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Performance of Energy Aware Routing Protocol (MECB-AODV): A Modified Energy Constrained Protocol for Mobile Ad hoc Networks

Fahamida Firoze

M. Tech.(CSE) Scholar, Dept. Of CSE, Al – Falah School Of Engineering & Technology, Dhauj, Faridabad, Haryana, India

ABSTRACT: Mobile Ad Hoc Networks (MANETs) also called mesh networks are self-configuring networks of mobile devices connected by wireless links. The aim of this paper is to evaluate the performance of an energy aware routing protocol, called MECB-AODV (Modified Energy Constraint protocol Based on AODV) which derives from the AODV protocol and which is based on the local decisions of intermediate stations to maintain the connectivity of the network as long as possible. The results obtained using the Network Simulator NS-2 demonstrates how small changes in the principle of the AODV protocol can efficiently balance the energy consumption between nodes, which increases the network lifetime as well as increases the throughput.

Keywords: Ad-hoc Network, AODV, MANET, Energy Efficiency.

I. INTRODUCTION

Mobile ad hoc networks (MANETs) are composed of a collection of mobile nodes which can move freely and communicate with each other using a wireless physical medium..Therefore, dynamic topology, unstable links, limited energy capacity and absence of fixed infrastructure are special features for MANET when compared to wired networks. MANET does not have centralized controllers, which makes it different from traditional wireless networks (cellular networks and wireless LAN) [1].

MANETs, find applications in several areas. Some of them are: military applications, collaborative and distributed computing, emergency operations, wireless mesh networks, wireless sensor network, and hybrid wireless network architectures [2].

MANET routing protocols could be broadly classified into two major categories based on the routing information update mechanism [5]:

- **Proactive Routing Protocols:** Proactive protocols continuously learn the topology of the network by exchanging topological information among the network nodes. Thus, when there is a need for a route to a destination, such route information is available immediately. If the network topology changes too frequently, the cost of maintaining the network might be very high. If the network activity is low, the information about actual topology might even not be used. Ex: DSDV, WRP, CGSR, etc.
- **Reactive Routing Protocols:** The reactive routing protocols are based on some sort of query-reply dialog. Reactive protocols proceed for establishing route(s) to the destination only when the need arises. They do not need periodic transmission of topological information of the network. Ex: DSR, AODV, TORA, etc.
- **Hybrid Routing Protocols:** Often reactive or proactive feature of a particular routing protocol might not be enough; instead a mixture might yield better solution. Hence, in the recent days, several hybrid protocols are also proposed.

In reactive protocols (also called ″on-demand″ routing approach) routing paths are discovered only on demand. A route discovery task invokes a route-determination procedure and which terminates when either a route is found or there is no possible route available. Because of nodes mobility, active routes may be disconnected and therefore route maintenance is important in reactive routing protocols. A reactive routing protocol has less control overhead as compared to the proactive routing protocol and therefore a reactive routing protocol has better scalability than a proactive routing protocol. However, source nodes may suffer from long delays for route discovery in reactive approach. Dynamic Source Routing (DSR) and Ad hoc On-demand Distance Vector routing (AODV) are popular reactive routing protocols for MANET.

Energy is a scarce resource in ad hoc wireless networks [3]. Each node has the functionality of acting as a router along with being a source or destination. Thus the failure of some nodes operation can greatly impede performance of the network and even affect the basic availability of the network, i.e., routing, availability, etc. Thus it is of paramount importance to use energy efficiently when establishing communication patterns. Energy management is classified into battery power management, transmission power management, system power management [2]. There are four energy cost metrics based on which we can decide the energy efficiency of a routing protocol. They are transmission power, remaining energy capacity, estimated node lifetime and combined energy metrics.

The totality of routing protocols, suggested by the Mobile Ad-hoc Network group (MANET) of the Internet Engineering Task Force (IETF), use the same routing metric which is the shortest path. In other words, the paths are computed based on the minimization of the number of intermediate nodes between the source and the destination. Thus, some nodes become responsible for outing packets from many source destination pairs. After a short period of time, the energy resources of those nodes get depleted, which leads to node failure. It is therefore significant that the routing protocols designed for ad hoc networks take into account this problem. Indeed, a better choice of routes is one where packets get routed through paths that may be longer but that contain only nodes that have enough energy.

Routing protocols in MANETs like AODV and DSR, usually intend to find a single path between a source and destination node. Multipath routing is finding multiple routes between source and destination nodes. It comprises of three components: route discovery, route maintenance, and traffic allocation. These multiple routes between a source node and a destination node compensate for the dynamism and unpredictability of ad hoc networks.

This paper aims at specifying an energy aware routing protocol based on this concept, and derives from the most known routing protocol: AODV (Ad-hoc on demand Distance Vector) and extension of AODV which is known as ECB-AODV. We show that this extension of ECB-AODV, called MECB-AODV (Modified Energy Constraint Based AODV), decrease the energy consumption by simply using energy aware routing metric.

The remaining part of our paper is organized as follows: In section II we will discuss the related work done in field of Energy Aware Routing in MANET and in section III we will discuss the proposed approach. The simulation result will be discussed in section IV and finally in section V we will conclude the paper and give the future scope of this paper.

II. RELATED WORK

The work done in this context could be grouped into two major groups; the first describes methods for reducing energy consumption in the AODV protocol with diversifying the routing strategy, and the second present's methods to reduce numbers of control messages in order to reduce the cost of consumption of energy.

AODV [5] is a reactive routing protocol instead of proactive. It minimizes the number of broadcasts by creating routes based on demand, which is not the case for DSDV. When any source node wants to send a packet to a destination, it broadcasts a route request (RREQ) packet. The neighboring nodes in turn broadcast the packet to their neighbors and the process continues until the packet reaches the destination. During the process of forwarding the route request, intermediate nodes record the address of the neighbor from which the first copy of the broadcast packet is received. This record is stored in their route tables, which helps for establishing a reverse path. If additional copies of the same RREQ are later received, these packets are discarded. The reply is sent using the reverse path. For route maintenance, when a source node moves, it can reinitiate a route discovery process. If any intermediate node moves within a particular route, the neighbor of the drifted node can detect the link failure and sends a link failure notification to its upstream neighbor. This process continues until the failure notification reaches the source node. Based on the received information, the source might decide to re-initiate the route discovery phase.

The proposed work is aimed at developing energy efficient AODV routing protocol. This section documents some of the many energy efficient schemes based on AODV developed by researchers in the field.

In [6], Jin-Man Kim and Jong-Wook Jang proposes an enhanced AODV (Ad-hoc On-demand Distance Vector) routing protocol which is modified to improve the networks lifetime in MANET (Mobile Ad-hoc Network). One improvement for the AODV protocol is to maximize the networks lifetime by applying an Energy Mean Value algorithm which considerate node energy-aware. Increase in the number of applications which use Ad hoc network has led to an increase in the development of algorithms which consider energy efficiency as the cost metric.

In [7], Yumei Liu, Lili Guo, Huizhu Ma and Tao Jiang propose a multipath routing protocol for mobile ad hoc networks, called MMRE-AOMDV, which extends the Ad Hoc On-demand Multipath Distance Vector (AOMDV)

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routing protocol. The key idea of the protocol is to find the minimal nodal residual energy of each route in the process of selecting path and sort multi-route by descending nodal residual energy. Once a new route with greater nodal residual energy is emerging, it is reselected to forward rest of the data packets. It can balance individual node's battery power utilization and hence prolong the entire network's lifetime.

In [14] authors propose a new version of AODV called (MAODV) derived from the AODV routing protocol by considering the bit error rate (BER) at the end of a multi-hop path as the metric to be minimized for route selection.

In [15], authors integrated the transmit power control and load balancing approach as a mechanism to improve the performance of on-demand routing with energy efficiency.

M.Veerayya, V. Sharma and A. Karandikar propose in [16] a crosslayering approach to exchange information about the residual energy in nodes to perform quality of service.

In [17] a new mechanism is proposed to set a timeout for a path. A path considered broken if a node leave by following the exhaustion of its energy.

In [18] authors integrate the runtime battery capacity in routing protocol and the estimated real propagation power loss, obtained from sensing the received signal power. This solution is independent of location information and using the propagation, they estimate the energy loosed.

Another type of the proposed work which aims to reduce the overhead of AODV to achieve energy efficiency, as described in [19]. Authors propose a new method in order to reduce overhead in AODV in urban area by predicting links availability. By predicting neighbor nodes positions it can be determined probability of link failure.

In [20] S.B. Kawish, B. Aslam, S. A. Khan studies the behavior of AODV in a fixed networks and those exhibiting low mobility with a view to highlight the reasons for reducing overhead and then reduce the energy consumption.

The same authors present in [21] an improvement in their idea of using route timeout adjusted to reduce the overhead.

In [22] Authors propose a new version of AODV an on-demand routing algorithm based on cross-layer power control termed as called CPC-AODV (Cross-layer Power Control Ad hoc On demand Distance Vector) taking account of the geographic location of nodes, the energy of packet transmission.

Furthermore, the approach presented in [23] consists of an algorithm that enables packet forwarding misbehavior and Loss Reduction based detection through the principle of conservation of flow on the routing protocol group nodes. First, unlikable the other proposed solution, our protocols, does not minimize the number of messages or the overhead, or use geographic coordinates of the nodes or the channel access using the MAC layer. Our solution simply changes the periodicity by random time for the receiver and set by the power level of the node battery the transmitter. This is an important feature and has a profound effect on energy consumption which could sustain the behavior of protocol. It is an available approach to incorporate routing protocols with power control in ad hoc networks.

Some algorithms with specific characteristics are-

A. Local Routing

In on-demand ad hoc algorithms, all nodes participate in the phase of path searching, while the final decision is made in the source or destination node. The Woo et al. [24] algorithm grants each node in the network permission to decide whether to participate in route searching, which thus spreads the decision- making process among all nodes. The Local Energy-Aware Routing (LEAR) algorithm has as a main criterion the energy profile of the nodes. The residual energy defines the reluctance or willingness of intermediate nodes to respond to route requests and forward data traffic. When energy Ei in a node i is lower than a predefined threshold level Th:

$$E_i < Th,$$

The node does not forward the route request control message, but simply drops it. Thus, it does not participate in the selection and forwarding phase. The technique of shifting the responsibility for reacting to changes in the energy budget of the nodes from the source-destination nodes to the intermediate nodes avoids the need for the periodic exchange of control information.

B. Expected Energy Consumption

The Conditional MMBC algorithm in [25] is proposed to maximize the lifetime of the nodes. It also uses transmission energy as a metric but the route is chosen on the minimum transmission energy basis until the residual

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energy of the constituent nodes in a network is above a predefined threshold. If there are any nodes on the discovered routes whose energy is below the threshold, the MMBC is applied.

The work done in [26] accounts not only for residual energy and transmission power but also for possible retransmissions. It brings an important aspect to light in the design of energy- efficient routing algorithms: the estimation of future energy consumption. The authors estimate the energy that is expected to be used in order to successfully send a packet across a given link. The cost metric as in Eq. (1) thus comprises a node-specific parameter (battery power Bi of node i) and a link-specific parameter (packet transmission energy Ei,j) for reliable communication across the link (between nodes i and j):

$$C_{i,j} = \frac{B_i}{E_{i,j}} \quad \text{.......(1)}$$

Whereas the expected transmission energy as in Eq. (2) is defined by the power to transmit a packet over the link between nodes i and j (Ti,j) and the link's packet error probability (pi,j):

$$E_{i,j} = \frac{T_{i,j}}{(1 - p_{i,j})^L} \quad \text{.......(2)}$$

The main reason for adopting the above is that link characteristics can significantly affect energy consumption and can lead to excessive retransmissions of packets. The maximum lifetime of a given path is determined by the weakest intermediate node, which is that with the lowest cost.

C. Battery-sensitive routing

The approach is presented in [27] by Chiasserini and Rao, and subsequently by Ma and Yang [28]. Their solutions make use of the available battery capacity by means of battery-sensitive routing. Both works study the lifetime of the battery and the algorithms proposed by their authors are based on two processes, namely, recovery (reimbursement) and discharging loss (over-consumed power). These processes are experienced when either no traffic or new traffic is transmitted. This line of study led to the design of a cost function that penalizes the discharging loss event and prioritizes routes with "well recovered" nodes. Thus, battery recovery can take place and a node's maximum battery capacity can be attained. The selection function is a minimum function over the cost functions of all routes.

D. Least hops and minimum remaining energy

The routing algorithm used in this method is based on AODV. In AODVEA [5], routing is based on the metric of minimum remaining energy. The node with minimum remaining energy in the route is identified and the route having maximum of minimum remaining energy is selected.

The protocol performs a route discovery process similar to the AODV protocol. The difference is to determine an optimum route by considering the network lifetime and performance; that is, considering residual energy of nodes on the path and hop count. In order to implement such functions, a new field, called Min-RE field, is added to the RREQ message as described above. The Min-RE field is set to a default value of -1 when a source node broadcasts a new RREQ message for a route discovery process.

Eq.(3) gives the calculation of Routing metric for modified AODV:

$$\alpha = \frac{(MinRE)}{HopCount} \quad \text{............(3)}$$

The optimum route is determined by using the value of α described above. The destination node calculates the values of α for received all route information and choose a route that has the largest value of α. Here Min- RE is the minimum residual energy on the route and Hop Count is the hop count of the route between source and destination.

Here in this paper we are proposing the concept of maximum energy in AODV that the neighbors that have maximum energy only they will receive the HELLO message.

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III. AODV ROUTING PROTOCOL

The AODV protocol is a reactive unicast routing approach for mobile ad hoc networks and therefore AODV only has to maintain the routing information about the active routes. Routing information in AODV is maintained in routing tables at nodes. Every node maintains a next-hop routing table that has the destinations to which it has an active route. A routing table entry drop dead if not used or reactivated for a predefined expiration time. Additionally, AODV assumes the destination sequence number mechanism as used in DSDV but in an on-demand way.

In AODV, in absence of available route, a source node initiates a route discovery procedure before sending a packet. The route discovery phase involves broadcasting of route request (RREQ) packets which contain source and destination addresses, broadcast ID, which acts as its identifier, the last visited destination’s sequence number as well as the source node’s sequence number.

Sequence numbers ensures loop-free and up-to-date paths. Flooding overhead in AODV is reduced by a node discarding RREQs by a node if it has seen before and the route discovery operation is done by expanding ring search algorithm. The RREQ initiates with a small Time-To-Live (TTL) value which is increased in the next RREQ if destination is not found.

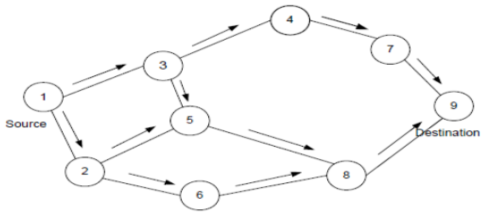

Fig.1: The Route Request Packets Flooding in AODV

IV. PROPOSED WORK

When a source node wants to reach a destination node, it starts the route discovery process and broadcasts the route request packets (RREQ), as in AODV. But when an intermediate node receives this request, there is an additional step that it has to do before sending the packet: it must compare its remaining energy with a certain threshold. If it finds that its energy level exceeds the threshold value, it rebroadcasts the request to all its neighbors. In the other case, the node concludes that its remaining energy is not enough anymore to route the others’ packets. Therefore, the node rejects the RREQ packets and ignores the request.

As soon as the destination receives the first RREQ packet, it transmits a RREP towards the source. The treatment of these RREP packets by the source is identical to that of AODV.

But we have modified this scenario by using the concept of remaining maximum energy of nodes. When a source node wants to communicate with destination then in route discovery process the route request packet will be sent to that node which has maximum remaining energy so that the path found will have that maximum energy and can survive for a longer time.

A. ALGORITHM

Begin

Step1. Initialize Network (Source, Destination)

Step2. Find Neighbors of Source Node

Step3. If (Maximum Remaining Energy> certain threshold Energy)

3(a) Send the packet to the neighbor nodeElse

3(b) Discard the request

Step4. $NEXTHOP = k : e_k^{remain} = max\{ e_j^{remain}\}$

Step5. If all the neighbors have same energy

All neighbors have to find their neighbors and tell the maximum remaining energy of next neighbor’s node.

Step6. Else follow step3 and 4.

Step7. Repeat Step2-5 until request is reached at the destination.

Step8. Reply via same path on which request is reached.

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End.

We will compare our modified model with existing AODV model and show that our model will gives better result in terms of network lifetime, energy consumption as well as signaling overhead will be shown via simulation but we will show with example that our model has longer network lifetime.

Example: Here we show that the example of our model in which we choose the next hop which have maximum remaining energy.

Node	**Minimum Residual Energy**
S	500J
1	400J
2	400J
3	700J
4	500J
5	400J
6	300J
7	600J
8	500J
9	400J
10	200J
D	500J

Table1: Energy table of all nodes

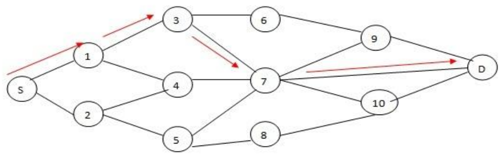

Figure2: Route Request in MECB-AODV

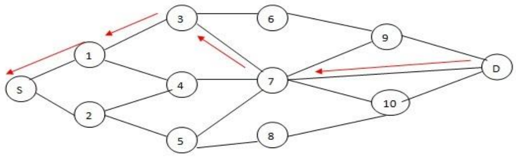

Figure3: Route Reply in MECB-AODV

V. PERFORMANCE EVALUATION

We have created several simulation scenarios with NS-2 to evaluate MECB-AODV protocol. The following aspects of MECB-AODV are emphasized:

- Adaptation with changes in the network topology.
- Signaling overhead.
- Energy Consumed
- Packet Delivery Ratio

The topology have used in our experiments is that shown in figure 3. The total band-width considered is 2 Mbps and the radio range of each node is 250 meters. A first TCP connection is established between nodes S and D after 10 seconds from the beginning of the simulation, which lasted 40 seconds. At t=18 seconds, we want to set up a new communication that connects node-5 to node-9. The results are shown in figure 4. We first look at the energy consumption of the network, when using the original routing protocols, AODV. The same experiment carried out with MECB-AODV leads to a very different result. Indeed, figure 3 shows that when reaching the threshold, the energy level stabilized around this value, which is represented by the linear part of the curve. Therefore, the second communication can be established normally at the given moment.

We used Network Simulator 2 (NS2) to evaluate the performance of MECB-AODV. To compare MECB-AODV with prior work in routing AODV, this uses flooding. In our simulation, the time intervals of the beacons and the global location updates were chosen to be 1s and 8s, respectively. We simulated 6 CBR traffic flows, originating from randomly-selected sending nodes. Each CBR flow sends at 1Kbps, and uses 64-byte packets. Each simulation lasts for 40 seconds of simulated time.

Matrices	**Dimension**
Area	1500*1500
No. of Nodes	21
Minimum Transmission Power	3.97e-6 mW
Data Rate	1kbps
Simulation Time	40 Sec
Pause time (QTR)	15 Sec
Periodic update	1-8 sec
MAC Layer	IEEE 802.11
Bandwidth	2Mbps
Radio Range	250m
Initial Energy	1000J

Table2: Simulation Parameters

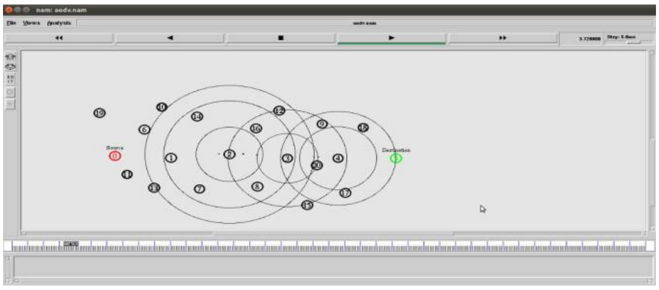

Figure3: Network Topology

In order to find the best available route, protocol MECB-AODV needs to propagate more control packets in the network during the process of route discovery. This signaling overhead can be measured, for each simulation, by the following formula:

Signaling overhead = (total number of control Packets) / (total number of data packets).

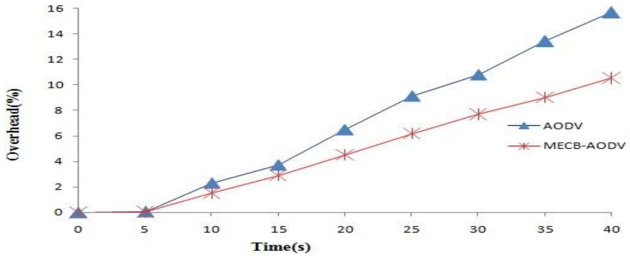

Figure4 (a): Overhead Vs Time

It is the percentage of ratio between the number of packets sent by sources and the number of received packets at the sinks or destination.

PDR = $\sum_i$ (No. of received packet at sink $_i$ / No. of packet sent by source $_i$)*100

The number of packets originated by the source at application layer to number of packets received by the destination node, which also known as the packet delivery ratio. Figure4 (b) shows that the delivery ratio in which result is shown between packet ratio and Time.

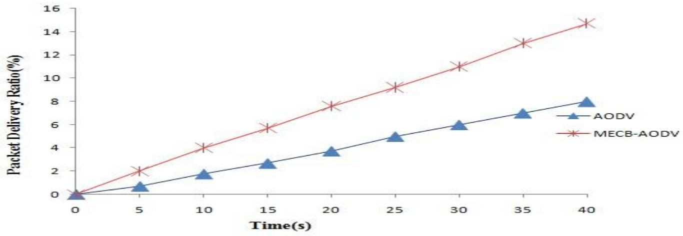

Figure4 (b): Packet Delivery Ratio

The next result shows energy consumed by AODV as well as MECB-AODV in which it shows that our proposed protocol performs better than AODV. The energy consumed in AODV is higher that MECB-AODV.

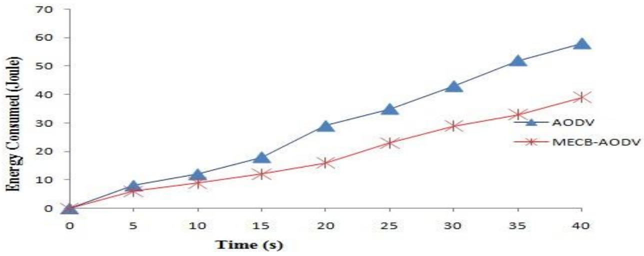

Figure4 (c): Energy Consumed Vs Time

VI. CONCLUSION AND FUTURE SCOPE

This paper provides an overview of MANETs and discusses how energy is one of the most important constraints for these types of networks. The objective of the proposed work is to develop an energy efficient AODV routing algorithm in a way which allows researchers to choose the most appropriate routing algorithm. We have also simulated our work by using network simulator and result shows that our proposed model always performs better than AODV. We can also extend this work proposing more efficient methods as well as can be implemented this work on sensor network.

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