A QoS Evaluation of AODV Topology-Based Routing Protocol in VANETs

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***Abstract*— Over recent years, a new technology named VANET (Vehicular Ad-hoc Networks) is highly recommended in a smart cities and especially in Intelligent Transportation Systems (ITS). VANET technology relies on the nodes acting like cars without the necessity for any controller or central base station by creating a wireless link among them. It enables cars to send and receive information between themselves and their environment. There are many network simulators that can support VANET environments such as NS-2, NS-3, OMNeT++, OPNET, and Qualnet. In this paper, we investigate the performance of a common reactive routing protocol; named (AODV) Ad-hoc On-demand Distance Vector routing where two scenarios are considered. The first scenario is a comparison between Vehicle to Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication modes. The second one is made between two maps Basrah city and Manhattan grid in Vehicle to Vehicle (V2V) mode; through the real-time interaction between OMNeT++ and SUMO. The implementation of AODV reveals a comparative results analysis using Quality of Service (QoS) parameters, such as packet delivery ratio, packet drop rate, and network throughput. The simulation results in a helpful guideline for researchers to improve and develop this protocol as compared to other existing works.**

Keywords*— *AODV, Vanet, QoS, OMNeT++, SUMO, Inet, Veins, V2V, V2I.

I. Introduction

Just imagine a situation in which a vehicle communicates its beacon information such as location, speed, directions, etc. with other vehicles in the neighborhood, as well as safety alerts, such as traffic, slippers, obstacles, and road conditions [1]. Thereby the vehicle should know the traffic status, crash, road conditions, etc. before it enters or faces such an environment. Since 1970, work has been started in the field of the ad-hoc network; the packet radio networks are known initially [1-3]. It is mainly a concept of creating a temporary wireless network between moving nodes. VANET (Vehicular Ad-hoc Network) is an improvement over MANET (Mobile Ad-hoc Network) that follows the movement of nodes based on road infrastructure.

VANET is a special case of mobile ad-hoc networks, which can be different from it in the high mobility of nodes (vehicles), the unusual or unequal distribution of vehicles, and the restricted connectivity among nodes because of the constraints enforced by the topology of highways and/or urban roads in VANETs, as in most networks, communication between nodes must follow the standardization of Open Systems Interconnection (OSI), which express general guidelines for the operation of the network.

VANET has a higher, more systematic mobility and a wider coverage area in comparison to MANET, it does not require much or no power and has no service charge. In order to upgrade the construction of roads, for instance, the number of road cars, the number of lanes, the number of roadside units(RSUs), etc., the continuous exchange of data is nevertheless necessary. In addition, to ensure appropriate and secure navigation and speed control of the vehicle, VANET requires quick, precise environmental data [4-5].

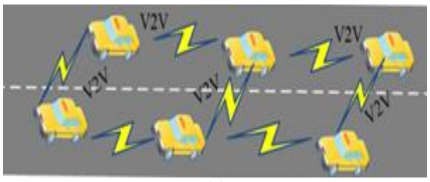
As the mobility and the number of nodes constantly change, the VANET throughput is low and packet loss is high as a result of connection failure. The VANET topology is difficult and not uniformly distributed. The ad-hoc on-demand distance vector (AODV) adapts rapidly toward variations in the dynamic link, has low overheads for storage and processing, and offers a low network usage to assign unicast routes to the destination of a network between VANET routing protocols.

The structure of this paper as following: Section II contains the context for VANET background. Section III describes briefly the AODV protocol. Section IV introduces the related work compared with the proposed network. In Section V, the simulation tools are explained to provide a suitable real-time environment for the proposed network. In Sections VI and VII, the simulation setup, and QoS performance metrics are shown successively. The results are discussed in Section VIII. Finally, the conclusion is drawn in Section IX.

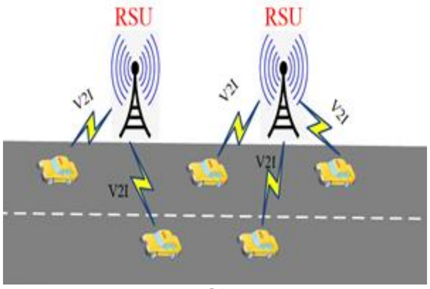
II. Vanet Background

The evolution of mobile communications, as well as current developments in ad-hoc networks, allow a wider range of applications with various QoS requirements to serve various architecture in highway, urban and rural areas. The purpose of VANET architecture is to enable contact between near vehicles and between vehicles and roadside infrastructure, which leads to the three following methods.

- Vehicle-to-Vehicle (V2V) ad-hoc network: Allows direct contact of vehicles without the assistance of fixed infrastructure and can be used primarily for distribution applications, security, and safety.
- Vehicle-to-Infrastructure (V2I) network: enables the communication of a vehicle with roadside infrastructure, primarily for applications for data collection and information.
- Hybrid architecture (V2X): merges both Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) [6].



(a)



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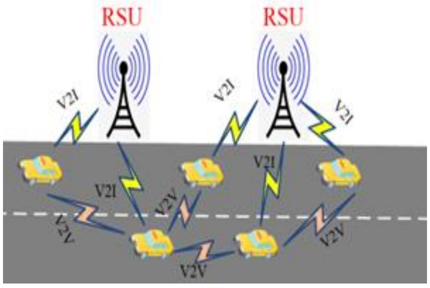

(c)

Fig.1. The architecture of VANET: (a) Vehicle-to-Vehicle (V2V) (b) Vehicle-to-Infrastructure (V2I) (c) Hybrid architecture (V2X).

III. AODV Routing Protocol

Ad-hoc On-Demand Distance Vector is a reactive routing protocol or an on-demand for an ad-hoc wireless network. When it is required to send data packets to the destination node, and discovers that it doesn't have a route to the destination node before the transmission of the data packets it starts a path discovery [7-10].

The network consists of three procedures:

(1) The route discovery process.

(2) The route message generation.

(3) Route maintenance.

Since the route is generated only when required, it needs less overhead than proactive routing protocols. Consequently, the low overhead needed is one of the main benefits of AODV.

AODV uses a basic request-reply method for the exploration of routes. The AODV protocol primarily consists of the following message type.

1. The route request (RREQ): is primarily used to set up packets from source to destination.
2. The route reply (RREP): is sent to the source by destination after the establishment of a route.
3. The route error (RERR): is sent from the destination or intermediate node under two conditions.

- When there is no route to the destination.
- When the connection break.

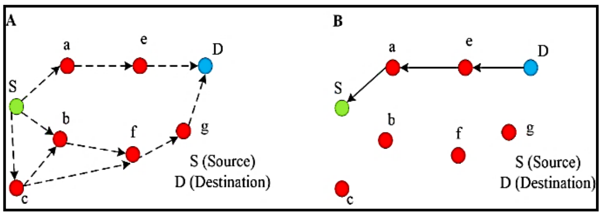

Fig.2. (a) Route Request (RREQ) in AODV (b) Route Reply (RREP) in AODV: Route Discovery in AODV Protocol.

IV. Related Work

In this section, some of the latest relevant work is reviewed in Table I. The comparative performance in the VANET environment involves several nodes (vehicles), a type of network simulator, simulation time, and QoS performance metrics such as packet drop rate, packet loss ratio, average end-to-end delay, jitter, routing load traffic, and network throughput.

TABLE I. A PERFORMANCE OF EXISTING WORKS.

Ref	Protocol	Software	No. of nodes	Simu lation time [sec]	Performance metrics
[3]	AODV	NS2, SUMO, MOVE	500	1000	Packet Drop Rate (PDR), Av. E2E Delay, Network Throughput, Jitter, Routing load
[5]	AODV	OMNeT, SUMO	100-800	1000	Packet lost, Throughput, Average E2E Delay, Packet Delivery Ratio
[8]	AODV, DSR, GRP, OLSR	OPNET	20,30	3600	Average Throughput, Average load, Delay, Average of routing traffic send
[11]	AODV, GPSR	OMNeT, SUMO	100-500 (High Vehicles Traffic)	600	Throughput, Packet Delivery Ratio, Packet Drop Ratio,E2E Delay
Our Scen ario	AODV	OMNeT,S UMO	10,15,20 ,25,30	600	Packet Delivery Ratio, Packet Drop Rate (PDR), Network Throughput

V. Simulation Methodology

Here the simulator tools are used to evaluate the behavior of AODV in VANET: The work is applied using two simulators: (a) The Network simulator OMNeT++ and (b) Traffic Simulator SUMO with the help of INET Framework and Veins [12].

A. SUMO

SUMO (Simulation of Urban Mobility) is a traffic modeling package built for massive, highly portable, microscopic, and continuous open-source networks [13]. It provides intermodal modeling, like pedestrians, and a wide variety of scenario-generating tools.

Fig.3. Basrah streets in SUMO 1.6.0.

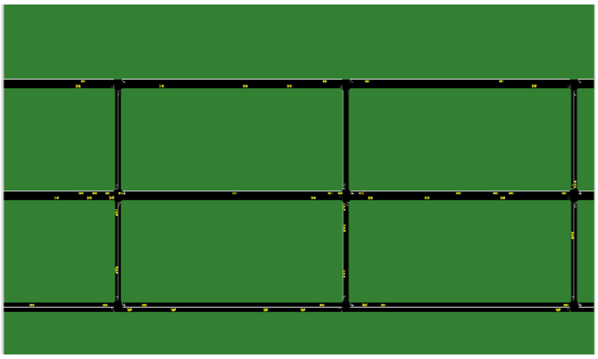

Fig.4. Manhattan grid in SUMO 1.6.0.

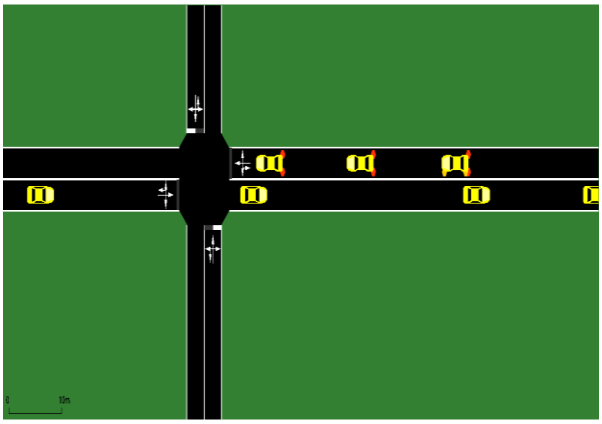

Fig.5. City Scenario in SUMO 1.6.0.

The following steps in the SUMO 1.6.0 are used to generate the maps.

Step 1:	From the "Open Street Maps" website, we select the desired region, and then export it as a (map.osm).
Step 2:	Generate the map file (x.net.xml).
Step 3:	Importing additional polygons (Buildings, Water, etc.), from the website, and save it as (typemap.xml).
Step 4:	Perform the command polyeonvert to generate the file (x.poly.xml)
Step 5:	Generate Vehicle movement (x.rou.xml)
Step 6:	Create (x.sumo.cfg) that contains: a. Net-file(x.net.xml) b. Route-files(x.rou.xml) c. Additional-files(x.poly.xml)
Step 7:	Run the simulation.

B. OMNeT++

OMNeT++ is an extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators[14]. "Network" is meant in a wider context, like wireless and wired communication networks, queueing networks, on-chip networks, etc. A model architecture developed as independent projects offer domain-specific capable functions, such as sensor network support, ad-hoc wireless networking, internet protocols, performance modeling, photonic networking, etc. OMNeT++ provides a graphical runtime environment and several other tools. Real-time simulation extensions, system C integration, database integration, network emulation, and numerous other functions are available. In the Academic Public License, OMNeT++ is distributed. After installing OMNeT++ from the official website we need an additional installation of the "INET framework" and "Veins framework" from their official website [15,16].

C. INET Framework

In the OMNeT++ simulation environment, the INET framework is the open-source model library. It offers protocols, agents, and other models for students and researchers working on communication networks. INET is particularly valuable when developing and authenticating new protocols or investigating new or unusual scenarios [17].

INET provides internet stack models (such as IPv4, IPv6, OSPF, TCP, UDP, BGP, etc.), mobility support, MANET, DiffServ, MPLSs with LDP, and RSVP-TE signaling, a range of applications, and several other protocols, INET includes wireless and wireless link layer protocols. INET is created around the notion of modules interacting via the transmission of the message. Components that can freely be linked to form routers, hosts, switches, and other networked gadgets are addressed to agents and network protocols.

The user could program new components, and existing components were written so that they could be easily interpreted and updated.

D. Veins

Vehicles in Network Simulation (Veins), is an open-source vehicle network simulation application. It is based on two well-developed simulators: OMNeT++, an event-based network simulator, and SUMO, a road-traffic simulator [18]. These are generalized to include a full suite of IVC simulation models.

The Veins architecture provides a robust collection of models designed to create network simulations of the vehicle as practical as reasonable. The OMNeT++ and SUMO interface and IDE can be used to quickly set up and run simulations on a collaborative basis.

The simulation needs sumo-launchd to be started and listening for connections on a TCP socket, in the MinGWx64 command line window Fig.6 shows the connection between OMNeT++ and SUMO.

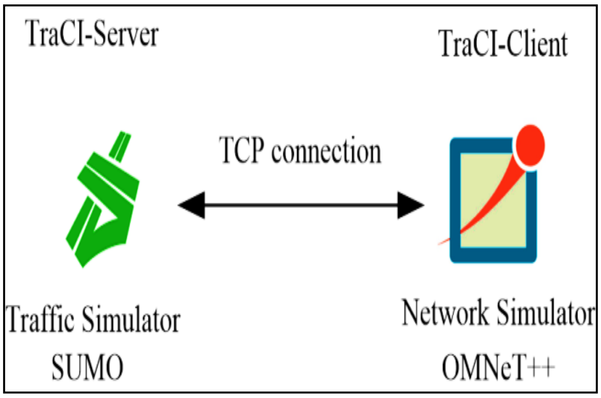

Fig.6. TCP connection of OMNeT++ with SUMO.

VI. Simulation Setup

The routing protocol is evaluated in Urban scenarios, in Basrah, Iraq, and the Manhattan grid as shown in Fig. 3 and 4 in urban streets. Where the speed is set to 30Km/h for the first scenario and 60Km/h for the second scenario. The required maps were downloaded from OpenStreetMap and configured for working with SUMO. The Scenario's details are shown in Table II. The calculation in the scenarios has been done using the simulation parameter as shown in Table III.

TABLE II. AODV SIMULATION SCENARIOS.

Parameter	**Scenario 1**	**Scenario 2**
Communication mode	V2V and V2I	V2V
Vehicle speed	30 Km/h	60Km/h
Number of vehicles	10,15,20,25,30	10,20,30
Number of RSU	1	------
Map	Basrah city	Basrah city, Manhattan grid
Simulation time	600sec	600sec

TABLE III. SIMULATION PARAMETERS.

Parameter	**Value or Protocol**
OMNeT++ version	OMNeT++ V 5.5.1
SUMO version	SUMO 1.6.0
INET version	INET 4.2.1
Veins version	Veins 5.0
Simulation area	2500 * 2500 m
MAC Protocol	IEEE802.11p
Routing Protocol	AODV

VII. Performance Metrics

The AODV routing protocol is applied here. The essential metrics are determined after the efficient execution of the program as follows:

1. *Packet Delivery Ratio:* It is obtained from the whole number of data packets that have arrived at destinations, divided by the whole data packets sent from the source.
2. *Packet Drop Rate (PDR):* The Packet Drop Rate is obtained by subtracting the whole packets sent from the whole packets received on the whole packets sent.
3. *Network Throughput:* It is obtained by dividing the whole data sent on the whole time.

VIII. PERFORMANCE EVALUATION

For the first scenario, two situations of V2V and V2I were investigated in Basrah city when the AODV protocol is considered. The implementation of AODV was provided using OMNeT++ and SUMO simulation tools. Such a protocol is the most vulnerable protocol for various routing attacks. Therefore, by introducing such a network routing attack, we can easily calculate the impact of various parameters on network performance. The Packet Delivery Ratio in Fig.7 is more suitable in the case of (V2V), than (V2I).

In addition, Fig.8 depicts that the Packet Drop Ratio (PDR) becomes lower in (V2V) compared to (V2I). Meanwhile, the throughput, as shown in Fig.9, it is slightly higher for (V2I) as the number of nodes is minimum, but the throughput becomes slightly higher in (V2V) as the number of nodes increases.

And for the second scenario where two maps are considered in V2V communication mode: (a) simple map (Basrah city) and (b) Manhattan grid map when the vehicle speed is 60Km/h and the number of vehicles does not exceed 30. The obtained results demonstrate that the packet delivery ratio in Fig.10, shows the Manhattan grid has approximately better performance, as for the packet drop ratio in Fig.11 both maps give a reasonable outcome. Meanwhile, in Fig.12 the Manhattan grid shows good throughput compared to Basrah city when the number of vehicles is increased to 30.

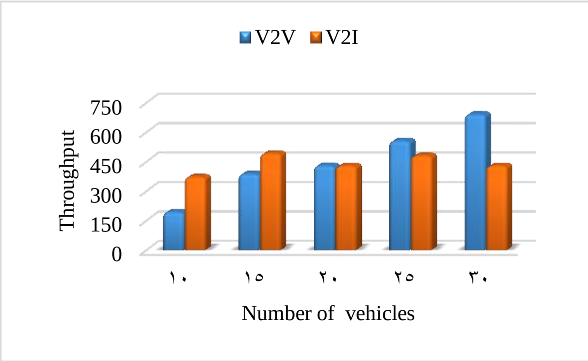

Fig.9. Throughput vs. The number of vehicles.

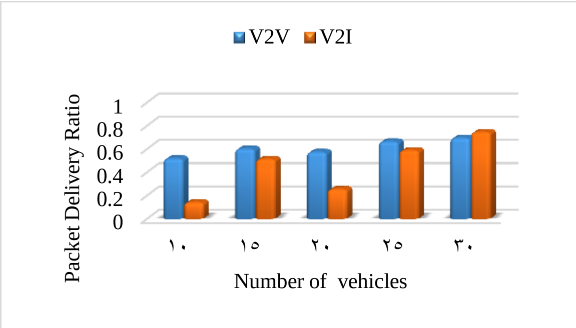

Fig.7. Packet Delivery Ratio vs.The number of vehicles

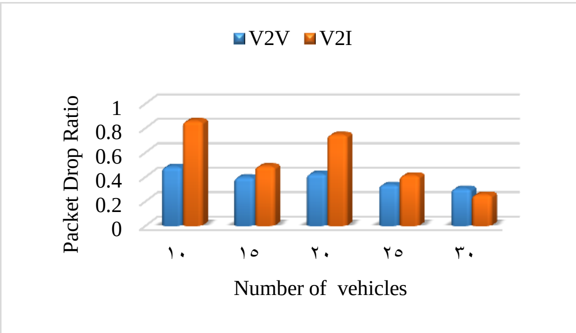

Fig.8. Packet Drop Ratio vs. The number of vehicles.

IX. CONCLUSION

We introduced the analysis of the "AODV" routing protocol in urban scenarios, by using the simulation programs SUMO, and OMNeT++, using the MAC protocol IEEE 802.11p. Our scenarios depend on varying the number of vehicles and two different maps in the case of (V2V) and (V2I). As the result, the AODV routing protocol reveals a good performance in terms of QoS metrics as obtained higher throughput in Manhattan grid map compared to the Basrah city map; while the packet drop ratio, that is obtained from the simulation seems satisfactory, but it needs to be reduced more when the number of vehicles changes during data packet transmission. Thereby, for future work, this AODV protocol can be enhanced by implementing or integrating one of the intelligent approaches such as a Fuzzy logic or GA, PSO, and ABC to obtain more significant improvement in its performanc.

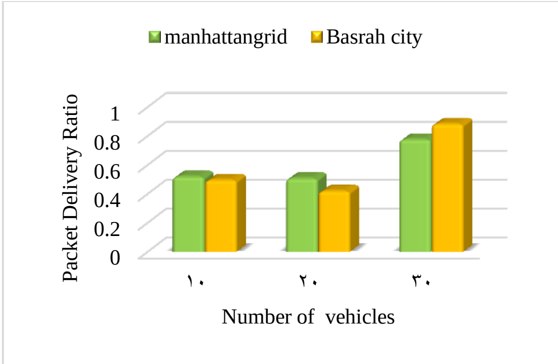

Fig.10. Packet Delivery Ratio in V2V mode.

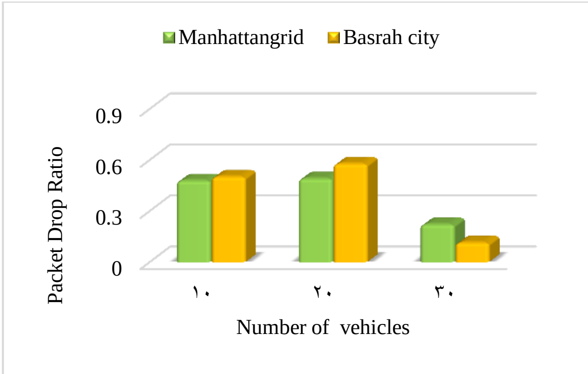

Fig.11. Packet Drop Ratio in V2V mode.

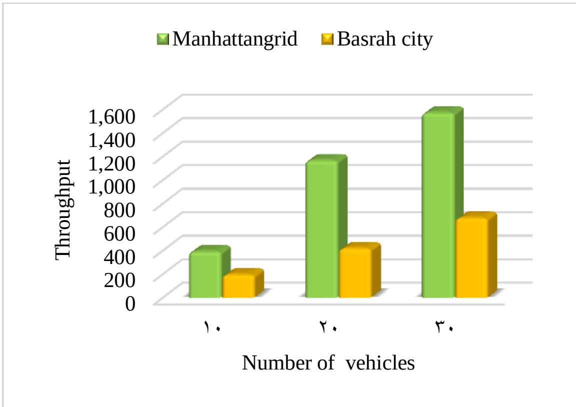

Fig.12. Throughput in V2V mode.

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