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Improving AODV Performance by Software Defined Networking Using NS3

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Abstract **– Nowadays, vehicular networks attract car manufacturers, network researchers, and governments as well. They represent one of the building blocks, for the intelligent transportation systems. Our task is to study the employment of SDN advantages to facilitate and improve the performance of vehicular ad-hoc networks. The goal of the research is to evaluate AODV routing protocol performance improved with SDN technology applied on VANET network in specified environment of a city. We have evaluated three parameters: packet delivery ratio, end-to-end delay and throughput using SUMO and NS3 simulators. The implemented evaluation protocol shows the importance of the adopted approach.**

Keywords **– AODV, NS3, OpenFlow, SDN, SUMO, trace mobility, vehicular network VANET.**

I. Introduction

The vehicular ad-hoc network (VANET) is a rather hot field of research during the past years [1]. Because of their specific characteristics such as high dynamicity and foreseeable mobility [2], VANET draws the attention of the academic world as well as the industrial one. It is a highly dynamic wireless ad-hoc network, which aims at establishing communication between vehicles without the need of any predesigned infrastructure [3].

The routing protocols in VANET are conceived for the urban environment where the vehicles are equipped with GPS and wireless devices for the continuous follow-up of the vehicles. The objective of these protocols is to select an optimal way with a minimum cost. Because of the dynamic behaviour of VANET, its topology changes consequently.

We can categorise VANET routing protocols according to their architecture into two main classes: vehicle-to-vehicle-based (V2V) and vehicle-to-infrastructure (V2I) based on VANET architecture. In V2V models [4], the communication between vehicles aims at providing all the necessary information about the traffic to drivers.V2I models [5] allow for a better use of the shared resources and multiply the abundant services by RSUs to install on the road side [6], but the problem of this mode is that it is very expensive.

During last years, routing protocols in VANET were largely studied [7]. From [8], we can define two major classes of routing protocols in VANET: protocols based on the geographical localisation [9] and protocols based on topology [10], which are divided into proactive protocols [11] such as DSDV (Destination-Sequenced Distance-Vector) [12], reactive protocols [13] such as AODV (Ad-hoc On-demand Distance Vector) [14] and hybrid protocols such as TORA (Temporally Ordered Routing Algorithm) [15].

This paper proposes a performance evaluation of an improved version of AODV routing protocol. The main contribution of our work is to consider the use of software-defined networking (SDN) architecture on the performance of this protocol. The rest of this paper is organised as follows. In Section II, we illustrate the architecture of VANET, and its challenging issues. In Section III, we explain details about routing protocols based on topology in VANET. In section IV, we explain the SDN OpenFlow technology. Section V explains our adopted methodology to improve AODV routing protocol in VANET using SDN OpenFlow technology. Section VI reports the experimental results with discussion. Finally, the last section presents the conclusions and future research areas.

II. VANET Challenging Issues

VANET is a technology that uses cars as nodes to create a mobile network. VANET swings each car of the network into a wireless router or node, allowing cars approximately to exchange information and, in turn, create a network with a wide range.

Moreover, VANET can be treated as a subset of Mobile Ad-Hoc Networks (MANETs) [16] and it is still necessary to classify VANETs as an independent research field, especially in the light of security apparatus. Fig. 1 illustrates the position of VANET between the most common wireless networks.

One of the most important design aspects of VANET is to implement an efficient, reliable and secure routing protocol.

The node in this wireless network can be even trucks, cars, buses and so on that can communicate between them V2V to exchange information on the road, broadcast warnings or advertisements. In this case, the nodes are placed near each other to establish V2V communication. Each vehicle has a random speed, which is set such that some vehicles move fast, and some slowly to increase and decrease the distance between the vehicles. In VANET networks, we may also have fixed

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unities as Road Side Units (RSU) that communicate between them with the purpose of controlling traffic information or to collect technical information from vehicles V2I such as speed, direction or destination. The whole architecture is presented in Fig. 2. The network is divided into two categories: the first one is to study the vehicular behaviour without being aware of its environment that is called the microscopic level.

The second one is the macroscopic level when the entire surrounding environment is studied.

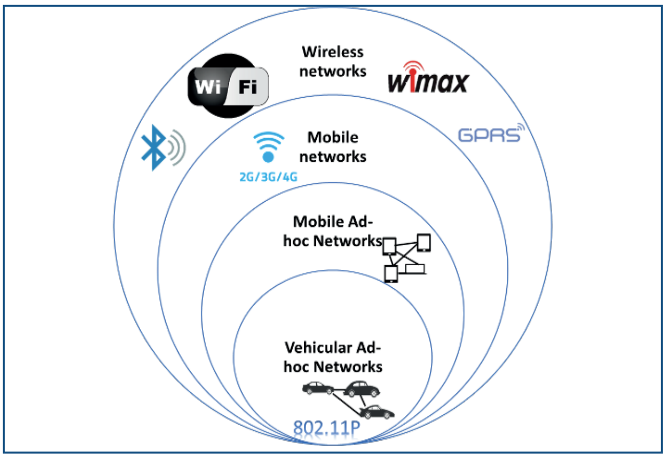

Fig. 1. VANET position in wireless networks.

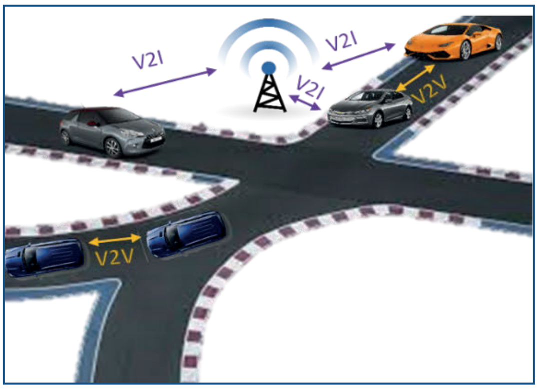

Fig. 2. VANET architecture.

Such VANET characteristics as fast mobility, expensive deployment of fixed units and security issues make it a challenging field of research [17].

VANET networking applications are classified into the following three categories:

- User comfort: the road users nowadays seek more entertainment especially over long distances, which needs stability even in high mobility roads like highways. A high bandwidth also remains a challenging task for HD video streaming abroad.
- Safety: to avoid traffic congestion and accidents, the real-time information and notification are needed and this remains a great challenge [18].
- Efficiency in traffic management: Channel propagation problems and efficient routing strategies must be treated with care to improve traffic systems.

III. Routing Protocols Based on Topology in VANETs

Routing protocol based on topology in VANETs uses mainly ad-hoc network routing protocols and employs the existing link information in the network to forward packets. It is divided into two categories: table driven routing or proactive [19] and on-demand routing or reactive [20] (Fig. 3).

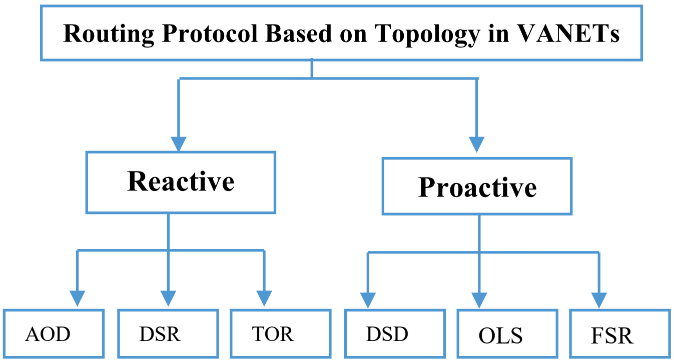

Fig. 3. Routing protocols based on topology in VANET.

Table driven routing protocols requires that each node in the network broadcast periodically the routing tables to update routing information in the network. This category of routing protocols includes: Destination Sequenced short Vector routing, DSDV [21] and Optimised Link State Routing, OLSR [22]. In DSDV, each vehicle in the network has to broadcast its own route tables to its neighbours. The neighbouring vehicles get help from two types of packets (full damp packets and increase packets) to update their routing table. Full dump packets contain information about each vehicle in the network.

These packets are transmitted periodically and are recorded in additional tables. The routes are privileged according to the least entry in the table. More detailed information about this protocol can be found in [23].

On-demand routing protocols do not need to update their routing table but just require to refresh according to the routing algorithm established by an agreement for routing when nodes need to communicate. This category of routing protocols includes the Dynamic Source Routing, DSR [24] and Ad hoc On-demand short Vector Routing, AODV [25]. Ad-Hoc On-demand Distance Vector is a reactive protocol that establishes a route when needed, rather than the routing tables in each node that must update it in every topology change.

The mechanism of the basic AODV is identified by three types of messages: Route REQuest RREQ, Route REPly RREP and Routing ERRor RERR transmitted twice: each node sends broadcast-id with regular procedures for new RREQ message. Every time a RREQ message comes to a node, it sends identification, which is smaller or equivalent to the earlier information to eliminate the packet. The mechanism of AODV routing protocol is illustrated in Figs. 4 and 5.

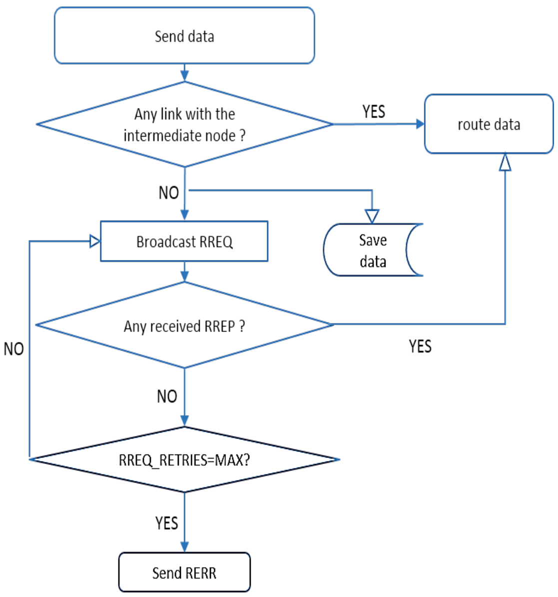

Fig. 4. AODV premise flowchart-route discovery [26].

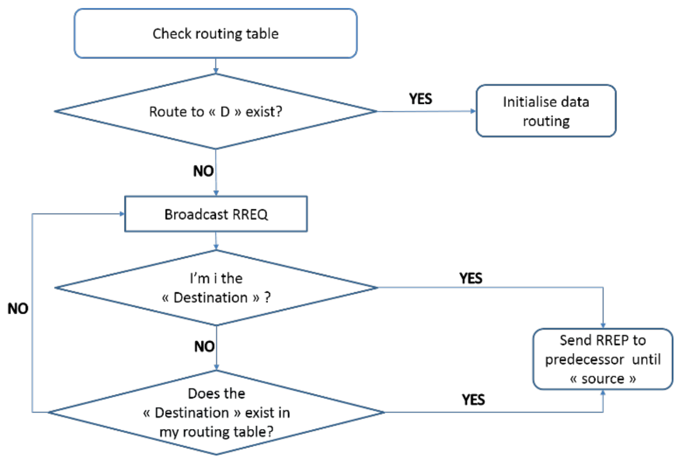

Fig. 5. AODV premise flowchart-route maintenance.

Table I resumes advantages and limitations of routing protocols based on topology in VANETs.

TABLE I
ROUTING PROTOCOLS BASED ON TOPOLOGY IN VANET

Category	Sub-category	Most popular protocol	Advantages	Limitations
Topology based	Proactive	DSDV	Desirable to use in a dense network	Bandwidth consumption by unused paths
	Reactive	AODV	Reduces memory requirement	Takes time to establish a route, it is not well scalable

IV. SOFTWARE-DEFINED NETWORKING OPENFLOW FOR VANETS

SDN (Software-defined networking) [27] is a programmable networking technology, which allows applications to interact directly with networks in a bidirectional way.

The main concept of this technology is to propose a new network architecture mainly based on the physical separation between the control plane and the data plane.

In SDN, the controllers have a global view of all the network status and manage other equipment in the network data plan. These become a simple transmitter/receiver data with minimal intelligence.

SDN promises to bring flexibility, scalability, and programmability to vehicle network architectures. They also facilitate network management and introduce new services [28]. The next figure illustrates the architecture of this technology.

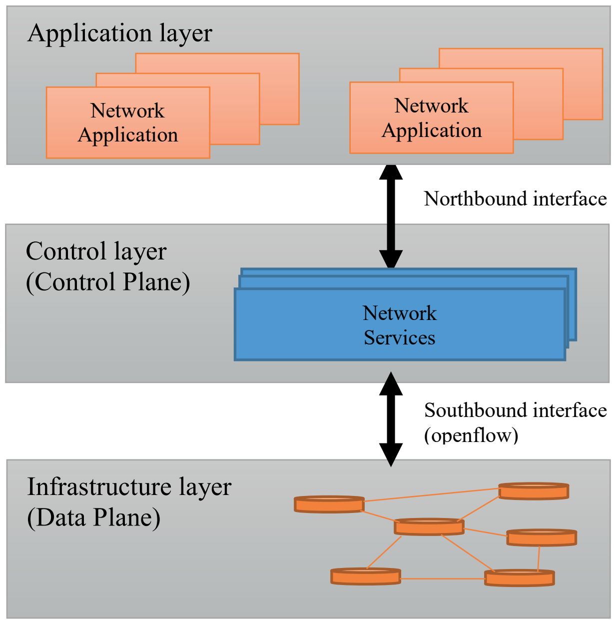

Fig. 6. SDN architecture.

SDN is based on a three-layer hierarchical architecture:

- Data plane layer: it represents all the network broadcast equipment, which only sends and receives data with minimal intelligence.
- Control plane layer: this layer represents the SDN controllers, which centralise network intelligence and manage other data plane streaming devices.
- Application layer: it gathers all the services and applications of the systems installed on the SDN controller.

To enable communication between the three layers, SDN establishes many unified communication interfaces:

- Northbound interface: it allows communication and data exchange between the SDN controller on the control plane and network applications. The type of information exchanged as well as its forms and frequencies depend on each network application.

- Southbound interface: it refers to the different applications that allow for communication between the control plane and the data plane devices. OpenFlow [29] is the most used standard for this interface. It is a communication standard for SDN that defines two types of network equipment:
- OpenFlow controllers: it is software that centralises all network control functions.
- OpenFlow vStwichs: they are virtual switches that only perform data packet transfer functions. Each of them has a flow table managed by the controller when installing flow rules.

Thus, the SDN approach is particularly suitable for VANETs due to its extremely changing nature where each node plays the role of a router [30]. As a result, the computational load associated with the controller is largely removed from the router nodes. The controller is therefore responsible for calculating and updating the routing tables.

Software Defined Vehicular Network is being a promising technology to manage the network configuration [31]. Fig. 7 illustrates the SDVN architecture.

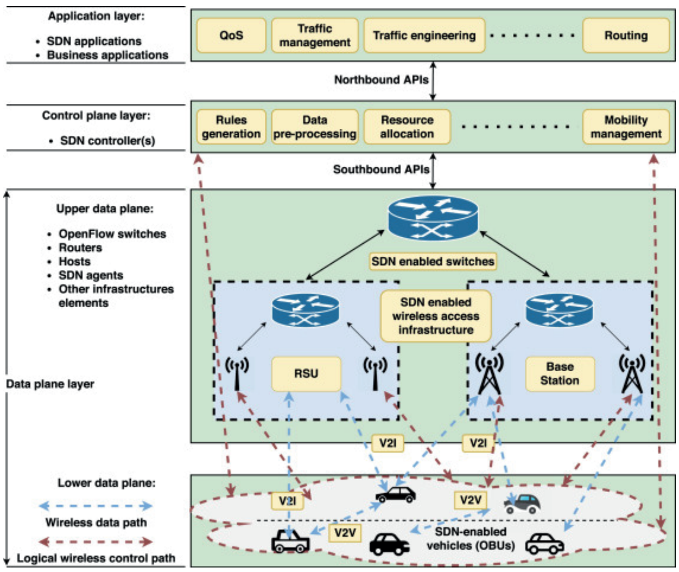

Fig. 7. SDVN architecture [32].

V. Adopted Methodology

The vehicular communication protocols are first simulated by the researchers using specific simulators. A real experimentation is very expensive.

The design of the mobility model is a very important stage in the simulation process of VANET.

In this section, we will explain our simulation of a realistic scenario combining many specific simulators. The goal targeted by our application is to improve the performances of AODV routing protocol using software-defined networking technology.

In our case, we have carried out numerous tests on AODV routing protocol using two distinct simulators: NS3 [33] for the network simulation and SUMO [34] for the road traffic simulation.

A. Simulation Configuration

The following table resumes the configuration parameters of our simulation.

TABLE II

Simulation Parameters

Parameter	Value
Type of channel	Wireless
Antenna type	Omni-directional
Network interface type	Physical wireless
Routing protocol	AODV
Simulation time	100 seconds
Number of nodes	9, 30 and 50
Vehicle direction	Two ways
Radio propagation model	Two Ray Ground
MAC protocol	IEEE 802.11

B. Map Generation

We have simulated a designed scenario while proceeding to a variety of simulators presented previously. During the process of simulation, it is very important to choose the appropriate tools for simulation at each stage of the process.

A real map has been imitated and simulated. SUMO simulator has been selected to generate the model of mobility and the traffic of our scenario. Concerning the network simulation and its evaluation, we have used the NS3 simulator.

The scenario of simulation occurs in an urban district. We have created our map under SUMO, which is made up of six intersections and 08 sections, each road contains two ways. Fig. 8 shows the treatment of our network using NetEdit under SUMO.

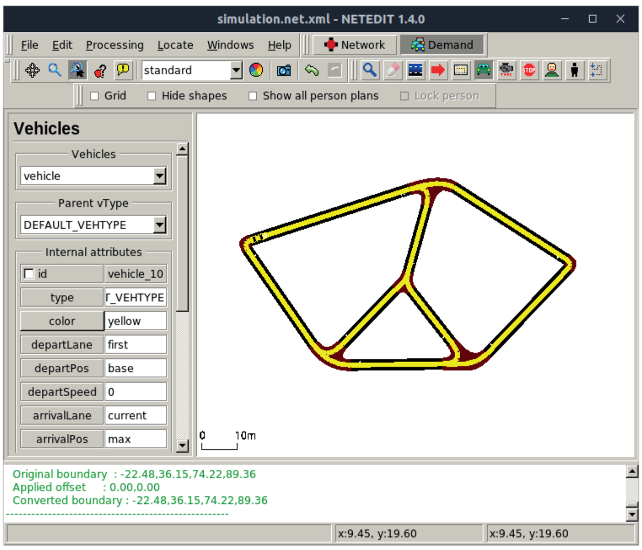

Fig. 8. The design of our scenario using NetEdit.

C. Simulation of the Traffic Model

This stage is devoted to create the vehicles, to define flows of traffic and vehicle movements, in order to define the mobility model and to visualise the traffic on the map created previously. These operations are done using SUMO and NS 3. Fig. 9 shows a part of our map with vehicles.

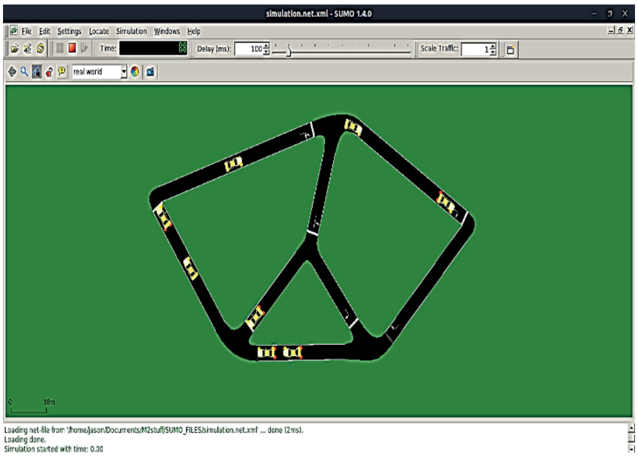

Fig. 9. Visualisation of the map using SUMO.

D. Simulation of the Network

In this final step of the simulation, we have used NS3 to configure our network parameters. NS3 allows us to define the routing protocol, the propagation model as well as the introduction of SDN OpenFlow technology.

It also allows us to evaluate our system by calculating network performance metrics.

VI. Results and Analysis

We have established our experiment for three different node densities (9, 30 and 50). The number of nodes used has been chosen to consider its impact on the performances of AODV with and without SDN OpenFlow. We have selected various parameters for performance evaluation which are:

A. Packet Delivery Ratio

Fig. 10 shows the obtained results in terms of Packet delivery ratio with and without SDN OpenFlow.

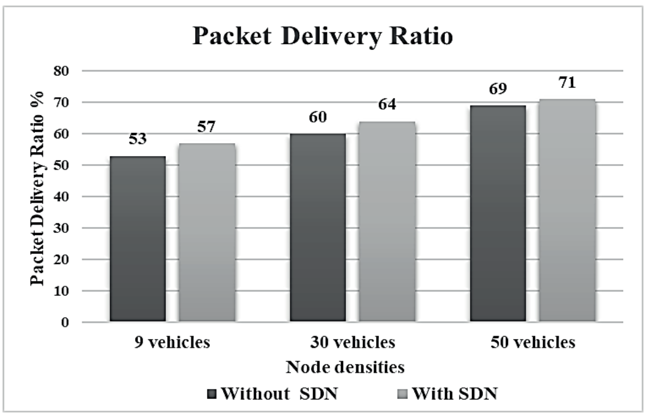

Fig. 10. Packet delivery ratio results (%).

B. End-to-End Delay

It represents the necessary time for the transmission of a packet from the source node to destination nodes through a network. Fig. 11 illustrates our obtained results with this parameter.

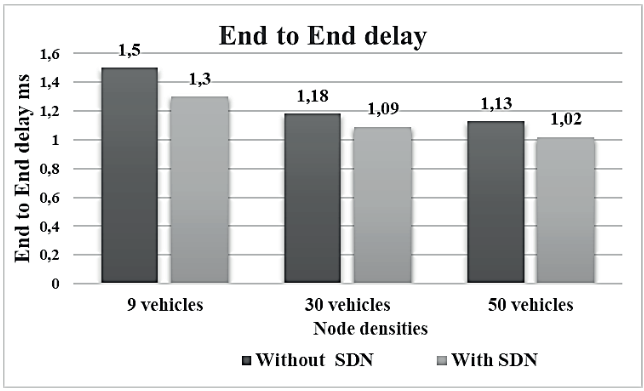

Fig. 11. End-to-end delay results (ms).

C. Throughput

It represents the amount of data transferred from a source to a destination at a specific time. Fig. 12 illustrates our obtained results with this parameter.

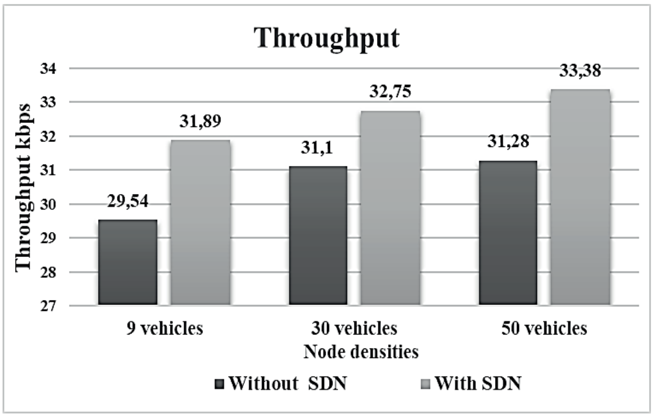

Fig. 12. Throughput results (kbps).

According to these results, we can say that the use of SDN OpenFlow technology has improved consequently the performances of AODV routing protocol in VANETs.

With a more saturated network, we have found that the SDN OpenFlow technology is more efficient. The number of transmitted packets increases even more than twice compared to an unsaturated network. The received packets increase even more compared to the transmitted packets.

We have noted a light difference in packet delivery ratio between the two situations (with and without SDN OpenFlow) and it is optimal when the network begins to be charged (50 nodes).

By using SDN OpenFlow technology, we notice an improvement of end-to-end delay in AODV protocol. The main reason for this improvement is that with the SDN OpenFlow technology real-time global view of the entire network topology and centralised control mode, it becomes easy to identify the current traffic status. This will make the allocation, of all types of network resources, more efficient.

Throughput parameter has also improved by the use of SDN OpenFlow. This improvement is due to the flexibility of SDN OpenFlow, which enables faster response to emergencies and sudden events.

VII. Conclusion

The main goal of this study has been to improve and evaluate AODV routing protocol under simulation scenarios with several parameters. To obtain valid results, we have simulated a real scenario using suitable and specific simulators. We have designed a new architecture of the AODV routing protocol based on the integration of the SDN in VANETs. The results obtained show the effectiveness of the adopted approach. We strongly believe that SDN technology is a promising choice to overcome the limitations of VANETs.

As future perspectives, we propose improving the performances of VANETs by the use of multiple distributed SDN controllers.

References

[1] W. Qi-wu, Q. Liu, and W. Wen, “Comparative study of VANET routing protocols,” *International Conference on Cyberspace Technology (CCT 2014)*, Beijing, China, Nov. 2014. https://doi.org/10.1049/cp.2014.1306

[2] K. T. Mahima, M. Ayoob, and G. Poravi, “Adversarial attacks and defense technologies on Autonomous Vehicles: A Review,” *Applied Computer Systems*, vol. 26, no. 2, pp. 96–106, Dec. 2021. https://doi.org/10.2478/acss-2021-0012

[3] N.V. Dharani Kumari and B.S. Shylaja, “AMGRP: AHP-based multimetric geographical routing protocol for urban environment of VANETs,” *Journal of King Saud University – Computer and Information Sciences*, vol. 31, no. 1, pp. 72–81, Jan. 2019. https://doi.org/10.1016/j.jksuci.2017.01.001

[4] M. A. Masrur, A. G. Skowronska, J. Hancock, S. W. Kolhoff, D. Z. McGrew, J. C. Vandiver, and J. Gatherer, “Military-based vehicle-to-grid and vehicle-to-vehicle microgrid – system architecture and implementation,” *IEEE Transactions on Transportation Electrification*, vol. 4, no. 1, pp. 157–171, Mar. 2018. https://doi.org/10.1109/TTE.2017.2779268

[5] C. N. Van Phu, N. Farhi, H. Haj-Salem, and J.-P. Lebacque, “A vehicle-to-infrastructure communication based algorithm for urban traffic control,” in 2017 *5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, Naples, Italy, 2017, pp. 651–656. https://doi.org/10.1109/MTITS.2017.8005594

[6] I. Wahid, A. A. Ikram, M. Ahmad, S. Ali, and A. Ali, “State of the art routing protocols in VANETs: A review,” *Procedia Computer Science*, vol. 130, pp. 689–694, 2018. https://doi.org/10.1016/j.procs.2018.04.121

[7] M. R. Ghori, K. Z. Zamli, N. Quosthoni, M. Hisyam, and M. Montaser, “Vehicular ad-hoc network (VANET): Review,” in 2018 *IEEE International Conference on Innovative Research and Development (ICIRD)*, Bangkok, Thailand, May 2018, pp. 1–6. https://doi.org/10.1109/ICIRD.2018.8376311

[8] R. A. Nazib and S. Moh, “Routing protocols for unmanned aerial vehicle-aided vehicular ad hoc networks: A survey,” *IEEE Access*, vol. 8, pp. 77535–77560, Apr. 2020. https://doi.org/10.1109/ACCESS.2020.2989790

[9] S. Boussoufa-Lahlah, F. Semchedine, and L. Bouallouche-Medjkoune, “Geographic routing protocols for vehicular ad hoc networks (VANETs): A survey,” *Vehicular Communications*, vol. 11, pp. 20–31, Jan. 2018. https://doi.org/10.1016/j.vehcom.2018.01.006

[10] S. K. Bhoi and P. M. Khilar, “Vehicular communication: A survey,” *IET Networks*, vol. 3, no. 3, pp. 204–217, Sep. 2014. https://doi.org/10.1049/iet-net.2013.0065

[11] A. K. Basil, M. Ismail, M. A. Altahrawi, H. Mahdi, and N. Ramli, “Performance of AODV and OLSR routing protocols in VANET under various traffic scenarios,” in 2017 *IEEE 13th Malaysia International Conference on Communications (MICC)*, Johor Bahru, Malaysia, Nov. 2017, pp. 107–112. https://doi.org/10.1109/MICC.2017.8311742

[12] D. S. Sandhu and S. Sharma, “Performance evaluation of DSDV, DSR, OLSR, TORA routing protocols – A review,” in *Mobile Communication and Power Engineering*, vol 296, V.V. Das and Y. Chaba, Eds. Springer, Berlin, Heidelberg, 2013, pp. 502–507. https://doi.org/10.1007/978-3-642-35864-7_77

[13] J. M. Garcia-Campos, D. G. Reina, S. L. Toral, N. Bessis, F. Barrero, E. Asimakopoulou, and R. Hill, “Performance evaluation of reactive routing protocols for VANETs in urban scenarios following good simulation practices,” in *9th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing*, Santa Catarina, Brazil, Jun. 2015, pp. 1–8. https://doi.org/10.1109/IMIS.2015.5

[14] S. Liu, Y. Yang, and W. Wang, “Research of AODV routing protocol for ad hoc networks1,” *AASRI Procedia*, vol. 5, pp. 21–31, 2013. https://doi.org/10.1016/j.aasri.2013.10.054

[15] L. Zhu, C. Li, B. Xia, Y. He, and Q. Lin, “A hybrid routing protocol for 3-D vehicular ad hoc networks,” *IEEE Systems Journal*, vol. 11, no. 3, pp. 1239–1248, Nov. 2017. https://doi.org/10.1109/JSYST.2015.2490341

[16] S. Goumiri, M. A. Riahla, and M. Hamadouche, “Security issues in self-organized ad-hoc networks (Manet, VANET, and FANET): A survey,” in *Artificial Intelligence and Its Applications*, *AIAP 2021. Lecture Notes in Networks and Systems*, vol 413, B. Lejdel, E. Clementini, and L. Alarabi, Eds. Springer, Cham, 2022, pp. 312–324. https://doi.org/10.1007/978-3-030-96311-8_29

[17] A. Rasheed, S. Gillani, S. Ajmal, and A. Qayyum, “Vehicular Ad Hoc network (VANET): A survey, challenges, and applications,” in *Vehicular Ad Hoc Network (VANET): A Survey, Challenges, and Applications,* vol. 548, A. Laouiti, A. Qayyum, M. Mohamad Saad, Eds. Springer, Singapore, 2017, pp. 39–51. https://doi.org/10.1007/978-981-10-3503-6_4

[18] S.Khatri, H. Vachhani, S. Shah, J. Bhatia, M.Chaturvedi, S.Tanwar, and N.Kumar, “Machine learning models and techniques for VANET based traffic management: Implementation issues and challenges,” *Peer-to-Peer Networking and Applications*, vol. 14, pp. 1778–1805, May 2021. https://doi.org/10.1007/s12083-020-00993-4

[19] K. Adhvaryu, “Performance comparison of multicast routing protocols based on Route Discovery Process for Manet,” in *Inventive Communication and Computational Technologies. Lecture Notes in Networks and Systems*, vol 89, G. Ranganathan, J. Chen, and Á. Rocha, Eds. Springer, Singapore, 2020, pp. 79–85. https://doi.org/10.1007/978-981-15-0146-3_9

[20] E. E. Akkari Sallum, G. dos Santos, M. Alves, and M. M. Santos, “Performance analysis and comparison of the DSDV, AODV and OLSR routing protocols under VANETs,” in 2018 *16th International Conference on Intelligent Transportation Systems Telecommunications (ITST)*, Lisboa, Portugal, Oct. 2018, pp. 1–7. https://doi.org/10.1109/ITST.2018.8566825

[21] M. Kaur and B. S. Sohi, “Efficient DAG task scheduling algorithm for Wireless Sensor Networks,” *International Journal of Computer Sciences and Engineering*, vol. 6, no. 12, pp. 735–743, Dec. 2018. https://doi.org/10.26438/ijcse/v6i12.735743

[22] J. Toutouh, J. Garcia-Nieto, and E. Alba, “Intelligent OLSR routing protocol optimization for VANETs,” *IEEE Transactions on Vehicular Technology*, vol. 61, no. 4, pp. 1884–1894, Mar. 2012. https://doi.org/10.1109/TVT.2012.2188552

[23] G. F. Ahmed, R. Barskar, and N. Barskar, “An improved DSDV routing protocol for wireless ad hoc networks,” *Procedia Technology*, vol. 6, pp. 822–831, 2012. https://doi.org/10.1016/j.protcy.2012.10.100

[24] C. O. Asogwa, X. Zhang, D. Xiao, and A. Hamed, “Experimental Analysis of AODV, DSR and DSDV protocols based on Wireless Body Area Network,” in *Internet of Things*, *Communications in Computer and Information Science*, vol 312, Y. Wang and X. Zhang, Eds. Springer, Berlin, Heidelberg, 2012, pp. 183–191. https://doi.org/10.1007/978-3-642-32427-7_25

[25] E. Amiri and R. Hooshmand, “Retracted article: Improved AODV based on Topsis and fuzzy algorithms in vehicular ad-hoc networks,” *Wireless Personal Communications*, vol. 111, no. 2, pp. 947–961, Nov. 2019. https://doi.org/10.1007/s11277-019-06894-x

[26] H. Brahmia and C. Tolba, "Vanet routing protocols: Discussion of various ad-hoc on-demand distance vector (AODV) improvements," in *2018 3rd International Conference on Pattern Analysis and Intelligent Systems (PAIS)*, Tebessa, Algeria, Oct. 2018, pp. 1–6. https://doi.org/10.1109/PAIS.2018.8598502

[27] O. S. Al-Heety, Z. Zakaria, M. Ismail, M. M. Shakir, S. Alani, and H. Alsariera, "A comprehensive survey: Benefits, services, recent works, challenges, security, and use cases for SDN-VANET," *IEEE Access*, vol. 8, pp. 91028–91047, May 2020. https://doi.org/10.1109/ACCESS.2020.2992580

[28] H. D. Ali and A. H. Abdulqader, "Using software defined network (SDN) controllers to enhance communication between two vehicles in vehicular ad hoc network (VANET)," in *2021 7th International Conference on Contemporary Information Technology and Mathematics (ICCITM)*, Mosul, Iraq, Aug. 2021, pp. 106–111. https://doi.org/10.1109/ICCITM53167.2021.9677720

[29] N. McKeown, T. Anderson, H. Balakrishnan, G. Parulkar, L. Peterson, J. Rexford, S. Shenker, and J. Turner, "OpenFlow," *ACM SIGCOMM Computer Communication Review*, vol. 38, no. 2, pp. 69–74, Apr. 2008. https://doi.org/10.1145/1355734.1355746

[30] Z. He, J. Cao, and X. Liu, "SDVN: Enabling rapid network innovation for heterogeneous vehicular communication," *IEEE Network*, vol. 30, no. 4, pp. 10–15, Jul. 2016. https://doi.org/10.1109/MNET.2016.7513858

[31] W.Ben Jaballah, M.Conti, and C.Lal, "A survey on software-defined VANETs: benefits, challenges, and future directions," *arXiv preprint*, arXiv:1904.04577, 2019. https://doi.org/10.48550/arXiv.1904.04577

[32] Md. Mahmudul Islam, M. T. R. Khan, M. M. Saad, and D. Kim, "Software-defined vehicular network (SDVN): A survey on architecture and routing," *Journal of Systems Architecture*, vol. 114, Mar. 2021, Art no. 101961. https://doi.org/10.1016/j.sysarc.2020.101961

[33] The Network Simulator ns-3. [Online]. Available: https://www.nsnam.org/. Accessed on: Oct. 26, 2022.

[34] SourceForge, "Eclipse SUMO – simulation of Urban mobility". [Online]. Available: http://sumo.sourceforge.net/. Accessed on: Oct. 26, 2022.

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