An Energy-Efficient Routing Protocol for MANET in Internet of Things Environment

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Abstract—MANET-IoT networks are currently being focus developed and expected to become popular in next-generation mobile networks due to their simplicity and efficiency in solving real problems in a wide range of areas such as smart agriculture, smart health care, intelligent traffic, military, entertainment, and smart cities. Because of the nature of mobile network nodes, saving energy for MANET is always a complicated problem. In this paper, we proposed a saving energy routing protocol that uses an integrated routing metric from hops number and remaining energy metrics for decision-making to selects a fit route. Besides, we evaluate the performance of the proposed protocol on NS2 simulation software. Simulation results demonstrated the proposed protocol improves the network lifetime and network performance parameters compared to traditional protocols.

Keywords—Saving Energy, Routing Protocol, EED, MANET-IoT

1 Introduction

The advent of the 5G network marked a breakthrough development in science and technology as well as forming an era of the Internet of Things (IoT). 5G allows extremely large device numbers to connect to the Internet with extremely high bandwidth and extremely low latency [1]. Moreover, according to the Cisco forecast, by 2023, there will be over 13 billion mobile devices connected to the Internet. These devices will be equipped with IoT modules to establish connections directly with each other without relying on base stations (the principle of the formation of MANET-IoT networks) [2]. In reality, MANETs (Mobile Ad Hoc Networks) were shaped in the 1970s. It is a set of mobile radio devices capable of self-configuration parameters to connect and transmit data in-network without relying on pre-existing backbone systems [3]. Although limited in capabilities, MANETs have been demonstrated superior ability and promising significant contributions to the future of the Internet [4-5].

In recent time, the solutions integrate IoT networks, and MANET have received great attention from the community of researchers with new series of emerging technologies and solutions are proposed in the fields of smart agriculture [6], intelligent transportation systems [7], intelligent cities [8-9], and retail utilities [10-12] to serve humanity. They are also known as IoT ecosystems [13-14]. These devices will consume a huge amount of electrical energy. Therefore, saving energy for MANET-IoT networks is of particular interest [15-16]. It requires the improvement of existing systems [17-18]. In MANET-IoT network, because mobile network nodes use batteries with limited energy.

Survey results show that a wireless network node consumes energy when sending or receiving packets or listening to the radio environment to serve communication requests from other nodes. Besides, when a network node is exhausted battery affects not only itself but also the ability to forward packets of the overall system [19]. Therefore, the fit routing protocol is the primary solution to enhance network performance and saving energy in MANE-IoT. Survey results also show that there are two main approaches, include (1) Minimum total energy consumption ($Power\ Control$) and (2) Maximum Network Lifetime ($Network\ Lifetime$). Accordingly, the Power Control approach determines the optimal route based on minimizing total energy consumption. In contrast, the Network Lifetime approach aims to maximize network lifetime by avoiding the use of nodes out of energy.

In this paper, we proposed a delay-based saving energy routing protocol for the MANETs. This protocol uses a combined metric from the hop number and the remaining energy metrics to select the fit route, improved from DSR, aim to enhance the network lifetime and enhance system performance. In Section 2, we present related works. Our proposed protocol is described in Section 3. Performance evaluations are presented in Section 4, and Section 5 is the Conclusion.

This study is the extended results from our research which was presented in The Book on Secure Communication for 5G and IoT Networks, in EAI/Springer Innovations in Communication and Computing series, 2021 [29].

2 Related Work

In recent years, the energy-saving research direction for MANETs based on the $Network\ Lifetime$ approach has been interested in research and achieved some positive results [20-25]. Accordingly, the specific purpose of this approach is to balance the energy of all network devices by choosing a route with energy-rich nodes rather than the shortest one. As a result, the path can longer, but packets will be routed through intermediate nodes with high remaining battery capacity. Protocols based on this approach do not provide the route with the lowest energy cost but prevent certain nodes from being overloaded, thus ensuring a longer-lasting network lifetime.

S.Hao et al., in [20] proposed a new learning automata-based energy-efficient routing algorithm for MANET. The focus of this work proposed a new node stability measurement model and defined an effective energy rate function based on learning automata theory. Simulation results showed that the proposed algorithm enhances network performance in terms of energy consumption, latency, and packet delivery ratio compared to some traditional routing protocols.

F. Al-Turjman et al., in [21] proposed a new energy-aware data delivery framework for multimedia applications in the urban-IoT network. This approach shows that the packet should be transmitted on QoS guarantee routes. Simulation results showed that the proposed framework enhances network performance in terms of energy consumption, latency, and throughput compared to the existing frameworks in other density and mobility urban-IoT scenarios.

In [22], J. S. Lee et al proposed a new TDMA scheduling-based energy-efficient routing algorithm for the tactical MANET. The focus of this work proposes a TDMA slot at the commander node and maximizes energy efficiency schemes based on the schedule. Simulation results showed that the proposed algorithm enhances system performance and energy efficiency in some tactical MANET scenarios.

In [23], D. O. Akande et al proposed a new MAC layer-based energy-efficient routing protocol for MANET. The focus of this work uses some routing metrics from the MAC layer such as transmit power, residual energy and gain to achieve a multi-objective optimizer. Simulation results showed that the proposed protocol enhances network performance and longer-lasting network lifetime compared to some traditional routing protocols in MANET scenarios.

In [24], U. Khan et al proposed a new heuristic-based energy-efficient routing protocol for flying ad-hoc networks (FANET). The focus of this work uses the ant colony optimization technique based on the energy parameters to select optimize route in FANET. Simulation results showed that the proposed protocol enhances network performance and energy consumption compared to some Ant Colony Optimization-based routing protocols in different density and mobility FANET scenarios.

In [25], A. Bhardwaj and et al. (2020) proposed the AOMDV-FFn protocol (AOMDV with FFn). The focus of research proposes a new routing algorithm based on integrating the genetic algorithm into the fitness function. Then, combining the proposed algorithms into the existing known AOMDV protocol. Simulation results showed that the proposed protocols outperform in terms of maximum residual energy and some performance metrics compared to the AODV, AOMDV, FF-AOMDV protocols.

Currently, there is still no solution or class of algorithms that can be applied to all scenarios. Each protocol has advantages and disadvantages and only suitable for a certain scenario. However, existing solutions can be combined to provide a more efficient energy routing mechanism.

3 The Proposed Routing Protocol

The routing protocols are used in the MANETs need be reflected the length of the route and the quality and stability of links. Aim to find an energy efficiency protocol; we focus on determining the routing parameters that directly affect the network lifetime, thereby proposing an energy-saving routing protocol, improved from the Dynamic Source Routing (DSR) protocol [26], it is called EED (Energy Efficient-DSR) routing protocol. According to [19], the energy of a network node is consumed by two main activities:

- Sending or receiving data packets
- Listen from neighboring nodes on the network environment.

We propose to put two main parameters into account in the route selection decision is the hop number and the remaining battery capacity of the node. Specific calculations are presented in subsections.

3.1 Protocol description

Such as the, traditional routing protocols have been proposed for MANETs. Our protocol called EED (Energy Efficient-DSR) is an on-demand protocol, improved from DSR. It operates based on the principle that when a source node has data needs transmission, it will call the RREQ procedure to determine a route to the destination node. The RREQ procedure will send broadcast router request packets (RREQs) with the header is modified as follows {*MinEnergy*, *TotalEnergy*, *DSR RREQ Header*}. Then, RREQs will reach the destination node through intermediate nodes.

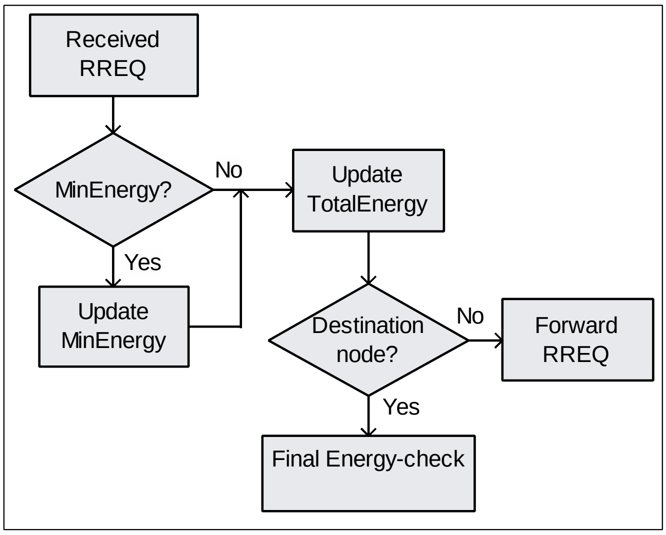

Fig. 1. Energy-check procedure

A different point compared to the traditional DSR protocol is the mechanism forwards packets at the intermediate network nodes. When an intermediate node is received the RREQ packet, it calls the *Energy-check* procedure, in Fig. 1. This schema aims to determine two parameters of the route:

- The minimum remaining energy level
- The total remaining energy

Last, the destination network node will select the suitable path based on parameters which are provided by RREQs. Then, the destination network node sends unicast the route reply packet (RREP) to the source network node. This protocol also has the route maintenance procedure through using route error packets ($RRER$). In this way, the source node will be received the route to transmission data, in Fig. 2.

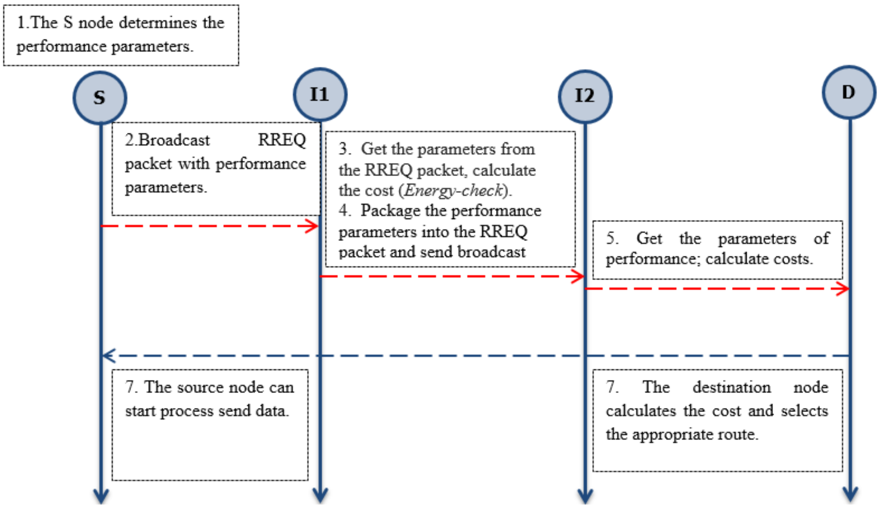

Fig. 2. Describe the method and route selection of the proposed routing protocol

3.2 Routing method

At the destination network node, thereafter it is received a set of candidate routes; this work defines two constraints as follows:

1. The hops number of a route must be within $[Hopmin, Hopmax]$. Routes that have hops numbers out of this range will be discarded.

$$Hopnumber = [Hopmin, Hopmax] \quad (1)$$

Where $Hopmin$ is the minimum hop number between the source and destination nodes. Aim to decrease the considered route numbers, this study defines:

$$Hopmax = Hopmin + 2 \quad (2)$$

2. Aim to determine the richest energy route, this study defines the cost function as follows:

$$\mathrm{EED}_{(\mathrm{P})} = \min_{1\le j\le \mathrm{P}}\left(\frac{\mathrm{E_{max}}}{\mathrm{E_t}+1}\right) + \sum_{i=1}^{\mathrm{P}}\left(\frac{\mathrm{E_{max}}/\mathrm{E_t}}{\mathrm{P}}\right) \quad (3)$$

Accordingly, the optimized route is determined by Equation 3. The route selection algorithm is summarized in Algorithm 1. Observe Equation 3. An Illustration of how to determine the EED cost with different values are presented in Table 1 and Fig. 3.

Algorithm 1: *EED Route Selection Algorithm*

```
routeset = AllRoute(S, D)
minhop = min(Shortest Routes (S, D).hopcount)
maxhop = minhop + 2 // k for the general case
validRoute = ∅
for each i in routeset do
   if minhop ≤ i.hopcount ≤ maxhop then
      validRoute ← i
   end if
end for
if |validRoute| == 1 then return validRoute
return Min(EED_Route) in validRoute
```

Assuming there exist six paths between the S (source) node and the D (destination) node. The remaining battery capacity of links in each route is shown in Fig. 3. The remaining battery capacity of the S and D nodes are equal to $5/10$, $Hopmin = 2$ and $Hopmax = 4$.

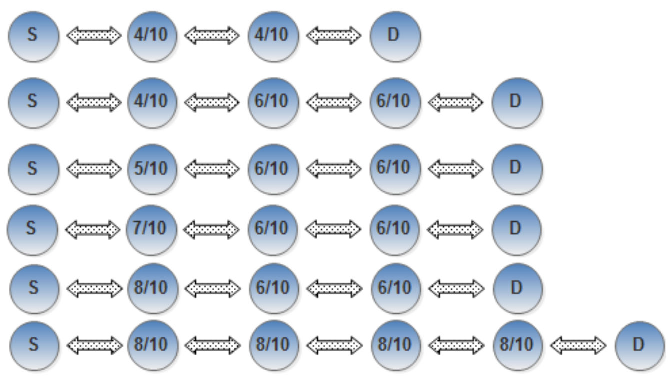

Fig. 3. An Illustration of candidate routes

With the obtained routing metrics, using the cost function (Eq. 3), the EED protocol will select route 6 with cost the $EED = 2.111$, as shown in Table 1.

Table 1. The method of calculating the route cost

Routes	Hop Number	Total Average Energy	Min Energy	EED
1	3	1.667	2.000	3.667
2	4	1.458	2.000	3.458
3	4	1.333	1.667	3.000
4	4	1.190	1.250	2.440
5	4	1.146	1.250	2.396
6	5	1.000	1.111	2.111

With our approach, a route between source-destination node pairs is always determined, ensuring a balance between two factors: the hop number and remaining energy. As a result, the EED protocol improves energy efficiency to the overall system lead to improve the network lifetime.

3.3 Modifications in the control packet

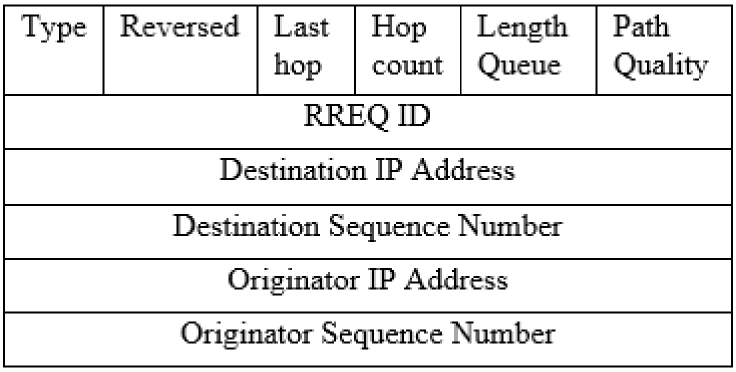

Fig. 4. The modified RREQ packet structure

In order to the EED protocol is received routing information and making-decision select a fit route based on Eq. (3). This work uses the $reserved$ field in the RREQ packet header to save the EED metric. This method has been introduced in recent studies [3, 9, 21-22]. Using the $reserved$ field in the RREQ packet header not only supports the cost storage of the route but also without consuming more energy of the system. RREQ packet header structure is modified as in Fig. 4.

4 Simulation and Result Analytical

Aim to evaluate systems performance; this work establishes simulations accordingly criteria: $remaining\ energy$, $network\ lifetime$ and $packet\ delivery\ ratio$ of protocols are DSR [26], AODV [27] and EED on the NS2 simulation software. The simulation system includes 200 nodes, distributed randomly in an area of $2.000m \times 2.000m$. The initialization energy of each node is 8 (J), the mobile speed of nodes is 1 (m/s), the size of the packets is 512 (byte). We perform two simulation scenarios to evaluate the performance criteria.

- ***Scenario 1***: Simulations are done with 25 CBR connections for a period of 350 (s) to consider the average remaining energy of the entire system.
- ***Scenario 2***: Simulations are done in 350 (s). The connection numbers are simulated: 5, 10, 15, 20, 25, 30, 35, and 40, respectively, to evaluate performance in terms of average latency and packet delivery ratio. The other parameters are in Table 2.

Table 2. The method of calculating the route cost

Routes	Hop Number	Total Average Energy	Min Energy	EED
1	3	1.667	2.000	3.667
2	4	1.458	2.000	3.458
3	4	1.333	1.667	3.000
4	4	1.190	1.250	2.440
5	4	1.146	1.250	2.396
6	**5**	**1.000**	**1.111**	**2.111**

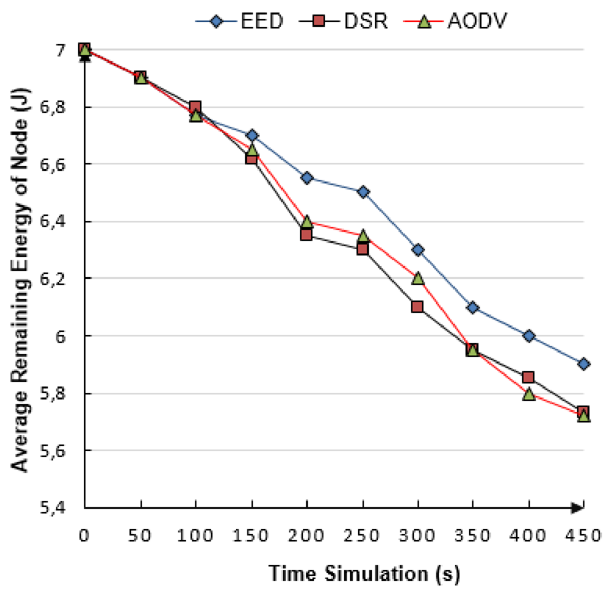

Fig. 5. Average Remaining Energy in Scenario 1

Fig. 5 shows the network performance of the three protocols based on the criteria: *Remaining Energy of Node*. Results showed that the energy consumption for the first 100 (s) of all three protocols is quite stable and equivalent. This consumption tends to increase faster towards the simulation end. However, the results of the EED protocol are always higher compared to the traditional routing protocols like AODV and DSR in the overall simulation process. It shows that thanks to combined the load distribution mechanism and find the shortest path, the EED protocol improved energy efficiency compared to the AODV and DSR protocols.

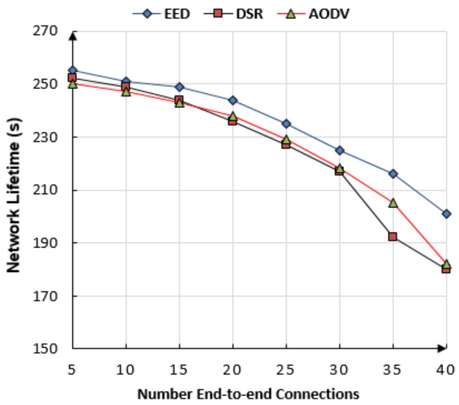

Fig. 6. Network Lifetime in Scenario 2

Fig. 6 shows the network performance based on the network lifetime criteria when applying EED, DSR, and AODV, respectively. Results showed that EED outperforms compared to other routing protocols. We can explain this as follows. Thanks to the proposed routing algorithm, packets can be load balancing to prevent nodes out of energy. By extending the lifetime of all nodes led to the network lifetime can be longer-lasting. Once again, this work can show that using the hop-count metric in the traditional routing protocols such as AODV and DSR is not enough information for routing optimizing in MANETs.

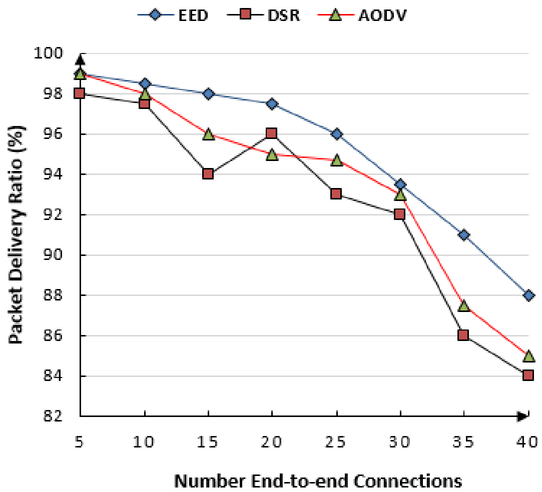

Fig. 7. Packet Delivery Ratio in Scenario 2

Fig. 7 shows the network performance based on the criteria: *packet delivery ratio*. Results demonstrated that the packet delivery ratio tends to decrease as the end-to-end connection number increases. When the traffic of the system is low, the end-to-end connection numbers are less than 15, the packet delivery ratio of the three routing protocols is of a similar value. However, when the network traffic increases, the EED protocol with the proposed routing mechanism significantly improves the average packet delivery ratio compared to the DSR and AODV protocols. Observing the results shows that the EED protocol improves the most obvious performance criteria when the end-to-end connection number is over 15 pairs.

5 Conclusion

In this study, we proposed a new energy-based routing protocol for the MANETs, called EED, using a load distribution routing mechanism with a cost function combining two parameters: the $Hop\ Number$ and the $Remaining\ Energy\ of\ Node$ to select the fit route. Simulation results showed that the proposed protocol improved energy consumption level, network lifetime, and packet delivery ratio better than traditional protocols like DSR and AODV. In the future, we will focus on research and propose suitable energy-efficient routing protocols for the IoT network.

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