تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

Evaluation of energy consumption in mobile ad hoc network routing protocols

Zayed Alarabi Khalifa **Salma Ali Alajeli Infeesh**

Lecturer at Faculty of Information Technology Computer Technology Dept. at the University of Zawia - Libya
M.zayed@zu.edu.ly S.infeesh@zu.edu.ly

ABSTRACT

Rapidly evolving wireless network technology continues to be one of the focal points in academic research. Mobile Ad hoc Networks (MANETs) consist of mobile nodes and the efficient transmission of data among these nodes is crucial for the network's operation. In this study, four of the most common routing protocols, namely AODV(Ad Hoc On-Demand Distance Vector), DSR(Dynamic Source Routing), OLSR(Optimized Link State Routing), and DSDV(Destination-Sequenced Distance Vector) were evaluated using different scenarios in the NS-2 simulation environment. As known, the lifetime of a wireless network is proportional to the battery limits of its nodes. Therefore, the choice of routing protocol for mobile ad hoc networks is critical for the network's lifetime. In this study, the energy consumption of the aforementioned routing protocols was analyzed under different conditions, and it was concluded that table-driven routing protocols, especially DSDV, demonstrated the best energy performance in various scenarios.

Keywords: AODV, DSR, OLSR, DSDV, energy consumption

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 32 العدد
Part 2 المجلد
July 2023 يوليو

المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

تقييم استهلاك الطاقة في بروتوكولات توجيه شبكة الاتصال اللاسلكية المعتمدة على الهاتف

د. زايد العربي خليفة

أ. سالمة علي العجيلي انفيش

جامعة الزاوية , كلية تقنية المعلومات – قسم تقنية الحاسوب

الملخص :

تتواصل تكنولوجيا الشبكات اللاسلكية التي تتطور بسرعة وتظل واحدة من مجالات التركيز في البحث الأكاديمي. تتألف شبكات المحمولة المتحركة (MANETs) من العقد المتحركة التي تنقل البيانات من خلال المسار الأنسب من هذه العقد, والمهم اختيار بروتوكول التوجيه المناسب لشبكات المحمولة المتحركة لضمان عمر أطول للشبكة، حيث يعتمد عمر الشبكة اللاسلكية على مدى قوة شحنات حدود بطاريات العقد التي تحتوي عليها في هذه الدراسة، تم تقييم بروتوكولات التوجيه الأكثر شيوعًا، وهي AODV وDSR وOLSR وDSDV، في بيئة محاكاة NS-2 باستخدام سيناريوهات مختلفة. تم تحليل استهلاك الطاقة لهذه البروتوكولات في ظروف مختلفة، واختتمت الدراسة أن البروتوكولات التي تعتمد على الجداول، وخاصةً DSDV، لديها أفضل أداء فيما يتعلق بالطاقة في سيناريوهات مختلفة .

الكلمات المفتاحية: AODV, DSR, OLSR, DSDV , استهلاك الطاقة.

1. Introduction

Wireless networks can be categorized into infrastructure-based and infrastructure-less (ad hoc) networks according to the architecture of the network. A Mobile Ad hoc Network (MANET) is a type of wireless network that operates without the need for any infrastructure support, such as base stations [1]. This network structure self-organizes and can be established spontaneously [2], consisting of mobile nodes, each voluntarily assuming the role of a router [3]. The mobile nodes can move in any unpredictable direction within the network [4], causing the topology of the existing network to change continuously. MANET is widely used in various fields, such as online conferences, mobile gaming, where multiple nodes collaborate, and this collaborative process is known as routing [5].

In a MANET, it is important for data to reach the destination node from the source node using the most suitable path [4]. The Internet Engineering Task Force (IETF) has standardized several different routing protocols. In this study, the energy consumption of the most commonly used routing protocols, such as Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR), and Destination Sequence Distance Vector (DSDV), has been evaluated under four different conditions: the number of nodes, the amount of load, speed, and area In today's technology world, achieving results with the least possible energy consumption is crucial. Especially in networks like MANET, which involve nodes with limited energy sources, energy management can be a life-saver under certain conditions. In emergency situations, communication is one of the most critical needs for notifying the current conditions. MANET provides a fast solution when the fixed communication network is unavailable. In such cases, the energy consumption of nodes within the network becomes a serious concern. Achieving the most efficient energy use is possible by selecting the routing protocol based on the current condition.

1.1. Routing Protocols for Mobile Ad hoc Networks (MANETs)

The fundamental principle of routing protocols is to select the most suitable path to deliver data to the destination node. Different routing protocols use different criteria to determine the best path. Depending on the requirements of the application, any routing protocol can be chosen. Based on the routing strategy, protocols

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

can be divided into two groups: table-driven, routing protocol, and on-demand, routing protocol.

In table-driven routing protocols, all possible path information between the destination and source is prepared in advance, and this information is stored in tables before it is needed. Each node in the network periodically sends routing information to other nodes, and the nodes update their tables accordingly. Protocols like Optimized Link State Routing (OLSR) and Destination Sequence Distance Vector (DSDV) fall into this routing class.

In on-demand routing protocols, route information is only created when needed. If there is no communication between two nodes, there is no need for route information between them. When a node in the network wants to send data to another node, the route discovery process starts. Due to this process, on-demand routing protocols take some time to determine the best path with the least delay. Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) are examples of protocols in this routing class.

2. Literature review

In this section, studies related to the evaluation of energy consumption for the mentioned routing protocols are presented along with their results. Energy consumption as a criterion was first used for AODV, DSR, TORA, and DSDV in the Network Simulator 2 (NS2) simulation environment [6]. This study evaluated the protocols under five different conditions: the number of nodes, area, pause time, the number of source nodes, and data size. Additionally, the same protocols were compared under different conditions, including the number of nodes, fixed speed, pause time, and random speed [7]. According to the results of both studies, the TORA routing protocol had the highest energy consumption under all conditions, while AODV, DSR, and DSDV

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

routing protocols showed similar energy consumption levels. In another study, the same protocols (AODV, DSR, TORA, and DSDV) were analyzed for energy consumption using the NS2 environment with varying the number of nodes and pause times. The results indicated that the DSDV routing protocol outperformed the others, while TORA exhibited the highest energy consumption [8]. In a different study, AODV, DSR, and DSDV protocols were compared in terms of the number of nodes and speed variables, and graphs were used to show that DSDV consumed the least energy [9].

Moreover, AODV and DSR yielded similar results in the speed change scenario. AODV was observed to have the highest consumption, while DSDV showed some slight improvements compared to OLSR in terms of efficiency [10] Finally, in an energy consumption evaluation using NS2 for AODV, DSR, and OLSR, the graphs showed that AODV and DSR protocols had similar performance under all conditions, while OLSR consistently performed the best [4].

3. performance metrics and simulation environment

In order to evaluate the energy consumption of the mentioned protocols, important variables and different scenarios used in the simulation environment are presented. Four different scenarios were used in this simulation environment.

In the area size scenario, the area where nodes are spread varies from 500×500 m² to 1000×1000 m². In other conditions, the area remains constant at 1000×1000 m². To analyze the effect of the number of nodes on energy consumption, the number of nodes in the network was increased from 10 to 60 in certain intervals. In different scenarios, this number was set to 50 nodes. In the load amount scenario, the specified load varies between 25 to 150

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

Kbit/s, while in other scenarios, the load amount remains fixed at 100 Kbit/s. Lastly, in the speed change scenario, nodes were given speeds ranging from 2 to 30 m/s. In other scenarios, the speed was set to 2 m/s. Nodes consume energy in four different states (modes): transmission mode, reception mode, idle mode, and sleep mode. If a node is sending data to another node, it is in the transmission mode; if it is receiving data from another node, it is in the reception mode. These nodes require energy for transmission and reception accordingly. If a node is neither sending nor receiving data but is ready for data transmission, it is in idle mode and consumes a certain amount of energy. The energy consumed by nodes in the idle mode is slightly less than the energy consumed in the transmission mode but close to the energy consumed in the reception mode. Additionally, if a node is neither sending nor receiving data and is not ready for data transmission, it is in sleep mode and requires a certain amount of energy. The energy consumed in this mode is negligible compared to the other modes, and in this study, nodes were designed to never be in the sleep mode.

For this reason, four different performance metrics were used to evaluate the energy consumption of the protocols in this study. These metrics are theTotal Energy Consumption of nodes in the network (in Joules), the percentage of energy consumed while in the idle mode compared to the total energy consumption (Idle Energy Consumption), the percentage of energy consumed while in the transmission mode compared to the total energy consumption (Tx Energy Consumption), and the percentage of energy consumed while in the reception mode compared to the total energy consumption (Rx Energy Consumption). The Total Energy Consumption is given in Joules, and other metrics are considered as percentages to observe the distribution of energy consumption among the modes.

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

4. RESULTS OF PERFORMANCE EVALUATION

In this section, the evaluation of the mentioned routing protocols using different scenarios and the results of these evaluations are presented. The data obtained for each scenario were determined by taking the average of 50 runs of the NS2 simulation program.

Table 1 (Parameters used in Simulation Environment)

Variables	Number of Nodes	load amount	HIZ	Area Size
Area Size	1000×1000 m^2			1000×1000 -500 ×500 m^2
MAC Protocol	IEEE 802.11a			
Channel Capacity		2 Mbit/s		
Initial Energy		1000 J		
Transfer Range		250 m		
Number of Knots	10-60 10-60 pieces	50 pieces		
HIZ	2 m/s		2-30 m/s	2 m/s
Duration of Pause	0 s			
Number of Source-Destination Pairs		10 Connections		
Load Amount	100 kilobits per second	25-150 kilobits per second	100 kilobits per second	
Transfer Mode Energy		1.4 watts		
Receiving Mode (Rx) Energy		1.0 watts		
Idle Mode Energy		0.32 watts		
Sleep Mode Energy		0 watts		
Simulation Time		300 seconds		

4.1. Number of Node Varying Scenario .

The energy consumption performance of all the mentioned routing protocols was evaluated based on the number of nodes, and the results are shown in Figure 1.

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

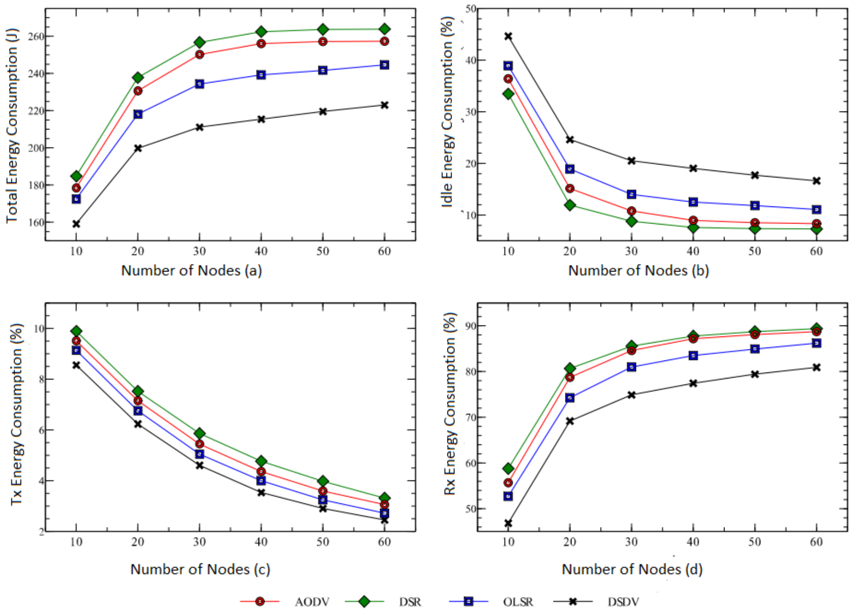

Figure1. Energy Consumption Performance of Routing Protocols in a Varying Node Scenario

Figure 1. (a) Total Energy Consumption (b) Idle Energy Consumption (c) Tx Energy Consumption (d) Rx Energy Consumption according to the Number of Nodes (Number of Node Varying)

As seen in Figure 1(a), the total energy consumption of all protocols increases steadily as the number of nodes in the network increases. Among the table-driven routing protocols, it was determined that DSDV has the lowest total energy consumption, with 223 J, in the scenario with the highest number of nodes. The table-driven protocol OLSR follows DSDV closely with 245 J. The on-demand routing protocols, AODV, and DSR fall into the same category and have very similar total energy consumption values, which are determined as 257 J and 262 J, respectively As shown in Figure 1(d), as the number of intermediate nodes

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

between the source node and the destination increases, the intermediate nodes regularly switch to the reception mode due to higher traffic density, resulting in spending more time in this mode As a consequence, they cannot stay idle for long periods. As mentioned before, DSDV and OLSR determine the most optimal route as the shortest path and transmit their data accordingly. AODV and DSR, on the other hand, use the least-delay path, which may not necessarily be the shortest. Therefore, DSDV and OLSR may spend more time in idle mode and consume more energy compared to the on-demand routing protocols.

4.2. Load Varying Scenario

The load variation graphs of the routing protocols are provided in Figure 2.

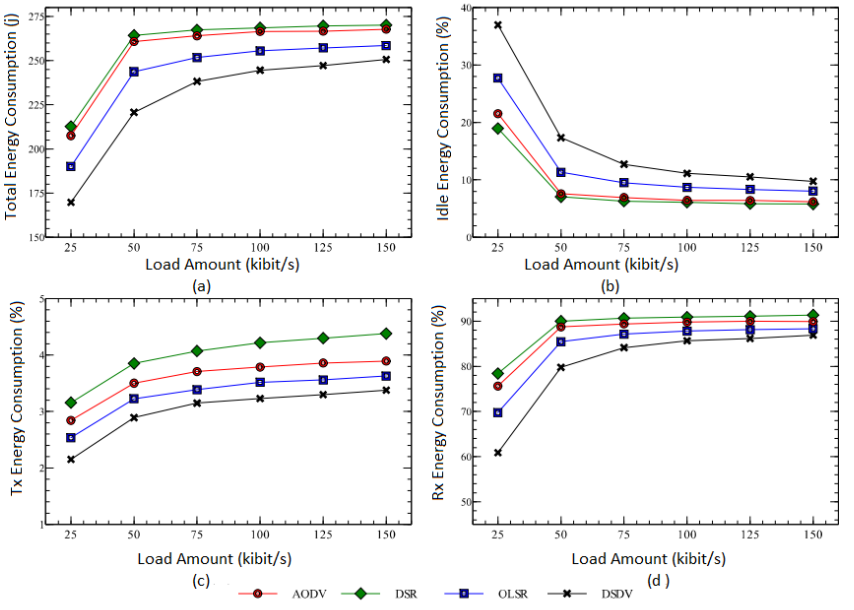

Figure2 . Energy Consumption Analysis for Different Load Amounts (Load Varying)

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

Figure 2. Total Energy Consumption (a), Idle Energy Consumption (b), Tx Energy Consumption (c), Rx Energy Consumption (d) for Different Load Amounts (Load Varying)

As shown in Figure 2(a), an increase in the load amount leads to an increase in the frequency of packet exchange between nodes, which in turn increases the total energy consumption of all protocols. In the scenario with the highest load amount of 150 Kbit/s, DSDV has the lowest total energy consumption of 251 J, followed by OLSR with 259 J, AODV with 268 J, and DSR with 270 J ,Since nodes continuously send and receive data, the Tx and Rx energy consumption graphs (Figure 2(c) and (d)) show an upward trend, resulting in less time spent in the idle mode (Figure 2(b)) by the nodes. Additionally, DSDV exhibits the lowest energy percentage in both Tx and Rx states.

4.3. Movement Speed Varying Scenario

An increase in the movement speed of nodes in the network, as shown in Figure 3(a), reduces the total energy consumption of all protocols. DSDV, as a table-driven routing protocol, still has the lowest total energy consumption compared to the other protocols in this scenario. The increase in node movement speed leads to continuous changes in the topology of the network and disrupts the stability of the network structure. This may result in link disconnections and cause packets to fail in reaching their destination nodes. While the Tx energy consumption percentage remains unchanged, the Rx energy consumption percentage decreases due to packet losses. The decrease in packet exchanges between nodes causes an increase in the idle time for all protocols, leading to higher energy consumption in this mode.

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 32 العدد
Part 2 المجلد
July 2023 يوليو

المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ

تم استلام الورقة بتاريخ:15/ 6/2023م وتم نشرها على الموقع بتاريخ:30/ 7/2023م

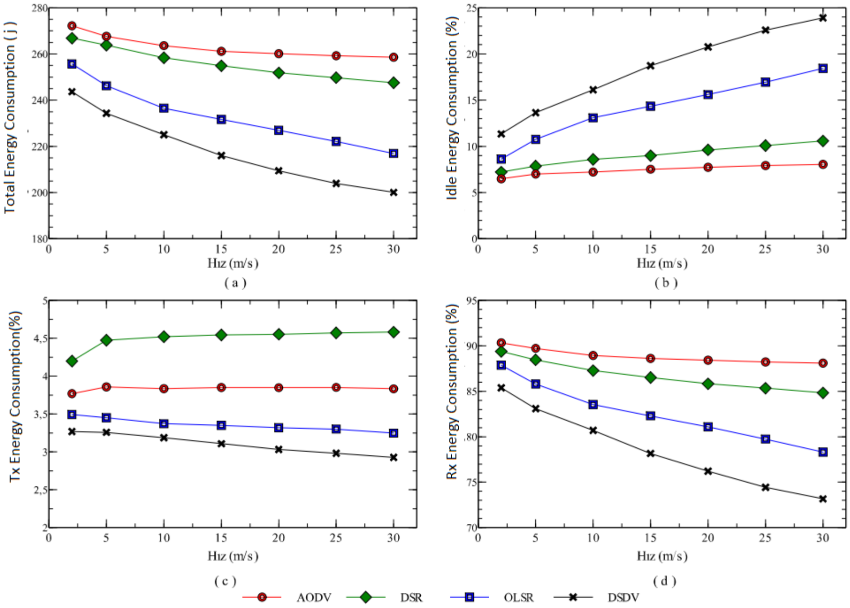

Figure 3. Impact of Speed Variation on Energy Consumption (Speed Varying)

Figure 3. Total Energy Consumption (a), Idle Energy Consumption (b), Tx Energy Consumption (c), Rx Energy Consumption (d) with respect to Speed Variation (Speed Varying)

4.4. Area Varying Scenario

The energy consumption of the mentioned routing protocols was evaluated based on the change in the area where the network is deployed, and the results are shown in Figure 4.

As seen in Figure 4(a), the total energy consumption of all protocols increases gradually from 500×500 m2 to 600×600 m2 and then starts to decrease in subsequent areas The increase in the area results in a decrease in the number of intermediate nodes between the source and destination nodes due to the nodes being spread out and going out of each other's communication range.

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

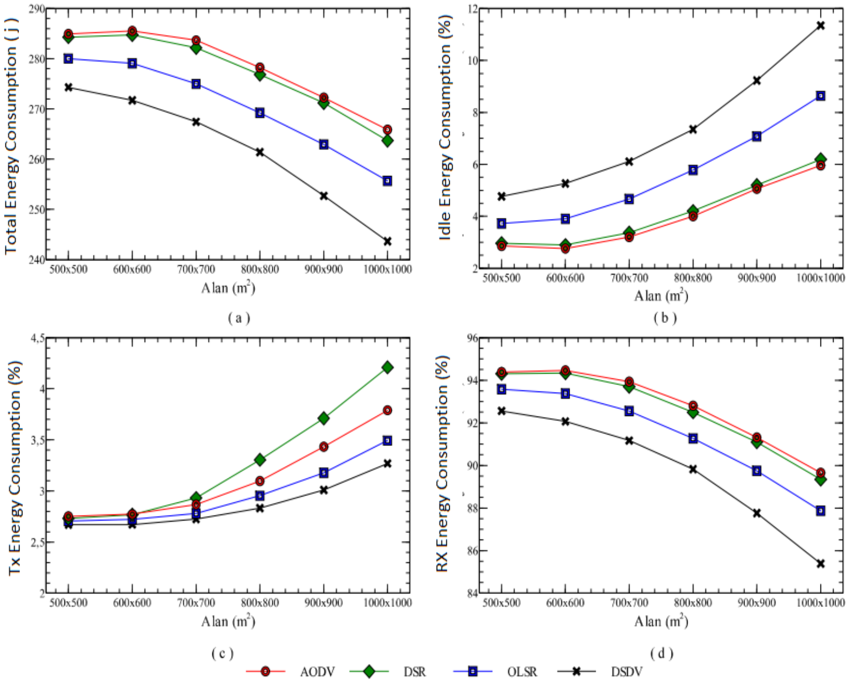

Figure 4. Energy Consumption Analysis for Different Network Deployment Areas (Area Varying)

Figure 4. Total Energy Consumption (a), Idle Energy Consumption (b), Tx Energy Consumption (c), Rx Energy Consumption (d) with respect to Area Variation (Area Varying)

As a result, the nodes spend more time in the idle mode (Figure 4(b)) and consume more energy in this mode. Similarly, the energy consumption percentage in the Tx mode (Figure 4(c)) increases, while it decreases in the Rx mode (Figure 4(d)) Consistently with previous scenarios, DSDV, along with other table-driven routing protocols, exhibits the lowest energy consumption in the area varying scenario.

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

5. CONCLUSIONS

In this study, the energy consumption of AODV, DSR, OLSR, and DSDV routing protocols was evaluated in various scenarios, including total energy consumption and energy consumption in different operational modes (idle, receive, and transmit). According to the obtained results, DSDV consistently consumes the least energy compared to all other protocols in all scenarios. OLSR, another table-driven routing protocol, performs well following DSDV in all scenarios compared to on-demand protocols. AODV and DSR exhibit similar energy consumption levels in all scenarios .For future work, our focus will be on developing new routing protocols that prioritize efficient energy consumption for MANETs.

REFERENCES

[1] Perkins, C. E., & Bhagwat, P. (1994). Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers. In Proceedings of the ACM SIGCOMM Conference on Communications Architectures, Protocols and Applications (SIGCOMM), 234-244.

[2] Johnson, D. B., & Maltz, D. A. (1996). Dynamic source routing in ad hoc wireless networks. In Mobile Computing (pp. 153-181). Springer, Boston, MA.

[3] Clausen, T., & Jacquet, P. (2003). Optimized link state routing protocol (OLSR). In Ad hoc On-Demand Distance Vector (AODV) Routing (pp. 121-166). Springer, Boston, MA.

[4] Perkins, C. E., & Royer, E. M. (1999). Ad hoc on-demand distance vector routing. In Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications (WMCSA), 90-100.

[5] Zhang, J., Zheng, H., & Qiu, X. (2012). Performance evaluation of MANET routing protocols in different network sizes. In Proceedings of the 7th International Conference on

تم استلام الورقة بتاريخ:15 / 2023/6م وتم نشرها على الموقع بتاريخ:30/ 7 /2023م

Communications and Networking in China (CHINACOM), 26-30.

[6] Bhuiyan, M. Z. A., & Kim, Y. S. (2012). Performance evaluation of reactive and proactive MANET routing protocols under mobility and traffic patterns. International Journal of Distributed Sensor Networks, 8(1), 876846.

[7] Lee, H., Choi, J., & Lee, S. (2013). Performance evaluation of MANET routing protocols under different mobility models. In Proceedings of the 5th International Conference on Computational Science and Engineering (CSE), 462-469.

[8] Huang, X., & Liu, Y. (2016). Performance evaluation of MANET routing protocols in urban vehicular networks. In Proceedings of the 2016 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (Cyber C), 221-225.

[9] Le, H. A., & Kha, H. H. (2017). Performance evaluation of reactive and proactive routing protocols for mobile ad hoc networks. In Proceedings of the 2017 International Conference on Computing, Management, and Telecommunications (ComManTel), 217-221.

[10] Fayed, M., & Al-Hagery, M. (2019). Performance evaluation of MANET routing protocols under different network conditions. In Proceedings of the 2019 International Conference on Advanced Science and Engineering (ICOASE), 1-6.