# A New NBEMV-AODV Energy Aware Routing Protocol in Mobile Ad-Hoc Networks

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**Abstract.** The mobile ad-hoc network consists of nodes driven by the battery with a limited life time. So, studies in relation to minimization of the total amount of energy consumed in the network are deemed to be mandatory. Until now, there haven't been sufficient studies on routing algorithms that can be specifically applied to the environment of the ad-hoc network even if many studies have focused on energy-efficient routing algorithms. Therefore, in this paper, we propose the online energy aware routing algorithm that is most suitable for the ad-hoc environment. The proposed algorithm is an improved version of the conventional AODV algorithm and it is referred to as the NBEMV-AODV (Neighborhood Energy Mean Value–AODV). In this algorithm, the overall network lifetime is significantly extended using the energy mean values of the neighboring nodes. The simulation results indicate that our energy-aware routing protocol achieves significant improvements in network lifetime by compared with existing AODV by using NS-2.

## 1 Introduction

A mobile ad-hoc network (MANET) is composed of a group of mobile, wireless nodes which cooperate in forwarding packets in a multi-hop fashion without any centralized administration. In MANET, each mobile node acts as both a router and an end node which is 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, energy depletion of nodes has been one of the main threats to the availability of MANET. Since the mobile nodes have limited battery power, it is very important to use energy efficiently in MANET.

Ad hoc wireless network has applications in emergency search-and-rescue operations, decision making in the battlefield, data acquisition operations in hostile terrain, etc. It is featured by dynamic topology (infrastructureless), multihop communication, limited resources (bandwidth, CPU, battery, etc.) and limited security. These characteristics put special challenges in routing protocol design [1]. The one of the most important objectives of MANET routing protocol is to maximize energy efficiency, since nodes in MANET depend on limited energy resources. Several routing protocols for MANET's have been suggested in late 90's: DSR, AODV, DSDV, TORA and others (see [2] for comprehensive review of these

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protocols). The classical MANET settings assume that neither node locations nor relative locations of other nodes are available. In this paper, we consider only protocols which do not rely on location knowledge – even if each node is supplied with GPS, the node mobility implies significant communication overhead caused by location updates. The primary objectives of MANET routing protocols are to maximize network throughput, to maximize energy efficiency, maximize network lifetime, and to minimize delay. The network throughput is usually measured by packet delivery ratio while the most significant contribution to energy consumption is measured by routing overhead which is the number or size of routing control packets. The general consensus based on simulations ( e.g., in the network simulator NS2 [3]) is that reactive protocols, i.e., those finding routes on fly by request with no work in advance, perform better than proactive routing protocols, which try to maintain the routs for all source-destination pairs (see [4]). In hop-by-hop reactive routing protocols (e.g. used in Ad-hoc On-demand Distance Vector routing (AODV) [2]), every intermediate node decides where the routed packet should be forwarded next. Rout requests are generated at each hop by local broadcasting in case of path discovery. A simple flooding broadcast for route requests generates a considerable redundant packet overhead which is a major cause of inefficiency of MANET routing protocols.

In this paper, we propose an improvement of AODV routing protocol of node energy-awareness. With a simple modification in applying the Energy Mean Value algorithm of AODV, our proposed routing protocols can achieve better load balancing among nodes, which results in a longer network lifetime.

The rest of the paper is organized as follows. In Section 2, we discuss to On-demand routing protocols in MANETs. Section 3 explains a proposed NBEMV-AODV which applies Neighborhood Energy Mean Value algorithm. Section 4 includes performance evaluation results of NBEMV-AODV compared with existing AODV using NS-2 (Network Simulator 2). Section 5 concludes the paper.

## 2 Description of AODV

In this section, we start with a general review of On-demand routing protocol, Ad-hoc On-demand Distance Vector (AODV), in MANETs. This protocol initiate route discovery only when a route is needed and maintain active routes only while they are in use. Unused routes are deleted.

AODV is based on distance vector algorithm. However, AODV, unlike other proactive distance vector algorithms, does not use periodic or triggered updates to disseminate routing information. AODV requests for a route only when needed and does not require nodes to maintain routes to the destinations that are not actively used in communications. Routing tables are built using route discovery techniques and maintained using Route maintenance, which are described as follows.

### 2.1 Route Discovery

When a node needs to send a Packet to a destination to which it does not have a routing entry. It broadcasts a route request (RREQ) packet. To prevent unnecessary broadcasts of RREQs the source node uses an expanding ring search technique as an optimization. In an expanding ring search, the source node initially uses a time-to-live (TTL) = TTL_Start in the RREQ packet IP header and sets a timeout for receiving a reply (RREP). Upon timeout the source retransmits a RREQ with TTL incremented by TTL_increment. This continues until TTL reaches the highest value. Source will retransmit the RREQ with the highest TTL if it does not receive any reply within time-out period. Maximum number of retransmission must be determined. Nodes receiving RREQs setup reverse paths to sources of RREQs in their routing tables, and either reply to the RREQ if they already have an entry for the destination or forward the RREQ. If there isn't any intermediate node, having a route to the destination, finally the destination will reply. Nodes receiving RREPs setup paths to the destinations and in this way desirable routes will be discovered.

### 2.2 Route Maintenance

An existing routing entry may be invalidated if it is unused within a specified time interval, or the next hop node is no longer reachable. In that case, the invalidation is propagated to neighbors that have used this node as their next hop. Each time a route is used to forward a data packet. Its route expiry time is updated when a node detects that a route to a neighbor is no longer valid. It will remove the invalid entry and send a route error message to the neighbors that are using the route. The nodes receiving route errors will repeat this procedure. Finally source will request a new route if it still needs the route.

## 3 NBEMV-AODV Routing Protocol by Applying an Neighborhood Energy Mean Value Algorithm

The NBEMV-AODV algorithm that we propose is a protocol based on the AODV, an on-demand routing protocol and it maximizes the overall network lifetime by allowing the network to effectively consume the limited battery of the moving nodes, which is one of the main limitations in the ad-hoc network. The NBEMV-AODV protocol is a very realistic online energy aware algorithm that is suitable for many applications in the actual ad-hoc network and it extends the network lifetime to its maximal permissible duration by using the energy mean values of the neighboring nodes and allowing the network to consume its energy more efficiently. The existing AODV protocol does not consider the energy status of each node but it rather sets the route according to the basic AODV route setting method. When a certain node has a higher rate of node participation, it will participate in many nodes and the battery energy will be consumed at a rapid pace unless it carefully considers how much energy it has. Eventually, the node won't be able to participate in the network.

In order to extend the network lifetime by preventing the energy from concentrating on a certain node and distributing it efficiently over the network, the status of energy of the network should be considered as well as the status of energy of each node. In the NBEMV algorithm that we propose is basically inspired by the fact that the communication is achieved between the neighboring nodes. In the route setting method of the AODV protocol, the RREQ message uses the status of energy of the node and the energy mean values of the neighboring nodes in order to delay the RREQ flooding. Consequently, the possibility for the node, whose status of energy is vulnerable, to participate in the route is greatly reduced through the method such that it eventually leads to the maximized network lifetime.

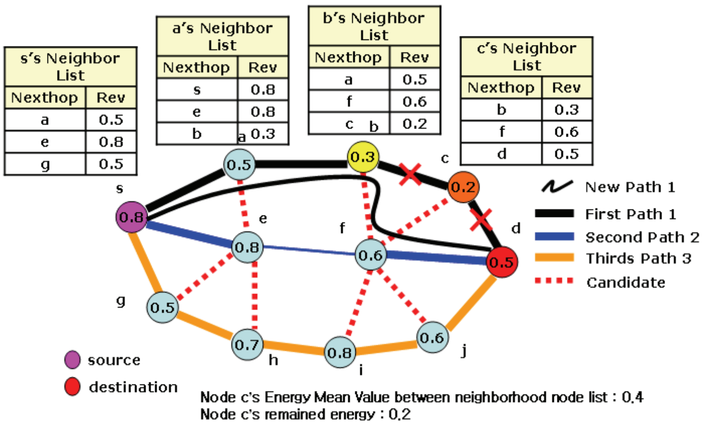



**Fig. 1.** NBEMV-AODVs Path Calculate and each node one-hop neighbor list

### 3.1 Operation of the Proposed AODV

In an existing AODV, if a source node is going to communicate with a destination node, the source node broadcasts RREQ messages first and a path is established by the RREP reply to RREQ arrive first.

Our proposed method is based on the fact that the actual communication is achieved between the neighboring nodes. We improved the two aspects of the existing AODV protocol in order to extend the entire network life.

First, the existing AODV protocol does not manage the list for the neighboring nodes. In addition, it doesn't manage the information of their energies either. Hence, we modified the existing AODV protocol and allow it to have the neighboring node list and manage the information on energy. The RREQ message is made available, so that each node can manage its neighboring node list. When a node broadcasts the RREQ message to the network for the purpose of route discovery for the data transmission, the RREQ messages includes the status of its energy in the 11 bits of the reserved fi eld. When the RREQ message being broadcasted to the network arrives at the intermediate node, that is, the neighboring node, the intermediate node browses its neighboring node list and determines whether the message originates from the neighboring node. If it is not listed in the neighboring node list then it will be newly added to the list. Otherwise, the list will not be updated. The neighboring node list and the energy information accompanying it are maintained for the duration specified by ACTIVE_ROUTE_TIMEOUT and the neighboring node list will be updated with the new RREQ message obtained from the route discovery of other source nodes.

Second, the Energy Mean Values, E(mv) for the current node and the neighboring nodes are obtained using the energy information of the neighboring node described above.

Energy Mean Value process can be expressed in a numerical formula as follows.

- Each node remained energy : $Ne\_R_{(ev)}$
- The number of neighbor nodes : $Neighbors_{(cnt)}$
- The neighbors node Energy Mean Value : $E_{(mv)}$

$$E_{(mv)} = ((\sum_{i=1}^{Neighbors_{(cnt)}} Ne\_R_{(ev)}) + Self_{(ev)}) / (Neighbors_{(cnt)} + 1)$$

The Energy Mean Values obtained as above are compared with the remaining energy in the node when the node is searching for another route after the initial route discovery. If it is below the mean value then the RREQ message is delayed by 2.0ms. If it's above the mean value, then the RREQ message is delayed by 0.01ms. This reduces the possibility for a certain node to participate in the route if it has a lower energy than the neighboring node. Therefore, the neighboring node with a relatively large energy participates in the route so that the overall network life can be extended.

Fig. 1 illustrates an example of the route discovery by the proposed NBEMV-AODV protocol that uses the neighboring node list and compares the energy mean values of the neighboring nodes. The remaining energy of the node c is 0.2 and the energy mean value for the nodes in the neighboring node list including itself is 0.4. So, when the RREQ message passes by the node b and finally arrives at the node c, the time delay is set to 2.0ms such that the possibility for it to participate in the subsequent route is reduced. In other words, the possibility for the route participation of a node with a relatively less energy is reduced. So, the energy consumption is distributed over the network by allowing the node with a relatively larger energy to participate in the route. As a result, the overall network life is extended significantly.

## 4 Performance Evaluation

In this section, we evaluated NBEMV-AODV routing protocols by comparing its performance with existing AODV and New-AODV[5]. We implemented our improved AODV protocol using NS-2, which is a discrete event-driven network simulator with support for various mobile ad-hoc network routing algorithms. We used a simulation model, an ad-hoc network model using the CMU (Carnegie Melon University) [6] of Monarch Research Group for NS-2. The used Channel is a Wireless channel/Wireless Physical, Propagation Model is Two-ray Ground reflection Model, Queuing Model is Drop-Tail/Priority Queue and MAC protocol which is 802.11. The radio network interface card (NIC) model includes collisions, propagation delay and signal attenuation with a 2Mbps data rate and a radio range of 250 meters.

## 4.1 Simulation

In our simulation model, a network with 49 mobile nodes is placed in a rectangular region size of 800 x 800 unit$^2$ where 49 nodes are uniformly distributed in the region. The initial energy of all the nodes is 10J. The transmission power is 600mW and the receiving power is 300mW. During the simulation, there are 100 CBR (constant Bit Rate) traffic streams between the source and destination pairs.

We evaluated the performance of our proposed NBEMV-AODV protocol (using Neighborhood nodes Energy Mean Value) by comparing the traditional AODV (Existing-AODV) and New-AODV (using Entire Network Energy Mean Value).

We analyzed the two main areas of performance of the proposed scheme through our simulation model. First, the number of nodes fully consuming its energy is analyzed. Second, the number of packets received by the entire receiving nodes is analyzed. The proposed NBEMV-AODV is compared with the existing AODV and New-AODV protocols. The New-AODV protocol is the result from preceding studies and it is a type of AODV protocol where the network life is extended by using the energy mean value of the entire network. The New-AODV shows an ideal performance in obtaining the energy mean value of the entire network under a specific constraint. Nevertheless, it is a very unrealistic and difficult matter to obtain the energy mean value for the entire network in reality. Thus, we proposed the NBEMV-AODV that is applicable to the actual ad-hoc networks and comparatively analyzed its performance vs. the existing protocols.

### 4.1.1 Simulation Model

The traffic model consists of five links, <0, 48>, <3, 45>, <6, 42>, <27, 21> and <43, 4>. it means that <”source”,”destination>. The formally AODV protocol’s RREQ messages delay time of NS-2 is determine to the formula “0.01 * Random::uniform()”, that is not fixed specifically.

We used three kinds of simulation models. The models are as follows.

First, we applied the simulation model, which was mentioned above, leaving the existing-AODV protocol unchanged and counted (for 100second) the number of nodes that consumed all energy in the entire network.

Second, we applied the simulation model, which was using Entire Network Energy Mean Value (New-AODV[5]. It compared energy states of each node with the energy state of the entire network, taking into consideration the Energy Mean value. If a node’s energy state is higher than that of the entire network, then the RREQ delay time is set at 0.01ms. And if a node’s energy state is lower than that of the entire network, then the RREQ delay time is set at 2.0ms.

Third, we applied the simulation model, which was our proposed NBEMV-AODV (using Neighbor Energy Mean Value). It compared energy states of each node with the energy state of the entire network, taking into consideration the Energy Mean value. If a node’s energy state is higher than that of the entire network, then the

RREQ delay time is set at 0.01ms. And if a node's energy state is lower than that of the entire network, then the RREQ delay time is set at 2.0ms.

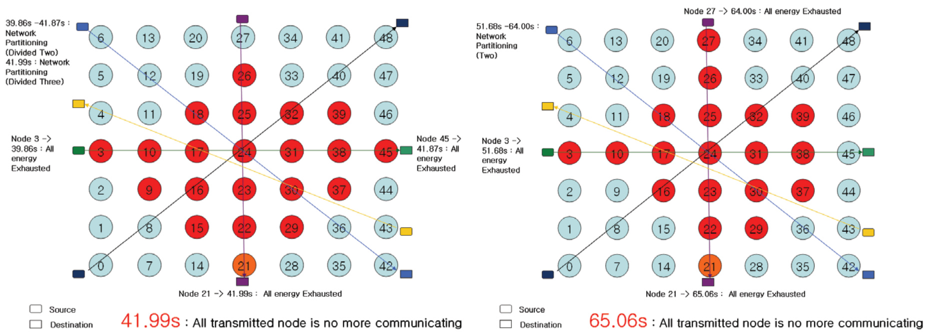
### 4.2 Simulation Results

Table 1 represents the nodes that consumed its full energy as time elapses.

As shown in Table 1, the existing AODV and New-AODV protocols and the NBEMV-AODV protocols become unable to communicate in 41.9907 seconds, 65.0685 seconds and 61.03859 seconds, respectively.

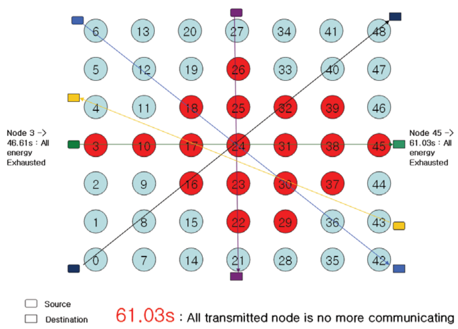
Fig. 3 is a graphical representation of these data. For our further analysis, we analyzed in which ways the nodes fully consume its power in the network.

Fig. 2 is a graphical representation of each case. In case of the existing AODV protocol in Fig. 2(a), the node 3 and the node 45 consume all of their energies in 39.986 seconds and 41.87 seconds, respectively. As a result, the network is divided in two and the source nodes can not transmit the data anymore.




(a) Existing-AODV

(b) New-AODV(using Entire Network Energy Mean Value)




(c) NBEMV-AODV(using Neighborhood node Energy Mean Value)

**Fig. 2.** Simulation results for different ways of the node consuming all of the energy

Fig. 2(b) corresponds to the case of New-AODV protocol. The node 3 and the node 27 consume all of their energies in 51.68 seconds and 64.00 seconds, respectively. The network is divided in two as well in this case. However, unlike the existing AODV protocol, several source nodes are still able to communicate. When the node 21 consumes its energy in 65.06 seconds, the rest of the source nodes cannot transmit the data anymore.

**Table1.** The number of nodes consuming all of the energy vs. time

| Existing AODV | | | New-AODV (Using Entire Network Energy Mean Value) | | | NBEMV-AODV (Using Neighborhood Nodes Energy Mean Value) | | |
|---|---|---|---|---|---|---|---|---|
| Time | Node | count | Time | Node | count | Time | Node | count |
| 35.61907 | 24 | 1 | 48.01164 | 24 | 1 | 44.1379 | 24 | 1 |
| 36.36335 | 23 | 2 | 50.08048 | 17 | 2 | 46.37262 | 23 | 2 |
| ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 39.80572 | 38 | 14 | 63.23194 | 3 | 14 | 57.93274 | 39 | 14 |
| 39.86968 | 3 | 15 | 63.98093 | 37 | 15 | 58.78723 | 3 | 15 |
| 40.36544 | 26 | 16 | 64.00492 | 27 | 16 | 58.84867 | 37 | 16 |
| 40.46846 | 37 | 17 | 64.68894 | 39 | 17 | 59.16575 | 29 | 17 |
| 40.6181 | 29 | 18 | 65.02778 | 29 | 18 | 61.03859 | 45 | 18 |
| 40.73804 | 39 | 19 | 65.06925 | 21 | 19 | | | |
| 41.87853 | 45 | 20 | | | | | | |
| 41.99076 | 21 | 21 | | | | | | |

Fig. 2(c) corresponds to the NBEMV-AODV protocol proposed by us. In this case, the node 3 and node 45 consume all of their energies in 46.61 seconds and 61.03 seconds. Consequently, the network is divided in two and none of the source nodes can transmit the data

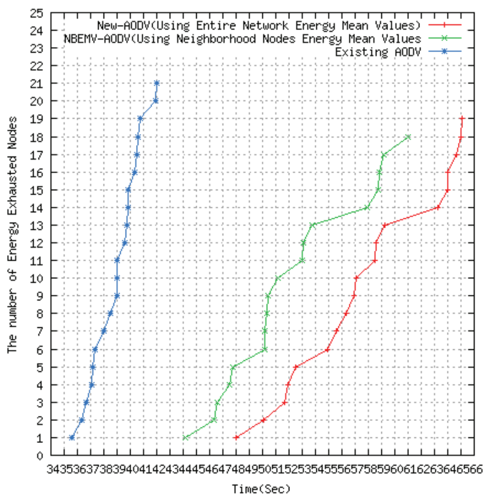



**Fig. 3.** Network life comparison of the NBEMV-AODV protocol, the existing AODV and New-AODV protocols

To summarize, in the existing AODV protocol, a total of 21 nodes consume all of their energies in 41.99 seconds. As a result, the network is divided in three and becomes unable to communicate. In the New-AODV protocol, 19 nodes consume all of their energies in 65.06 seconds. As a result, the network is divided in three and becomes unable to communicate. In the NBEM-AODV protocol, 19 nodes consume all of their energies in 61.06 seconds. As a result, the network is divided in two and becomes unable to communicate

The following is an analysis of the packet transmitted in each type of AODV protocol.

**Table 2.** The number of packets received by the entire receiving nodes

| Link : (0,48) (3,45) (6,42) (27,21) (43,4) | | | |
|---|---|---|---|
| Destination | existing-AODV | New-AODV (Using Entire Network Energy Mean Value) | NBEMV-AODV (Using Neighborhood Nodes Energy Mean Value) |
| 48 | 386 | 156 | 250 |
| 45 | 747 | 1012 | 1050 |
| 42 | 69 | 96 | 212 |
| 21 | 760 | 878 | 920 |
| 4 | 633 | 832 | 541 |
| Total | 2595 | 2974 | 2973 |

Table 2 represents the total number of received packets. According to this table, the total number of the received packets in the existing AODV protocol, the New AODV protocol and the NBEM-AODV protocol are 2595, 2974 and 2973, respectively

## 5 Conclusions

We propose a NBEMV-AODV protocol which extends the entire network lifetime in an Ad-hoc network environment through NS-2. Our study does not state that the New-AODV is necessarily the best solution. Since the New-AODV uses the energy mean value for the entire network, it is quite impractical to apply it to an actual network environment. Therefore, based on the fact that the actual communication is achieved between the neighboring nodes in the network, we proposed the NBEMV-AODV that is applicable to an actual network environment. From our simulation result, it is clear that the NBEMV-AODV protocol is suitable for applications in an actual network environment and much more energy-efficient than the existing AODV protocol as well as its performance is almost as good as the New-AODV protocol.

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## References

1. P. Sinha, R. Sivakumar, and V. Bharghavan, “Cedar: Core extraction distributed ad hoc routing,” in Proc. of IEEE INFOCOM, 1999.
2. C. Perkins, Ed., Ad Hoc Networking. Addison-Wesley, 2001.

3. K. Fall and K. Varadhan, "The vint project, uc berkeley, lbl, usc/isi, and xerox parc," 1997. [Online]. Available:http://www-mash.cs.berkeley.edu/ns/
4. J. Broch, D. Maltz, D. Johnson, Y. Hu, and J. Jetcheva, "A performance comparison of multi-hop wireless ad hoc network routing protocols," in Proc. of the ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom98), 1998.
5. Jin-Man Kim, Jong-Wook Jang, "AODV based Energy Efficient Routing Protocol for Maximum Lifetime in MANET," in Proc, of the AICT/IEEE International conference, 2006.
6. The CMU Monarch Project, "The CMU Monarch Project's Wireless and Mobility Extensions to ns," Carnegie Mellon University, Aug, 1999.