PERFORMANCE EVALUATION OF DIFFERENT MOBILITY MODELS IN VEHICULAR DELAY-TOLERANT NETWORK (VDTN) WITH VANETS OR IEEE 802.11P STANDARD

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Abstract

Vehicular Delay-Tolerant Networks (VDTN) is a spatial sort of Delay-Tolerant Network (DTN) for next-generation vehicle communication. However, limited resources in terms of delivery ratio while higher overhead are the key challenges. Therefore, a reliable with satisfying quality of service (QoS) of delay tolerable dynamic communication is required for vehicular ad-hoc networks (VANETs). This paper evaluates the varying number of mobile vehicles/nodes and two different types of Mobility Models; Traced based Mobility and Random based Mobility Model. The above scenarios were investigated based on Epidemic routing, PRoPHET routing, and SprayAndWait flooding routing. The performances were evaluated using Network Simulator (NS-3.29) with VANETs or IEEE 802.11p standard. Finally, three QoS metrics were considered: Delivery Ratio, Overhead, and Average Delay. The simulation result shows that the RWayPoint Mobility has recorded better performance metrics for all routing protocols in both (lower and higher) density vehicle scenarios. Hence the QoS are improved.

***Keywords*: IEEE 802.11p/1609.4; DSRC; OBU; MANETs; Epidemic; PROPHET; SprayAndWait; Mobility.**

1. Introduction

Annually, millions of human lives are lost due to roadside accidents (Nearly 1.3 million), and over 3000 deaths are recorded daily. In the present situation, roadside accidents are alarmingly high because of increasing vehicle density.

Statistically, the annual increase in the number of vehicles density is estimated at fifty million [Sharma *et al.*, (2016)], which is mainly attributed to a lack of driver assistance and awareness. In the last decades, different technical organizations (Such as ITs, ETSI ITs-G5, ASTM, FCC, IEEE 802.11p/1609.x) attempted to develop VANETs communication to reduce the rate of roadside accidents. RFID framework will guarantee successful activity control amid crest periods to maintain a strategic distance from crashes, spare time and assets, and as well spare our planet [Matthews *et al.*, (2017)]. The Intelligent Transportation Systems (ITs) are considered two types of vehicle communication for Vehicular Ad hoc networks: vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) [Venkatesh *et al*., (2014)]. On the other hand, Bluetooth Low Energy (BLE) is the advancement and test of an intra-vehicular framework, comprising an outline to demonstrate real-time information collected from numerous sensors dispersed inside a car, utilizing an Android smartphone [Silva *et al.*, (2017)]. Real-time checking framework and execution of a framework that screens end-to-end perceivability based on the Internet-of-Things stages was demonstrated in a previous study [Juarizo *et al*., (2019)]. The framework has three components: the sensors framework, the checking framework, and the show framework. Furthermore, the security plan of VANET must guarantee keenness, verification, and privacy administrations. In another study [Ibraheem *et al*., (2019)], the components and characteristics of VANET, its security challenges, and comprehensive information on the various potential attacks and their classification were presented. ITs facilitate the deployment of QoS, effectiveness, and future safety transportation systems. In IEEE, 802.11.x and 1609.x groups have determined the standard of convention stack IEEE 802.11p/1609.x/ or Wireless Access for Vehicular Environment (WAVE) for vehicle communication [Figueiredo *et al*., (2001)]. The WAVE contains IEEE 802.11p and IEEE 1609.4 benchmarks. Specifically, the IEEE 1609.4 standard provides suitable channel switching, priority queues delivery, and specific timing requirements strategy. In particular, the IEEE 1609.4 is a multichannel strategy plan, whereas the VANETs or IEEE 802.11p PHY standard is half from the traditional IEEE 802.11a PHY standard. In addition, the VANETs protocol uses the OFDM modulation scheme [Bahn, (2016)]-[Miao *et al*., (2011)].

The IEEE 802.11p device can operate as a WAVE mode, providing Dedicated Short-Range Communication (DSRC) 5.9GHz (5.850-5.925GHz). The US government enables V2V technology using DSRC technology. The On-Board Unit (OBU) or radio interface is served the DSRC mechanism which is mounted in a vehicle. Also, the DSRC standard can support the IEEE 802.11p (5.850-5.925GHz) frequency band strategy with a limited spectrum. It is very close to the IEEE 802.11a 5GHz based frequency band and it has been declared a 75MHz band, which has made seven 10MHz channel bandwidths. These seven-channel bandwidths are divided into two categories; one is a control channel and another one is a service channel. Where the DSRC channel allocation are contained control channel (CH178) to use for safety message information and service channels (CH172,CH174,CH176,CH180,CH182 and CH184) to use for infotainment [Kenney, (2011)]. These two-channel plans contain two different intervals namely the control channel interval (CCHI) and service channel interval (SCHI). Both channel intervals exist 50 ms (CCHI) and 50 ms (SCHI). These channels are separated by 4 ms or 6 ms Guard interval when no data service execution happen. The control channel interval (CCHI) is served for the wellbeing data, whereas the service channel interval (SCHI) is served for the non-security data [Kim, (2016)]. The IEEE 802.11p MAC protocol is formed from the QoS service MAC, IEEE 80.11e, or enhanced distributed Channel Access (EDCA) MAC protocol. The EDCA MAC mechanism executes different types of Access categories (ACs), comprising three different types of data traffic (Best effort, Background, Voice, and video). These different types of data traffic are disseminated by the IEEE contention-based MAC control protocol. In addition, the EDCA MAC has contained four dominant components (AIFS, TXOP, CWmin, CWmax). It can control the whole data transmission process of the EDCA mechanism [Bahn, (2016)]. Previous authors have published 2-D and 1-D Markov Chain analytical models to control the abovementioned 802.11e MAC layer components for IEEE 802.11p [Han *et al*., (2016)]-[Zheng *et al*., (2016)]. Several papers have been published by the different back-off periods, which calculates the accuracy of vehicle communication [Yan *et al*., (2017)].

The Route selection mechanism will disseminate service information and control information within the lowest time. It is very difficult to calculate the appropriate route for ongoing dynamic vehicular communication. So, many researchers have published effective route selection routing algorithms that were evaluated and compared based on simulation work [Ali *et al*., (2016)]. The taxonomy of VANEs routing protocols is Unicast, Broadcast, Multicast, Geocast, and Hierarchical categories [Venkatesh *et al*., (2014)]. Furthermore, the traditional MANETs routing protocol is trying to adopt VANETs networks. Hence, the following three types of MANETs routing have been tested with different VANETs scenarios, such as Proactive routing (OLSR, DSDV), Reactive routing (AODV, DYMO, DSR), and Hybrid routing (ZRP) [Ali *et al*., (2016)]. The Zone routing protocol (ZRP) is a hybrid type that is proactive and reactive. In a previous study [Setiabudi *et al*., (2016)], the authors demonstrated different QoS comparison metrics. Finally, they concluded that the GPSR is better than the ZRP. Most of the MANETs routing protocols have been evaluated by QoS parameters, such as PDR, Average Delay, Throughput, Received packets, routing packets, dropped packets, the ration of packet loss, and Average Jitter [Ali et al., (2016)], [Setiabudi *et al*., (2016)]-[Priya *et al*., (2016)]. The overall traditional MANETs routing protocols are not fulfilling the distinctive nature of the parameters (end-to-end delay, packet delivery ratio) for the VANETs network.

Therefore, it is necessary to adopt another alternative approach for highly dynamic vehicle communication, namely vehicular Delay Tolerant Network (VDTN) with VANETs or the IEEE 802.11p standard. Thus, the Delay-Tolerant Networking Research Group (DTNRG) provides DTN records and delineates the start to finish of the protocol, square configurations, and theory of DTN [Scoot *et al*., (2007)]. The foremost and core requirement of DTN is to provide sparse connectivity, long or variable delay, where no end-to-end connectivity exist and intermittent connectivity is present. The DTN architecture adapts with the Store-Carry and Forward (SCF) functionality. These network messages (called Bundle) are disseminated from the source node to intermediate nodes in the vicinity of the destination node [Scoot *et al*., (2007)]. The transitional node stores and conveys this message until the following contact node is not accessible. When the receiver node appears into the transmission range then it forwards the message to the next node. So, this message forwarding process is called hop by hop or node by node until reaching the destination.

In recent years, more software has appeared to simulate VANETs simulation Network Simulator-3/Network Simulator-2 (NS-3/NS-2) [Figueiredo *et al*., (2001)]-[Lakkakorpi *et al*., (2013)]. On the other hand, the Opportunistic Network Environment (ONE) is executed only for the simulation of the DTN network [Hossen *et al*., (2016)]. To simulate the VANETs network, a mobility model needs to be created that could consider real-world or customized mobility models. As a result, the Simulation of Urban Mobility (SUMO) [Behrisch *et al*., (2011)] is a very familiar and powerful traffic simulator. It creates a real-world (open street map) and customized mobility models by the installation of MOVE.jar. It is intended to create traffic planning and road design optimization.

The following segment is divided into different sections. Section II entails a review of the DTN routing protocols, whereas Section III focuses on Mobility Models. The NS-3 simulators and simulation environment setup were introduced in Section IV while the simulation results and discussion are discussed in Section V. Finally, Section VI includes the conclusion and recommendation for future works.

2. Related Work

The Store-carry-Forward mechanism provides two different types of routing strategies for the DTN network. The routing strategies are "Flooding or Replication or Single copy message" and "Forwarding or Knowledge or Multi-copy message" [Jain *et al*., (2004)]. These types of routing protocols have both advantages and disadvantages. The Forwarding based routing protocol is a relatively less-resourced consuming process because it delivers only a single copy message over the network at any time. However, it does not ensure the best delivery ratio since it has to find the destination node followed by the probability scheme. Furthermore, the Replication-based routing protocols are resourced hungry process. Hence, they are reliable for the best delivery ratio because several multi-copy messages exist in the current network. Above all, at least one message will reach the destination node. Intuitively, the first routing protocol consumes less resources and low probability for successful delivery. The replication base routing protocols on the other hand are more resourced consume and have a high possibility of successful delivery.

2.1. *Epidemic*

Epidemic routing is the foremost "Flooding–based" protocol. The node uniformly repeats and transmits messages to the newly discovered contacts node which possesses a copy of the message [Vahdat *et al*., (2000)]. Next, a single copy of the message is sent to the next neighbor, ensuring the successful message delivery to the destination node. In a large network, a high overhead and message congestion scenario may occur.

2.2. *SprayAndWait*

SprayAndWait is another type of "Flooding-based" routing protocol. It attempts to reduce the number of replicas for message delivery and keep track of low resource utilization to forward the message. It executes the resource efficiency by setting the fixed upper bound message creation policy. The SprayAndWait protocol is formed by two phases: the spray phase and the waiting phase. In the waiting phase, the relay node receives a copy of the message. This is the holding up stage, where the relay node basically holds a specific message until the goal is experienced legitimately [Spyropoulos *et al*., (2005)]. The SprayAndWait routing protocol is formed by two principals, known as Vanilla and Binary, respectively. Every mechanism will trigger "spry" and L copies of the message. The Vanilla principal is a relatively simple way to transmit a single copy of the message to L distinct nodes. Next, the Binary process starts at the source nodes with L duplicates of the message. It encounters the first node before transferring the L/2 copies of the message. Each of the nodes exchanges halves of the message duplicates to the next node. Thereafter, all copies give way and switch to the waiting phase, which searches for a direct transmission opportunity with a final destination of the message.

2.3. *PRoPHET*

The PRoPHET routing strategy is simply to maintain delivery predictability of bundles or messages, where message sending relies on the likelihood by every node to every destination. It executes opportunistic occurrences between two nodes. The nodes are purely random in realistic situations and encounters are rare or completely random [Lindgren *et al*., (2003)]. The PRoPHET routing protocol concept is similar to the Epidemic routing protocol; hence it improves the delivery probability of a message. During opportunistic encounters, each node follows the three rules for delivery predictabilities,

- When node A meets another node B, then the prediction of 'B' will be increased. Eq. (1) shows this calculation.

$$\mathrm{P} = \mathrm{Pre}_{(a,b)old} + (1 - \mathrm{Pre}_{(a,b)old}) * \mathrm{Pre}_{init} \qquad (1)$$

Here Pre init is an initialization constant.

- The delivery predictability is created by age. So, if two nodes are not meeting each other in a period, then there is a lower chance of forwarding the messages to each other. Eq. (2) shows this aging equation.

$$\text{Pre}_{(a,b)} = \text{Pre}_{(a,b)old} * \gamma^k \quad (2)$$

- The delivery prediction leads to the transitivity process. Assuming that node A frequently tries to meet node B, while node B frequently tries to meet node C. So, node C probably is a good node to forward message towards node A. Eq. (3) expresses the transitivity calculation of delivery prediction.

$$\text{Pre}_{(a,b)} = \text{Pre}_{(a,b)old} + \left(1 - \text{Pre}_{(a,b)old}\right) * \text{Pre}_{(a,b)} * \text{Pre} * \beta \quad (3)$$

where β is a scaling constant. It expresses the scalability of the transitivity process regarding delivery prediction.

3. Method

This study evaluates different types of mobility models with three DTN routing. All these routing protocols have been simulated in NS-3 (version NS-3.29). The NS-3 is able to visualize the simulation results in the NetAnim file. The NetAnim file extracts the Node location, current path, connection between nodes, and the number of packets transmitted. In addition, the NetAnim.xml file was extracted in order to visualize the different protocols.

3.1. *Simulation Environment Setup*

The employed DTN network is regarded as a single group of vehicles. Simulation parameters and routing algorithms are specified in Table 1. It illustrates the simulation configuration for analyzing the performance metrics by the different mobile nodes (i.e., 50, 150, and 200) for each mobility model (i.e., RWaypoint, RW2d, RDi2d, and SUMO based on the Ns-2 formatted trace file).

Parameters	Values
Simulation Time	500 seconds
Maximum Speed of Vehicles	40m/s (Uniformly Random variable)
Propagation Model	Nakagami
Mobility Model	Random Waypoint (RWayPoint), Random walk 2d (RW2d), Random Direction 2d (RDi2d), and Ns-2 formatted trace file created by SUMO
Size of bundles	256 bytes and generating 234 bundles
Number of vehicles	50, 200
Bundle Expiration time	200 seconds
Routing Protocols	Epidemic, Spray-and-Wait, and Prophet
MAC protocol	802.11p

Table 1. Simulation environment parameters

3.2. *Performance metrics*

To evaluate and compare this work based on the three Quality of Service metrics; Delivery ratio, Overhead Ratio, and Average Delay. The authors assumed Bundle Creation (B_C), Bundle Replica (B_R), Bundle Custody (B_{CT}), and successful Bundle Receive (B_{REC}).

- Delivery Ratio (DR) was calculated as shown in Eq. (4). It indicates the successful data delivery to the destination.

$$\text{DR} = B_{REC} / B_C \quad (4)$$

- Average Delay (AD) is the measurement of the average time between bundle creation and bundles received as shown in Eq. (5). Here, B_{RT}= Bundle Received Time, B_{CT} = Bundle Creation Time, N_{BR} = Number of Bundles received

$$\text{AD} = (B_{RT} - B_{CT}) / N_{BR} \quad (5)$$

- Overhead Ratio is defined as the replica and transmitted bundles with the received ones as shown in Eq. (6).

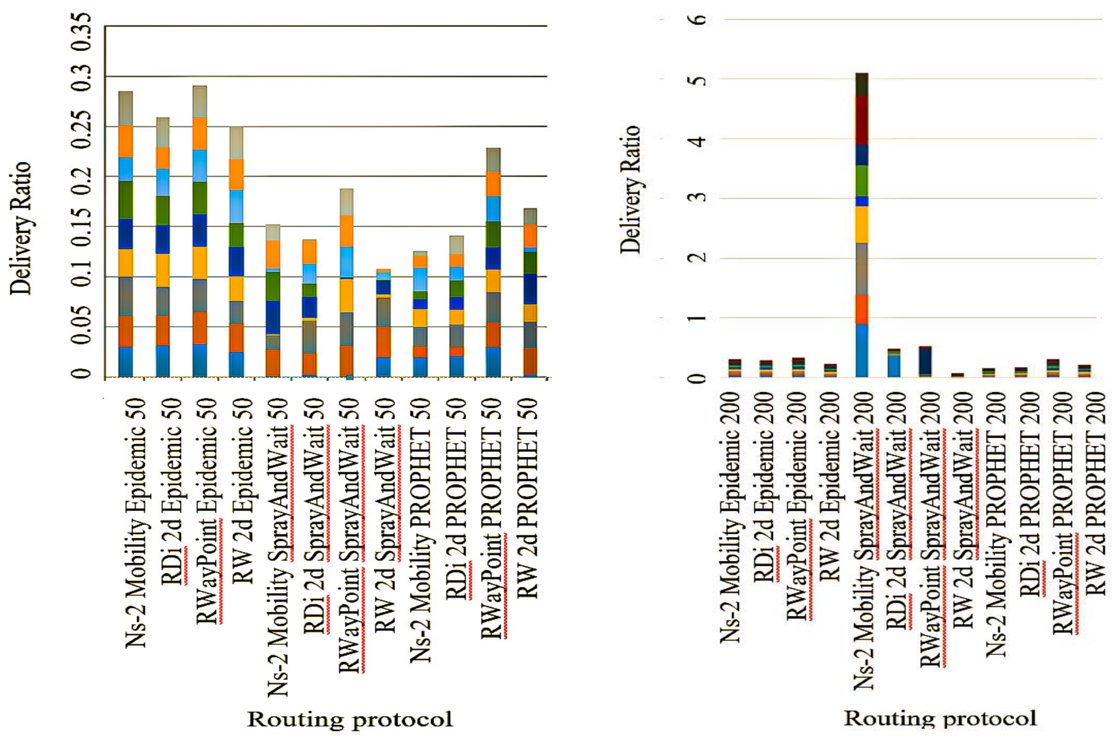
$$\text{Overhead} = [(B_R + B_{CT}) - B_{REC}] / B_C \qquad (6)$$

4. Simulation results and discussion

The empirical results are presented in this section based on the above simulation parameters in Table I. These different results of types of QoS metrics could be evaluated according to the concept of this study as expressed in Figures 1, 2, and 3.

4.1. *Performance Analysis on delivery ratio*

The delivery ratio has been executed for the different routing protocols with various mobility models as shown in Fig. 1. This metric was extracted from the different behavioural patterns of DTN routing protocols in vehicular ad-hoc networks with different mobility models. The delivery ratio is maximum with the RWaypoint mobility model, and being minimum with RW2d (for Epidemic and SprayAndWait) as shown in Fig. 1(a). When the number of vehicles increase from 50 to 200, the delivery ratio become decreases due to congestion occur. Overall, all the routing protocols provided better delivery ratio results with the Random waypoint mobility model (RWayPoint), respectively.

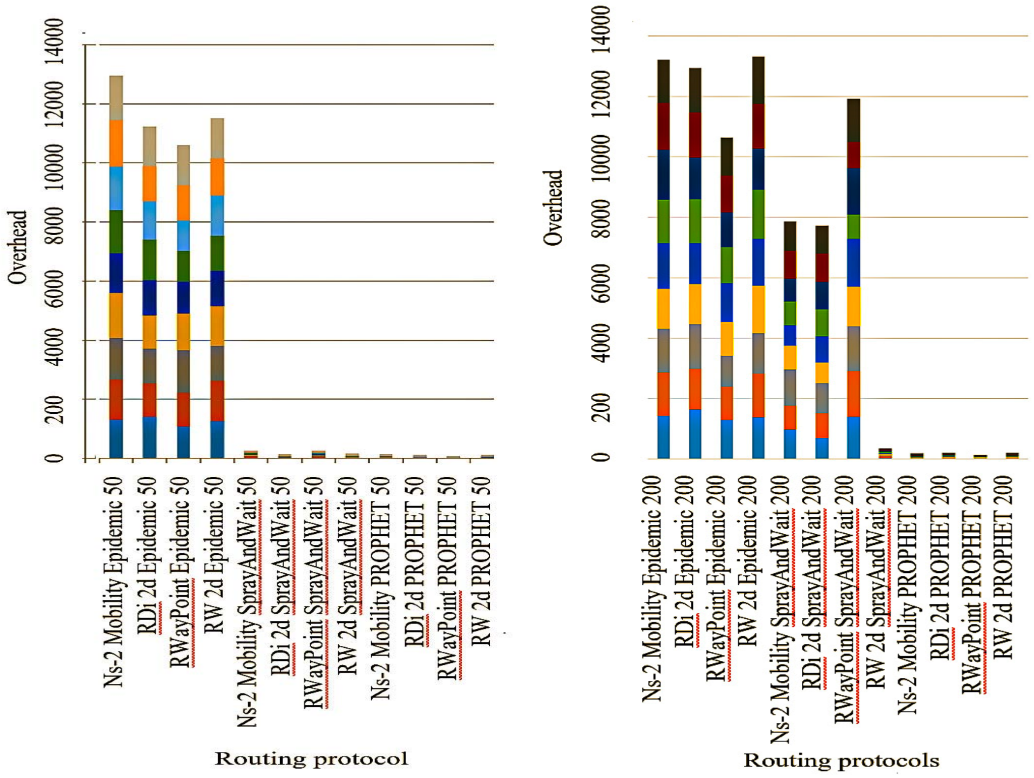


(a) (b)

Figure 1. Delivery Ratio for four different mobility models with the three DTN routing

4.2. *Performance Analysis on overhead*

The overhead is illustrated in Fig. 2. Here, the Epidemic overhead is very significant from other routing protocols. Above all, the RWayPoint mobility model executes the lowest overhead (for Epidemic, SprayAndWait and PRoPHET), except for the SprayAndWait routing protocol. But when the number of vehicle increases to 200 as shown in Fig. 2(b) where high traffic in urban areas might occur, the overhead transmission become increase due to suspected roadside accidents might have increased significantly.

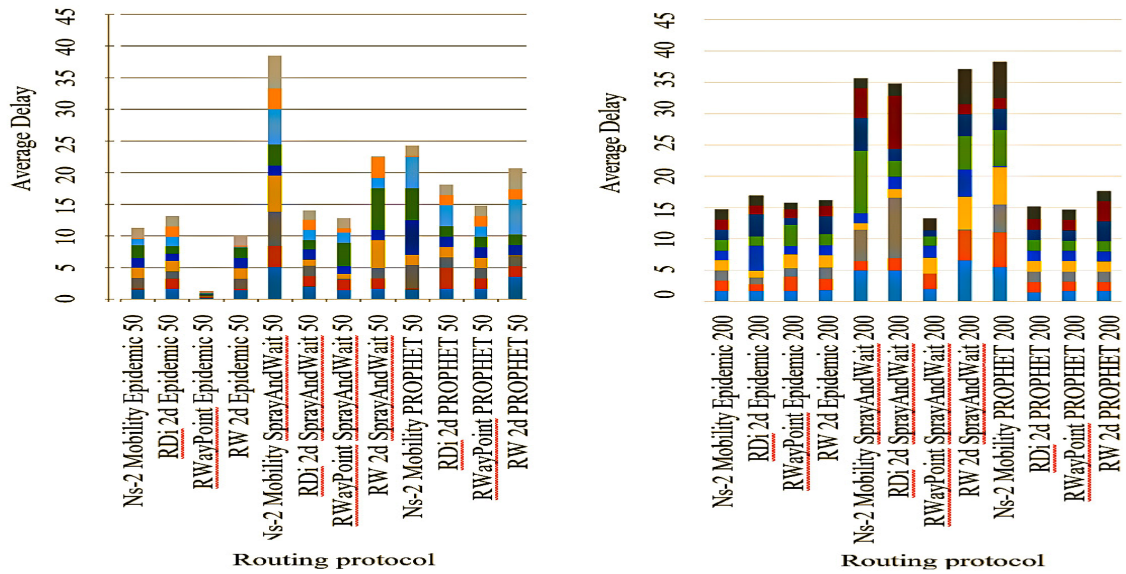


(a) (b)

Figure 2. Overhead for four different mobility models with the three DTN routing

4.3. *Performance Analysis on average delay*

The average delay is depicted in Fig. 3. The mobility models have been extracted with different DTN routing protocols. However, the RWay Point showed the desire minimum average delay compared to the other (RW2d, Ns-2 trace file formatted, and RDi2d) mobility models in all routing schemes. Therefore, the RWayPoint mobility model revealed better average delay performance than the other mobility models. Unfortunately, when the number of vehicles increases by 150 as shown in Fig. 3(b), the average delay become increases due to sharing wireless channel become saturated in VANET.



(a) (b)

Figure 3. Average Delay for four different mobility models with the three DTN routing

5. Conclusion

In this study, the three DTN routing protocols in a vehicular ad-hoc environment were used to test a variety of mobility models' performance. All the performances were executed using the NS-3 simulator with two types of mobility model, namely the Random Way Point (RWayPoint) file-based Mobility Models and NS-2 or Trace file-based Mobility Models. The simulation results revealed that the Random Waypoint (RWaypoint) mobility model performed better QoS metrics (higher delivery ratio while achieving lower overhead and average Delay) than the other mobility models. Future works might consider including the execution of a new routing protocol implementation for the vehicular delay-tolerant network, which will cover the above situation and investigate better QoS performance.

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