Indonesian Journal of Electrical Engineering and Computer Science
Vol. 30, No. 3, June 2023, pp. 1509~1515
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v30.i3.pp1509-1515

A comparison of the performance of the ad hoc on-demand distance vector protocol in the urban and highway environment

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Article Info

Article history:

Received Aug 17, 2021
Revised Jan 20, 2023
Accepted Jan 26, 2023

Keywords:

Ad hoc on-demand distance vector
Intelligent transportation system
Onboard unit
Roadside unit
Vehicular ad hoc network

ABSTRACT

In recent years, the vehicular ad hoc network (VANET) has received great attention, as it is involved in the design of the intelligent transportation system (ITS). The VANET network includes message flows from vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) where the network is propped by wireless communication technology, such as IEEE 1609 WAVE and IEEE 802.11P. The VANET network implementation faces challenges, and one of these challenges is the design of routing protocols that transfer reliable and efficient packets from vehicle to vehicle. In VANET, steering is a challenging task in the highway and urban environment. Therefore, this paper presents an assessment of ad hoc on-demand distance vector protocol (AODV) performance in the highway and urban environment and to study the effect of vehicle density on protocol performance. The AODV protocol was simulated by MATLAB. In this study, the performance of AODV protocol was evaluated through four measures, namely, packet delivery ratio (PDR), overhead, end-to-end (E2E) delay, and dropped packets. The study in our paper showed that the best performance of the AODV protocol is in an environment where vehicle speed and vehicle density are low.

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1. INTRODUCTION

World health organization (WHO) issued a report regarding the number of deaths and injuries caused by traffic accidents, and the report indicated that the cause of these accidents is due to lack of information about the streets, violation of traffic rules, severe traffic congestion, neglect of drivers and an increase in the population [1]. To avoid these accidents, there must be transportation facilities and intelligent traffic. And to reduce traffic congestion, the vehicular ad hoc network (VANET) has been applied, because it seeks to provide services for the intelligent transportation systems (ITS) [2]-[6]. Many of the features of mobile ad hoc networks (MANETs) are offered by VANET, but with the addition of other services such as inter-vehicle communication (IVC) for data exchange between pedestrians, roadside units, and vehicles within a limited range. In other words, VANET is an advanced class of (ITS) applications. The vehicles in VANET can communicate with each other within a communication range of 100-1000 m. The VANET design includes two communication units, which are the roadside unit (RSU) and the onboard unit (OBU). RSU is installed near traffic lights or the intersection of the road while OBU is installed inside the vehicles, as shown in Figure 1. The vehicle is used in VANET as an interface, source, or router to transmit messages while (RSU) acts as an access point [3], [7], [8]. To support vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) connection, the federal communication commission (FCC) has proposed a frequency band between (5.850–5.925) GHz. Dedicated short-range communications (DSRC) have been developed to quick link establishment, high data rate, reduce connection delay, and support high traffic conditions [9], [10].

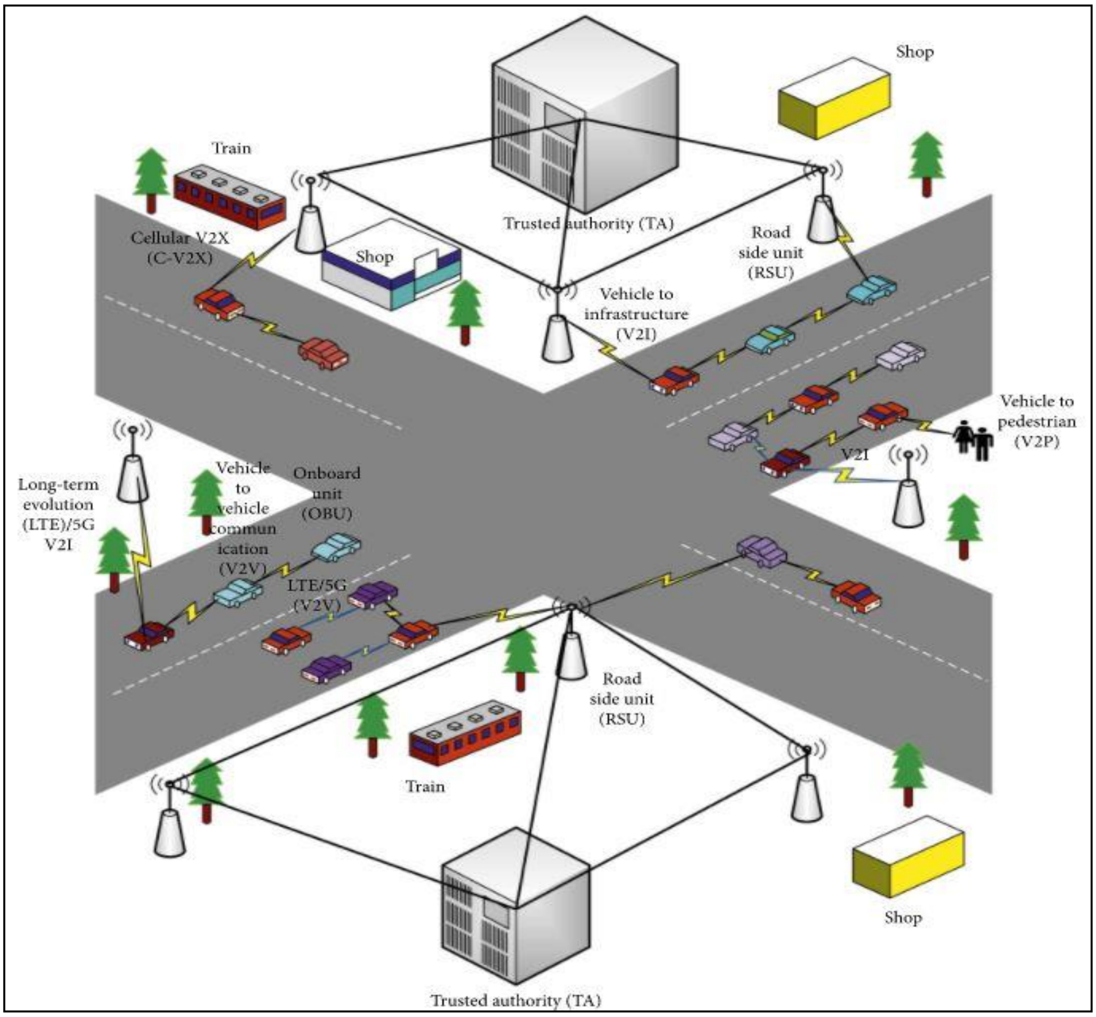

Figure 1. Architecture of VANET [11]

Besides, the wireless access in vehicular environment (WAVE) is a standard developed by the IEEE research for VANET [12], [13]. For wireless access, VANET deals with two standards IEEE 1609 and IEEE 802.11p, IEEE 802.11p manages the higher-layer protocols while IEEE 1609 administers the MAC and physical layer [14]. In this paper, the focus will be on the ad hoc on-demand distance vector protocol (AODV) protocol, which is one of the VANET protocols based on topology. We have studied the performance of AODV protocol because it considers one of the most widely used protocol in VANET, which can be used in smart transportation system and providing compfort services for vehicles. AODV was already proposed and studied by many researchers as a nominee protocol in VANET because the ease of using it in delivering packets through routes from source to destination [15]. The AODV protocol will be applied in the urban and highway environment and the performance and effectiveness of the protocol will be evaluated in the event of a change in vehicle density.

The remainder of the paper will be arranged as follow: section 2 is the routing protocols. Section 3 is the research method. Section 4 presents results analysis. The conclusion is presented in section 5.

2. ROUTING PROTOCOLS

Researchers have difficulty designing effective routing protocols due to the high dynamic topology of VANET. VANET routing protocols can be categorized into two classes which are position-based and topology-based routing protocols. The most common sub-protocols in VANET are AODV, geographic routing protocol (GRP), temporarily ordered routing algorithm (TORA), dynamic source routing protocol (DSR), destination-sequenced distance-vector routing (DSDV), fisheye state routing (FSR), and zone routing protocol (ZRP), as shown in Figure 2 [16], [17].

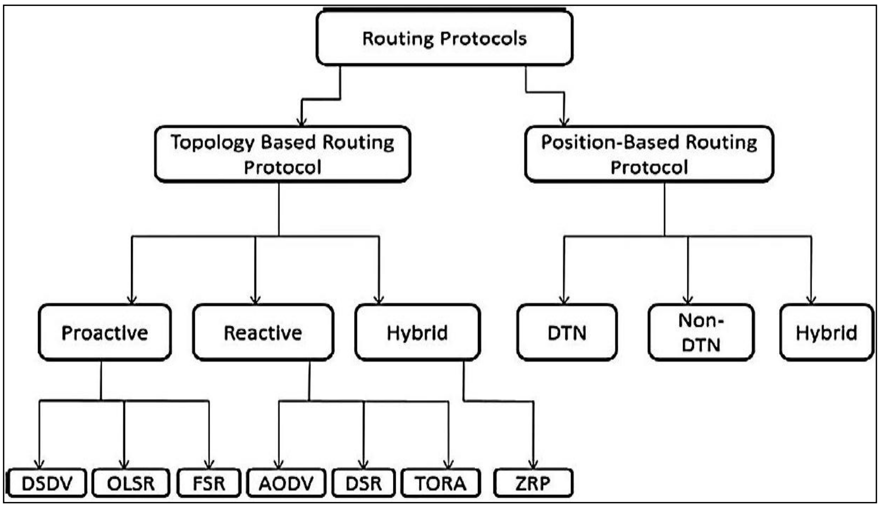

Figure 2. VANET protocols [18]

2.1. Topology-based routing protocol

This type uses link information to transfer data packets between vehicles via the VANET. This mechanism is divided into three subcategories, namely reactive, proactive, and hybrid routing protocols. Reactive protocols depend on routing techniques related to on-demand methodology while proactive protocols depend on routing techniques related to table-driven methodology [17].

2.1.1. Reactive routing protocol

This protocol relies on algorithms related to demand actions. Vehicles begin to detect the path only when two vehicles want to communicate. And one of the benefits of reactive routing protocol is network traffic reduction. Examples of this type are the AODV, DSR, and TORA routing protocols [19]-[21].

Ad hoc on-demand distance vector (AODV) protocol: it is one of the reactive routing protocols, and this protocol relies on an on-demand approach [22]. The AODV protocol starts working when the source vehicle starts generating (Hello) beacons to identify its neighbors, and when the source vehicle detects the neighbors; it sends a route request message (RREQ) to all neighboring vehicles [23], [24]. The RREQ message contains (a counter that counts the number of times an RREQ message was generated for a specific vehicle, the broadcast ID, interface and source address, and their sequence numbers). When the source vehicle broadcasts (RREQ), the neighboring vehicles re-broadcast (RREQ) to their neighbors until it reaches the destination vehicle as shown in Figure 3. When the destination vehicle receives (RREQ), it replies with a route reply message (RREP) to the source vehicle via the same path from which it received (RREQ) as shown in Figure 4.

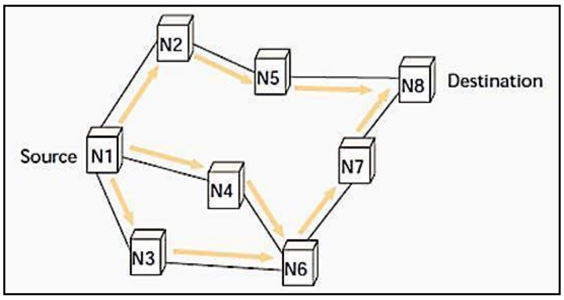

Figure 3. RREQ path to the destination [24]

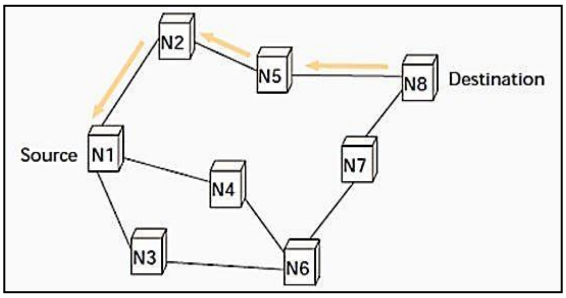

Figure 4. RREP path to the source [24]

3. RESEARCH METHOD

This section describes how the AODV protocol simulation and the environment were designed and implemented, and how the process of comparing performance was done using performance measures. In this work, the AODV protocol was simulated by MATLAB. The AODV protocol was implemented in an urban and highway environment with a vehicle density of 20 and 40 vehicles; vehicle speed is between 40-120 km/h, the simulation area size is 5 km*5 km, and the simulation time is 200 seconds. The several parameters were used to simulate the AODV protocol, as shown in Table 1.

Table 1. Simulation parameters

Parameter	Value
Protocol	AODV
Number of vehicles	20,40
Simulation area	5 km* 5 km
Simulation time	200 second
Simulation environment	Urban, Highway
Speed	(40-120) km/h
Data rate	5 Packet/s
The size of control message	64 Bytes
The size of packet	512 Bytes

4. RESULTS AND DISCUSSION

The AODV protocol was simulated in an urban and highway environment, and the effect of vehicle density on the performance of the AODV protocol in both environments was studied, as the protocol was simulated in (an urban environment with 20 and 40 vehicles, and a highway environment with 20 and 40 vehicles). The AODV protocol performance was evaluated by four measures: packet delivery ratio (PDR), overhead, E2E delay, and dropped packets.

4.1. Packet delivery ratio

PDR is the ratio of packets received by interface vehicles over the ratio of packets sent by source vehicle. Figure 5 shows the PDR [25], [26]. The result of the comparison showed that the AODV protocol in the urban environment with low vehicle density has the highest rate of packet delivery, while in a highway environment and an urban environment with high vehicle density, the packet delivery rate is lower because in these cases, the AODV protocol suffers from a high rate of packet loss due to the occurrence of collisions.

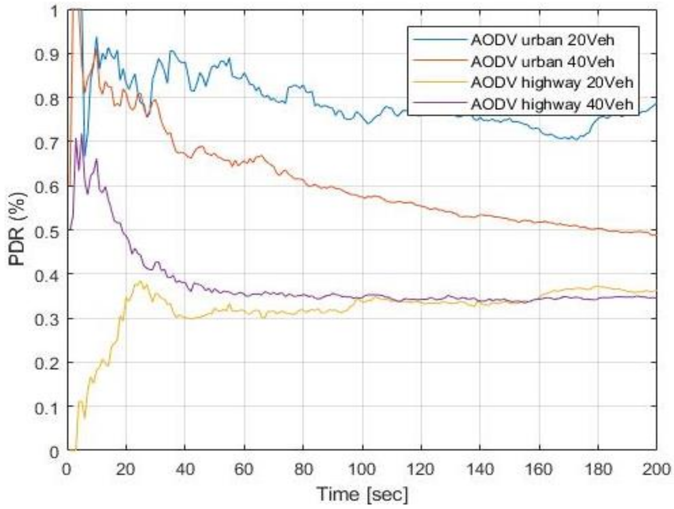

Figure 5. Packet delivery ratio

4.2. Overhead

Overhead is the number of messages protocol sends to discover the path between the source and destination vehicle. Figure 6 shows the overhead [27]. The comparison result showed that the AODV protocol was less overhead in a low-density urban environment, while in the highway and high-density environment; the protocol obtained a higher overhead because in these cases the protocol needed more control messages to detect the path.

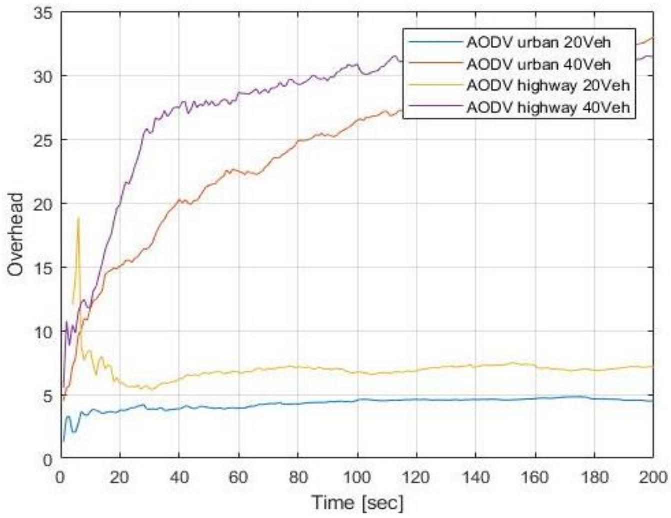

Figure 6. Overhead

4.3. End to end delay

It is the difference between the time of sending data from the source vehicle and the time of delivering the data to the interface vehicle. Figure 7 shows the delay ratio [28]. The comparison result showed that the AODV protocol had the lowest E2E delay in the low-density urban environment, while in the highway and high-density environment; the protocol obtained a higher E2E delay due to flooding in path detection and network congestion, resulting in a delay in the delivery of packets to the destination vehicle.

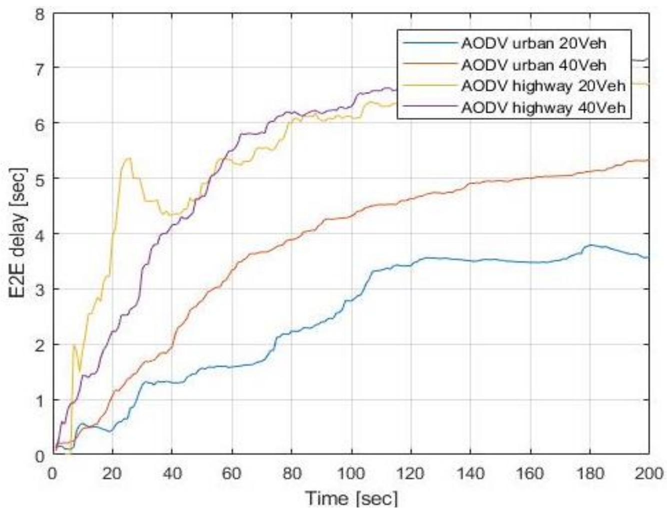

Figure 7. E2E delay

4.4. The number of dropped packets

In this work, the number of dropped packets during the simulation time was calculated for three reasons, which are packets lifetime and path break [8], [29]-[31]. Table 2 shows the dropped packets 2. The comparison results showed that dropped packets due to the packet lifetime are few in a low-density urban environment, while the dropped packets due to path break were low in the highway environment.

Table 2. Number of dropped packets

Environment	Number of vehicles	Dropped packet due to packet life time	Dropped packet due to path break
Urban	20	165	2
Urban	40	697	2
Highway	20	457	0
Highway	40	971	1

5. CONCLUSIONS

In this paper, the effect of vehicle density on AODV protocol performance in an urban and highway environment was studied, and AODV performance was evaluated using four measures (PDR, overhead, E2E delay, and dropped packets). The comparison results showed that the AODV protocol in the low-density urban environment has the highest packet delivery ratio, the lowest percentage of overhead and delay, and the fewest number of dropped packets due to the packet lifetime. While in the highway and high-density environment, the AODV protocol had the lowest performance rate. It can be concluded from this study that the best performance of the AODV protocol is in an environment where vehicle speed and vehicle density are low.

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