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Mobile Ad Hoc Network Routing Protocols: Performance Evaluation and Assessment

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Abstract: Recently a great deal of attention has been paid to Mobile Ad Hoc Networks (MANETs) due to their important roles in many different applications that include, but are not limited to: civil, military, and health applications. This kind of network can reach places that difficult for human beings to reach such as disaster areas. In spite of the rapid development of MANET technologies, the routing process still poses a real challenge due to the high mobility and dynamic topology features of such networks. This paper presents an investigation into some popular MANET routing protocols. This investigation aims to evaluate the performance of MANET routing protocols using the key performance indicators: throughput, end to end delay, and data packet delivery ratio. These indicators are commonly used in such evaluations. Our investigation results showed that DSR and AODV outperform DSDV. In a high-density network (a network with a large number of nodes), AODV outperforms DSR; while, in a low-density network the DSR performs better than the AODV. So, DSR is applicable for small networks; while AODV is applicable for large networks.

Keywords: Mobile ad hoc network, Evaluation, Performance, Assessment, MANET, Routing Protocols, DSR, DSDV, AODV, Throughput, Packet Delivery Ratio, End-to-end Delay

1. INTRODUCTION

The advanced development in wireless technology has made the deployment of wireless networks possible for many important areas (e.g. the health field [1-3]).The Mobile Ad Hoc Network (MANET) is a wireless network that has no fixed infrastructure [4] and can be deployed easily regardless of time or place. Therefore, MANET networks have become applicable to many applications such as military operations, emergency deployments, search and rescue missions, and disasters [5].

MANETs are commonly described by the absence of physical infrastructure [6, 7] since each node operates as a router, in which, it has the capability to discover and define routes to other nodes. Moreover, the mobile nature of these networks leads to the dynamic changes in their topologies as their nodes are moved freely [8].

The main challenges in MANETs are: limited power, no central control authority, and the continuous need to attain a proper route due to its high mobility and the nodes that join and leave the network at any time [6].

In spite of the wide benefits of MANETs, some of their characteristics have limited their use such as the high bit error rate (BER), dynamic topology, limited bandwidth, limited capacity of batteries, and lack of physical security [9, 10].

As a matter of fact, the better performance of a MANET is heavily based on the efficiency of the routing protocol that is being used. Therefore, this paper offers a great contribution on evaluating the routing performance of some popular MANET protocols to come up with a realistic result that assists in defining which protocol can perform better in different scenarios and based on different keys of performance indicators. Also, the paper investigates the shortcomings of theses protocols. Many recent works in the evaluation of routing protocols performance were presented based on different metrics and situations. However, due to the rapid development in routing protocols, the evaluation of their performance is a continuous process.

This paper sets out to evaluate the performance of three common routing protocols in MANETs. These protocols are: On-demand Distance Vector routing (AODV), Dynamic Source Routing (DSR), and Destination-Sequenced Distance Vector routing (DSDV). Our implementation of theses protocols takes into consideration the investigation of three-performance metrics or indicators: (i) throughput, (ii) end-to-end delay, and (iii) data packet delivery ratio. The experiment is

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carried out for seven topologies of various numbers of nodes :10, 20, 30, 40, 50, 60, and 70 nodes. The seven topologies are implemented for each protocol using NS-2.35 simulator.

This section provides a brief introduction to MANET systems, while the rest of the paper is organised as follows: Section 2 sheds lights on MANET routing protocols with a focus on flat routing protocol classifications (reactive, proactive, and hybrid); a thorough investigation on the related work is presented in Section 3; subsequently, the protocols implementation parameters and details are given in Section 4. This section illustrates the simulation tool and parameters. It then gives a short introduction to the performance metrics and comprehensive analysis details of our simulation results. Eventually, the conclusion is given in Section 5 and the future work in Section 6.

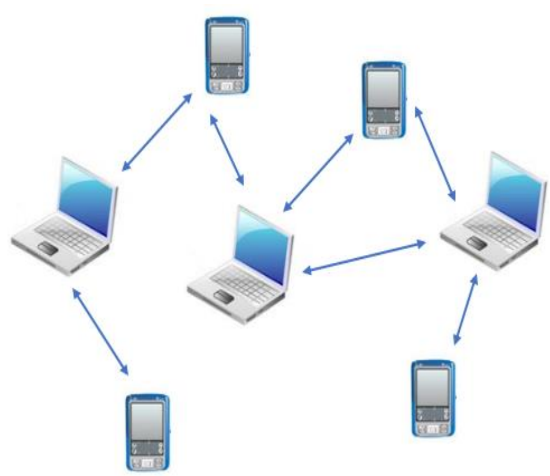

Figure 1. Moblie Ad Hoc Network.

2. MANET ROUTING PROTOCOLS

Due to MANET's mobility, its connections can change dynamically and nodes can join and leave the network at any time. Therefore, routing is a crucial issue in such types of network. It is a highly challenging task to attain a routing protocol that fully satisfies this hyper dynamic network.

Numerous protocols have been developed, each of which has attained a certain level of routing operation in MANET systems [11]. As well, many works have been presented to improve routing protocols in order to enhance the network performance [12-15]. The developing in routing protocol is a continuous process as the technology of communication is being rapidly developed and extended.

Routing protocols in MANETs are categorized into three classes: geographical routing protocols, hierarchical routing protocols and flat routing protocols [16]. In our study we are considering the flat routing protocols which are classified into three categories: reactive, proactive, and hybrid protocols [17, 18]. Figure 2 illustrates these classifications. The three subsections give a brief demonstration of MANET flat routing protocols.

A. Proactive Routing Protocols

The routing process in proactive protocols depend on predefined routing tables which consist of routes to all destinations on the network. These routing tables are periodically updated to involve any update that can happen to the network. Throughout the network, proactive protocols are periodically distributing the routing tables. However, and especially in the large network, proactive protocols can cause extra overheads as they are required to attain up-to-date routing information to satisfy the proper routing process, and thus reduce the network throughput [19]. In terms of security, this type of protocols is capable to noticing any malicious behavior immediately [17]. OLSR, TBRPF, and LANMAR are examples of proactive protocols.

B. Reactive Routing Protocols

In this type of protocols, routes are computed when required [10]. A reactive protocol floods a control message to discover a route. Compared to proactive protocols, reactive protocols cause few overheads and do not need much routing information as they calculate a route when needed. However, when the network topology is changed, reactive protocols need to introduce huge control messages during the route discovery process. Unfortunately, change in network topology regularly happen in MANET systems which means, reactive protocols diminish MANET throughput by causing more messaging overhead [19]. In addition, the initial delay (the route acquisition delay) does not suit the applications in which quality of service is required (e.g. video, audio, etc.) [10]. In terms of security, malicious behavior cannot be detected rapidly [17] compared with proactive protocols. Readers interested in more information concerning protocols security are advised to see [20-26]. DSR, AODV, TORA, and RLG are examples of popular reactive protocols.

C. Hybrid Routing Protocols

This type of protocols is aimed at taking advantage of the two aforementioned types of protocols (reactive and proactive). It attains a balance between them to benefit from their positive returns. It is a combination of the properties of both proactive and reactive to form a hybrid approach [10, 19]. An example of hybrid protocol is Zone Routing Protocol (ZRP) [27].

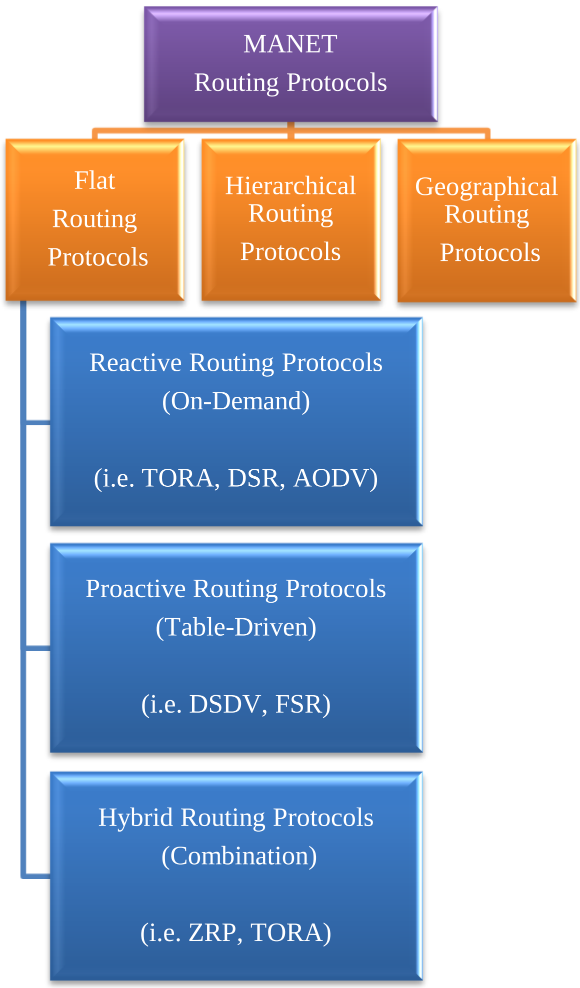

Figure 2. MANET Routing Protocols.

3. Related Work

The advanced development in network technology has given rise to solid research interest in the field of Wireless Networks. Recently many research works have been engaged on designing routing approaches to suit the real-time environment of MANET. MANET is a self-configured, dynamically changed, and multi-hop wireless network. Routing data packets via this dynamic changing network is a real challenge.

Routing protocols operate at the network layer of the TCP/IP model; many protocols are developed to secure connection between source and destination node (i.e. DSR, AODV, DSDV, TORA, OLSR etc.). The transport layer controls the transmission of data packets from the source to the intended destination based on the routes that are generated by the network layer. To control the packet transmission, the transport layer uses transmission protocols such as UDP and TCP. Suvarna et al. evaluated the performance of three protocols, one proactive protocol and two reactive protocols: DSDV, DSR, and AODV protocols respectively [28]. Their evaluation took into consideration different transport layer protocols (TCP, UDP, and SCTP). According to their experimental results, the authors have figured out that the AODV protocol outperforms the other two protocols, the DSDV and DSR. However, to support their findings, it would be better if the experiment was also conducted on more topologies with a large number of nodes (high density), since the performance of some routing protocols is subject to change due to the number of nodes (network size).

Mobility changes cause some communication link breaks in a network. These link breaks diminish the network performance. Panda et al. studied the effect of mobility changes on routing protocol performance [8]. In their experiment using the GloMoSim network simulator, two reactive routing protocols were considered: AODV and DSR. Their simulation results indicated that the AODV outperforms the DSR. However, our scenario will take different evaluation metrics and a different simulator.

Tuteja et al. compared the performance of DSDV DSR, and AODV routing protocols taking into consideration three situations: when changing in data packet size, when changing of time interval between packet sending, and when changing on mobility of nodes [6]. Their results showed that, with regards to throughput, DSDV protocol lagged behind compared to DSR and AODV protocols. DSR outperforms AODV in terms of the average of the end to end delay. In addition, the authors indicate that, the performance of all investigated protocols is decreased as mobility of nodes is increased. However, their simulation used only one topology size of 25 nodes.

Gupta and Kumar conducted a simulation experiment on DSDV, AODV and DSR to evaluate and analysis their performance [29]. They figured out that DSR is outperformed the other investigated protocols as DSR receives more packets and loses fewer compared with the DSDV and AODV. But the authors conducted their simulation based only on a topology of 100 nodes, therefore their findings would have been more agreeable if more different sizes of topology had been investigated.

Araghi et al. compared the performance of DSR, AOMDV, and AODV [17]. Their results showed that AOMDV and AODV perform better in large networks (networks with large number of nodes), while DSR outperforms them in small networks. The authors also stated that choosing suitable protocol to satisfy better routing is related to the network size and other conditions such as nodes mobility. Their experiment was conducted in topologies of 6, 10, 15, and 20 mobile nodes. Their results would be more concrete if topologies of more sizes were involved.

MANET throughput is subject to the mutual interference that is caused by the high density of radios in such dynamic networks. The authors in [30] developed a Dynamic Power-AODV protocol (DP-AODV) to improve the network throughput and then this developed protocol was evaluated by comparing its performance with the following three protocols: AOMDV, DSR, and AODV [31]. The companion results reflected that the DP-AODV outperforms the other investigated protocols but in terms of network delay the AOMDV shows better performance.

Dhakal et al. surveyed the performance of DSR and AODV. They came up with the result that, most often DSR performed better in small networks and less mobility while AODV is preferred when node density and mobility are high [32].

Basing their work on some performance metrics (i.e., end to end delay, packet delivery ratio and routing overhead), Sharma et al conducted experiments to assess the performance of two selected MANET routing protocols [33]. Their findings indicated that MAODV outperforms the AODV in case of high mobility rate while AODV perform better when there is low mobility rate. So, in this situation, choosing the best protocol is based on the mobility rate.

Recently, Rathod and Dongre have evaluated three routing protocols: AODV, Enhanced Video Streaming in MANET (EVSM), and AOMDV in terms of packet delivery ratio, routing overhead, throughput, and delay [34]. Their results show that the EVSM outperforms the other protocols in terms of packet delivery ratio, throughput and delay, but it causes more routing overheads. The AODV outperforms the others in terms of routing overheads by causing the least amount of overheads compared with the other protocols. However, more routing overheads should result in more delays and affect the throughput and packet delivery ratio.

Based on various simulation setups, Bai et al. presented a performance evaluation of some proactive and reactive routing protocols [35]. The performance is measured by evaluating different metrics such as the throughput, end-to-end delay and routing overhead. They also justified their simulation results. However, their simulation was only based on three topologies of 5, 10, and 30 nodes. It would be better if this range was extended to consider topologies of a greater number of nodes which would reflect reliable and agreeable results.

Readers interested in more works in MANET routing protocols analysis and evaluation are referred to [36-42].

4. SIMULATION RESULTS AND ANALYSIS

A. Simulation Tool

Numerous simulation tools are used to implement MANET systems, such as OMneT++, Network Simulator -2 (NS-2), and GloMoSim. Our experiments in this paper are implemented using the NS-2.35 simulator. These experiments concern the evaluation of MANET routing protocols performance. NS-2 is one of the most popular network simulators which is written in C++ and OTcl languages [29]. NS-2.35 is a particular version that is used in implementing our experiment.

B. Simulation Parameters

The simulation is carried out for seven topologies of various numbers of node :10, 20, 30, 40, 50, 60, and 70 nodes. The seven topologies are implemented for each one of the protocols under investigation: DSR, AODV, and DSDV. The simulation is done using NS-2.35 simulator and based on the simulation parameters illustrated in Table 1. The wide range of topologies with different sizes aims to attain reasonable and reliable results.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Operating System	Ubuntu 14.04
Simulator	NS 2.35
Protocol	AODV, DSR, , and DSDV
Number of mobile nodes	10, 20, 30, 40, 50,60, and 70
Simulation time	150 sec
Traffic source	CBR
Topology dimention	500 x 400
Antenna type	Omini directional
MAC type	Mac/802_11

C. Performance Metrics

- Throughput: this commonly indicates the ratio of the received data to the time it takes till the recipient gets the last packet [43]. In other words, it can be defined as a measure of how fast the data is sent from its source to its intended destination without loss [44]. It is measured in Kbps, Mbps, or Gbps [29]. A better performance is indicated by a higher value of throughput.
- Packet Delivery Ratio: this refers to the ratio of the received to the sent data packets. It reflects data packets delivery level (received packets/sent packets). A higher value denotes better performance
- End-to-end delay: this refers to the average time a data packet takes to arrive at its destination. End-to-end delay also encompasses delay, MAC retransmission delays, propagation, etc. [43]. A

lower value of end-to-end delay reflects better performance.

D. Simulation Results

A practice deployment was done using the NS-2.35 simulator for 21 different topologies, seven topologies for each protocol. Accordingly, the concerned output files were generated; trace files (.tr files) and 'nam' files. As an example, Figure 3 shows the execution of a nam file of a topology of 10 nodes. The trace files (.tr files) for all topologies were read and analyzed.

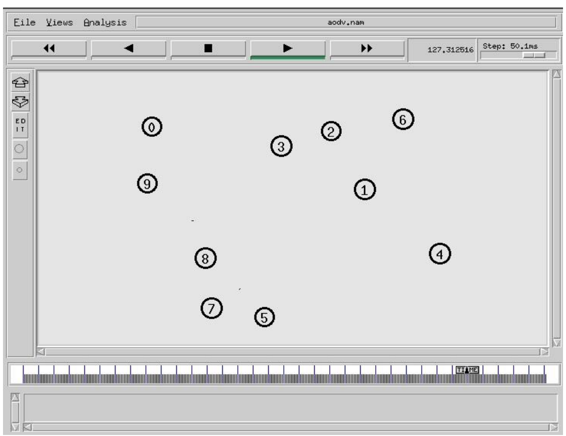

Figure 3. Simulation of a Topology of 10 Nodes.

Based on each topology, the implementation results are illustrated below:

1) Topology of 10 nodes:

In terms of throughput, Figure 4 shows that DSR performs better followed by AODV whereas, in terms of end-to-end delay, DSDV performs better as is clearly seen in Figure 5. With regards to data packet delivery ratio, again DSR performs better and then DSDV, whereas AODV lags behind as shown in Figure 6.

2) Topology of 20 nodes:

In terms of throughput, Figure 4 indicates that DSR achieves higher throughput, followed by AODV whereas DSDV remains at the bottom. With regards to the end-to-end delay, DSDV is still performing well and DSR comes next as shown in Figure 5. With regards to the packet delivery ratio, DSR is still outperforming the other protocols, and then DSDV comes next. Some enhancement in AODV is clearly noticed as seen in Figure 6.

3) Topology of 30 nodes:

In terms of throughput, and as shown in Figure 4, DSR outperforms the other protocols. While in terms of the end-to-end delay, DSDV is still performing well, and DSR comes next as shown in Figure 5. With regards to packet delivery ratio, DSR performs better followed by DSDV as seen in Figure 6.

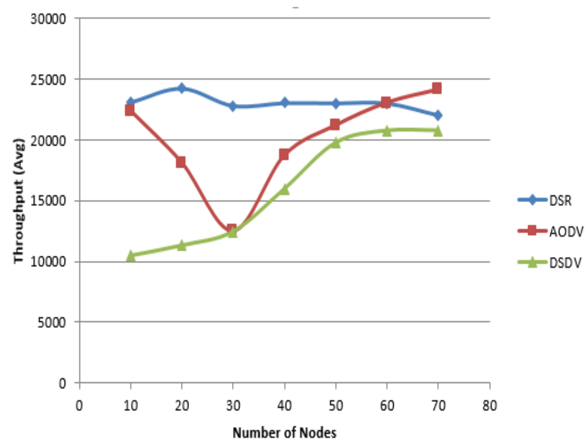

Figure 4. Throughput of DSR, AODV, and DSDV (Seven Topologies of 10, 20, 30, 40, 50, 60 and 70 Nodes).

4) Topology of 40 nodes:

In terms of throughput, and as shown in Figure 4, DSR still outperformed the other protocols, while a notable enhancement in AODV and DSDV performance is clearly shown. With regards to the end-to-end delay, and as seen in Figure 5, DSDV is still performing well, and DSR comes next. While concerning the packet delivery ratio, DSR still performs better followed by DSDV and threr is a notable enhancement in AODV performance as shown in Figure 6.

5) Topology of 50 nodes:

In terms of throughput, and as seen in Figure 4, a slight difference in the protocols performance is clearly shown. However, DSR is still dominant. With regards toend-to-end delay, both DSDV and DSR are performing well, while some enhancement in AODV is notable in Figure 5. On the subject of packet delivery ratio, the protocols are closed to each other, but DSR still performs better as seen in Figure 6.

6) Topology of 60 nodes:

In terms of throughput, and as seen in Figure 4, DSR still performs better followed by AODV. The rapid enhancement of AODV performance is clearly noticed when the number of nodes is increased. With regards to end-to-end delay, still DSDV and DSR are performing well, while an enhancement in AODV is notable in Figure 5. On the subject of packet delivery ratio, the DSR is on the top followed very closely by AODV. Also, the enhancement in AODV is very notable when the number of nodes is increased as seen in Figure 6.

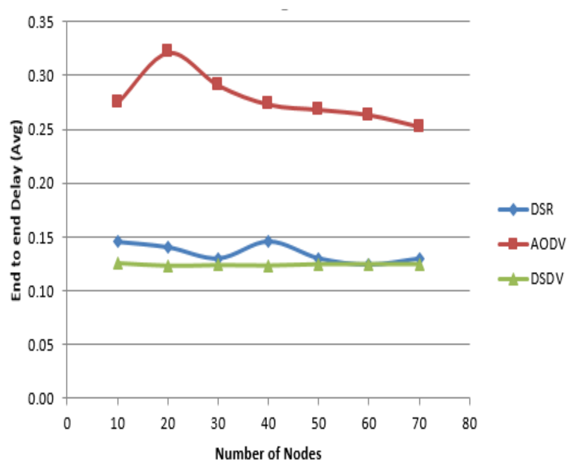

Figure 5. End-to-end Delay Avg for DSR, AODV, and DSDV (Seven Topologies of 10, 20, 30,40, 50, 60 and 70 Nodes)

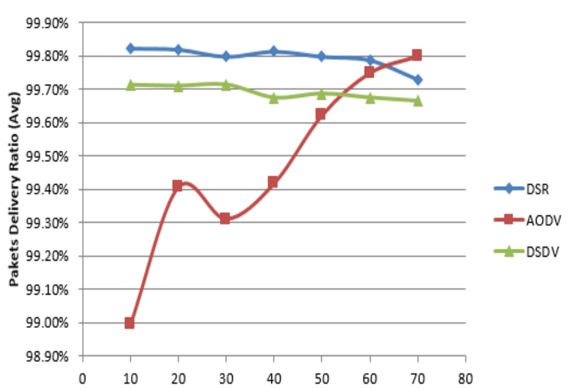

Figure 6. Packet Delivery Ratio of DSR, AODV, and DSDV (Seven Topologies of 10, 20, 30, 40, 50, 60 and 70 Nodes).

7) Topology of 70 nodes:

In terms of throughput, after the rapid enhancement in AODV, AODV deserves the better performance followed by the DSR. The decrease in DSR performance is clearly noticed as the number of nodes is increased as seen in Figure 4. While, on the subject of end-to-end delay, still DSDV and DSR are performing well, while the enhancement in AODV is still continued as the number of nodes is increased as shown in Figure 5. In terms of packet delivery ratio, AODV is dominant followed by DSR, as seen in Figure 6.

5. CONCLUSION

MANET is a dynamic network that does not require the support of any fixed infrastructure. The hosts (nodes) in MANET are self-configurable and movable. Each node can serve as a router to deliver data to its destination.

Due to MANET's mobility, its connections change dynamically and nodes join and leave the network at any time. Therefore, routing is a crucial issue in such types of network. It is a highly challenging task to attain a routing protocol that fully satisfies this hyper dynamic network.

Although many routing protocols have been developed to suit the requirements of MANET systems, further enhancement is still required to fully satisfy this hyper-mobile and infrastructure-less network. The major challenges when designing and developing MANET routing protocols are power constraints, bandwidth constraints, mobility of nodes and unstable channel states.

In this paper, simulations are carried out to compare and analyze routing protocols based on various performance indicators such as throughput, end-to-end delay, and data packet delivery ratio. The investigated routing protocols are DSR, AODV, and DSDV which represent two reactive protocols and one proactive protocol. This selection represents the most common routing protocols in MANETs. Seven topologies for each protocol were implemented. The seven topologies are varied in the number of nodes from 10 nodes which represents the lowest density to 70 nodes which represents the highest density in our scenario.

The simulation results show that, the performance is varied across the different topologies. Generally, DSR and AODV outperform DSDV. In a network with a large number of nodes, AODV outperforms the other protocols; while, in a network with a small number of nodes, the DSR performs better than the other protocols.

In terms of throughput and data packet ratio: DSR performs better in a low-density network (a network with a small number of nodes); while, AODV performs better in a high-density network.

In terms of end-to-end delay: regardless of the number of nodes DSDV performs better than the other protocols. A rapid enhancement in AODV is notable when the number of nodes is increased.

As routing is desired for an appropriate operation of MANETs, a network designer should select the suitable routing protocol for the network. In other words, a designer has to select the routing protocol which fits sufficiently the network purpose. As each protocol can work effectively in particular situation, the continuous evaluation of the protocols performance that is based on different metrics and criteria is an important issue which always helps network designers to choose the appropriate protocol for a given situation and also helps protocol designers to enhance their products.

6. FUTURE WORK

Future research would be focused on engaging more routing protocols to our performance investigation in order to come up with a rich and informative comparison result that effectively contribute to the area of developing

MANET routing protocols. In addition, we are highly interested and motivated to compare MANET secure and non-secure routing protocols in order to evaluate how much overheads that secure protocols can cause. As it commonly known that, security overheads should be very light in order to keep network performance intact.

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