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# An Energy-Efficient Routing Protocol in Mobile Ad-hoc Networks

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## ABSTRACT

In recent time, with the fast development of the mobile system, Mobile Ad-hoc Networks (MANETs) have been fucus studied and applied in many areas such as rescue, military, medical applications and smart cities. Due to the characteristics of MANETs, routing protocols must be designed to be flexible, energy-efficient and highly performance achievable. Increasing network lifetime by reducing energy consumption level is a major method in the design of saving energy routing protocols in MANETs. In this study, we propose an improved routing protocol from AODV with a new cost function, applied to MANETs. The simulation results show, our proposed protocol saves energy consumption, increases network life, packet delivery rates, and improves performance over AODV.

**Key words:** Energy-Efficient, AODV, MANET.

## 1. INTRODUCTION

Energy saving is of particular interest and is the mandatory requirement of most mobile networks [**1**]. This problem requires a significant impact on the design of new generation wireless communications systems, as well as the need to improve existing systems [**2**]. In the 1970s, Mobile Ad-hoc Networks (MANETs) was first proposed. It is a type of wireless network to exchange data within the network very advantage. Although limited in ability and capacity, MANET has proven in communicating with flexible infrastructure. It promises an important contribution to the future of the Internet [**3**].

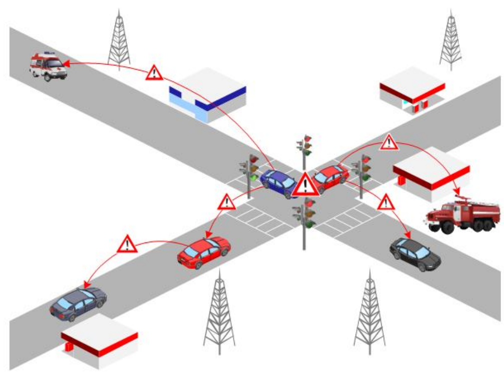

**Figure 1:** MANETs applied in smart traffic

The next generation (5G) of mobile networks is shaping up and is expected to become the main communication technology of the Internet in the future. In [**2**], different from previous generations, 5G will be the unified technology system, strongly, oriented to the ability to increase data transfer speed, reduce latency, energy-efficient. Besides that, MANET has also reached unprecedented levels of flexibility and intelligence to integrate into many areas of human life such as medical, rescue or smart city. **Figure 1** is a MANET application in the field of intelligent traffic. Research in technology is inherited and developed. Several research results on the MANET can be extended to 5G networks [**4-5**].

In this study, we study the routing protocols to save energy and improve MANET performance. It should be emphasized that the level of power consumption, network lifetime and packet delivery capabilities are the main characteristics that reflect the performance of the network [**6**].

In the MANET, because network nodes must work together to transmit packets, the routing protocol has an especially important role in improving network performance [**7-8**]. In the next section, we set up a new routing protocol, called EERP (Energy-Efficient Routing Protocol), based on the extension of known routing protocols for the MANET. Our main idea is to integrate two parameters: Hops number and remaining battery capacity of the node to select reliable routing information.

The structure of this paper is presented as follows. In the next section, we present related works. The proposed routing protocol is presented in Section 3. Section 4 presents simulation results and performance of the proposed protocol. Some conclusions are given in Section 5.

## 2. RELATED WORK

In recent time, the field of energy efficiency in MANET has been focus studied and achieved some positive results, as follows:

In [**9**], J. S. Lee, *et al.* (2019) proposed a new scheduling algorithm aim saving energy for communication between unmanned aerial vehicles (UAV) in the tactical mobile ad-hoc network (tactical MANET), unmanned vehicles are deployed for surveillance and reconnaissance. Simulation results show that the proposed algorithm is more saving energy and quality of service compared with traditional routing protocols.

In [**10**], A. Taha and *et al.* (2017) proposed a new multipath routing protocol aim saving energy for MANET, called FF-AOMDV (AOMDV with the fitness function). The work focus combines the fitness function technique into ad hoc on-demand multipath distance vector routing protocol to optimize the energy-efficient in MANET. This protocol uses the fitness function to select the optimal route from the source mobile network node to the destination mobile network node. As a result, energy consumption in the whole system will be decreased. Simulation results show that the proposed routing protocol (FF-AOMDV) improves network lifetime, time delay, and other performance metrics compared with other multipath routing protocols

In [**11**], D. O. Akande, *et al.* (2019) proposed a new cooperative MAC routing protocol aim to optimize the energy-efficient and longer network lifetime, called Network Lifetime Extension-Aware Cooperative Medium Access Control (LEA-CMAC) routing protocol for MANET. The focus of the LEA-CMAC protocol proposal a cooperative transmission to achieve a multi-objective target orientation. Simulation results show that this proposed routing protocol improves in terms of time delay, saving energy, longer network lifetime for MANET.

In [**12**], J. Li, *et al.* (2017) proposed a new routing solution based on dynamic Cloudlet-assisted aim saving energy for MANET. Due to mobile network devices frequently leave or join the overlay of MANETs, the routes between network nodes and Cloudlet will be usually disconnected lead to packets will be re-transmission as well as the searching and routing services will usually be must re-established. As a result, the system will be a huge consumption energy for unnecessary operations. In order to solve these issues, this work proposes a cooperative solution include three-step:

(1) Each mobile network node storage a temporary network map, called DCRM map to save information related to services and routes performed.

(2) Cloudlets can be considered as a small network map.

(3) Rely upon this map; each mobile network nodes can fast access to services or routes in this map.

Simulation results show that this solution saving time and energy whole system. In addition to the above solutions, in reference [**13**], V. K. Quy, *et al.* (2018) proposed saving energy and high-performance routing protocol very close to our research direction, called AERP. The focus of this study proposes a method to select the route with the more rich remaining energy nodes. Simulation results show that AERP routing protocol improves network lifetime and other performance metrics compared with other traditional routing protocols for density MANETs environment in 5G.

## 3. PROPOSED ROUTING PROTOCOL

The main goal of our routing protocol is to saving energy and increase the network lifetime of MANET. In this work, we define the network lifetime of MANET is the time period from when the network start activated until one of the first nodes out of energy. A visual way, the routing cost function necessary include parameters related to the energy of the node when the calculation and route selection.

### 3.1 Routing Metrics

We are focused in identifying the parameters that affect the lifetime of the MANET network. The visual way, to select a set of parameters suitable for energy-efficient routing, first, consider the main energy consumption causes. The energy of a mobile node is consumed by two main activities, include:

(1) Each mobile network node consumes a certain amount of power when each packet is transmitted or received.

(2) Overhearing from the neighbour nodes: Due to the nature of radio waves, when a node transmits information, it sends broadcasts to all nodes in the wireless environment.

Our routing protocol proposes two main parameters to calculate the metric of a route, as follows:

- *Remaining battery capacity*: The selected route directed to the more power nodes;
- *Hops number*: Choosing the route with the shortest hops number.

To balance between two parameters: The total remaining battery capacity of the entire route and the node with the lowest energy level in the route with the goal of limiting the use of routes containing the mobile node with the remaining battery capacity low. We propose the routing cost function to select the fit route in the MANET, as follows:

$$\text{EERP} = \sum_{i=1}^{P}\left(1 - \frac{E_i}{2E_{\max}}\right) + \left(1 - \min_{1 \le j \le P}\left(\frac{E_j}{2E_{\max}}\right)\right) \quad (1)$$

Where:
$E_i$, is remaining energy capacity of node *i*;
$E_{max}$, is the initial maximum energy of each node;
*P*, is the hops number of the route from the source node to the destination node.

There are two ways to explain parameters in routing cost function. The first, we can see the balance between the total energy of the route and the node with the lowest remaining battery capacity in the route. The second shows the relationship between the most influential node and the entire node in the route. Put parameter the lowest remaining battery capacity into the cost function can be seen as an attempt to balance these two problems. Specific examples of how to calculate EERP values with different values are shown in **Table 1** and **Figure 2**.

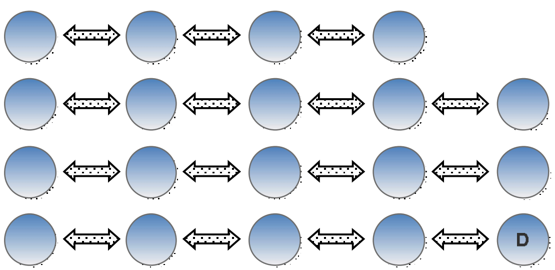


**Figure 2:** An Illustration of the candidate route

**Table 1:** The method to calculate EERP cost

| Route | P | Average Energy | $E_{min}$ | EERP |
|---|---|---|---|---|
| 1 | 3 | 0.4 | 0.2 | 2.7 |
| 2 | 4 | 2.1 | 0.5 | 1.7 |
| 3 | 4 | 2.2 | 0.6 | 1.6 |
| 4 | 4 | 2.2 | 0.4 | 1.7 |

Assume, there exist four routes between a pair of source nodes (S) and the destination node (D); each node has the remaining battery capacity, as shown in **Figure 2**. With the information about the cost of the route obtained, using the routing cost function in Equation (1), the EERP routing protocol will select route 3 with cost (EERP = 1.6), as shown in **Table 1**.

### 3.2 Modified the RREQ packet structure

The AODV protocol (Ad-hoc On-demand Distance Vector) [**14**] uses RREQ (Router REQuest) and RREP (Router REPly) packets to identify the route from the source node to the destination node.

```
 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|   Reserved          |   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            RREQ ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Residual Energy Field                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination IP Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP Address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

**Figure 3:** The header of the RREQ is modified

Based on the received routing information, the source node will select the route with the smallest hop number to transmit data. According to our propose, in the process of calculating the routing cost, the node must account the total remaining battery capacity of the entire route and the remaining battery capacity lowest in the route. An effective way is to insert this information into the header of the RREQ packet. This technique has been proposed in many recent studies [**15-20**], which has the advantage of not significantly increasing the packet size and affecting the overall performance of the entire network. We extend the RREQ packet, as shown in Figure 3.

## 4. SIMULATION RESULTS AND ANALYSIS

In this section, we set up a simulation on the NS2 software to evaluate the performance of the MANET according to the criteria presented in subsection 4.1. The protocols tested are AODV and our proposed protocol in Section 3, called EERP.

### 4.1 Performance Evaluation Criteria

We consider the performance of the protocol based on the following criteria:

*Packet Delivery Ratio (PDR)*: Defined as the percentage of total packets received per the total packets sent.

*Network Lifetime*: Defined as the period from the network operates until one of the network nodes is out of energy, or more exactly, the energy level decreases to the threshold. Unit is seconds (s).

*Average Residual Energy of Node*: Defined as the total energy in the whole system / total node at that time. Unit is Joules (J).

### 4.2 Setup Simulation

Our simulation system consists of 500 mobile nodes, arranged randomly in an area of 2000m×2000m. We use the IEEE 802.11b standard at 11Mbit/s and the UDP traffic type. Simulations were made in 350s. The number of end-to-end connections measured is: 5, 10, 15, 20, 25, 30, 35 and 40. Simulation parameters are listed in **Table 2**.

**Table 2:** Simulation Parameters

| Parameter | Value |
|---|---|
| Simulation Area | 2000 m × 2000 m |
| Number Nodes | 500 |
| Traffic Type | CBR |
| Size of Packets | 512 byte |
| Time Simulation | 350 s |
| Mobile Node Speed | 2 m/s |
| Initialization Energy of the Nodes | 7 J |
| Transmission Power | 1 W |
| Receive Power | 0,02 W |
| Overhearing Power | 0,01 W |

### 4.3 Simulation Results.

**Figure 4** shows simulation results based on the criterion: Average residual energy of the node with the case has 30 end-to-end connections.

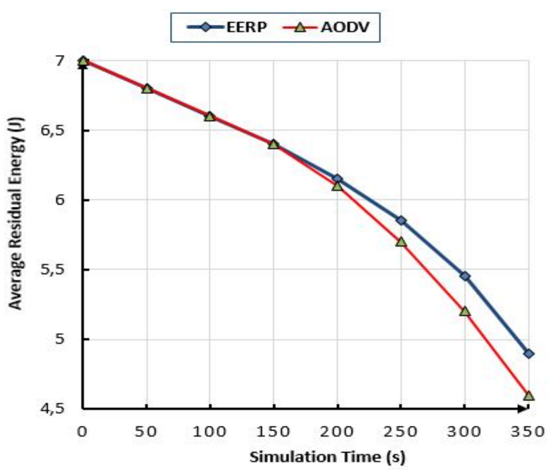


**Figure 4:** Average Residual Energy

The results show that the average residual energy of the node in the EERP protocol is always higher than the AODV protocol and increases at the end of the simulation. This is perfectly consistent with theoretical calculations. Due improved, the EERP is not only based on the hops number as AODV, but also integrate the energy of the node is in the cost function. As a result, higher-power total routes will be selected, and the network lifetime of nodes is longer. Therefore, the performance of the network is significantly improved at the end of the simulation and will be analyzed in the next subsection.

Initially, when nodes are full of energy, the route selection mechanism of AODV and EERP are basically the same. When the node has about 20% of the original power level, the EERP can switch to another route, unless it is the only node to reach the destination. Simulation with cases different end-to-end connections number have similar results. Due, in this study, we present only a simulation result graph for the case of 30 end-to-end connections as **Figure 4**.

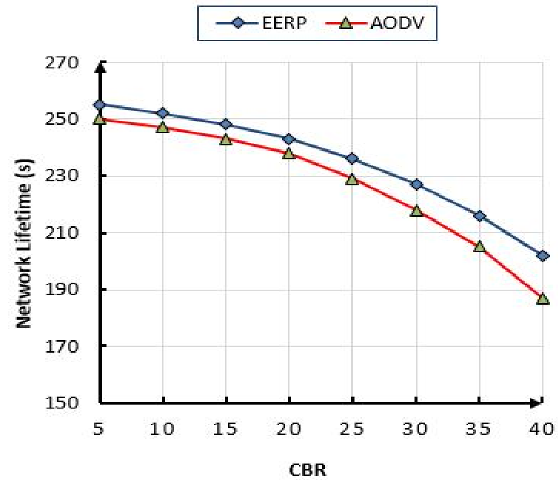


**Figure 5:** Network Lifetime

**Figure 5** show the performance of the network based on the criteria: network lifetime and Figure 5c, show network performance based on criteria: average packet delivery rate. Observing the results, we find that the network lifetime and average packet delivery rates of both protocols are decreasing as the number of end-to-end connections increases. However, the EERP protocol always shows better performance than the AODV protocol in both criteria. Because, as the number of connections increases, network traffic will increase, which causes congestion. This is the main reason that the average packet delivery rate and the lifetime of both protocols are downtrend. In Figure 5, the lifetime of EERP is always higher than AODV. Due, EERP not only chooses route has the smallest hop count, but also it is certainly the most energy-efficient route. This mechanism always helps EERP increase the lifetime of the network higher than the AODV protocol.

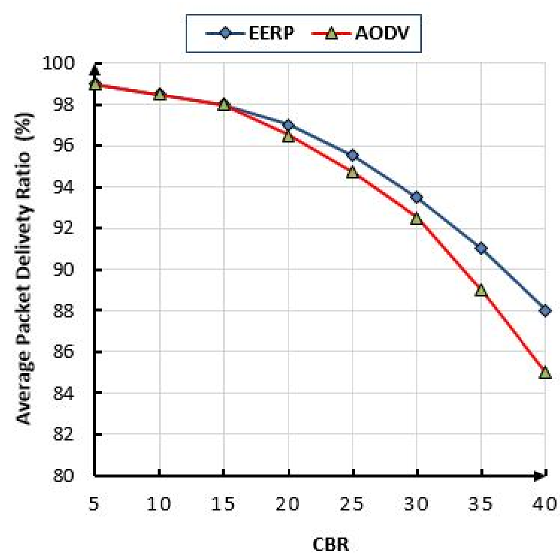


**Figure 6:** Average Packet Delivery Ratio

**Figure 6**, the average packet delivery rate for EERP is always higher than for AODV and the increase as the number of connections increases. Because, as the number of connections increases the power consumption of the nodes increases rapidly. The AODV protocol uses the shortest route mechanism, so the large load nodes are rapidly exhausted. This leads to congestion. As a result, packet delivery rates decreased. At the same time, the EERP limited the number of nodes out of energy. Therefore, the network structure is stable than AODV. As a result, packet delivery rates of EERP is higher.

## 5. CONCLUSION AND FUTURE RESEARCH

In this study, we have proposed an on-demand routing protocol, improved from AODV for the MANET, called EERP. The EERP protocol uses the routing cost function to the trade-off between the hops number and residual battery capacity for the purpose of restricting the use of the route containing the node, which the remaining battery capacity is too low. The proposed routing protocol can restrict the nodes out of energy, therefore, improve network performance. Simulation results proved the EERP protocol improve the average resident battery remaining of the node, network lifetime as well as average packet delivery ratio better than the AODV protocol. However, routing information security has not yet been considered. In the future, we will focus on proposed secure routing protocols in the next-generation MANET.

## AUTHOR CONTRIBUTIONS

We have conducted the research, analyzed the data, and performed simulations together. All authors had approved the final version. Corresponding Author is Quy Vu Khanh.

## ACKNOWLEDGEMENT

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