know about the queue length of the neighboring nodes. A threshold value for congestion is set. If it increases than the threshold value, the data traffic is shared on some other route. Hence in C-AODV algorithm each node is having two alternate paths to avoid congestion. Hence load balancing and energy can be saved.[30]

IV. CONCLUSION AND FUTURE WORK

In mobile and ad-hoc networks, energy consumption factor is a very crucial factor. Due to depletion of energy of nodes, link failures may occur.[25] hence researchers enhanced the AODV routing algorithm to make it energy efficient. In this paper, we have discussed various different enhanced and energy efficient algorithms. For future work, optimized routing will be done by using flower pollination algorithm.[31,32] Hence the optimized path will be selected on the basis of maximum energy level. Further work can be done in this area by proposing more energy efficient techniques and to save the energy of the nodes when idle. As it is merely wastage of energy.

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