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Abstract: Mobile Ad-Hoc Network (MANET) is a decentralized, self-organizing and a dynamic network. These futures make MANET becomes more and more used in many domains. However, this kind of network 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 between the source and destination, while they don't take in consideration the energy level or the lifetime of the intermediate nodes. In this work, 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 solution, we tend to obtain a sufficient result in terms of the stability a lifetime of the different path in the network, by adding the energy consumption among the selection criteria of the AODV routing protocol. The different simulation results show that EE-AODV outperforms EQ-AODV (Energy and QoS supported AODV) and the basic AODV by reducing significantly the energy dissipation, also enhances certain parameters that are affected by the energy issue like Packet Delivery Ratio (PDR) and Normalized Routing Load (NRL).

Keywords: Ad-hoc, MANET, energy, AODV, routing protocol.

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1. Introduction

Mobile Ad-hoc Network in the last years has a certain attention due to their unlimited potential. Mobile Ad-hoc Network (MANET) is the new emerging technology which allows users to communicate with each other without any physical infrastructure regardless of their geographical location, that’s why it is sometimes referred to as an “infrastructure less” network. Nevertheless, like other wireless networks it is still subject to the risks of its dynamic behavior [5, 6, 13, 15]. As the conditions of the transmission channel are unpredictable and variable in time. The failure of routes, the degradation of the quality of links and the interference are frequent. Like their computing capabilities: limited storage and especially their dependence on limited power supplied by a battery which is one of the major problems facing MANET today [3, 10].

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 (IETF) Mobile Ad-hoc networking group, based on different assumptions, such as Ad-hoc On-demand Distance Vector (AODV) [18], Dynamic Source Routing (DSR) [12], Destination Sequenced Distance-Vector (DSDV) [17] and Temporally Ordered Routing Algorithm (TORA) [4].

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 [7, 9]. 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 [1].

Many protocols have been proposed to reduce these problems, we cite as example in [11] authors propose a new protocol Energy and QoS supported AODV (EQ-AODV) for better performance in Wireless Multimedia Sensor Networks (WMSNs). EQ-AODV it is an enhancement of the AODV protocol and make it operative for multimedia data in WMSNs. This improvement is based on the adaptation of the routing process of AODV according to two metrics. The first one is the energy of sensors belonging to path and the second metric is the nature of the packets received by these sensors. Authors of [14] 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 [2] 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.

In [16] authors propose to use an adaptive route lifetime through a fuzzy logic system, to determine dynamically and accurately the value of Active Route Timeout (ART). This value is measured depending on the situation of the transmitter and intermediate nodes instead of using the statistical value. Local Energy-Aware Routing based on AODV (LEAR AODV) in [20] 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 $E_r$ 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 [22], 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 nodes [19] 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 metric in 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 Enhanced Energy-AODV (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) [18] routing protocol is an adaptation of the DSDV [17] and DSR [12] 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 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 which includes latest known sequence number for that destination. This message is flooded until it is received by the destination or an intermediate node that know the rest of the path. 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 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.

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 Figure 1 present the detailed process of the protocol. In case of link failure, the node that detects a link failure, it sends a Route ERR or (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
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 and links stability.

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 1). 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 mean $H_{mean}$ 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.

$$E_{CR_i} = \frac{R_E(i(t_1)) - R_E(i(t_2))}{t_2 - t_1}$$

Where $R_E(i(t_1))$ is the estimated remaining energy computed at time $t_1$ and it is computed as follows:

$$R_E(t) = \max\{CE_t - \sum_{j=1}^{Nbr-pkts} E_t(j), 0\}$$

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 $E_{RTL}(t)$ in each node considering $R_E(t)$ and $E_{CR}(t)$ values computed at each update period number $t$ as follows:

$$E_{RTL}(t) = \frac{R_E(t)}{E_{CR}(t)}$$

The harmonic mean of the energy is computed as follows:

$$H_{mean} = \frac{\text{Nbr of Hops}}{\sum_{i}^{Nbr-hops} \frac{R_E}{R_{T_i}}}$$

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
        - 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

Figure 3 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):

```
<table>
<thead>
<tr>
<th>Type</th>
<th>J</th>
<th>R</th>
<th>G</th>
<th>D</th>
<th>U</th>
<th>Rsrvd</th>
<th>rte_energy</th>
<th>Hop Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>RREQ ID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Sequence Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Originator IP Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
```

4. Simulation and Result

To evaluate the performance of the routing protocol EE-AODV and perform a comparative study with the
basic AODV and EQ-AODV protocol proposed in [11], we use the network simulator NS-2 [21] under
different network load conditions.

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 [8]. The other parameters of
simulation are shown in Table 1. Following metrics
have been used for performance analysis.

- **Packet Delivery Ratio (PDR):** is the percentage
of the number of data packets received at the
destinations vs the number of data packets sent to
the network. This measure 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 measure 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.

- **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>
<thead>
<tr>
<th>Parameter Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology</td>
<td>1500m ×1500 M</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>50</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Random waypoint</td>
</tr>
<tr>
<td>Mac layer</td>
<td>Ieee 802.11 DCF</td>
</tr>
<tr>
<td>Propagation model</td>
<td>TwoRayGround</td>
</tr>
<tr>
<td>Antenna type</td>
<td>Omni directional</td>
</tr>
<tr>
<td>Transmission range (m)</td>
<td>20</td>
</tr>
<tr>
<td>Simulation time (s)</td>
<td>200</td>
</tr>
<tr>
<td>Traffic type</td>
<td>Cbr</td>
</tr>
<tr>
<td>Packet size (b)</td>
<td>512</td>
</tr>
<tr>
<td>Traffic rate (packets/s)</td>
<td>5</td>
</tr>
<tr>
<td>Initial energy (joule)</td>
<td>20-50</td>
</tr>
<tr>
<td>Mobile connection</td>
<td>5-25</td>
</tr>
<tr>
<td>Mac type</td>
<td>Mac/802.11</td>
</tr>
<tr>
<td>Interface Queue Type</td>
<td>Queue/DropTail/PriQueue</td>
</tr>
<tr>
<td>Maximum speed of nodes</td>
<td>5 M/S</td>
</tr>
</tbody>
</table>
```

```
Number of connection
```

![Figure 4. Normalized control overhead vs number of connection.](image-url)
Figure 5 presents the number of packets received on the number of packets sent. As it can be seen the PDR 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 shows the energy consumption vs number of connection. The energy consumption increases respectively with the increase of the number of connection in all protocols. However, EE-AODV and EQ-AODV perform better than AODV with more 15 connections. This is because they tend 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.

Figure 7 depicts the average end-to-end delay. Protocols have higher end-to-end delay with high number of connections. Mostly because the dead of intermediate nodes increase the delay to reach the destination. But EE-AODV reduces this problem and still perform better than AODV and EQ-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 and EQ-AODV.

5. Conclusions

In this paper, we have proposed an optimized routing protocol which is an enhancement of the basic AODV routing protocol. The energy efficiency and the lifetime of the network are the main purpose in our approach. Since, in the reactive protocols as AODV the breakage of the route at time of data transmission is very expensive. As well as, the cost of the route discovery procedure is very high in terms of the number of control packets, and also in terms of energy. So, in our enhanced protocol we introduce the energy among the criteria of selection during the phase of route discovery. The route created between any pair of nodes consists only of nodes whose energy level is higher than a threshold. 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, PDR, energy-efficiency and the number of dead nodes provides better lifetime compared with AODV and EQ-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.

Reference

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