An Optimized Energy Aware Routing (OEAR) Scheme for Mobile Ad Hoc Networks using Variable Transmission Range

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ABSTRACT

Mobile Ad hoc Networks (MANETs) are energy constrained since nodes operate with limited battery energy. This not only leads to degradation in performance of the network but also reduces the lifetime of the network and in some cases makes the network partitioned. In order to maximize the lifetime of MANETs, routes having nodes with low energy and nodes with more buffered packets should be avoided. In this paper, a new energy efficient scheme has been proposed which takes into consideration the above mentioned characteristics of nodes. Energy consumption is further optimized by using variable transmission range. Common transmission range is used in existing popular routing protocols like AODV and DSR. Simulations are done in Network Simulator-2. It is shown that the algorithm improves the network energy consumption and increases the lifetime of the network.

General Terms

Ad Hoc Networks, Energy Conservation

Keywords

Routing algorithm, MANETs, variable transmission, AODV.

1. INTRODUCTION

Mobile Ad Hoc Networks are self organizing, self configuring, multi-hop and infrastructure-less networks that provide flexibility and convenience in setting up dynamic networks. Each node may also have to serve as an intermediate node to transmit the packets between a pair of nodes which are geographically far enough. The failure of these nodes may result in disconnection of the communication link. Such type of networks are suitable for applications like virtual classrooms, emergency search and rescue operations in remote areas, in battle field for coordination among soldiers, environment monitoring (sensors), patient monitoring, ad hoc collaborative computing (Bluetooth) and vehicle to vehicle communications etc.

One important characteristic of MANETs is that the nodes are energy-constrained. Since, nodes are battery-operated, recharging frequently or replacing batteries may become undesirable or even impossible. This makes energy-efficiency an important metric in MANETs. Many different power-aware routing algorithms and protocols have been proposed to conserve the energy of the node at different protocol layers.

The physical layer can save energy by adapting transmission power according to the distance between nodes [13]. At the data link layer, energy conservation can be achieved by sleep mode operation [13]. Thus, the node's energy is minimized not only during active communication but also when they are in inactive state. Some of the most commonly and successfully used energy efficient approaches are "shutting down nodes when not in use", "transmission power control" [1] - [4], [7] and "load distribution" [5], [6].

The power saving schemes which work at network layer are: Minimum Total Transmission Power Routing (MTPR), Minimum Battery Cost Routing (MBCR), Min-Max Battery Cost Routing (MMBCR), and Conditional Min-Max Battery Cost Routing (CMMBCR) [12]. These schemes not only have advantages but also disadvantages. MTRP minimizes the transmission power but it does not take care of load balancing in the network while MBCR and MMBCR considers load balancing as the basis for route selection but does not save energy. This paper focuses at the network layer for optimization of the nodal energy. The proposed scheme chooses a route with nodes possessing more than 50% of battery life and dropping others. The number of buffered packets of each node is also considered while selecting a node to be added in a route. Further, energy is conserved by using variable transmission range of the nodes instead of common transmission range at physical layer.

The paper is organized as follows: Section 2 gives a brief overview of the existing routing protocols. The proposed algorithm is explained in detail in section 3. Section 4 and section 5 present the simulation setup and results and discussion respectively. Finally, section 6 concludes the paper

2. MANET ROUTING PROTOCOLS

Routing protocols in MANETs can be classified as table-driven and on-demand. On-demand protocols include Ad-hoc On-demand Distance Vector routing (AODV) and Dynamic Source Routing (DSR). These protocols do not take into account the energy of the node while selecting a route.

A. DSR

This routing protocol uses source routing to forward the packets aggressively utilizing route cache to store full paths to the destination. Thus, in DSR the sender knows the complete hop-by-hop route to the destination [8], [9]. DSR makes
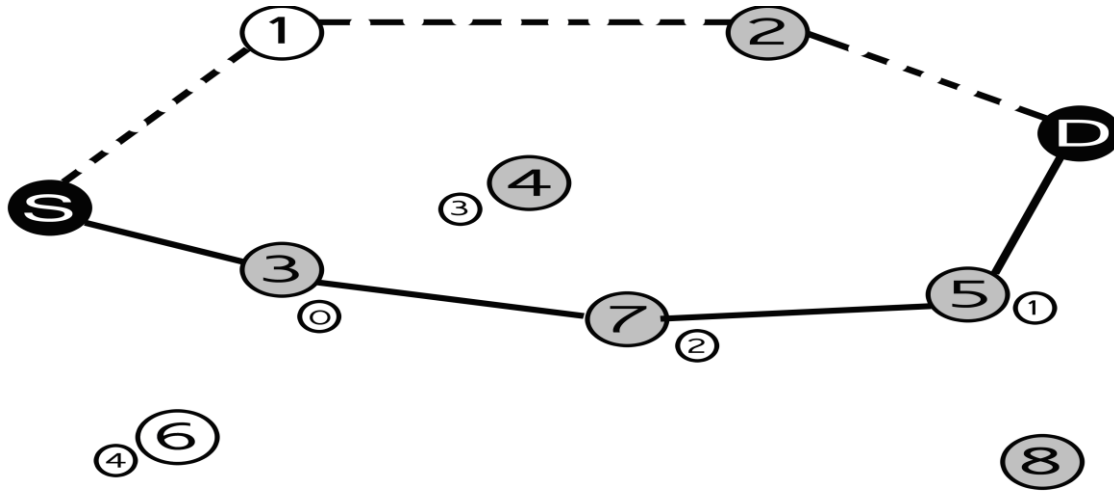
Fig 1: Proposed Scheme OEAR

packet routing loop-free. It also avoids the need for up-to date routing information at the intermediate nodes and also allows nodes to cache routes by overhearing data packets. The main advantage of DSR is that it does not make use of periodic routing advertisements, thus saving bandwidth and reducing power consumption. Also if a link to a route is broken, the source node can check in its cache for another valid route [9]. These factors contribute to energy conservation in DSR. Also the assumptions for the DSR protocol is that it operates in a network which has a relatively small diameter and the mobile nodes can enable promiscuous receive mode.

B. AODV

AODV shares DSR's on-demand characteristics and discovers routes as needed on demand basis via similar route discovery process [10], [11]. It uses traditional routing tables and maintains one entry per destination. Being a single path protocol, it has to invoke a new route discovery, whenever the path from source to destination fails. It uses destination sequence numbers to prevent routing loops and to determine freshness of routing information. AODV also uses a timer-based route expiry mechanism to promptly remove stale routes. Frequent changes in the topology cause more often initiation of route discovery. This can be inefficient as route discovery flooding is associated with overheads which can cause significant energy consumption. AODV is suitable when traffic diversity (number of active connections) increases, a condition with which DSR is not quite able to adjust.

3. PROPOSED ALGORITHM

This section first describes the energy model used and then the new optimized energy aware routing scheme.

3.1 Energy Model

The energy consumed $e_c(T)$ [3] by a node after time T is calculated as

$$e_c(T) = n_t \times a + n_r \times b \qquad (1)$$

where, n_t and n_r are number of packets transmitted and received by a node after time T respectively, a and b are constants with value between 0 and 1.

The residual energy $e_r(T)$ [3] of a node at time T, is calculated as

$$e_r(T) = e_i - e_c(T) \qquad (2)$$

where, e_i is the initial energy of a node.

3.2 Optimized Energy Aware Routing (OEAR) Scheme

The OEAR finds the most stable path out of the entire existing paths from source to destination using on-demand routing. The popular on demand routing protocols use shortest path between source to destination without considering the energy of the intermediate nodes in the path. This can lead to path breakage if any node runs out of energy. The proposed algorithm not only considers energy of the node while selecting the route but also takes into account the number of packets buffered in the node. More number of buffered packets means remaining energy will be less and time taken to deliver a packet will be more. Further optimization in energy is done by varying the transmission range of the individual nodes. Once the route is known, each individual node then controls the transmission range as per the distance between source and destination node, so that optimum energy is utilized for packet transmission. The proposed scheme is explained with the help of example as shown in Fig. 1

The proposed algorithm does not always choose the shortest path between source and destination. In Fig 1, nodes with grey color have more than 50% of remaining energy. The small circle with the nodes gives the number of buffered packets. As shown, the shortest path from source S to destination D chosen by DSR and AODV is S-1-2-D (shortest hop), but due to low residual energy of node 1, it is not chosen. Node 3 and 6 also lie in the transmission range of S. Out of the two, node 3 is chosen as it has the maximum residual energy, minimum packets in buffer and also it is the nearest to S. Thus the route selected on basis of above mentioned criterion is S-3-7-5-D which is more stable and more number of packets can be transferred before any node die.

Algorithm

When any node has data to send, it generates route request packet (RREQ) and floods it on the network with a common transmission range. The intermediate nodes having an active route to destination send the route reply. The proposed scheme adds the following parameters in the header of route reply packet.

- **Residual Energy Status** (RES)

The residual energy of the node is calculated using equation 2. Residual Energy Status (RES) is found as

If (Residual energy) < 50%

Then set RES = 0

If Residual energy > 50%

Then set RES=1

- **Buffered Packets** (BP)

This gives the number of packets buffered in the node.

- **Position of the node** (locX, locY)

These parameters give the location of the node sending the route reply.

Each node waits for a time (T_{wait}) till it receives all the route reply messages meant for that node. The node chooses the next hop node with RES=1 (maximum energy) and low value of BP. The node also calculates the distance between itself and the chosen next hop node using its own location and locX and locY parameters. The next hop location values are also stored in the routing table as two entries nhopX and nhopY. Friis transmission equation in free space is used to calculate transmission power required to transmit the data to the next hop node using the distance calculated between intermediate node and next hop node. This established route is maintained between source and destination for data transfer till the route is broken. If route break occurs, RREQ is again flooded in the network.

4. SIMULATION SETUP

Simulation study has been carried out to study the performance of OEAR scheme and AODV. The proposed scheme has been implemented on AODV. The event driven simulation tool Network Simulator-2 (ver. 2.34) and the wireless extensions provided by CMU are used. The setup consists of field size of 800 X 800 m^2 with 50 nodes. The simulations are carried out under the following conditions:

- Wireless channel/Wireless Physical,

- Free Space Propagation Model,

- Drop Tail/Priority Queue,

- Random Waypoint model and

- MAC protocol 802.11.

To emulate the dynamic environment, all the nodes move around in the entire region. The nodes move at varying speeds with minimum speed of 2m/sec and maximum speed of 40 m/sec have been considered. The packet size considered is 512 bytes with Constant Bit Rate (CBR) traffic source. The route was established using different source-destination pair (5-35 connections). Total simulation interval considered for experiment is 200 sec. The initial energy of each node is set as 100 Joules with transmission and reception power of 5 W and 1W respectively. Table 1 gives the used simulation parameters.

Table 1. Simulation Parameters

Parameter	Value
Number of Nodes	50
Grid Area	800m x 800m
Number of Connections	5 sources
Pause Time	0 sec, 50 sec
Speed	2m/sec
Traffic Model	CBR
Data Packet Size	512 bytes
Simulation Time	250 sec
Initial Energy of Node	100 J
Transmitted Power	5 W
Received Power	1W
Idle State Power	0.0005 W
Sleep State Power	0.0002 W
Transition from sleep to active state	.03W

5. RESULTS AND DISCUSSION

In this section, simulation results for OEAR and AODV are presented with different number of nodes and connections. Both the protocols have been compared for different performance metrics as follows

5.1 Total Energy Consumption

Total energy consumed in the network is the difference of the total energy supplied to the network and residual energy left with the network.

Scenario 1: Number of Nodes 50, Number of Connections 5-35

The comparison of total energy consumed with varying number of connections is done in Fig 2 and Fig. 3. Speed of the nodes is taken as 2m/sec. Pause time of 0 seconds is considered for Fig. 2. As shown, OEAR performs better than AODV as it consumes less energy compared to AODV under all traffic conditions. Fig. 3 is plotted for a pause time of 50 sec. As depicted, during initial stage of simulation, under low traffic conditions (5 connections), OEAR consumes more energy. Later on, for more numbers of connections AODV shows a sharp increase in total energy consumption as compared to OEAR indicating better performance of the proposed algorithm compared to AODV. The smooth curve of OEAR indicates a uniform distribution of energy among the nodes.

Scenario 2: Number of Nodes 50, Speed 2-30 m/sec, Number of Connections 5

In next simulation, energy consumption of the nodes is measured for varying speed of nodes with pause time of 0 sec (Fig. 4) and 50 sec (Fig. 5). As seen from Fig. 4, there is a remarkable reduction in the total energy consumed in the network in OEAR as compared to AODV. At a speed of 30m/sec, energy consumed by OEAR is 27 Joules lesser than AODV, which shows an improvement over AODV. In Fig. 5, at lower speed (2, 5 m/sec) energy consumption is less in AODV, but with increase in node mobility, OEAR outperforms AODV.

5.2 Network Lifetime

Network Lifetime is considered as the time taken in seconds from the start of simulation till 50% of the nodes (25 nodes) get exhausted. It is assumed that network becomes partitioned or impaired after 50% of the nodes die out. This happens mainly because most of the connections get broken and repairing of them is not possible till all exhausted nodes are active again either by changing or charging their batteries.

Fig. 6 gives the variation of network lifetime with number of connections. The nodes are moving at speed of 2m/sec with pause time of 0 seconds. As seen, the network lifetime has been improved for OEAR. For 5 sources, the network lifetime (death of 50% nodes) is 164 sec for OEAR as compared to 150 sec for AODV. On increasing the number of connections there is a gradual decrease in network lifetime in OEAR, whereas in AODV a sharp decrease in network lifetime can be observed.

In Fig. 7, network lifetime is plotted with varying number of nodes. Nodes are varied from 10-50. As depicted, OEAR again outperforms AODV with greater network lifetime. With increase in number of nodes, the number of possible routes from any source to destination increases and thus OEAR selects the best route (maximum energy and least congested) from all the available routes. This leads to increase in lifetime of OEAR as compared to AODV.

6. CONCLUSION

In this paper, a new routing scheme (OEAR) has been proposed which can be incorporated on any of the on demand routing algorithms to make it energy efficient. As a case
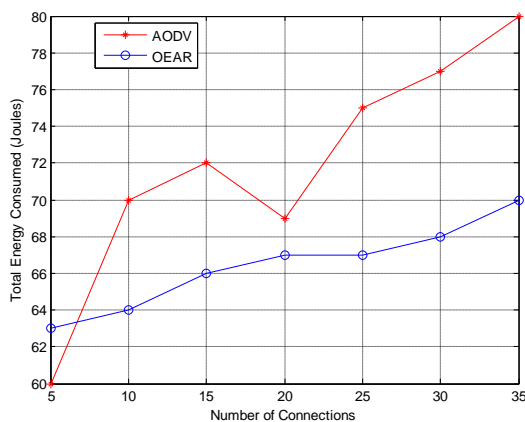
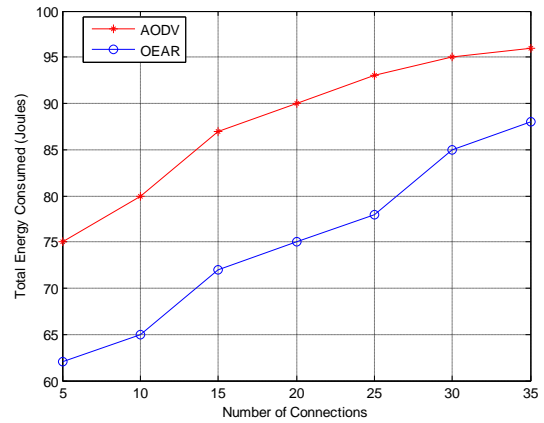**Fig. 3: Total Energy Consumed vs No. of Connections (Pause Time = 50 sec)**

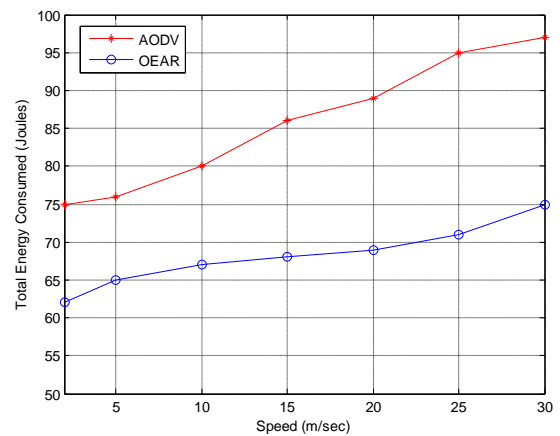**Fig. 4: Total Energy Consumed vs Speed (Pause Time = 0sec)**

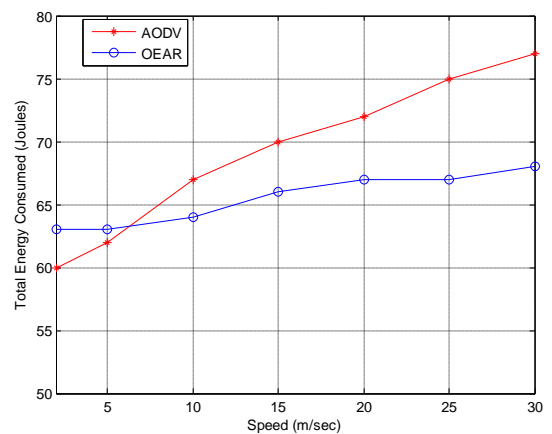**Fig. 2: Total Energy Consumed vs No. of Connections (Pause Time = 0 sec)**

Fig. 5: Total Energy Consumed vs Speed (Pause Time = 50sec)
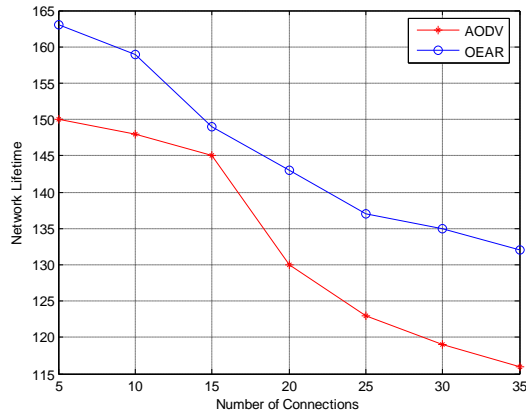
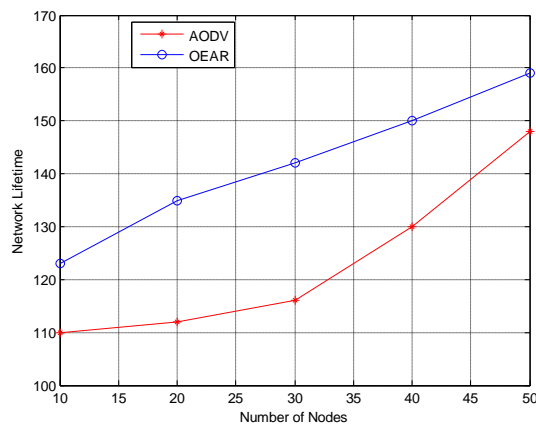**Fig. 6: Network Lifetime with No. of Connections**

Fig. 7: Network Lifetime with No. of Nodes

study, the scheme has been implemented on AODV and it shows better performance over existing AODV protocol in terms of energy related parameters even under high mobility scenarios. Simulations performed under all scenarios show 10% - 20% reduction in energy consumption and 10% increase in the lifetime of the network. This improvement is achieved without any increase in routing overheads. Thus, the proposed scheme results in significant power saving and long lasting routes.

In future, the proposed scheme can be examined under self-similar traffic like Pareto and Exponential Traffic. The proposed scheme will also be analyzed for real life scenarios and sparse medium

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