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Real time Fair sharing Bandwidth analysis using Game Equilibrium in VANET

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Abstract
Vehicular Ad Hoc Networks (VANET) is network of vehicles communicating between each other and to the deployed roadside units. They share information regarding traffic and infotainment. In the next generation of VANET with 5G networks, software defined network (SDN) technology will place a very important role for the network management. To optimize strategy to balance the latency requirement and the cost on cellular networks, in which we encourage vehicles send the SDN control requests through the cellular networks by rebating network bandwidth. Further, we model the interaction of the controller and vehicles as a two-stage Stackel-berg game and analyze the game equilibrium. From the experiment results, the optimal rebating strategy provides smaller latency than other control plane structures. Index Terms—Software-Defined Network (SDN), vehicular ad-hoc network (VANET).

Keywords— *Software-Defined Networking (SDN); Vehicular Ad-hoc Network (VANET); Road Side Unit (RSU), On Board Unit (OBU), wireless networks;*

1. Introduction

Vehicular Ad Hoc Networks (VANETs) is an active area of research because of its potential to improve vehicle road safety, enhance traffic and travel efficiency, and provide network connection service convenience and comfort for passengers and drivers. One example would be the Intelligent Transport Services (ITS) .The growth in mobile devices and mobile traffic, Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications are expected to become more in demand and will continue to growth. VANETs can be used to provide a wide range of services, including both safety and non-safety. The design of the transport protocol for VANETs is rather at its initial phase. No transport protocol modified for vehicular networks so far, and it is also very complex to either design new protocols or adapt existing protocols by modification. Most often, transport messages must be error free because a message will not be able to be retransmitted in the case where two cars are passing each other while going in opposite directions. VANET have to process its transport layer protocols significantly from current ad hoc network technologies that are used in today's world. Most it will have to use a specialized protocol other than TCP. The current challenges need to be overcome to create a successful transport protocol fact that high packet loss rates, long round trip times, short connection durations, high probability of packet reordering are part of the reality of current ad hoc networks. Mobile ad hoc networks add to the complexity due to the fact that the nodes are travelling at high rates of speed. Meanwhile, fifth generation (5G) cellular networks will improve existing vehicular communications in performance, user experience.

In the development of 5G networks and VANETs, Software Defined Networking (SDN) technology which decouples the network management from the data transferring will be an important approach to the network structure. In the SDN structure, two different planes, namely the control plane and data plane with software defined VANETs. The data plane associates with the network devices to transferring network flows, implemented with SDN interfaces.

VANET support SDN protocols, the roadside units (RSUs), vehicles and cellular networks can be converted to SDN devices for the data plane. Considering the latency of packet forwarding brings less influence to the network performance. Control plane especially in the control (management) communication between the controller and the data plane problems to the network performance. With existing technologies, three types of control communication structures, VANET based, cellular network based and hybrid structure. In VANET based structure or ad-hoc network based communication, control events transferred with network data in the ad-hoc network. In cellular network based structure, is transferred to the controller through the specific cellular network while hybrid structure combine both cellular links and the ad-hoc networks .The hybrid structure is a trade-off between the latency in the ad-hoc networks and the expensive cost of the cellular networks, for this the control plane is used for the future software defined VANETs that balancing between ad-hoc networks and cellular networks for transferring control event problem to the hybrid structure. The optimal method to leverage the latency requirement and the cellular network cost. We design a rebating mechanism to optimize the southbound communication. Therefore, we employ a game-theoretic analysis, the interaction between the controller and vehicles as a two-stage leader-follower (Stackel) game. In the first stage, the controller decides the rebated and assigned bandwidth for each vehicle and in the second stage; every vehicle decides how many event packets should be sent by the cellular network. We analyse the best decisions of both the vehicles and the controller, and find the game equilibrium. It including various system of it's the scale and Bandwidth of the VANETs.

To evaluate our work, VANET simulators to simulate both VANETs and the SDN structure. The main contributions of this paper are summarized as follows.

- The hybrid control plane structure in software defined VANETs with 5G cellular networks. This structure, propose a rebating method to make a tradeoff between cellular network access cost and network control latency. Our first work to optimize the performance of the control plane.
- The optimal rebating strategy to balance the cost of the cellular network access cost and the SDN management latency, that impact of rebating the assignment of bandwidth.
- The two-stage Stackel-berg game, and analyze the game equilibrium. The general variable system setting is applicable for different software defined VANET scenarios.

The performance evaluation of the strategy with wide-ranging of simulations with realistic maps, it discuss the latency and cost for different settings. We also compare our rebating strategy with some other control plane structures.

The paper summarized as follows. Related Work and gives the basic information about VANET and SDN/OpenFlow. Our network scenario and motivation are to be introduced. It presents the problem formulation. An optimal rebating and assignment policy used. It presents the simulation results. Finally, concludes this paper and give the future work

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2. Related Work

In this section, first brief some works to introduce basic knowledge's of SDN in VANETs. Then, as a VANET is a type of wireless networks, we discuss some works on wireless southbound communications.

2.1 Information about Vanet and SDN/ OpenFlow

This section describes some background information and terms on VANET and SDN/ OpenFlow used through the paper.

2.1.1 VANET

VANET Vehicles communicate with each other through V2V communication in Ad-hoc and V2I communication through road-side-units (RSU) and mobile broadband (e.g. 4G or 5G/LTE). Traditional VANET services include vehicle and road safety services, traffic efficiency, management services and infotainment services.

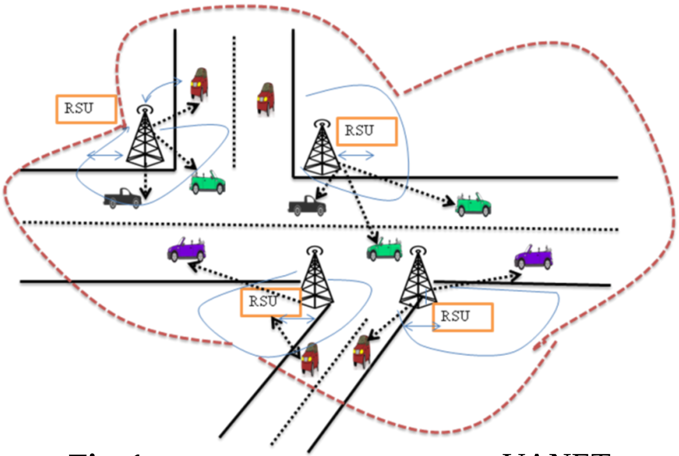


Fig. 1 VANET Component and Communications

2.1.2 OpenFlow

SDN is the separation between the control plane and the data plane. The finally used for the data forwarding while the other is demoralized for the network traffic control. OpenFlow is the most commonly used protocol for communications between the SDN control plane and data plane and it have a high level concept of SDN and OpenFlow is used as base and is integrated to VANET wireless environments. In this different action been taken to specified the OpenFlow enabled switch can encapsulate the packet and send it to the controller through the secure channel or directly drop the packets.

The controller has two ways to add the switch.

- Proactively, where the controller takes the initiative and adds rules before packet arrival into the network.
- Reactively, where the controller reacts because of an in the network, such as a previously unrecognized packet.

In mobile networks, the introduction of SDN and OpenFlow will enables the base stations' wireless data plane programming. It improves the management resources, mobile devices for new services and control functions. VANETs, is an wireless mobile environment in this SDN can reduce interference that improves the usage of channels and the routing of data in multi-hop and multi-path scenarios are the benefits of Software-Defined VANETs.

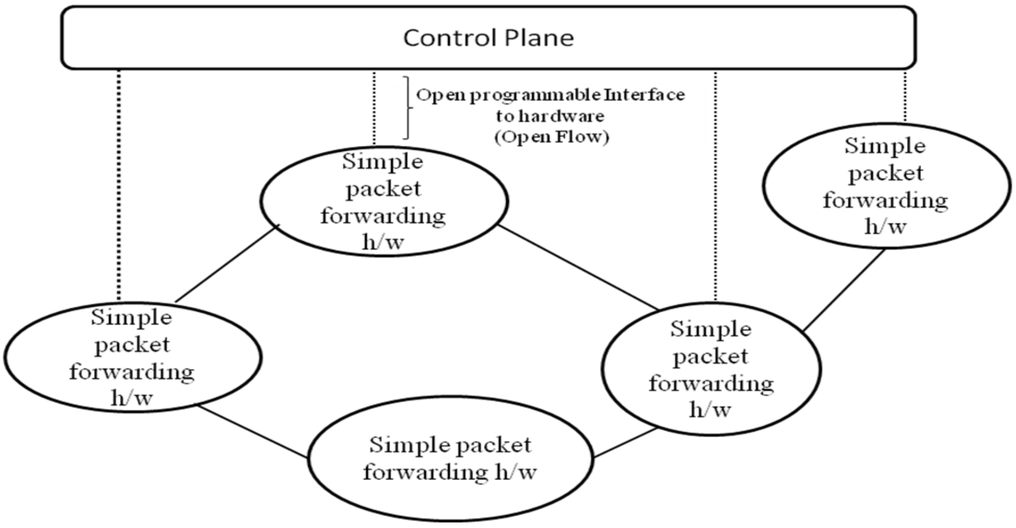


Fig. 2 Software Defined Networking Concept

2.1.3 SDN in VANETs

SDN technology to the wireless network environment, including ad-hoc networks.is an intermediary connection between the ad-hoc networks. An infrastructure-based wireless access network applied in SDN is a heterogeneous network used to reconfigure for the intermediary communication. Since VANET is different from the ordinary SDNs, they also discuss some potential operating modes and fallback mechanisms. The work is compared to the common VANET and the results show the benefits brought by SDN technology. RSU cloud architecture in VANET named as RSU micro data center. The RSU cloud consists of ordinary and SDN enabled RSU to support network virtualization of SDN technology and used for cloud controller control their VANET architecture. VANET architecture named FSDN to add support of SDN and Fog computing to VANET. Mean while, Fog orchestration in the SDN controller to support Fog computing and discussed the two cases of the work including data streaming and lane-change service.

2.1.4 Wireless Southbound Communication

Wireless networks bring more latency and packet loss than the traditional SDNs, the works focus on control plane problems in wireless networks. Wireless communications are different from data center networks, some works proposed specific models for southbound communications. The Open Networking Foundation (ONF) OpenFlow protocol is a possible implementation of controller-switch interaction and also defined the southbound communication between the OpenFlow devices and the network controller. OpenFlow support for encrypted Transport Layer Security communication and certificate exchange between the devices and the controller.to support SDN for mobile networks, consideration with dense networks used for southbound interface for managing different networks (e.g., LTE, Wi-Fi). SDN mechanisms services from the IEEE 802.21standard. Implemented their framework over open-source software in a physical testbeds in better performance and signaling. Furthermore, works plan for some solutions on wireless southbound communications and sensor Open Flow to enable SDN in wireless sensor networks, (WSN). The TCP/IP connectivity is not available in WSN, is designed a SOF channel as an end-to-end connection to transmit control message between the controller and a sensor. The overlaying a WSN transport protocol for the non-IP solution as the southbound communication and for the IP solution, simply introduced some existing ready-to-use TCP implementations is to support WSN. SDN-based mobile cloud architecture in ad-hoc networks to build their mobile cloud architecture, for different wireless environment.

3. Methods and Motivation

In this first present the scenario of software defined VANET with 5G cellular network. Then, discuss the motivation of the control plane optimization.

3.1 Software Defined VANET with 5G

Software defined networking, which decouples the control and data planes of transitional networks, is an important technology for the next generation network. Here present a scenario that merging the SDN technology into a VANET with 5G cellular networks. Each vehicle as a 5G cellular network radio interface, and can connect to the IP network through the cellular base station. In the VANET, vehicles use RSUs to connect to the IP network. The SDN controller also connects to the same IP network to manage the VANET, including routing, access control, and flow control. The controller deploys the SDN rules to each RSU and vehicle to execute the forwarding strategies. To leverage the cost and the performance for the southbound communication, consider the hybrid control network structure in which control events can be sent through either the 5G cellular network or the ad-hoc network. Therefore, for transmitting some emergence control messages, the latency is guaranteed by the high performance cellular network.

3.2 Motivation

In the software defined VANET scenario, since the controller use both the ad-hoc network and the cellular network to control the network, the control plane of this SDN is combined structure of both the 5G cellular network and the VANET.

In this the data plane includes the communication modules in the vehicles, the links between vehicles, RSUs. In the control plane the scenario includes the 5G cellular links between base stations and vehicles and the parts in the data plane due to the hybrid mode in which the SDN controller can use both the 5G cellular network and the ad-hoc network to control the VANET. When compared to controller the hybrid mode reduces the cost of the energy and radio spectrums. It improves the stability of the control plane for forwarding strategies.

First, the cellular network costs more energy and budget for the network management, it is efficient to arrange the SDN events to different links with their priority. Second, vehicle needs to absorb the cost brought by the 5G cellular network, encourage vehicles to transfer control events through the cellular links. We design are bating mechanism that focuses on these two issues and present a two-level game model between the controller and vehicles.

4. Problem Statement

Vehicular Ad-Hoc Network (VANET) is a group of wireless mobility nodes and it is self-organized into a network without the need of any infrastructure. High mobility is big challenging issue in Vehicular Ad-Hoc Network (VANET). In the SDN structure, there are two different planes, namely the control plane and data plane. From some prospective works, software defined VANETs will have a similar structure. Usually, the data plane associates with the network devices for transferring network flows, which can be implemented by ordinary hardware with SDN interfaces. In VANET, after adding support for some mature SDN protocols, the roadside units (RSUs), vehicles and cellular networks can be converted to SDN devices for the data plane. Considering unique features of VANETs, where the latency of packet forwarding brings less influence to the network performance in some applications, it is possible to use common memories. In this work propose current an optimizing strategy to balance the latency requirement and cost on cellular networks, in which we encourage vehicles send the SDN control requests through the cellular networks by rebating network bandwidth. Vehicular interaction of the controller and vehicles as a two-stage Stackel-berg game and analyze the game equilibrium.

The project adopts an IEEE 802.11Ext standard for wireless access and aim at implementing a reference system. Now the list of notations is used in the rebating strategy of the software defined VANET is given below.

Table. 1 Notations in the Software Defined VANET model

Notation	Description
V	Set of all vehicles
v_i	One vehicle in set V
T	Set of all time slots
t_j	One time slot in set T
c	Rate that the VANET rents bandwidth from ISP
b_i	Bandwidth arranged to vehicle v_i in time period T
r_i	Rate that vehicle v_i pays for cellular links
e_i^c	Energy consumption for vehicle v_i sending one packet through the cellular links
e_i^a	Energy consumption for vehicle v_i sending one packet through the ad-hoc links
η_i	Rebating ratio for vehicle v_i in time period T
k_{ij}	Number of packets that vehicle v_i want to transfer in time slot t_j
k_i	Vector of the number of packets sent by vehicle v_i in the entire time period
s_{ij}	Number of event packets transferred by vehicle v_i through the cellular links in time slot t_j
s_i	Vector of s_{ij} in time period T
s_{ij}^t	Event packets to be sent by vehicle $v_i$in time slot t_j
l_{ij}^a	Latency of the vehicle v_i send one event packet in time $t_j$through the ad-hoc network
l_i^c	Latency of the vehicle v_i send one event packet in time period T through the cellular network

In this the game equilibrium in the arranging and rebating strategy with the controller and vehicle's payoff functions.

Algorithm 1: Single-Slot Strategy

```
Initialization: $s_{ij} \leftarrow 0$
while ($s_{ij} \le s^t_{ij}$) and ($f_{ij}(s_{ij}) > 0$) do
    $s_{ij} \leftarrow s_{ij} + 1$;
end while
```

Algorithm 2: strategy for Time Period T

```
Initialization: $s^*_i \leftarrow 0$
for $j \leftarrow 1$ to T do
    if ($f_{ij}(s^t_{ij}) > 0$) then
        $s^*_{ij} \leftarrow s^t_{ij}$;
    else
        $s_b = s^t_{ij}$;
        $s_e = 0$;
        while ($s_b > s_e$) do
            if ($f_{ij}(s^*_{ij}) > 0$) then
                $s^*_{ij} \leftarrow s^*_{ij} + \frac{s^*_{ij} + s_b}{2}$;
                $s^e \leftarrow s^*_{ij}$;
            else if ($f_{ij}(s^*_{ij}) < 0$) then
                $s^*_{ij} \leftarrow \frac{s^*_{ij} + s_e}{2}$;
                $s_b \leftarrow s^*_{ij}$;
            else if ($f_{ij}(s^*_{ij}) = 0$) then
                break;
            end if
        end while
    end if
    $s^*_i \leftarrow s_i \cup \{s^*_{ij}\}$;
end for
```

Algorithm 3: Newton's method for solving the game equilibrium

```
Find $h_i'(\eta_i^0) < 0$ as a given guess;
$\eta_i \leftarrow \eta_i^0$;
$\eta_i' \leftarrow 0$;
while $\eta_i' \leftarrow \eta_i > \Delta$ do
    $\eta_i \leftarrow \eta_i' - \frac{h_i(\eta_i')}{h_i'(\eta_i')}$;
    $\eta_i' \leftarrow \eta_i$;
end while
if $h_i'(\eta_i) < 0$ then
    $\eta_i^* \leftarrow \eta_i$;
end if
```

5. Performance Evaluation

This section, evaluate the performance and cost of the southbound communication in the software defined VANET with the cellular network with simulations. First, introduce the simulation settings and tools. Then, discuss the latency and cost in different settings.

Table. 2 Value of parameters used in simulations

PARAMETERS	VALUES
Simulator	NS2.34
Studied protcoals	AODV and DSDV
Simulation area (Grid size)	5000m x 500m
No. of nodes	93
Simulation time	100seconds
MAC type	IEEE 802.11
Traffic type	CBR
Mobility model	Random
Mobility speed	5 m/s

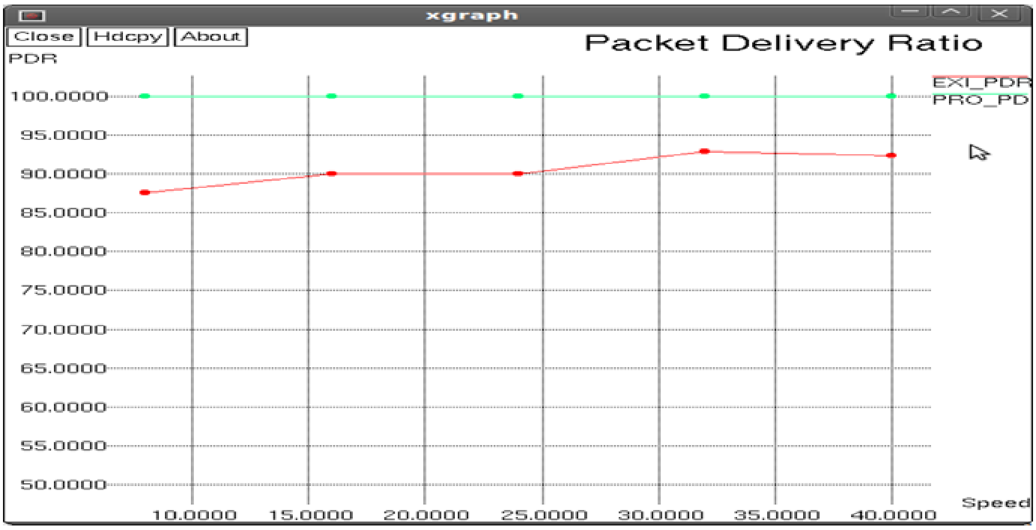
5.1 Results and Discussion

The controller-vehicle game under complete information, where both the controller and the vehicles know all system parameters. The game by backward induction. The vehicle's best cellular usage strategy in the communicates with the Road Side Unit (RSU) and On Board Unit (OBU) in the dynamic network, through simulations. The performance evaluation metrics and the comparison of the Cooperative vehicle safety system result are described through the NS2 Simulator.

Three metrics to evaluate the performance of the proposed mechanism are given. The route life time is defined as the link between the transmitting and receiving vehicles in the dynamic network. The data delivery ratio is the ratio of the number of successfully received data packets reached to destination vehicle through wireless medium. The delay is defined as the average time gap between the source vehicle and destination vehicle.

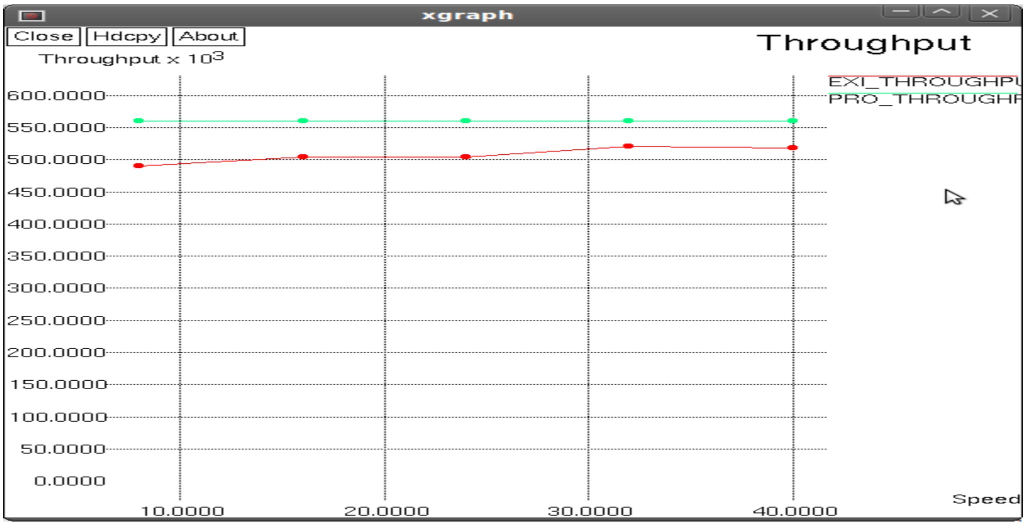
1. Packet Delivery Ratio

The ratio of the number of received data packets to the number of total data packets sent by the source.



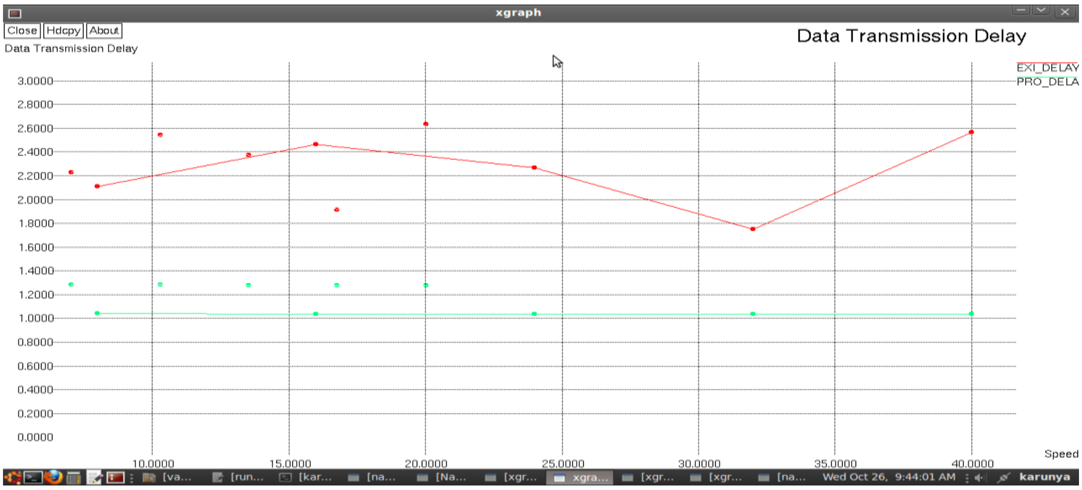
2. THROUGHPUT

Average rate of successful message delivery over a communication. Throughput is usually measured in bits per second.



3. DELAY

The average time elapsed for delivering a data packet within a successful transmission.



6. Conclusion and Future Enhancement

The development of control plane in software defined VANET with 5G cellular networks. Since the ad-hoc connections bring higher latency than high performance cellular networks while cellular networks cost much more energy and budget than the ad-hoc network, we design a bandwidth rebating strategy to balance the cost and performance in the southbound communication. The bandwidth rebating problem as a two-stage leader-follower (Stackelberg) game, and analyze the game equilibrium. Our hybrid mode with extensive simulations and compare its performance and cost with other southbound communication mode. From the result of performance evaluation, the hybrid southbound communication mode archives the balancing of the network cost and the network performance for the software defined VANET.

Ad-Hoc On demand Distance Vector (AODV) is one of the reactive routing protocols in wireless ad-hoc networks. The source vehicle sends a RREQ packet to its neighbors and it maintain the sender address and broadcast the RREQ till it reaches either to their destination or an intermediate node that has a valid route to destination, and the routing table is used to deliver a RREP packet to the source. The nodes add the next hop address to their routing table for destination during transferring the RREP. In AODV, when a link breakage occurs, a broken node would send a RERR message to a source node and again generate a new RREQ to find a new route.

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