International Arab Conference on Information Technology (ACIT'2016)

Energy Enhancement of Ad-hoc On-demand Distance Vector Routing Protocol for Maximum Lifetime in MANET

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Abstract: *Nowadays, Mobile Ad hoc NETwork (MANET) becomes more used in many domains. Nevertheless, it still suffers from various types of restrictions. Among these restrictions, and the biggest one is the energy consumption. The classical routing protocols proposed by Internet Engineering Task Force (IETF), in its establishment of the routes, searches for the shortest path in terms of the number of hops, while they not take on consideration the energy level or the lifetime of the intermediate nodes. In this paper, we propose a solution called Enhanced Energy-AODV (EE-AODV), which is an enhancement of the Ad-hoc On-demand Distance Vector (AODV) routing protocol. In our proposed protocol, we have added the energy consumption among the selection criteria of the AODV routing protocol in order to obtain a sufficient result in terms of the connectivity and the lifetime of the network. Simulation results show that EE-AODV outperforms AODV by reducing significantly the energy dissipation, also certain parameters affected by the energy issue like Packet Delivery Ratio (PDR) and Normalized Routing Load (NRL).*

Keywords: *Ad-hoc, MANET, Energy, AODV, Routing protocol.*

1. Introduction

Mobile Ad-hoc Network in the last years has a certain attention due to their unlimited potential. Nevertheless, like other wireless networks it is still subject to the risks of its dynamic behavior [1][2][3]. The conditions of the transmission channel are unpredictable and variable in time. The failure of routes as well as the degradation of the quality of links because of mobility, multipath, interference, and lack of resources are frequent, like their computational capabilities, limited storage and especially their dependence on a limited power supplied by a battery that is one of the major problem that face MANET today [4][5].

To design and develop a routing protocol, which can discover and establish routes efficiently between nodes is becoming a challenging task. Various routing protocols have been submitted to the Internet Engineering Task Force Mobile Ad Hoc Networking group, based on different assumptions, such as AODV [6], Dynamic Source Routing (DSR) [7], Destination Sequenced Distance-Vector (DSDV)[8] and Temporally Ordered Routing Algorithm (TORA)[9]. Most of these protocols take the shortest path as the main metric and focus on packet loss, routing message overhead and route length for the evaluation of routing performance. But this route selection philosophy causes traffic concentration on certain part of nodes, which results in the consumption of large amount of resource (e.g. energy) of these nodes [10][11]. Such excessive use of nodes resources may lead to a faster death for some nodes, and thus causing a break in the routes. Generally, in reactive routing protocols, route recovery and maintenance procedures consume substantial amount of resources in terms of wireless bandwidth, energy, processing capacity at nodes and introduce extra delay in quality of service (QoS) flows[12].

Many protocols have been proposed to reduce these problems, we cite as example in [13] authors give a new protocol, Route Stability and Energy Aware based RSEA-AODV to achieve route stability, which selects the route according to four performance metrics: delay between two communicating nodes, signal strength of received packet, total remaining energy and draining rate of nodes in order to decide whether to add these nodes in path or not. Also, the protocol minimizes the chance of route breakage by two factors: distance between two communicating node and energy depletion. All these metrics are compared with defined threshold value, if this metrics value satisfies the threshold condition so the node will be selected in the route and it forwards the route request packet. Otherwise, it drops the packet.

As well in[14] the authors propose an energy efficient routing protocol EERP which is based on AODV routing protocol. The proposed solution reduces the transmission power of the intermediate nodes in case of the next hop node is closer, and this leads to the reduction of the battery consumption.

Local Energy-Aware Routing based on AODV (LEAR AODV) in [15] uses a threshold approach during the route discovery phase. When node Ni receives a Route REQuest message (RREQ) at time t, it compared its current residual energy $Er^i$with the predefined threshold value. If it is lower than the threshold, the node will drop the RREQ message. In the other case the node will forward the message. In [16], the authors propose a similar approach, Energy-Aware Probability Routing protocol (EAPR) but more complicated compared to LEAR-AODV. The proposed mechanism used a probability model to determine whether to forward or drop the RREQ message.

Both protocols based on predefined threshold value to determine if an intermediate node participates in the route or not. Otherwise, for LEAR-AODV, intermediate node drops the message, while for EAPR, the node forwards the message with a probability which is determined by the remaining energy capacity.

Our purpose is to achieve more the stability of the links; this factor indicates how long a link between two nodes can support the communications. This parameter can be measured using different ways for example: signal strength, pilot signals, relative speed between two nodes forming the link, link duration distributions and remaining battery power of the nodes [17] etc. To reduce the possibilities of route breaks during data transmission, it is important to find routes that persist longer time, by taking into consideration the importance of the energy conservation at route selection phase. In this paper, we are interested in describing a reactive routing algorithm that is an enhancement of AODV protocol which is based on the interaction between the MAC and routing layer. We propose a new adaptive approach designed to incorporate the energy metricin the process of route selection. Indeed, it defines the rate of energy consumption for each node to estimate its lifetime. Then, we compute the harmonic mean of the energy level of each route. Using this information allow us to select the optimum path between the available paths.

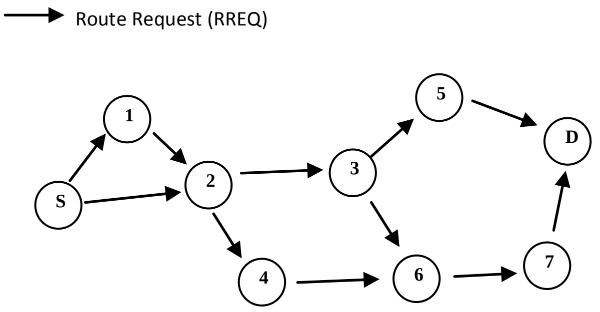
The rest of the paper is organized as follows. Section 2 gives a brief description of AODV routing protocol. Section 3 describe the proposed Routing protocol EE-AODV. The performance of the proposed protocol evaluated and compared with the classical AODV in Section 4. Finally, Section. 5 concludes the paper.

2.The Ad Hoc On Demand Distance Vector Protocol (AODV)

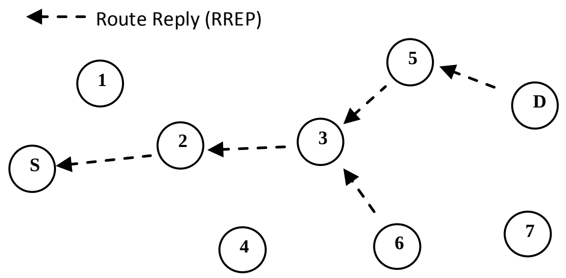
Ad Hoc On-Demand Distance Vector (AODV) [6] routing protocol is an adaptation of the Destination-Sequenced Distance-Vector (DSDV) [8] and DSR [7] algorithms. It is an on-demand protocol because the routes discovered at the time when a source node needs to send data packets to a destination node for which it has no cached route.

The AODV protocol establishes routes using a Route REQuest (RREQ) / Route REPly (RREP) query cycle. So, when a node in the network need to communicate with another node (destination), it broadcasts RREQ message to its neighbors (Figure 1(a)) which includes latest known sequence number for that destination. This message is flooded until information required is complete by any means. Each node receiving the message creates a reverse route to the source and rebroadcasts the RREQ message. When the destination receives the RREQ message, it sends back RREP message which includes number of hops traversed and the most recent sequence number for the destination of which the source node is aware. Note that if an intermediate node has a fresh route to the destination it doesn't forward the RREQ and it generates a RREP toward the source. Each node receiving the RREP message creates a forward route to the destination Figure 1 (b). Thus, each node remembers only the next hop required to reach the destinations, not the whole route. Each node receiving a duplicate of the same RREQ, it dropped it. Moreover, AODV uses sequence numbers to ensure the freshness of routes. In fact, the routes to any destination are updated only if the new path toward that destination has greater sequence number than the old one, or it has the same sequence number but with less number of hops. in case of link failure, the node that detects a link failure, it sends a Route ERRor (RERR) message to the source node informing it that the destination is now unreachable and to stop the transmission of data packets (see Figure 2). If the source node still needing the route to this destination, it must initiate the route discovery process again.

According to description, we can say that the protocol AODV select routes between nodes which have the less number of hops and does not consider the other QoS parameters such as the residual energy, links stability.



(a) Network Flooding of RREQ Packet



(b) Unicasting of RREP Packet

Figure 1. Route discovery process of AODV

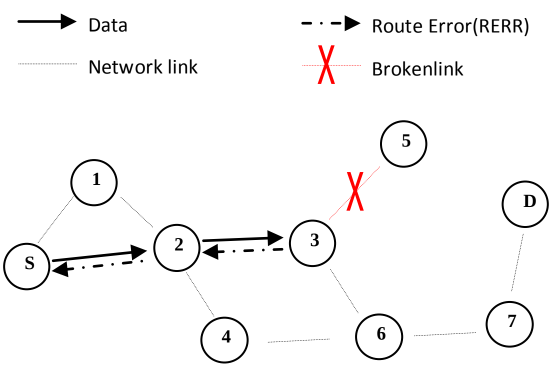


Figure 2. Route maintenance process of AODV

3. Our approach Energy Enhanced AODV

In traditional AODV, routes are established based on the minimum number of hop to make a decision about route selection. Indeed, route is taken if it has less number of intermediate nodes, other factors like residual energy and node congestion of these intermediate nodes, are not considered in the route selection process. In our proposed EE-AODV we try to improve the performance of the existing on-demand routing protocol AODV, by solving the problem caused by the bad selection of nodes at the moment of the construction of the route. We modify the existing route request phase of AODV in such a way to give a great performance than the traditional AODV. When a source node needs to initiate a data session with a destination, but does not have any route information, it searches a route by broadcasting a route request packet to its neighbors. Each intermediate node calculates its residual energy, and by following its lifetime. Then, at the reception of the route request packet, the node compares its residual lifetime with a defined Threshold value (in this study, it is a time for a node to stay alive for the ten next seconds), if it satisfies the condition, the node add its residual energy in the RREQ packet that is slightly modified by adding an extra field (rte_energy) contain the harmonic mean of the remaining energy of the traversed nodes (Figure 3). Thereafter, it pursues the route request procedure. If the condition is not verified, the intermediate node discards the RREQ message. As this way, destination node gets the RREQ message through the path which meets the above condition true. Finally, the destination computes the harmonic meanH_{mean} of the energy level of the route, then it selects the optimal path which has more energy and minimum number of hops. thereafter, the destination node updates its routing table by the best route computed.Using this approach, we find a path with sufficient energy from source to destination. Algorithm 1 gives the detail processing of our approach.

To compute the energy consumption rate, we calculate the difference of the energy level of two distinct time t_1 and $t_2$divided on this period of time.

$$ECR_i = \frac{\mathrm{RE_i}(t_1) - \mathrm{RE_i}(t_2)}{t_2 - t_1} \tag{1}$$

Where $\mathrm{RE_i}(t_1)$ is the estimated remaining energy computed at time *t* and it is computed as follows:

$$\mathrm{RE_i}(\mathrm{t}) = max\left\{CE_t - \sum_{j=1}^{j=Nbr-pkts} E_t(j), 0\right\} \tag{2}$$

Where CE_t is the current energy value of the node. For more accurate estimation of this residual energy, we reduce the value of the power that will be consumed to transmit the remaining packets in the buffer noted by Nbr-pkts. The parameter $E_t(j)$ represents the needed energy for transmitting the packet number *j*.

Then, we can estimate the expected residual lifetime $ERLT_i(\mathrm{t})$in each node considering $\mathrm{RE_i(t)}$ and $ECR_i(t)$ values computed at each update period number *t* as follows:

$$ERLT_i(\mathrm{t}) = \frac{\mathrm{RE_i(t)}}{ECR_i(t)} \tag{3}$$

The harmonic mean of the energy is computed as follows:

$$H_{mean} = \frac{\mathrm{Nbr\ of\ Hops}}{\sum_{\mathrm{i=1}}^{\mathrm{Nbr\ -Hops}} \frac{1}{\mathrm{RE_i}}} \tag{4}$$

Algorithm 1:*the proposed protocol EE-AODV*

Each intermediate node calculates its residual energy
When a node receives a route request.
If** node == IntermediateNode**Then
If**timetolife>ThresholdTime**Then
*- Update the field **rte_energy**of the packet **RREQ** by accumulate their energy level.*
*- Forward **RREQ** to the neighbors nodes.*
Else
- Reject the session, and DROP the RREQ
End if
Else if** node == DestinationNode**Then
If**rreq_seqno>= rt_seqno**Then
- computes the harmonic mean H_{mean} of the energy level of the route
- select the optimal route taking into consideration the energy level
- send a route reply towards the source node
Else
*- Reject the session, and DROP the **RREQ***
End if
End if

0 shows the format of modified Route Request Message, our contribution focused on using 7 bits from the reserved bits to indicate the amount of residual energy (rte_energy) of the route (the traversed nodes by the packet):

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |J|R|G|D|U|   Rsrvd | rte_energy|   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            RREQ ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination IP Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP Address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Originator Sequence Number                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3. New Format of Route Request (RREQ) Message

4. Simulation and result

To evaluate the performance of the routing protocol EE-AODV and perform the comparative study with AODV under different network load conditions, an extensive simulation is performed using NS-2[18].

Each run of the simulator accepts as input a scenario file that describes the behavior of each node. Hence, to evaluate the performance at a particular factor, we consider 20 random simulation runs to generate 20 random scenario patterns. The performance of the considered factor is the average values of these 20 outputs of the measured performance metrics.

A random traffic pattern with UDP connections between mobile nodes is used in the simulation. The position and connections between nodes and starting time of various connections are generated randomly in each simulation[19]. The other parameters of simulation are shown in Table 1. Following metrics have been used for performance analysis.

- **Packet Delivery Ratio:** is the percentage of the number of data packets received at the destinations vs the number of data packets sent to the network. This measures the quality of the discovered path.
- **Normalized Control Overhead:**is the percentage of the number of control packets sent to the network vs the number of data packets are successfully delivered to all destinations. This measures the overhead induced by the protocol.
- **End-to-End Delay***:* is the average time delay that a data packet has spent from the time it was sent by a source to the time it was delivered at the destination. This measures the delay performance of the QoS flows.
- **Total number of Dead Nodes**: Is the total number of nodes that depleted their energy.
- **Energy consumption:** The sum of the energy consumed by all the nodes in the network.

Table 1. Simulation parameters.

Parameter name	Value
Topology	1500m ×1500 m
Number of nodes	50
Mobility model	Random waypoint
MAC layer	IEEE 802.11 DCF

Propagation model	TwoRayGround
Antenna type	Omni directional
Transmission range(m)	20
Simulation time (s)	200
Traffic type	CBR
Packet size (B)	512
Traffic rate (packets/s)	5
Initial energy (Joule)	20-50
Mobile Connection	5-25
MAC Type	Mac/802_11
Interface queue type	Queue/DropTail/PriQueue
Maximum Speed of nodes	5 m/s

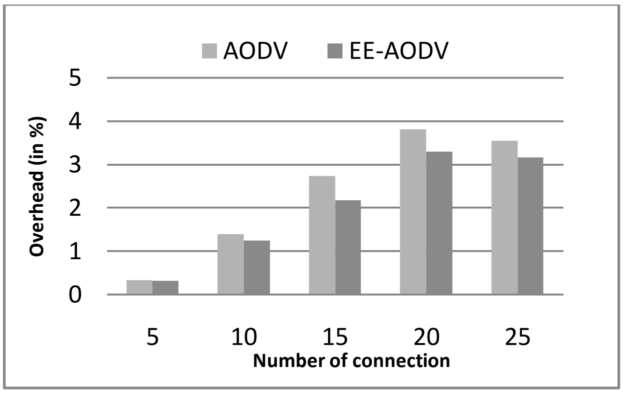


Figure 4. Normalized Control Overhead Vs Number of connection

According to the result of Figure 4, which presents the overhead with varying the number of connections in the network. We observe that the overhead generated by the protocol EE-AODV is less than AODV protocol, especially when the number of connections is more than 10, and that with 15%. These improvements are due to the decrease in the number of retransmissions of control packets (RREP and RREQ) to construct a new route after link breakage, which engendered by the bad selection of intermediate nodes that have a low remaining energy.

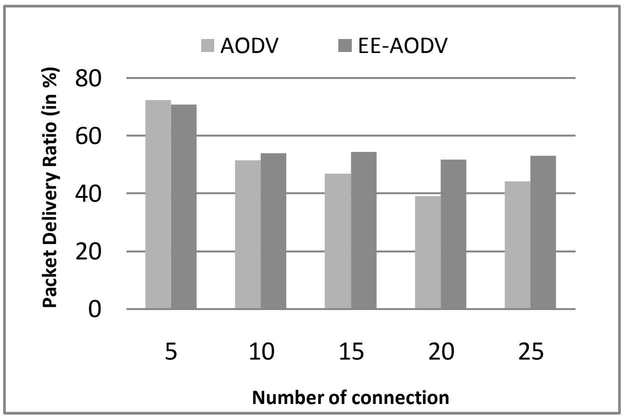


Figure 5. Packet Delivery Ratio vs number of connection

0 presents the number of packets received on the number of packets sent. As it can be seen the packet delivery ratio is greater in our approach and that with more 10 connections, it delivers 53% while in the AODV protocol only 44% are delivered. So, EE-AODV delivers more than 9% of packets than AODV.

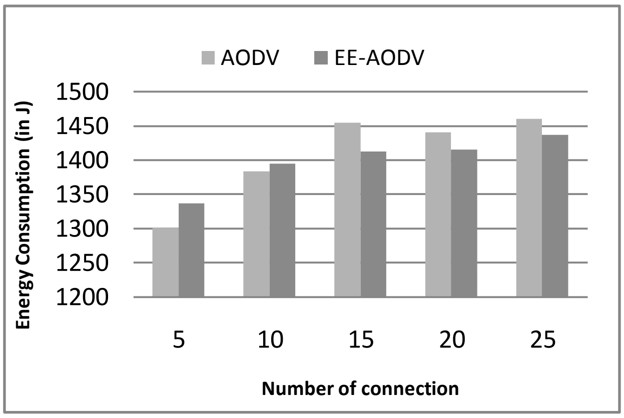


Figure 6. Energy consumption vs number of connection

0 shows the energy consumption vs number of connection. The energy consumption increases respectively with the increase of the number of connection in both protocols. However, EE-AODV performs better than AODV with more 15 connections. This is because the EE-AODV tends to avoid intermediate nodes with low remaining energy in its construction of the path to the destinations. As our protocol leads to decrease the number of link failure, the energy lost during the broadcast of the route request packet to reconstruct the path after link failure are eliminated. Consequently, the lifetime is significantly improved.

0 depicts the average end-to-end delay. Both protocols have higher end-to-end delay with high number of connections. Mostly because the dead of intermediate nodes increase the delay to reach to the destination. But EE-AODV reduces this problem and still perform better than AODV, even if the traffic load increases. As result of the decrease in the number of link failure, the time lost during the reconstruction of the route after link failure are eliminated, the thing that explains the ability of EE-AODV to significantly reduce the delay compared to the AODV.

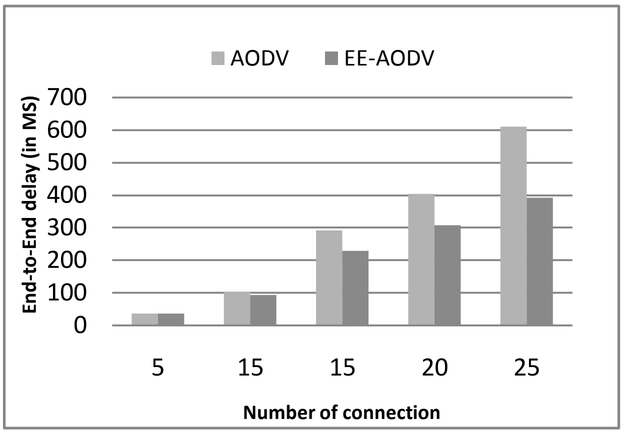


Figure 7. Average end to end delay vs number of connection

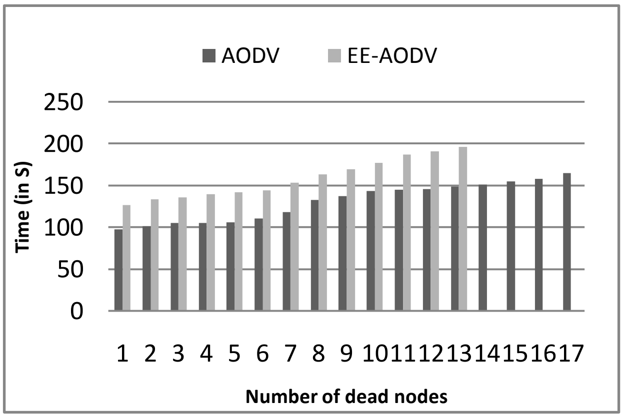


Figure 8.Total number of Dead Nodes during the time

0present the number of nodes which have died during the simulation. This number gives us the information about the connectivity of the network. In our solution, the first node dead at 126 Sec while in the protocol AODV the first node dead at an early time 97 Sec. Additionally, we can see the death of approximately 17 nodes successively in AODV however, in EE-AODV we have less number of the dead nodes at the end of simulation and more time between the death of nodes and this is due to the EE-AODV protocol avoid the intermediate nodes having low remaining energy during the construction of the route.

5. Conclusions

In the reactive routing protocol, stability of the route is very important, since the breakage of the route at the time of data transmission is very expensive. Consequently, the cost of the route discovery procedure will be very high in terms of the number of control packets, also in terms of energy. In order to minimize this problem in Mobile Ad hoc network, we have proposed in this paper an energy efficient routing protocol called EE-AODV which is an enhancement of the protocol AODV. We use the residual energy and hop count as parameters in the route selection process. Therefore, a route with a high residual energy and minimum hop count will be chosen. Simulation results have clearly shown significant performance improvements in terms of normalized control overhead, packet delivery ratio, energy-efficiency and the number of dead nodes provides better lifetime compared with AODV, especially in a dense network with many connections. Taking into account the benefit of the solution proposed in this paper, in future work we try to expand the solution by proposing a model for computing link stability and use the genetic algorithm mechanism to resolve the problems mentioned in this paper.

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