Energy Efficient Routing in Mobile Adhoc Networks based on AODV Protocol

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Abstract

Mobile Ad hoc Networks (MANETs) suffer from power exhaustion as many nodes use batteries as their source. Energy consumption is one of the most important system design optimization criterion in MANETs. The conventional routing protocols do not consider energy of nodes while selecting routes. So, using the same route for a longer duration leads to partitioning of the network. Therefore, considering energy of the nodes while selecting a route efficiently utilizes the nodal energy and helps prolong the lifetime of the network. This paper attempts to modify the popular on demand routing protocol AODV to make it energy aware. The proposed algorithm also varies the transmission power between two nodes as per their distance. The protocols are simulated using Network Simulator (NS-2.34). The performance of both the protocols is analyzed under various conditions and the proposed scheme shows efficient energy utilization and increased network lifetime.

Keywords: *MANET, AODV, energy aware, energy efficient, routing*

1. Introduction

A mobile ad hoc network is an autonomous system of mobile nodes (also serving as routers) connected by wireless link. Since the nodes are mobile, the network topology dynamically changes in an unpredictable manner [1]. The traditional routing methods for wired network cannot be directly applied to these networks as there is no established infrastructure for central administration (e.g. base stations, drop points etc).

The routing protocols, at network layer provide the method and the constraints by which the information among the mobile nodes is exchanged. Mobility of nodes, resource constraints, error prone channel states, and hidden and exposed terminal problems are the major challenges faced while designing a routing protocol for ad hoc wireless network. Since the nodes are battery operated, extending the battery lifetime has become an important objective and a great amount of research has been done to consider energy-aware design of network protocols for MANET. For establishing communication among different nodes, each mobile node in a MANET performs the routing function; the "death" of even a few of the nodes due to energy depletion might cause disruption of service in the entire network and can lead to network partition. The conventional on demand routing algorithm like DSR, AODV [10, 11] being unaware of energy of nodes, establishes connections between nodes through the shortest path routes. These algorithms may result in a quick depletion of the battery energy of the nodes along the most heavily used routes in the network [2]. This paper attempts to modify the most popular on-demand routing protocol AODV. A number of parameters are added to AODV that balances the energy of nodes inside the network while selecting a route to the desired destination. The transmission power of the nodes is also varied according to the distance between the nodes, thus optimizing energy utilization further. The proposed protocol increases the battery lifetime of the nodes and hence the overall useful life of the network.

The rest of the paper is organized as follows. Section 2 presents a discussion on the related work in energy aware routing. Section 3 gives the detailed working of the proposed algorithm. Section 4 includes the simulation environment setup used in NS-2 simulator. The simulation

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results are explained in section 5. Finally, section 6 concludes the work.

2. Energy Efficient Routing

A few reasons for energy management in MANETs are limited energy of the nodes: difficulty lies in replacing the batteries, lack of central coordination, constraints on the battery source, selection of optimum transmission power, and channel utilization [3,4]. Ongoing research in power optimization in MANETs have targeted all the layers especially network layer. Various routing protocols for effective energy utilization have been proposed. PAMAS [5] protocol uses two different channels to separate data and signaling. Authors in [6] proposed several power-aware metrics that result in energy-efficient routes. The Minimum Total Transmission Power Routing (MTPR) [7] was initially developed to minimize the total transmission power consumption of nodes participating in the acquired route. The Min-Max Battery Cost Routing (MMBCR) [7] considers the remaining power of nodes as the metric for acquiring routes in order to prolong the lifetime of network. Conditional Max-Min Battery Capacity Routing (CMMBCR) protocol [7] presents a hybrid protocol that tries to arbitrate between the MTPR and the MMBCR. The Energy Aware Source Routing (EASR) [8] finds paths without overlapping, each path does not overhear other data transmission and it reduces the overhearing energy waste among selected paths by using the overhearing ratio.

3. Proposed Algorithm

The proposed algorithm aims to increase the network lifetime and minimize the energy consumption during the source to destination route establishment. The algorithm provides energy efficient path between a source and destination pair. The proposed algorithm has been implemented on AODV. The algorithm focuses on the following two parameters:

1**. Total Energy of a path**: This is the sum of energies of the all the nodes encountered in route from Source to Destination.

2. **Residual Battery Power of a Node:** This parameter indicates the power left in a node.

A. Parameters Appended on Each Node

Each node has been appended with two variables:

1. INDEX: Unique identifier of the node.

2. E_{res}: This indicates the status of battery of a node and is calculated as:

If (residual battery status < 20% of the initial energy of a node)
Set E_{res}= 1
Else if (20% of initial energy of a node < residual battery status < 60% of initial energy of a node)
Set E_{res} = 2
Else (Battery Status > 60% of initial energy of a node)
Set E_{res} = 3

3. **Locx, Locy**: These variables give the position of the node in the network.

B. Parameters added to Route Request

At the time of route discovery, a route request (RREQ) packet is broadcasted by the source. The header of the RREQ packet includes **<source index, destination index, A_B_I (Accumulated Battery Indicator of the Route), N_{drain} (number of drain nodes) and INDEX**>.

The number of **drained node (N_{drain})** counts the number of nodes possessing energy less than 20 % of the initial energy of a node.

Initially A_B_I = 0 and N_{drain}=0 at source node. As RREQ packet propagates along the path, A_B_I is updated at each intermediate node i as follows:

If (E_{res} = 1) Then
Ndrain = N_{drain} + 1
Else-if (E_{res} = 2) Then
A_B_I = A_B_I + 1
Else-if (E_{res} = 3) Then
A_B_I = A_B_I +3

C. Route Selection Criteria

The destination node waits for a certain time T_{wait} till all route requests meant for the destination are reached. The destination node compares the destination sequence number, hops count and accumulated battery indicator (A_B_I) of a route in the RREQ packet received with destination sequence number, hop count and accumulated battery indicator (A_B_I) of a route in the routing table and then selects the route with maximum energy and minimum number of drain nodes. The method implemented is as follows:

For all RREQ
Reject RREQ's with N_{drain} >=3,

The destination node then calculates the following parameter to for all the remaining RREQ packets.

$$R_i = A\_B\_I / hop\_count$$

where, R_i is the route selection ratio for RREQ packet i.
The destination node then selects the route with maximum R_i. The changes are made in the routing table also.

D. Parameters Added to Route Reply

The selected nodes in the path send out the route reply. Each selected node adds its position (Locx, Locy) in the route reply. These location parameters are used by each sending node to find the distance between next hop node and itself. The minimum transmission power required is then calculated using Friis transmission equation in free space based on the distance, which is the distance between the current node and the next hop node [12]. The received power threshold of the node is kept constant throughout. Thus, varying the transmission power further leads to efficient battery utilization.

4. Simulation Scenario

The simulation setup consists of square flat topology covering an area of 800 * 800 m^2 and a test bed of 20 nodes randomly and uniformly distributed in the entire area. The number of wireless mobile nodes is fixed to 20. The random waypoint model is used to model mobility. All random scenarios have been generated for a maximum speed of 10 m/s with a pause time of 5 seconds and an idle time of 500ms. Traffic sources are chosen as UDP with a packet size of 210 bytes. All traffic sessions are established at random times near the beginning of the simulation run and they remain active until the end of the simulation period. A constant transmission range of 250 m is considered for all RREQ packets. The transmission range and power varies with distance between two nodes when actual data transfer occurs after route establishment. The simulations are run for 180 seconds. Each of the 20 nodes has 100 Joules of energy at the start of every simulation. The number for traffic connections was taken as 6. Identical mobility and traffic scenarios are used across the protocol variations. Track of residual energy of a node is done by using in an inbuilt energy model of NS - 2 that uses a traditional method of keeping track of the residual energy of a node. Once the trace file is generated, AWK scripts extract the information from the trace file. Based on the output of these AWK scripts graphs were plotted for average residual energy v/s time for the network using MATLAB.

Network animator (NAM) is use to visualize the simulation of network designed using NS-2. The NAM window shows the node topology and the connection establishment and release. Packet transmission as well as routing table broadcast is shown with great resolution. The current battery status of the nodes is also shown, depicted by the changing colours of various participating nodes (green to yellow to red). A snapshot of NAM window with various states of nodes indicated by different colours is depicted in Fig. 1

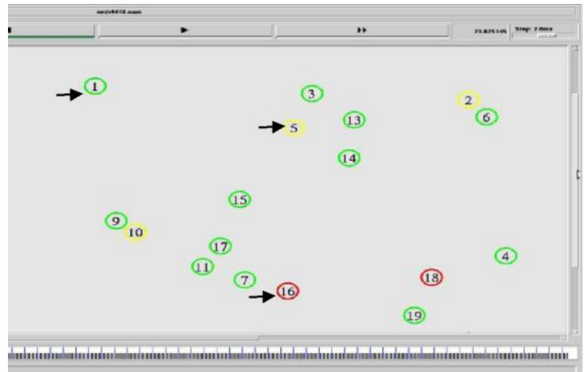

Fig. 1 NAM window depicting various energy levels of nodes

Table 1: Simulation Setup

PARAMETER	VALUE
Number of nodes	20
Simulation Time	180s
Pause Time	5s
Environment Size	800m X 800m
Traffic Type	ON or OFF (Pareto)
Packet Size	210 bytes
Packet Rate	20 kbps
Burst Time	500 ms
Idle Time	500 ms
Maximum Speed	10 m/sec
Initial Energy Of Node	100 Joules
Transmission Power (for RREQ)	5 W
Reception Power Utilized	10 W
No. of Connections	6
Simulator	NS-2.34
Antenna Type	Omni directional
MAC type	IEEE 802.11
Agent	User Datagram Protocol (UDP)

NS-2 supports four types of traffic. Firstly, EXPO Traffic generates traffic for network using an exponential ON/Off distribution. The POO Traffic, although, identical to exponential on/off traffic distribution uses pareto distribution for on/off delay. The CBR Traffic generates traffic according to a deterministic rate and the packets are in constant size. The TRACE traffic generates traffic according to a trace file containing 32 bits field, which contains micro-seconds time until the next packet is generated. In the simulation POO traffic (Pareto) is employed. Table 1 shows the various simulation parameters being used.

5. Results and Analysis

The comparison of the proposed routing scheme and AODV routing protocol is done. The graphs are plotted between the average residual energy and the time. The results are obtained for the different combinations of the number of connected nodes in the network and the varying node velocity. Average residual energy is the average sum of the remaining energy of all the nodes connected in the network after broadcast of the information in the network once. Different scenarios are taken into consideration while obtaining the average residual energy of the nodes

5.1 Average Residual Energy with Time

As seen from Fig 2, that proposed scheme outperforms AODV drastically. At simulation time 28 sec, average residual energy of proposed algorithm is 90 Joules whereas for AODV only 42 Joules energy is left in the network. This is mainly due to the fact that this scheme analyses various route energy before selecting a route for transmission. On the contrary, AODV selects the quickest route (shortest hop) irrespective of the route energy. Hence, its network lifetime is reduced significantly when compared with proposed algorithm.
As evident from Fig 3, residual energy further gets reduced as compared to previous results due increased number of connections. The proposed algorithm still shows better performance than AODV. It can be noted from the following graph that increased connections lead to a reduced network lifetime

5.2 Average Residual Energy with speed

Fig. 4 compares the average residual energy and speed for AODV and proposed algorithm. The values for average residual energy are taken at a constant time of 37sec for different values of speed of nodes. Two cases have been considered, one with six connections and the other with 20 connections. As the speed of the nodes increases, there is a reduction in the amount of energy available to be used for transmission of packets leading to reduced network lifetime.
Therefore, the amount of energy available decreases with increased rate of mobility. But the proposed algorithm has 20-30% increase in the residual energy as compared to AODV
In Fig. 5 number of nodes considered for the simulation is 50. As seen from the graph, average residual energy is reduced as compared to previous results due increased number of connections.

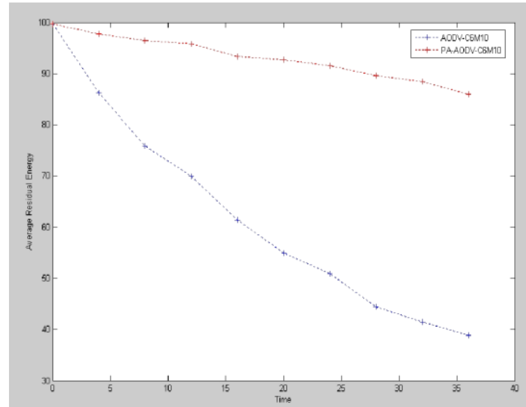

Fig. 2 Average Residual Energy (Joules) with Time (number of connected nodes=6)

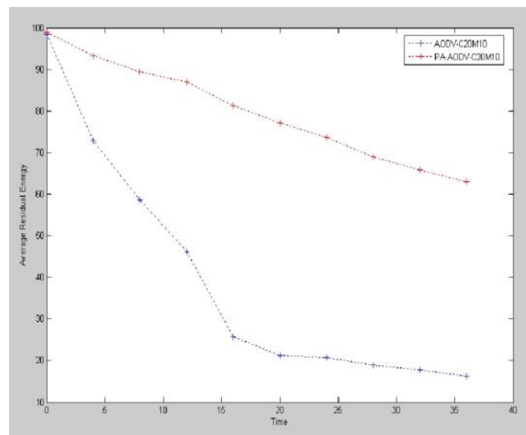

Fig. 3 Average Residual Energy (Joules) with Time (number of connected nodes=20)

Proposed algorithm, however, still has better performance than AODV. The comparison indicates that the network lifetime reduces when the speed of nodes increase. As compared with precious scenario, the overall network lifetime has reduced primarily due to increased numbers of connections.

5.3 Average Residual Energy with Nodes

Fig. 6 and 7 give the comparison between average residual energy and number of nodes for different speed of nodes. The values for average residual energy are taken at a constant time of 37s and a constant number of connections for different number of nodes. In this comparison, the average residual energy gradually decreases with number of nodes. However, the magnitude of expended energy does not vary much with increase in the number of nodes.

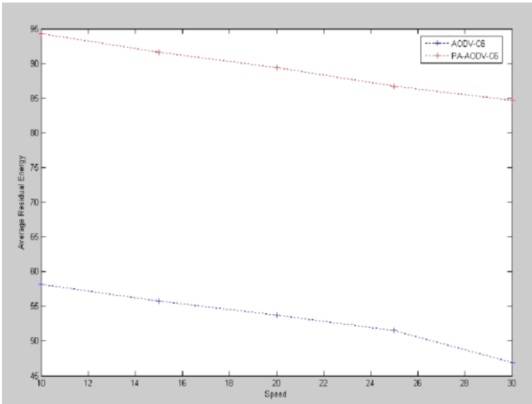

Fig. 4 Average Residual Energy (Joules) with Speed (number of connected nodes=6)

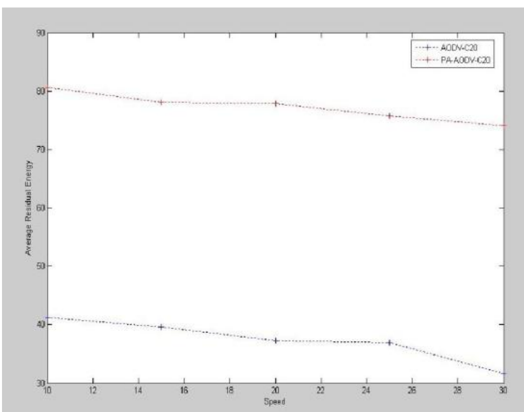

Fig. 5 Average Residual Energy (Joules) with Speed (number of connected nodes=20)

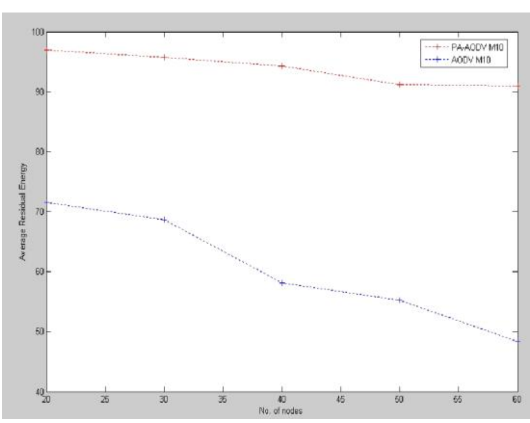

Fig. 6 Average Residual Energy (Joules) with nodes (speed = 10m/sec)

In this scenario too, the proposed algorithm drastically outweighs AODV primarily due to its ability to select the route with maximum energy. This, hence, has rendered the network to be usable for a longer duration.

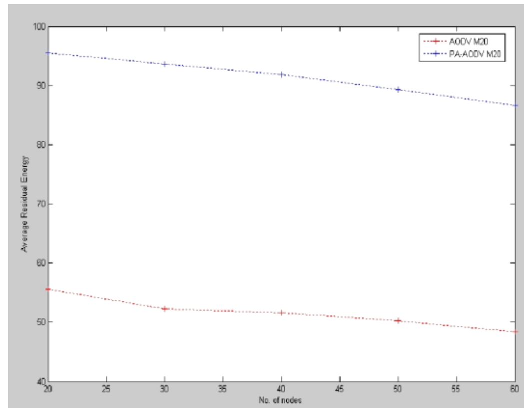

Fig 7: Average Residual Energy (Joules) with nodes (speed = 20m/sec)

6. Conclusions

Energy efficiency is one of the main problems in a mobile ad hoc network, especially designing a routing protocol. The proposed work aims at discovering an efficient energy aware routing scheme in MANETs that not only uses the node energy effectively but also finds the best route and increases the lifetime of the network. Simulation result shows that the proposed scheme outperforms in terms of different energy related parameters over AODV even in high mobility scenarios. At the time of route selection, the proposed algorithm takes care of crucial things, battery status of the path, and number of drained nodes in the path. With these factors in consideration the proposed scheme always select more stable route for data delivery. Energy of the network is also reduced using variable transmission power when data transmission is done. The results obtained from implementing these techniques are favorable and encouraging. Performance evaluation using a NS-2.34 shows that the longevity of the network can be extended by a significant amount. For the chosen simulation parameter set, in low traffic scenario, the average residual energy of the network is increased by 30-40%. For high traffic scenarios this goes up by 45%. Thus results obtained indicate that proposed scheme outperforms AODV for low and heavy traffic scenarios. This is mainly due to the fact that the proposed scheme analyses various route energy before selecting a route for transmission. On the contrary, AODV selects the quickest route irrespective of the route energy. Hence, its network lifetime is reduced significantly when compared with proposed scheme. The proposed energy-aware scheme can be further studied and analyzed for different parameters in scarce medium.

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