A Review: Performance Improvement Routing Protocols for MANETs

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Abstract —Mobile Ad Hoc Networks (MANETs) are more and more popular and applied in a wide range of applications such as healthcare, traffic control, military, rescue, and smart cities. However, the real performance of MANETs is still far from our expectations. Hence, there exists a massive amount of works considering this problem. Due to the performance of MANETs mainly dependent on the routing protocol employed, in this paper, we review the proposed routing protocols for MANETs published on the IEEE digital library in the last decade to determine an overall purpose about research directions. Based on these results, we perform a comparison of the performance of four typical traditional routing protocols, namely AODV, DSR, OLSR, and DSDV. We first design and implement different simulations so that all necessary performance metrics can be observed and measured. Then, we give comparative analyses of the obtained numerical results. From insight experiments, we may conclude that, for light traffic and low mobility MANETs, OLSR and DSDV work well. However, for heavy traffic and high mobility MANETs, AODV and DSR are dominant. Thus, we believe that new routing protocols for MANETs must have the ability to work efficiently in both cases.

Index Terms—High-Performance, Routing Protocol, MANETs.

I. Introduction

According to Cisco Visual Networking Index Global Mobile Data Traffic Forecast, to 2022, the number of global mobile devices will increase over 1.5 times compared to 2017 with about 12.5 billion devices, and there will be 1.5 mobile devices per capita. The global mobile data traffic will increase over seven times between 2017 and 2022, reaching 77.5 exabytes per month by 2022. In particular, mobile devices will be equipped with M – to – M modules (capable of setting up machine-to-machine connections without relying on base stations), which is the principle of forming Mobile Ad-hoc Networks (MANETs) [1]. MANETs, born in the 1970s, is a set of mobile radio devices, capable of setting up configuration parameters to connect each other without relying on any base station system [2], [11]. Despite being limited in ability and capacity, MANETs have proven to be superior in communications with flexible infrastructure and are applied in many areas such as health care [3], [4], transport [5], [6], military [7], rescue and disaster recovery [8], [9], as well as promise an vital contribution to the future development of the Internet [10]. A set of rich and diverse MANETs applications and services in smart cities is introduced in Fig. 1.

Due to network architecture is highly dynamic and distributed, the performance of MANETs is generally quite low. To improve MANETs performance, routing is the main problem [11], [12]. Over the years, there have been many studies on this issue [13]-[27]. However, proposals usually only apply to a specific system or architecture. Therefore, evaluation and improvement of MANETs performance is always the topical research field.

In this work, first of all, we conducted a short survey to highlight the research trend of improving MANETs performance in recent years. Then, in Part 3, we performed the analysis of typical routing protocols proposed for MANETs. In Part 4, we compared the performance of these routing protocols with different scenarios about mobility and network traffic and Part 5 is the conclusion and direction for further research.

This paper is the result extended from our research which was presented at the conference on Fundamental and Applied Information Technology Research [2].

II. The Recent Research Trend

In order to clarify research trends of improving MANETs performance in recent years, we conducted a short survey of proposed routing protocols to improve performance for MANETs in the last decade (period 2011 - 2020) published on IEEE Xplore Digital Library database. Survey results are presented in Table I.

Survey results show that many routing protocols have been proposed over the recent ten years based on improvements from traditional protocols. About 80% of the studies compared the performance of the proposed protocol with traditional protocols such as AODV or DSR. About 90% of the studies performed simulations and performance evaluation on simulation software such as NS2 and Matlab. The performance criteria commonly used for comparison are time delay (about 88%), packet delivery ratio (about 95%), and routing load (about over 75%). The number of studies in recent years has increased. In particular, over 65% of the total works are proposed in the recent five years (period 2016 - 2020). The survey results also show that most of proposed new

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routing protocols are based on improvements from known traditional routing protocols.

The above survey results show that there are great interest and research trends in the field of improvement of MANETs performance. To resolve this issue, an important direct, we can improve a traditional routing protocol to obtain a new routing protocol. Therefore, we need to consider the performance of the traditional protocols for MANETs.

Fig. 1. An illustration of MANETs application in smart cities.

TABLE I: ROUTING PROTOCOLS ON IEEE DIGITAL LIBRARY FOR THE PERIOD OF 2011 – 2020

No.	Proposed Protocol	Year	Simulation	Compared with	Delay	PDR	Overh.
1	LBRP [13]	2011	GloMoSim	AODV, DSR, ZRP	Yes	Yes	Yes
2	CA-AOMDV[14]	2011	Matlab	AOMDV	Yes	Yes	Yes
3	EDRP [15]	2011	NS2	AODV, PGP	Yes	Yes	Yes
4	D-ODMRP [16]	2012	NS2	ODMRP	NO	Yes	Yes
5	3DLIS [17]	2013	NS-2	MDART	Yes	Yes	Yes
6	OANTGPS [18]	2013	NS2	AODV, AOMDV, DSR	Yes	Yes	No
7	PSR [19]	2014	NS-2	OLSR, DSDV, DSR	Yes	Yes	Yes
8	IAR [20]	2016	NS-3	CLWPR, PIAR, SPIAR	Yes	Yes	Yes
9	DCFP [21]	2016	Designed	NCPR, AODV	Yes	Yes	Yes
10	TLRC [22]	2016	NS2	GyTAR, STAR	Yes	Yes	No
11	iCAR-II [23]	2016	MATLAB	GPSR, GSR, GyTAR	Yes	Yes	Yes
12	3MRP [24]	2017	NS2	GPSR, VIRTUS	Yes	Yes	No
13	MoZo [25]	2017	NS2	CBDRP, Brave	Yes	Yes	Yes
14	CBLTR [26]	2017	MATLAB	CBVANET, AODV-CV	Yes	No	Yes
15	RARP [27]	2017	Designed	Traditionnal Protocols	No	Yes	No
16	CLOLSR [28]	2018	OPNET	Traditionnal Protocols	Yes	Yes	Yes
17	RDBTMA [29]	2019	NS2	EDCA, DBTMA	Yes	Yes	Yes
18	CBMLB [30]	2019	NS2	AODV, AOMDV	Yes	Yes	Yes
19	QTAR [31]	2020	QualNet	RTAR, iCar-II, GyTAR, GPSR, LAR	Yes	Yes	Yes

III. TRADITIONAL ROUTING PROTOCOLS

A. *On-demand Routing Protocols*

In the MANETs, two typical reactive routing protocols were standardized by IETF are AODV [32] and DSR [33]. On-demand routing protocols that operate on the principle that whenever the data is needed, the source node will discover and find a route to the destination node.

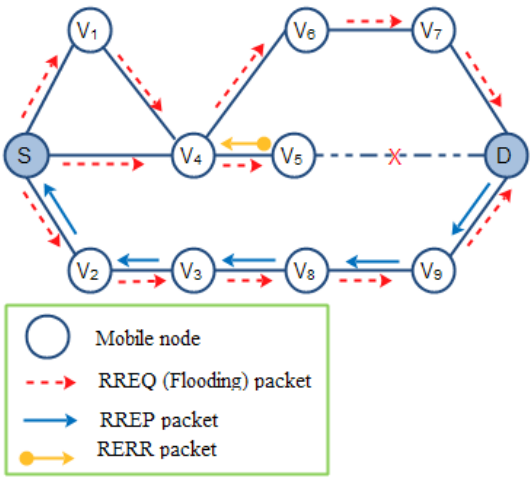

Fig. 2. The route discovery phase in the on-demand protocol.

The route discovery process begins with the broadcast send Route REQuest packets (RREQ) to find path. Then, these packets will be forwarded through intermediate nodes to reach the destination node (Fig. 2, red line).

The destination node or intermediate node (the node that knows the route to the destination) will respond by sending the identifier the Route reply packet (RREP) to the source node. When the source node receives the RREP, the path is set and data can be transmitted (Fig. 2, blue line). Besides the route discovery procedure, AODV and DSR also have route maintenance procedures using Route Error (RERR) packets (Fig. 2, yellow line). Although it is designed to fit with the characteristics of MANETs, there is a difference between AODV and DSR. AODV does not pre-build a route to transfer data from source to destination. The transmission route will be determined by each network node when the incoming data is available, based on the system status information obtained by the network node. At the same time, AODV also uses a sequence number of destinations/sources to determine the new route as well as to avoid loop routing. Meanwhile, DSR builds the route at the source node. The source node will fully determine the route from the source node to the destination node for transmission. Therefore, the structure of the RREQ and RREP packets in DSR must be further extended to contain address information of intermediate nodes. Besides, DSR maintains a temporary memory to store routes and use them until it is no longer valid.

Both AODV and DSR use efficient resources, save energy, and support the characteristics of mobile ad hoc network architectures/organizations such as self-organization, self-configuration, and mobility. However, with limited capabilities, more flexible and efficient routing protocols that are suitable for MANETs environments need to be further studied and evaluated.

B. *Proactive Routing Protocols*

Proactive routing protocols use a routing table to determine the route to all nodes in the network. The nodes are regularly updated with routing information about the network architecture and link-state to refresh the routing table. This allows the routing table to control the overall state of the links in the network. However, in networks that have highly dynamic structure, the routing table updating constantly in the network with high frequency can greatly affect the performance of the network.

1) *Optimized Link State Routing Protocol (OLSR)*

OLSR [34] is an improvement from the link-state routing protocol based on multi-hop, using three mechanisms for routing: (1) Sending Hello packets to neighbouring nodes periodically, (2) control packets broadcast on the network with MPR (Multi-Point Relay), and (3) determine the route by the shortest path first algorithm. OLSR is proposed to reduce the overload of broadcast packets by selecting a small number of nodes that act as multi-point relay nodes (MPR). Only these nodes are able to forward broadcast packets, which reduces the number of broadcast packets as well as the size of the control packets. In order to elect an MPR node, Hello packets are sent within two hops to determine neighbouring nodes. Then these nodes perform to elect MPR node in the region (Fig. 3). OLSR protocol has better performance in a dense network environment and large data traffic, however, the limitation of OLSR is to occupy a lot of network resources.

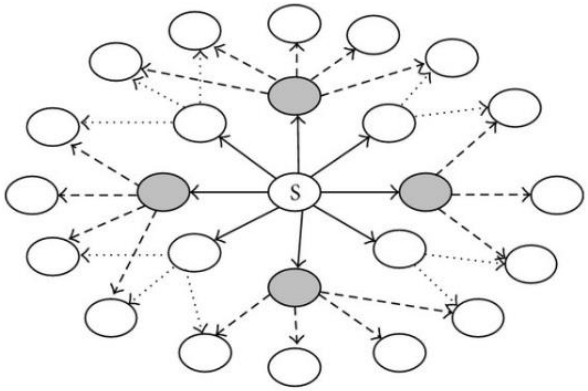

Fig. 3. The process of identifying the MPR node in the OLSR protocol.

2) *Destination sequenced distance vector*

DSDV [35] is a proactive routing protocol that uses the hops number metric to select the route. The protocol is proposed to solve the loop-back problem by adding a sequential number field to the routing table. Unlike link-state routing protocols, DSDV does not have a routing table to identify the route to all nodes in the network. Each node maintains a routing table to the destination nodes it knows and this information is exchanged and updated periodically. When selecting a route, DSDV prioritizes the use of the route with the highest sequential number, in case there are multiple routes with the same serial number, the protocol will prefer the lower-cost route. Due to the principle of periodic exchange and update of routing information, in the MANETs environment, DSDV often wastes system resources if

network architecture has little change as well as overload when the network routes exist for a long time in routing tables that are not used.

IV. Simulation Results and Evaluation

A. Performance Evaluation Criteria

In order to perform simulations that determine the performance of routing protocols in different traffic and mobility scenarios, we define the performance evaluation criteria as follows:

1) Packet Delivery Ratio: Defined as the ratio of the number of packets received by the destination node divided by the total number of packets sent from the source node. Packet delivery ratio (PDR) reflects specifically the packet number lost in the transmission and prove the effectiveness of routing protocols:

$$\boldsymbol{PDR_{avg}} = \frac{P_r}{P_s} \times 100\% \quad (1)$$

2) Time Delay: Defined as the time to transfer the packet from a source node to a node of the application layer, unit: seconds (s). The average end-to-end delay (Delay) is determined as follows:

$$\boldsymbol{Delay_{avg}} = \frac{\sum_{i=1}^{n}(t_r - t_s)}{P_r} \quad (2)$$

3) Throughput: Defined as a multiplication of the data packet numbers and the packet size in a unit of time, unit: bit/second (bps). The following formula determines the throughput:

$$\boldsymbol{Thoughput_{avg}} = \frac{P_r \times KT}{T} \quad (3)$$

4) Normalized Routing Load (NRL): Defined as the ratio of the total control packet numbers and the total data packet numbers received in a simulation. The NRL parameter shows how many control packets are needed, including route discovery and maintenance packets to successfully transmit a data packet from the source node to the destination node. The following formula determines NRL:

$$\boldsymbol{NRL_{avg}} = \frac{P_{Control}}{P_r} \times 100\% \quad (4)$$

where:
P_r is the packet number received by the destination node
P_s is the packet number sent by the source node
t_r is the time the packet is received at the destination node
t_s is the time the packet is sent at the source node
T is the time of the measurement process
KT is the size of the packet.

B. Scenarios and Simulation Parameters

To evaluate the performance of the four routing protocols analyzed in Part 3, AODV, DSR, OLSR, and DSDV, we set up a simulation system on NS2 software, version 2.34 and compared the performance of protocols with changes in the mobility speed of nodes (mobility scenario) and network traffic (traffic scenario). In these simulations, we used CBR traffic with 200 mobile nodes distributed randomly in an area of 1000m × 1000m. The transmission area of the network nodes is set to 150m. The movement speed of each node is set randomly in the range [0, V_{max}].

In the mobile scenario, we set the number of end-to-end connections to be 50 in all simulations. The movement speed of the network node was set randomly in the range [0, V_{max}], in which, V_{max} are: 5, 10, 15 and 20 (m/s) respectively, corresponding to the travel speed in the range [15]– [70] (km/h) which is the real movement speed of vehicles in urban areas. The performance evaluation of protocols with the movement mentioned above speeds also aimed at finding an appropriate communication protocol for vehicles in smart cities.

In the network traffic scenario, we set the number of end-to-end connections to be: 20, 40, 60 and 80, respectively. The maximum movement speed of the network node in all the simulations was set at the same value $V_{max} = 10$ (m/s). Detailed simulation parameters are presented in Table II.

Table II: Simulation Parameters

Parameters	Value
Simulation area	1000m ×1000m
Number of nodes	200
Time simulation	600 (s)
Type traffic	CBR
Throughput	2 (Mbit/s)
Size of Packet	512 (byte)
MAC Layer	802.11
Transport Layer	UDP
Mobility Modern	Random Way Point
Mobile Speed of Nodes	[5-20] (m/s)
Transmission Area	150 (m)

C. Mobility Scenario

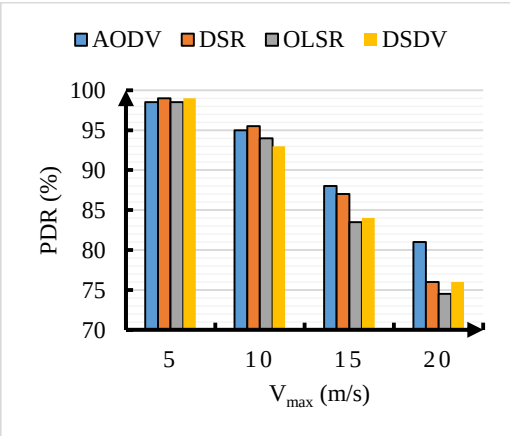

Fig. 4. Packet delivery ratio – mobility

Simulation results also show that, in the MANETs environment, the mobility characteristics of network

nodes have a significant effect on system performance. When the nodes move at high velocities, the links have a higher break probability, because the routes can be rerouted and data packets retransmitted more and more. As a result, the packet delivery ratio (Fig. 4) and the throughput (Fig. 5) will decrease rapidly while the delay (Fig. 6) and the routing load (Fig. 7) will quickly increase.

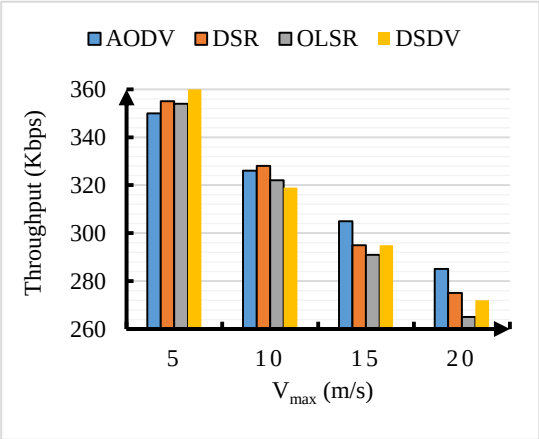

Fig. 5. Average throughput – mobility

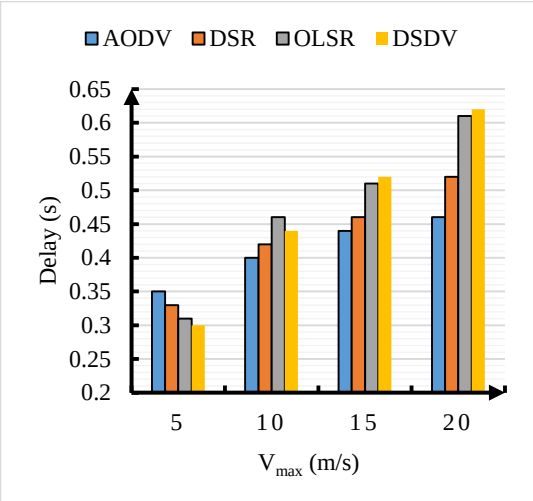

Fig. 6. Average delay – mobility

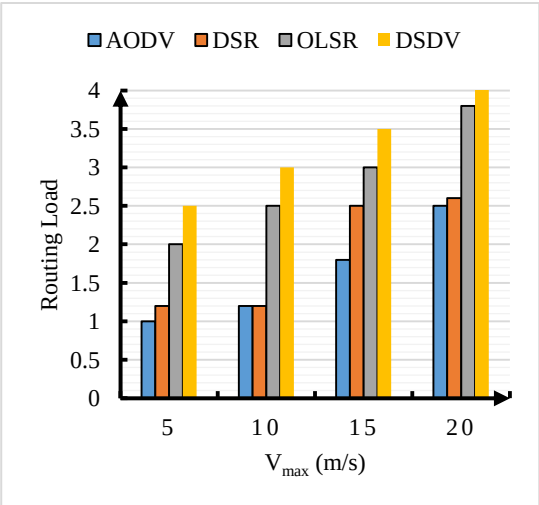

Fig. 7. Normalized routing Load - mobility

In general, under the condition, the network nodes with low movement speed, proactive routing protocols such as OLSR work quite well. However, when the movement speed of network nodes is increased make the network structure is continually changing, proactive routing protocols are limited with a higher delay, lower packet delivery ratio and the throughput are significantly reduced compared to the on-demand routing protocols. Moreover, the routing load metric of the on-demand protocols is also much lower than the proactive protocols. This reflects the energy efficiency of on-demand routing protocols.

D. *Traffic Scenario*

The simulation results show that, similar to the mobility scenario, when the network traffic increases (the number of end-to-end connections increases), the packet delivery ratio (Fig. 8) and throughput (Fig. 9) show a downtrend. In contrast, the delay (Fig. 10) and the routing load (Fig. 11) show an uptrend with all protocols.

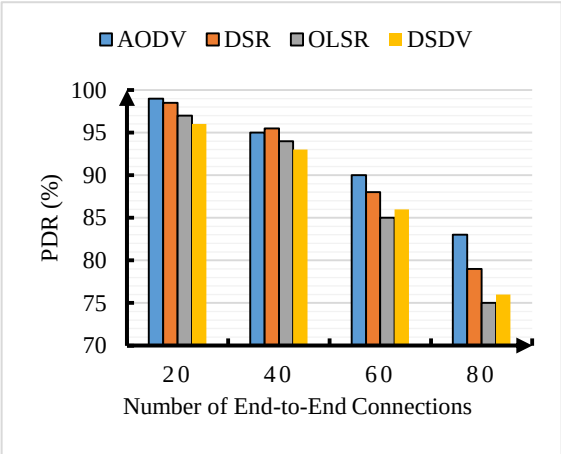

Fig. 8. Packet delivery ratio – traffic

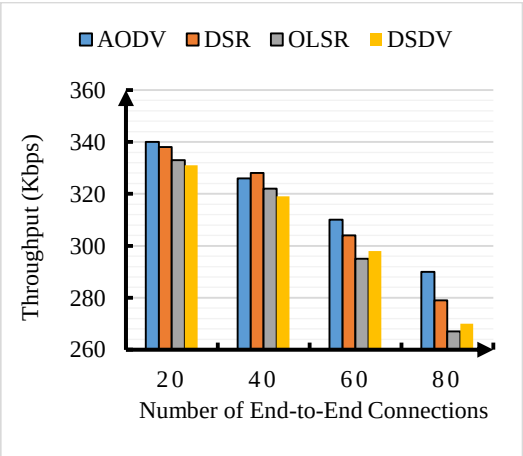

Fig. 9. Average throughput – traffic

When the network traffic is low (end-to-end number connections equals to 20), the difference between the protocols is not much, the packet delivery ratio of all protocols is very high, over 97%, while the delay of OLSR is the lowest. However, as the network traffic

increases, the packet delivery ratio and throughput of OLSR and DSDV protocols decrease, and the delay increases rapidly compared to the AODV and DSR protocols.

At the end-to-end connection number equals to 80, the performance of AODV is most significantly improved. These issues show that, when the network has high traffic, the possibility of congestion and collision occurs more frequently. This is the main cause of retransmission, thereby increasing time delay, routing load as well as reducing throughput and packet delivery ratio of the overall system.

In general, when the network has low traffic, proactive routing protocols such as OLSR work quite well. However, when the system has high traffic, on-demand routing protocols such as AODV have superior performance indicators compared to the remaining protocols. Moreover, the routing load metric of the on-demand protocols is also much lower than the proactive protocols. The issues reflect the energy-saving capability of reactive routing protocols compared to proactive routing protocols.

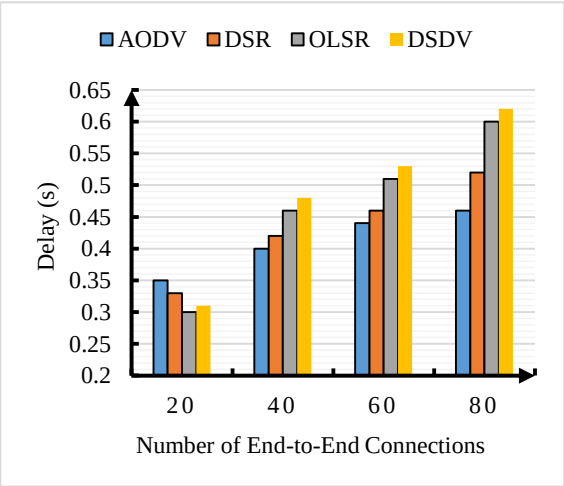

Fig. 10. Average delay - traffic

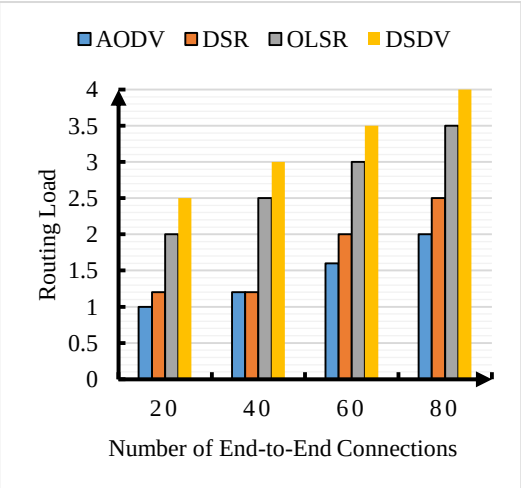

Fig. 11. Normalized routing load – traffic

V. Conclusion and Future Research

In this work, we have conducted a survey of high-performance research trends for mobile ad hoc networks in recent times to clarify methods and approaches. Then, we selected and analyzed four typical protocols proposed for MANETs, which are AODV, DSR: use on-demand routing method and OLSR, DSDV: use proactive routing method. To clarify the network performance of each protocol in different scenarios about traffic and mobility, we performed a performance evaluation of protocols with different mobility and traffic network scenarios.

Simulation results show that when the network system has low mobility and traffic, proactive routing protocols such as OLSR or DSDV work well. Otherwise, when the network system has high mobility and traffic (the movement speed of nodes is over 10 m/s), the on-demand routing protocols achieve performance criteria better than proactive routing protocols, especially AODV protocol. That shows proactive routing protocols are suitable for networks with stable structures and on-demand routing protocols are suitable for networks with high mobility.

However, with limited capabilities of the MANETs, more flexible and efficient routing protocols to be suitable for mobile ad hoc environments need to be further studied. Based on the results of this work, in the next time, we will focus on researching and proposing routing protocols, improved from AODV protocol to achieve high performance and energy saving for MANETs.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

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

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