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An Improved Energy Efficient AODV Routing Protocol for MANETs

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***Abstract*—** MANETs are a collection of unstructured wireless mobile nodes which provides independence and scalability for mobile topologies. Energy conservation being cardinal in applications such as Emergency and Military operations requires energy efficient solutions. The proposed work is a newer variation of the AODV routing protocol, which tackles major issues in MANETs like adaptability and energy efficiency. It is achieved by evaluating energy values of the nodes and forwarding packets along least drained nodes path, making the network adaptive in nature. Performance evaluation with respect to network lifetime, throughput, packet delivery ratio, end-to-end delay is done using simulation tools like NS2/QualNet.

***Keywords*-** MANETs, energy efficiency, drain count, NS2, network lifetime

I. INTRODUCTION

In today's fast evolving era, wireless communication is bringing fundamental changes to the field of data networking and telecommunication, and is making integrated networks a reality. One of the popular ad hoc networks is Mobile Ad-hoc Network (MANET) . It is regarded as a system of wireless mobile nodes that can self-organize into arbitrary and temporary network topologies freely and dynamically. Different protocols that are used in MANETs are evaluated based on different parameters such as average end-to-end delay, packet drop rate, average routing load etc. MANET offers an independent, scalable and flexible solution for mobile and dynamic topologies.

One of the greatest challenges in the design of MANETs is the limited availability of the energy resources. Energy-efficient communication is critical for increasing the life of power limited wireless ad hoc networks. Each of the mobile nodes is operated by a limited energy battery and usually it is impossible to recharge or replace the batteries during a mission. Since wireless communications consume significant amount of battery power, this limited battery lifetime imposes a severe constraint on the network performance. Power failure of a mobile node not just affects the node itself but the node's ability to forward packets on behalf of others and also the overall network lifetime. A mobile node consumes its battery energy not only when it actively sends or receives packets, but also when it stays idle listening to the wireless medium for any possible communication requests from other nodes. Thus, energy-efficient routing protocols minimize both the active communication energy required to transmit and receive data packets and the energy during inactive periods.

The need for judicial usage of energy and intelligent self-organization in MANETs has been the main motivation to design an energy efficient routing protocol for MANETs by integrating the principles of AODV protocol and drain count (energy metric) in order to obtain increased overall network lifetime to conserve the battery life of mobile nodes.

II. LITERATURE SURVEY AND RELATED WORK

A. *Traditional Routing Protocols for MANETs*

MANETs mainly use three types of routing protocols. The reactive protocols such as Dynamic Source Routing (DSR), Ad hoc On -demand Distance Vector (AODV) and Temporally Ordered Routing Algorithm (TORA) dynamically determine the routing path as and when there is a demand to transmit some data. The proactive protocols such as Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR) and Fisheye State Routing (FSR) dictates that routing tables be maintained at each node. Hybrid routing protocols such as Zone Routing Protocol (ZRP) are also used, which integrates the characteristics of proactive and reactive protocols, but also has demerits i.e. cannot be evaluated for unidirectional links and it can be applied only for very large networks [2].

AODV protocol favors the least congested route instead of the shortest route and it also supports both unicast and multicast packet transmissions even for nodes in constant movement. It also responds very quickly to the topological changes that affect the active routes. AODV does not put any additional overhead on data packets as it does not make use of source routing. Whereas, DSR protocol is not scalable to large networks and even requires significantly more processing resources [3][4]. Basically, in order to obtain the routing information, each node must spend lot of time to process any control packet it receives, even if it is not the intended recipient. Even DSDV introduces large amounts of overhead to the network due to the requirement of the periodic update messages [4].

B. AODV Routing Protocol

Ad-hoc on demand Distance Vector is a reactive protocol which create routes when demanded by the source host andthe routes are maintained and used when needed. Hello messages are used to detect and monitor links with neighbours. Each active node periodically broadcasts a Hello message that all its neighbours receive. In case a node fails to receive several Hello messages from a neighbour which are broadcasted, a link break is found [2].

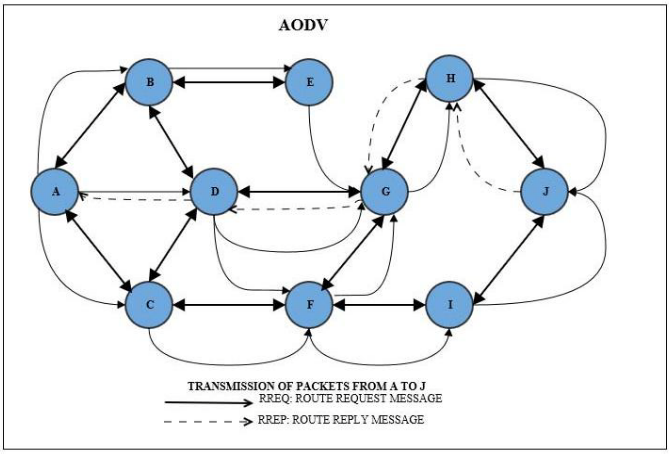

Figure 1. Transmission of data between source and destination as per AODV routing algorithm

AODV mainly has three distinct features, firstly every request is assigned a sequence number so that the nodes do not repeat route requests that have already been passed on. Secondly, time to live is present for every route request, which limits the number of times they can be retransmitted. Also, in a situation where a route request fails, we cannot assign another route request unless and until twice as much time has passed since the timeout of the previous request.

AODV has a few advantages over other routing protocols like OLSR, which makes it one of the most preferred protocols. It doesn't require a central administrator to manage. The control traffic messages are reduced, but it is at the cost of increased latency in finding new routes. Minimal routing is practiced as the route information exists in the routing table, which shows the active routes in the network. It reacts quickly to topological changes and updates any host affected by the change in Router Error message (RRER).

C. Energy Efficiency in MANETs

In this section, some of the energy efficient schemes developed by researchers in the field have been described. Energy is the most scarce resource and nodes spend energy during transmission and reception of data [5]. Four modes that must be considered for the total energy consumed are:

a) *Transmission mode*. Transmission energy is the energy spent to transmit a message, and is dependent on the size of the packet.

$$T_X = \frac{(330 * Plength)}{2 * 10^6} \quad (1)$$

$$P_T = \frac{T_X}{T_t} \quad (2)$$

Where is T_X transmission Energy, is Transmission P_T Power, T_t is time taken to transmit data packet and $Plength$ is length of data packet in Bits.

b) *Reception mode*. Energy spent to receive a packet is Reception energy.

$$R_X = \frac{(230 * Plength)}{2 * 10^6} \quad (3)$$

$$P_R = \frac{R_X}{T_X} \quad (4)$$

Where is a Reception Energy, PR is a Reception

R_X

Power, T_X is a time taken to receive data packet, and $Plength$ is length of data packet in Bits.

c) *Idle mode*. In this mode, the node is neither transmitting nor receiving any packet. But energy is spent because the nodes have to listen to the network for any incoming packet. The node then has to move from idle mode to reception mode.

$$P_I = P_R \quad (5)$$

Where P_I is the power consumed in Idle Mode and P_R is power consumed in Reception Mode.

d) *Overhearing mode*. Energy spent by the node when it receives the packet that is destined to it. Unnecessary receiving of such packets consumes energy.

$$P \quad = P_R \quad (6)$$

Where P is power consumed in Overhearing Mode and P_R is power consumed in Reception Mode.

In [12] focus is given to emergency search and rescue operations which rely heavily on the availability of the network. The availability is a direct cost of the overall network lifetime, i.e., energy of the nodes. There are many strategies available at different levels of the OSI model to improve the network lifetime. The focus is given to develop a network layer strategy, i.e., one that uses routing protocols. AODV protocol is seen to be the most energy efficient protocol. An existing energy efficient routing protocols based on AODV is proposed, each of which is based on a different energy cost metric. And then the protocol is designed which is a combination of both. Secondly, evaluation of the performance of this protocol against the single energy metric AODV protocol and against traditional AODV is done. Energy can be efficiently conserved by toggling between two parameters such as the transmission energy and remaining energy capacity. The performance metrics used for evaluation are packet delivery ratio, throughput, convergence time, network lifetime and average energy consumed.

In [13] it is emphasized that MANETs require special management because of their hardware and energy limitations (when compared to wired networks). A key concept that could help provide this management is Self-organization. Here the concentration is on typical MANET scenarios that rely heavily on the reliability of the network. The reliability is a direct cost of the overall network lifetime, i.e., energy of the nodes. In this paper the Self-Organizing AODV protocol (which will henceforth be referred to as SO _AODV) has been developed by choosing a leader node with maximum energy and all the packets are forwarded via the leader node to the destination. SO_AODV has been compared with Traditional AODV and basic EESOA using the following metrics: network lifetime, average end to end delay, delivery ratio and convergence time. In the results it is found that SO_AODV has better network lifetime and end to end delay than Traditional AODV and has better convergence time than EESOA.

Energy related metrics used by power aware routing protocols are classified into four categories: transmission power, remaining energy capacity, estimated node lifetime, and combined energy metrics [6]. The *Minimum Total Transmission Power Routing* (MTPR) attempts to minimize the total transmission power consumption of nodes participating in an acquired route and transmission power is proportional to transmission distance [7]. Considering transmission power as the only cost metric increases the number of hops and end-to-end delay. Adding a power cost metric helps in reducing the hop count. In MBCR (Minimum Battery Cost Routing), the sum of residual energy of all the nodes is calculated and the path with the least cost and maximum energy is chosen, allowing the nodes with less energy to participate in transmission. The improved approach to this is Min-Max Battery Cost Routing (MMBCR) which always chooses the path with maximum residual energy and hence increases the network lifetime [8]. The lifetime of the network is decided based on the energy metric, drain rate, which is defined as the rate at which energy is consumed by the node. Network lifetime can be maximized if the path with least drain rate is chosen and hence it is denoted by,

$$DR_i(t) = \alpha \times DR_i(t-\tau) + (1-\alpha) \times DR_i^{sample} \quad (7)$$

Where, $DR_i(t)$) and DR_i^{sample} represents the previous and
WKH_QHZOW_PRQLWRUHG_GUDLQ_UDWHV__IJ_UHSUHVHQWV_WLPH_LQWHUYDO_

D. Applications of IEE_AODV Protocol

This energy efficient Ad hoc Net protocol finds various applications. A few of them have been listed here.

- Vehicular Ad hoc Networks(VANETs) - A set of vehicles that depart from a depot has to serve a set of customers before returning to the depot, while utilizing the minimum number of vehicles and the total distance traveled by them. More than one route might be required to serve all orders. This can also be replicated and applied for any type of traffic maintenance, such as finding the least congested path for emergency services like ambulance and fire brigades.[11]
- Aviation sector – inter and intra aircraft communication
- Military combat operations - Bugs released for investigation purposes
- Wireless Sensor Networks
- Disaster Recovery - for recovery of communication channels in times of natural disasters such as earthquakes.

III. PROPOSED SOLUTION

The protocol that is proposed in this paper integrates the concept of drain count into AODV in order to make it energy efficient. If the energy of a node is lesser than the set threshold energy, then the drain count value of the path is incremented by a factor of 1. The path that has the least drain count, i.e. the path which has least number of nodes having energy below the threshold energy, is chosen from among the paths that are traversed by the first few control packets that arrive at the destination node. This ensures that a path with a reasonably short distance is chosen. In the case that two or more paths have the same drain count value, then the path with the least hop count is selected in accordance with AODV. If two or more paths with equal hop count exist, then the path containing nodes with least transmission power is chosen. This also helps in obtaining a longer network lifetime. In case of a link failure in the chosen path, then an alternate path is chosen with low convergence time as the paths that were discovered initially are stored at the destination.

<table>
<tr><td>Type</td><td>Reserved</td><td>Hop Count</td></tr>
<tr><td colspan="3" align="center">RREQ ID</td></tr>
<tr><td colspan="3" align="center">Destination IP Address</td></tr>
<tr><td colspan="3" align="center">Destination Sequence Number</td></tr>
<tr><td colspan="3" align="center">Originator IP Address</td></tr>
<tr><td colspan="3" align="center">Lifetime</td></tr>
<tr><td colspan="3" align="center">Timestamp</td></tr>
<tr><td colspan="3" align="center">Remaining Energy</td></tr>
<tr><td colspan="3" align="center">Drain Count</td></tr>
<tr><td colspan="3" align="center">Record</td></tr>
</table>

Figure 2. IEE_AODV packet header, modified version of AODV RREQ packet header

The path that is traversed by the control packets is tracked by a record field that is added to the AODV packet header so that the data packets can be sent along the chosen route. The record also helps in updating the routing table along the chosen path. The remaining energy is determined at every node, and is compared to the set threshold value.

The implementation methodology that is being used to simulate this protocol on MANETs is NS2, and is simulated for networks of different sizes from 10 to 50 nodes, in steps of 20, and pause times of 3s, 5s and 8s.

IV. TESTING AND RESULTS

In order to be able to cover most if not all the types of scenarios the algorithms might face, both the node density (number of nodes) and the node mobility (pause time) is varied. The node density (number of nodes) is varied for 10, 30, 50 nodes (3 different node densities). Thus 10 nodes represent the low node density case, while 50 nodes represent the high node density case. Also, three different pause times were used: 3, 5 and 8 seconds. The pause time of 8 implies that the nodes pause in their initial positions for 8 seconds. It represents nodes which have low mobility. Similarly, pause time 3 represents very high mobility where the nodes are in constant motion. Thus each algorithm is tested over 3 node densities x 3 pause times = 9 scenarios. Also, each scenario is generated by varying initial energies in a range of 0-10 with the same parameters. Each of these cases is run for IEE_AODV, SO_AODV and traditional AODV. Connection Patterns and Mobility Scenarios are kept the same for all three protocols to achieve consistent behavior. The network scenario for the simulation is summarized in Table 1.

Table 1. Network Scenario for NS2 simulation topology

Performance Measurement Parameter	Value
Number of Simulated nodes	10,30,50
Dimension of topography(m)	800x800
Packet size(bytes)	512
Pause time(s)	3,5,8
Traffic type	CBR
Simulation time(s)	180
Simulated routing protocol	IEE_AODV
Performance evaluation Metrics	Average End to End Delay, Network Lifetime, Packet Delivery Ratio, Throughput

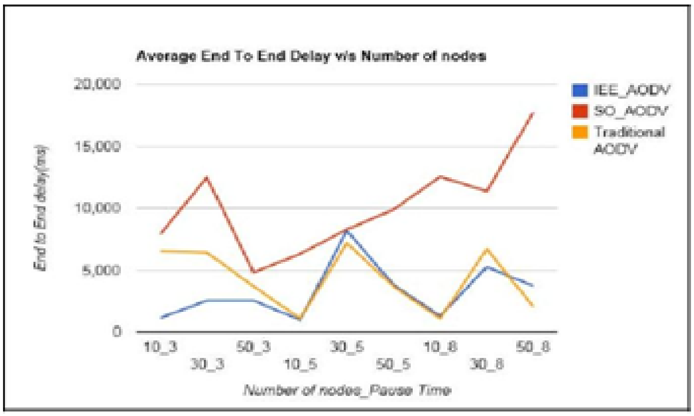

Figure 3. Result for Average End to End delay v/s Number of Nodes and Pause time

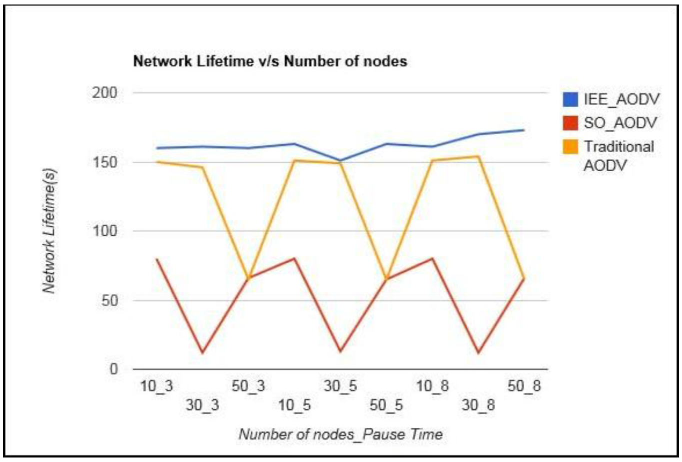

Figure 4. Result for Network Lifetime v/s Number of Nodes and Pause time

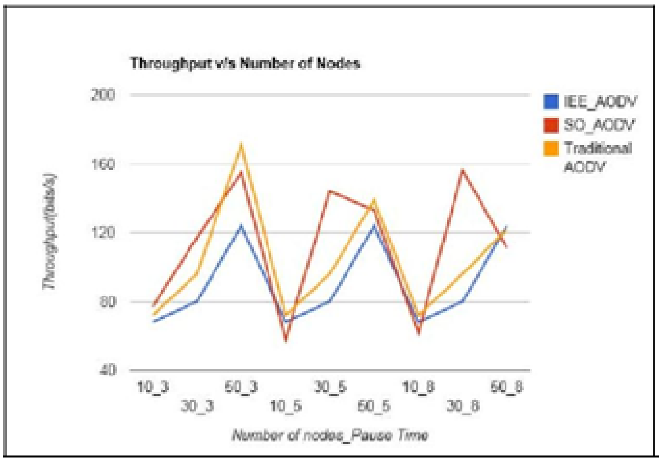

Figure 5. Result for Throughput v/s Number of Nodes and Pause time

From the graph shown in Figure 3, it can be observed that when the mobility of the nodes is high (pause time 3 seconds) the end to end delay of traditional AODV is quite high. As the density of nodes increases, the end to end delay of all three algorithms increases. However the end to end delays of IEE_AODV is comparable to AODV, and there is no significant difference between the two. The reduction in end to end delay can be attributed to the virtual backbone created.

From the graph shown in Figure 4, for the high mobility case (pause time 3 seconds), it can be seen that IEE_AODV and traditional AODV show consistently better network lifetimes than SO_AODV. For the low density situation (10 nodes), the network lifetime for all 3 protocols is quite high. This can be attributed to the fact that there are far fewer connections and much lesser traffic through each node. On close observation for this case, it can be seen that IEE_AODV still has the best lifetime when compared to traditional AODV and SO_ AODV. In all the cases, the performance of IEE_AODV can be truly appreciated. The protocols show a large increase in network lifetime for different node densities. Thus the selection of the most energy efficient path to perform the bulk of the routing has ensured that nodes with lower energies last longer.

From the graph shown in Figure 5, it can be seen that in the high mobility situation, AODV has consistently better values for packet delivery ratio. This could be attributed to the fact that in IEE _AODV, the most energy efficient path might not be the most reliable and the traffic along this path is high, and may thus drop more packets than AODV does. The packet delivery ratio for all three protocols drops as node density and number of connections increases.

For the cases with lower mobility, a similar situation can be seen. In Figure 6, AODV has the highest packet delivery ratio. Packet delivery ratio again drops as node density increases as the packets traverse many numbers of nodes and chances of packet drop are higher.

From the graphs, it can be seen that in the high mobility situation, AODV has consistently better values for throughput. This could be attributed to the fact that in IEE_AODV, a lot of control packets are exchanged, and computation occurs at every node in order to calculate drain count. The throughput for all three protocols drops as node density (and number of connections increases), and for most node densities, the delivery ratios of IEE_AODV and AODV are comparable. However in nearly all the test cases, the delivery ratio of IEE_AODV is quite acceptable.

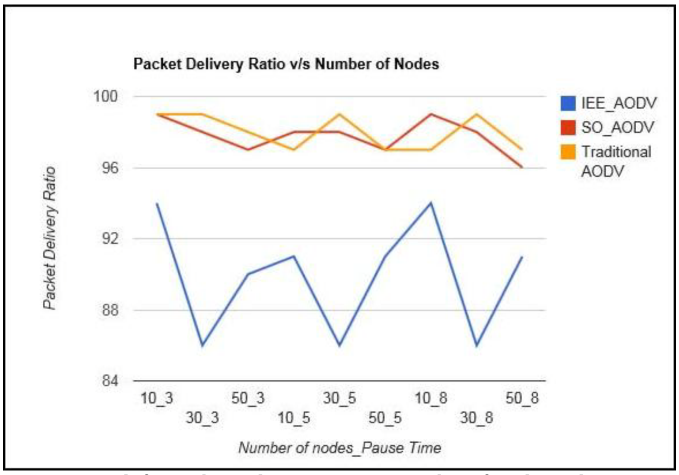

Figure 6. Result for Packet Delivery Ratio v/s Number of Nodes and Pause time

V. CONCLUSION AND FUTURE WORK

In this work, it is observed that battery life of the nodes in IEE_AODV protocol has been efficiently utilized by choosing a path with maximum energy. It has also been analytically proved that, the amount of remaining energy helps to probabilistically determine an efficient path. Further to the proposed work, the algorithm has been implemented and is evaluated using performance metrics like throughput, network lifetime, packet delivery ratio and end to end delay. The results are statistically analyzed using network simulation tools such as NS2 by varying the node density from 10 to 50 in steps of 20, and pause time of 3s, 5s and 8s. It is noted that energy of each node is monitored to choose an efficient path with no drained nodes. This has helped to maximize the network lifetime by avoiding frequent link failures due to drained nodes.

This concept of drained nodes can be amalgamated to Bio-inspired computing such as Ant colony optimization. This energy efficient AntHoc algorithm can be implemented on hybrid routing protocol [14] to conserve energy in an efficient manner. The results can be compared with traditional AODV and IEE_AODV protocols to evaluate its performance.

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