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Research Article

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Posted Date: March 29th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-192207/v1

Performance Evaluation and Discrimination of AODV and AOMDV VANET Routing Protocols Based on RRSE Technique

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***Abstract*:** The routing protocol is an applied standard to determine the communication scheme of different entities with each other to transfer and process the desired data in considerable time via the best routes from the source to the destination. This paper presents the performance evaluation and discrimination for various parameters of two different routing protocols using the Root Relative Squared Error (RRSE). The two protocols under study are Ad-hoc On-demand Distance Vector (AODV), and Ad-hoc On-demand Multipath Distance Vector (AOMDV). The literature reviews reveals the simulation results of number of nodes that varies approximately between 5 to 100 nodes. Therefore, that he simulation results will be analyzed for two different experiment as follows the first, the effect of initial node energy variation between 50 to 100 Joules at a fixed network size. Whereas in the second, reveals the impact of the network size, which varies between 50 to 450 nodes at constant initial node energy that it is tested between 50 to 100 Joules. The obtained results of the selected parameters prove that the AOMDV protocol is more efficient, robust, and reliable than the AODV protocol for the first experiment, while the RRSE values of AODV are better for the second. Moreover, the proposed technique based on the RRSE algorithm advantageous to compare the two routing protocols.

Keywords: VANET, Throughput, Packet Delivery Ratio, Average End to End Delay, AODV, AOMDV.

I. INTRODUCTION

Ad-hoc is a Latin phrase that means "for this special purpose" [1]. It is a special type of a local area network (LAN), with an infrastructure-less network that coordinates the flow of messages between vehicles, (V2V) communication, and communication between roadside Infrastructure units (RSUs) (V2I) [2]. The possibility of the exchange of data between vehicles over an ad-hoc network environment is called Vehicular Ad-Hoc Network (VANET). VANET is a sub-class of the Mobile Ad-Hoc Network (MANET) that uses radio-frequency channels as their physical medium where the vehicles are used instead of the mobile nodes. The nodes are moving separately in any direction so that the network topology is changing continuously.

VANET is an urgent need to cut back the carbon emissions and environmental pollution by emitting less amount of gasses, mitigate road incidents, conserve energy, and relieve congestion [3]. It helps vehicle drivers to communicate and to coordinate among themselves in order to improve traffic safety by transmitting information to drivers and concerned authorities [4], transportation efficiency, and to avoid any critical situation through V2V communication (e.g. road accidents, traffic jams, over-speed, free passage of emergency vehicles and unseen obstacles… etc.). [4].

The routing protocol is a standard specifies how different entities communicate with each other in the shortest path, to transfer the desired information in considerable time via the best routes from the source vehicle to the destination. The VANET routing protocols are classified as follows: Position-Based, Topology, Broadcast, Cluster, and Geo-cast based routing protocol [5]. This paper concentrates on topology based routing protocols. In VANETs, the term topology routing refers to find the shortest path between source and destination nodes [6]. It is divided into Proactive, Reactive, or Hybrid routing protocols [7]. In the proactive routing protocols, each node inside the network uses a routing table, which maintained and updated periodically to identify the next hop towards the destination besides all hop counts for the destinations [8], regardless of network load, bandwidth constraints, or network size. In the reactive routing protocols, the source nodes search on-demand the routes to the destination then creates the connection to transmit and receive the packets. The hybrid routing protocols utilize the capabilities of both reactive and proactive protocols and unite them together to achieve better results [4].

In this paper, two different routing protocols will be evaluated and discriminated, Ad-hoc On-demand Distance Vector (AODV) protocol, and Ad-hoc On-demand Multipath Distance Vector (AOMDV) protocol, based on the Root Relative Squared Error (RRSE) technique, with the same simulation parameters. The selected parameters of performance evaluation are sent packets (SP), Packet Delivery Ratio (PDR), Normalized Routing Load (NRL), Average End-to-End delay (AETED), and an Average Through-Put (ATP). In this study, two different scenarios are presented: the first scenario, the effect of changing the initial node energy is ranging between 50 and 100 Joules at a fixed network size, which is selected between 50 and 450 nodes. The second scenario offers the impact of varying the network size between 50 and 450 nodes at constant initial node energy, which is pre-determined between 50 to 100 Joules.

II. LITERATURE REVIEW

There are many papers developed for evaluating the performance of various routing protocols such as AODV, AOMDV, CBF, ASTAR, and GPCR, DSDV, GPSR, OLSR, and GPCR. Five routing protocols (AODV, DSDV, GPSP, OLSR, and GPCR) were simulated in [9]. The simulation results revealed that OLSR was the best in terms of throughput and PDR. In contrast, the GPSR and GPCR confirmed to be more efficient in the event of overhead and latency. Paper [10] presented the performance investigation for diverse environments (Real-world, Highway Scenario, and Manhattan Grid) by density variation of vehicles for three protocols (AODV, DSR, and DSDV). It observed that the DSR performance, in general, is efficient in both terms of throughput and latency, as compared to AODV and DSDV. DSR showed maximum throughput for the scenario of real-world and Manhattan grid whereas its performance vanished in the case of the highway. In this case, study, the AODV performed efficiently with respect to DSDV in terms of throughput. The latency for DSR in all scenarios is the minimum, whereas the AODV verified the maximum latency for the real world and the grid scenarios. The paper [11] developed the mobility model of DSDV based on speed nodes variation. The results proved that as the nodes speed increased both PDR and throughput gave a poor performance. In [12], the comparison of eight VANET protocols (AODV, DSR, FSR, DSDV, OLSR, ZRP, GPSR, and DYMO) for the parameters (PDR, latency, throughput, and the routing cost as performance metrics) in an urban environment using realistic node mobility. The results showed that the geographic routing protocols performed better than the rest of the protocols; as this type of protocol uses the information of the node's position proving it suitable for this kind of network. In [13], the performance of (AODV, OLSR, and DSDV) was compared in the cases of low-density, low-speed scenarios, an increase in the density or speed of nodes. The results displayed that DSDV and OLSR performed better than AODV. The analysis of produced results concluded that OLSR outperformed better than the other two protocols in the event of increasing the density or speed of nodes. The routing protocols (AODV, DSR, and DYMO) were evaluated in [14]. It was noticed that in case of latency the AODV has a better performance than others do. The DYMO has low latency and large throughput so that it is better than the other two protocols. In [15], the simulation results were performed using AODV and MAODV in terms of PDR. The obtained results confirmed that the MAODV had performed more efficiently than the AODV. The performance parameters (throughput, packet loss, latency, and PDR) are estimated in [16] for the routing protocols AODV, AOMDV and DSDV. The produced results showed that AOMDV outperforms AODV and DSDV for packet loss and PDR. In spite of this AODV throughput was efficient than that of AOMDV and DSDV. Moreover, the results confirmed that DSDV performance is better than AODV and AOMDV in case of latency.

III. TOPOLOGY BASED ROUTING PROTOCOLS

The topology-based routing protocols are classified as (reactive, proactive, and hybrid). This paper concentrates on the reactive routing protocol that protocol has two phases as follows:

- Route discovery: the source vehicle issues a route discovery broadcast packets within the network to exchange data when there is a demand if the route towards the destination is not included in the current source vehicle routing Table.
- Route maintenance: it is required when the route is broken. It is due to the continuous links failure within the established route. The confirmation of correctly received packet is done by backward Route.

The paper presents a simulation of two reactive based routing protocols: AODV and AOMDV. They are briefly described as follows:

A. Ad-hoc On-Demand Distance Vector (AODV) Protocol:

AODV minimizes the number of required broadcasts by creating routes on demand. When a route to a specific destination is needed, the source node broadcasts a Route REQuest message (RREQ) to its neighbors. Each request has a sequence number to eliminate the possibility of forwarding the same packet more than once. Information with a higher serial number represents a more correct and fresh value [7]. When the destination node receives the request, it sends back a Route REPly message (RREP) to the source node, through a temporary path to it. Both route requests and route replies are responsible for the route discovery phase. Then update the entries in the node routing table, with only the next hop. The unused routing table entities are removed after a period of time [17]. If a link fails, then a Rout ERRor (RERR) message passed back to the source that contains a list of all nodes that affected by link failure [18]. When the source node receives it, it can reinitiate route discovery again [19].

B. Ad-hoc On-Demand Multipath Distance Vector (AOMDV):

It is an extension of the AODV routing protocol, which is an on-demand multipath decision-making protocol. It discovers multipath between the source and destination in single route discovery. The paths are computed and guaranteed to be loop-free and disjointed. This protocol uses alternative paths to reach the destination when all routes fail. It avoids the possibility of congestion and increases reliability. On the other side, it increases the network overhead in the discovery phase [8]. The protocol has extra RREP and RERR for multipath discovery and maintenance along with extra fields in routing control packets. It has a loop-free and disjoint path so that each node needs to follow two rules [20]: First, for the same destination sequence number, nodes never advertise a route shorter than one already advertised. The advertised hop-count is defined in [6] as the maximum hop-count of the multiple paths for destination available to the source node. Second, nodes never accept a route longer than one already advertised. It keeps up connectivity, fast, and useful approach for recovering errors. On the other hand, it has more message overheads during new path discovery because of grown-up steeping since it is a multipath routing protocol [7].

IV. SIMULATION SETUP AND PARAMETERS

A. **Simulation Setup**

NS-2 is an open-source discrete event-driven simulator designed specifically for research in computer communication networks [17]. The network simulator tool (NS-2 version 2.34), is based on a Virtual machine that uses Ubuntu operating system release 16.04 with an Intel Xeon processor with 48 GB RAM. NS-2 utilizes Network Scenario Generator version 2.1 (NSG 2.1). NSG is a TCL script generator tool, which generates TCL (.tcl) scripts automatically. When running it, a new format of trace file (.tr) will be generated. The Network Animator (NAM) tool visualizes the movement of the vehicles. To read the output trace file and to evaluate the performance results the (.awk) scripts are used. In this paper, the performance of AODV and AOMDV is evaluated with a number of connection counts of 50% from the network size within the simulation area of two km^2 during a time of 100 Sec. The simulation parameters are listed in Table (1).

Table (1) Simulation Parameters of Network

Simulator Parameter	Values
Network Simulator	NS-2 version 2.34
Antenna Model	Antenna/ Omni Antenna
Radio-propagation model	Propagation/ Two Ray Ground
Channel type	Channel/ Wireless Channel
Interface queue type	Queue/ Drop Tail/ PriQueue
MAC type	MAC /802.11
Routing protocol	AODV and AOMDV.
Number of Vehicles	50,100,150,200,250,300,350,400, and 450
No. of Connections	50% of Number of Vehicles.
Vehicles Speed	Min 10 m/s, Max 40 m/s
Simulation time	100 Sec.
Simulation area	(2000*1000) = 2 km^2
Packet Size	512 Packets per Second
Initial node energy	50 , 60, 70, 80, 90, and 100 Joules

The simulation results are evaluated in two experimental as follows:

1. The effect of initial node energy changes at a certain network size.
2. The effect of network density changes at a certain initial node energy.

*B. **Performance Parameters:***

In this study, the performance is measured using the following five parameters: Sent Packets (SP), Packet Delivery Ratio (PDR), Normalized Routing Load (NRL), Average End-to-End Delay (AETED), and Average Throughput (ATP). These parameters are defined as follows:

1. Sent Packets (SP): it is the total number of packets sent from any source node through the network in a particular time interval.

2. Packet Delivery Ratio (PDR): it is the ratio of total data packets received at the destination to the total data packets sent from the source nodes [21]. This parameter is useful for measuring the reliability and capacity of the tested routing protocol. The PDR high value means a better routing protocol. PDR can be formulated as follows:
$$PDR = 100 * \frac{\sum_{i=0}^{n} Number\ of\ receivedPackets}{Total\ Number\ of\ Send\ Packets} \quad (1)$$

3. Normalized Routing Load (NRL): it is the total amount of data traffic being carried by the network. It is defined as the number of transmitted routing packets divided by the number of data packets delivered to the destination successfully. The network load happens when there is more traffic coming in the network, and it is difficult for it to handle this large data. High network load reduces the packet delivery to the destination [22]. The lower value of NRL means a better routing protocol. NRL can be estimated as follows:
$$NRL = 100 * \frac{Total\ Number\ of\ received\ packets}{Total\ Number\ of\ sent\ Packets} \quad (2)$$

4. Average End-to-End Delay (AETED): it is the time for one trip of data packet transmission from a source node to a destination node [23]. The AETED is the average time of all these network connection trips. Besides, it includes all possible delays caused by buffering during the route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation delay, and transfer times, and carrier sense delay for carrier sensors [24]. The lower delay indicates higher protocol performance [22]. VANET requires a small latency to deliver quick messages. The AETED can be computed as follows:
$$AETED = \frac{\sum_{i=0}^{n} Time\ at\ received\ packet - Time\ of\ sent\ Packet}{Total\ Number\ of\ received\ Packets} \quad (3)$$

5. Average Throughput (ATP): it is the total number of packets that have been successfully delivered from source node to destination node in a particular time interval, the simulation Time Interval Length (TIL) [24]. It is considered a measure of how fast a node can actually send data through the network [23] to reach its destination. In addition to that, it is a measure used to determine the efficiency of the network. Moreover, it is the maximum data rate transfer between two terminal nodes in a network [24]. This item can be improved by increasing node density, and it is measured in bits or packets per Sec. [21]. The ATP can be calculated as follows:
$$Average\ Throughput = \frac{Number\ of\ received\ packets * packets\ size}{Total\ duration\ of\ the\ simulation\ (TIL)} \quad (4)$$

V. RESULTS ANALYSIS:

In this section, the simulation and performance investigation of AODV and AOMDV protocols are examined on the basis of the mentioned metrics, Sent Packets (SP), Packet delivery Ratio (PDR), Normalized Routing Load (NRL), Average end-to-end delay (AETED), and Average Throughput (ATP). The node density changes between 50 and 450 nodes with the step of 50 nodes and the initial node energy varies from 50 to 100 joules with step of 10 joules. To compare the simulation results for AODV and AOMDV, the numerical formula of Root Relative Squared Error (RRSE) is applied. Mathematically, the RRSE of each step is evaluated by the following equation:
$$RRSE = \sqrt{\frac{\sum_{k=1}^{N}(xf(k) - xo(k))^2}{\sum_{k=1}^{N}(xo(k) - xm)^2}} \quad (5)$$
Where,

RRSE= Root Relative Squared Error,

$x_{f(k)}$ = The forecast value at sample *k*.

$x_{o(k)}$= The observed value at sample *k*.

x_m= The mean value.

N= the number of observations.

The simulation results are analyzed for two scenarios:

1. The Effect of Initial Node Energy Change at Certain Network Size.

Table (2) summarizes five cases for the effect of initial node energy (50, 60, 70, 80, 90, and 100 joules) as the X-axis, and Y-axis is the performance parameter (SP, PDR, NRL, AETED, and ATP). This is performed at each network size, which is selected from 50 to 450 nodes with a step of 50 nodes. Where the number of vehicles connection is 50% of the network size.

Table (2) Simulation parameters of scenario (1)

Case study	Initial Energy (X)	Parameter RRSE (Y)	Network Size
Case 1	(50, 60…& 100 joules)	SP	This is performed at each network size, which is selected from 50 to 450 nodes with the step of 50 nodes.
Case 2		PDR	
Case 3		NRL	
Case 4		AETED	
Case 5		ATP	

Scenario (1) Case (1):

In case 1, Table (3) summarizes the RRSE values of Sent packets (SP) of both protocols, which are computed by Eqn. (5). These values are plotted in Fig. 1(a). For different network, sizes and initial node energy between 70 and 100 joules the RRSE values of both protocols are similar and equal to zero. Except for RRSE values of AODV at network size 200 nodes while for AOMDV the RRSE values are equal to zero and for network sizes of 50,100, and 150 nodes where RRSE values of AODV is better than AOMDV. At network sizes of 50,100, 150, and 250 nodes, and the initial node energy between 50 and 70 joules the RRSE values of AODV are less than those of AOMDV. Vice versa, for the network sizes of 300,350, 400, and 450 nodes, and the initial node energy between 50 and 70 joules the RRSE values of AOMDV are less than those of AODV.

Table (3): Scenario (1) case (1), the effect of changing initial node energy at different network density for the Sent Packets (SP).

RRSE of SP at different initial node energy for AODV									
Initial Node Energy	The network Density Size								
	50	100	150	200	250	300	350	400	450
50-60	0.91	0.80	0.76	4.25	0.69	0.70	0.70	0.68	0.68
60-70	4.06	2.51	2.30	0.68	2.05	2.07	2.08	2.03	2.02
70-80	0.00	0.00	0.00	1.23	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00
90-100	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
RRSE of SP at different initial node energy for AOMDV									
50-60	0.96	0.89	0.80	0.75	0.71	0.69	0.69	0.67	0.65
60-70	7.19	3.54	2.52	2.23	2.11	2.07	2.05	2.00	1.97
70-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-100	0.07	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00

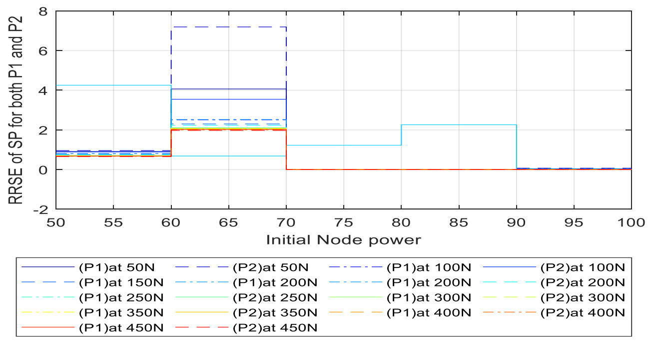

Fig.1 (a): Scenario (1) case (1), the RRSE of sent packets of AODV (P1) and AOMDV (P2) at different initial node energy and certain network density size (N).

Scenario (1) Case (2):

In case (2), Table (4) the RRSE values of Packet Delivery Ratio (PDR) for AODV and AOMDV routing protocols are mentioned and plotted in Fig.1(b). For different network, sizes and initial node energy between 70 and 100 joules the RRSE values of PDR for both protocols are similar and equal to zero, exclude for network sizes between 50 and 150 nodes and initial node energy between 90 and 100 joules, the RRSE values of PDR for AODV is only equal to zero. In addition to at network size of 200 nodes and initial node energy between 70 and 100 joules the RRSE values of AOMDV is better than AODV and is equal to zero. It also is better at initial node energy and about 0.90 between 50 and 60 joules, and between 60 and 70 joules, the RRSE value of AODV is better and approximately equal to 0.74. At network, size of 50 nodes and initial node energy is between 50 and 60 joules the RRSE values of AOMDV are better than AODV. When the initial node energy between 60 and 70 joules and between 90 and 100 joules the RRSE values of AODV are better otherwise both protocols have equilibrium and zero RRSE values. At network size of 100, 300 and 450 nodes and initial node energy between 50 and 60 joules, the RRSE values of AODV is better than those of AOMDV. This is valid also network sizes 50, 200, 300, and 450 nodes at initial node energy between 60 and 70 joules. The RRSE values of AOMDV is better than AODV for the network sizes of 50, and 200 nodes for initial node energy between 50 and 60 joules. Also at network size of 100 nodes and initial node energy between 60 and 70 nodes. For the network, sizes of 150,250,350 and 400 nodes at initial node energy between 50 and 70 joules the RRSE values of PDR for AOMDV are better than AODV.

Table (4) case (2), the effect of changing initial node energy at different network density for the packet delivery RATIO (PDR).

RRSE of PDR at different initial node energy for AODV									
Initial Node Energy	The network Density Size								
	50	100	150	200	250	300	350	400	450
50-60	1.08	0.72	0.86	1.21	0.93	0.77	0.89	0.86	0.79
60-70	1.78	2.14	3.08	0.74	4.87	2.35	3.46	3.04	2.42
70-80	0.00	0.00	0.00	1.48	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00
90-100	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
RRSE of PDR at different initial node energy for AOMDV									
50-60	0.96	1.93	0.31	0.90	0.79	1.00	0.76	0.83	0.87
60-70	2.83	0.50	0.15	3.66	2.42	5.20	2.31	2.74	3.21
70-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-100	11.56	3.84	5.54	0.00	0.00	0.00	0.00	0.00	0.00

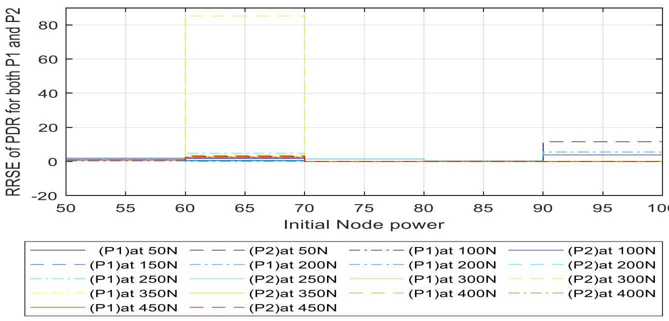

Fig. 1(b): scenario (1) case (2), the RRSE of the PDR of AODV (P1) and AOMDV (P2) at different initial node energy and certain network size (N).

Scenario (1) Case (3):

In case (3), it is concluded in table (5), also it is plotted in Fig. 1(c), which presents the RRSE values of Normalized Routing Load (NRL) for AODV and AOMDV at different network densities. The results show that when the initial energy between 70 and 100 joules, the RRSE values of NRL for different network sizes show that both protocols are at equilibrium and their values are equal to zero. Except for initial node energy between 90 and 100 joules the RRSE values of AODV is better than AOMDV and equal to zero, while AOMDV is not equal to zero. In addition to, at network size of 200 nodes the RRSE values of AOMDV are equal to zero and for RRSE values for AODV are not equal to zero. For initial node energy between 50 and 70 joules and network size between 50 and 350 nodes the RRSE values of AODV is better than AOMDV, and for 400 and 450 nodes the RRSE values of AOMDV is better than AODV. When the initial node energy is between 60, and 70 joules, and network density of 50, 250,300, 350, 400, and 450 nodes the RRSE values of AOMDV are better than the AODV. While when the network size between 100 and 150 nodes the RRSE values of AODV are better than AOMDV.

Table (5) scenario (1) CASE (3), the effect of changing initial node energy at different network density for Normalized Routing Load (NRL)

RRSE of NRL at different initial node energy for AODV									
Initial Node Energy	The network Density Size								
	50	100	150	200	250	300	350	400	450
50-60	0.99	0.31	0.78	0.82	0.92	0.58	0.87	0.81	0.66
60-70	1.00	1.61	2.40	0.48	4.23	1.85	3.13	2.55	1.98
70-80	0.00	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00
90-100	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
RRSE of NRL at different initial node energy for AOMDV									
50-60	1.81	0.80	1.05	1.10	1.07	1.37	1.16	0.72	0.52
60-70	0.40	2.63	7.17	1.21	2.53	0.57	0.29	2.13	1.77
70-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-100	3.61	0.33	1.79	0.00	0.00	0.00	0.00	0.00	0.00

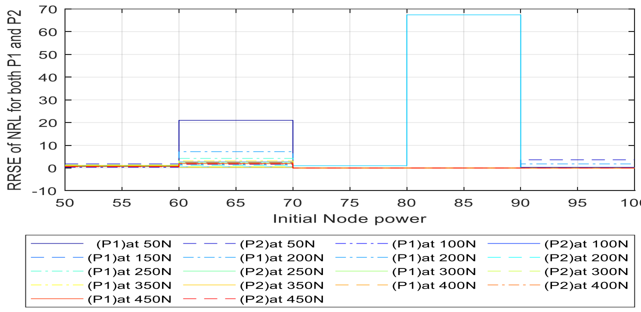

Fig.1(c): scenario (1) case (3), the RRSE of NRL of AODV (P1) AND AOMDV (P2) at different initial node energy and certain network size (N).

Scenario (1) Case (4):

In case (4), the results of RRSE values of AODV and AOMDV at different network densities are summarized in Table (6) and are plotted in Fig.1 (d) for AETED. The results illustrate that when the initial node energies, between 70 and 90 joules the RRSE values of both protocols are equal to zero. In addition to for network size densities greater than 200 nodes the RRSE of both protocols between 90 and 100 are zero. For initial node energy between 50 and 60 joules for all network sizes that are less than 400 nodes, the RRSE values of AOMDV are better than those of AODV. On the other side when network density is more than 400 nodes, the RRSE values of AODV are better than that of AOMDV and is equal to zero. Between 60 and 70 joules, the AODV has RRSE values that are lower and equal to zero and better than those of AOMDV for all network densities except at 200 nodes which is not equal to zero.

Table (6) case (4), the effect of changing initial node energy at different network density for average end-to-end delay (AETED).

RRSE of AETED at different initial node energy for AODV									
Initial Node Energy	The network Density Size								
	50	100	150	200	250	300	350	400	450
50-60	1.20	1.20	1.20	9.51	1.20	1.20	1.20	0.00	0.00
60-70	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00
70-80	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
90-100	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
RRSE of AETED at different initial node energy for AOMDV									
50-60	0.95	1.04	0.82	0.75	0.72	0.69	0.70	0.67	0.65
60-70	4.27	7.33	2.87	2.24	2.15	2.05	2.07	2.00	1.97
70-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-100	1.88	1.01	0.49	0.00	0.00	0.00	0.00	0.00	0.00

Scenario (1) Case (5):

In case (5), the information is illustrated in Table (7) and it is appeared in Fig. 1(e). It presents the Average throughput (ATP)

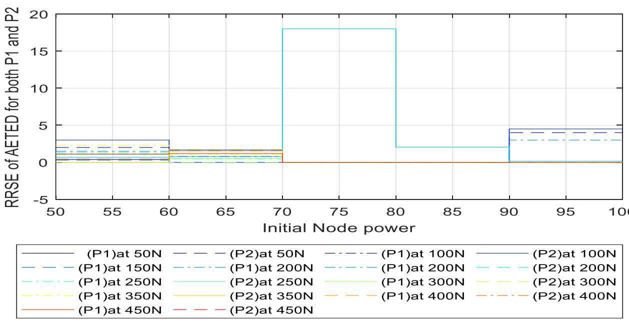

Fig.1 (d): scenario (1) case (4), the RRSE of AETED of AODV AND AOMDV at different initial node energy and certain network size (N).

of RRSE values for AODV and AOMDV at different network densities. The results reveal that when the initial node energies are between 70 and 90 joules, the RRSE values of both protocols are similar and are equal to zero, also when the number of nodes are greater than 200 nodes, the RRSE values of both protocols between 90 and 100 joules are zero. When number of nodes is less than 200 nodes, the RRSE values of AODV is equal to zero only. For initial node energies, between 50, 60 joules, and network density is less than 200 nodes the RRSE values of AODV are better than AOMDV. Otherwise, they are for AOMDV is better. For the initial node, energies between 60 and 70 joules the RRSE values for the AODV are better than that of AOMDV, which is equal to zero for all network densities.

Table (7) case (5), the effect of changing initial node energy at different network density for Average Throughput (ATP)

RRSE of ATP at different initial node energy for AODV									
Initial Node Energy	The network Density Size								
	50	100	150	200	250	300	350	400	450
50-60	1.20	1.20	1.20	9.51	1.20	1.20	1.20	0.04	0.06
60-70	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00
70-80	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
90-100	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
RRSE of ATP at different initial node energy for AOMDV									
50-60	0.95	1.04	0.82	0.75	0.72	0.69	0.70	0.67	0.65
60-70	4.27	7.33	2.87	2.24	2.15	2.05	2.07	2.00	1.97
70-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-100	1.88	1.01	0.49	0.00	0.00	0.00	0.00	0.00	0.00

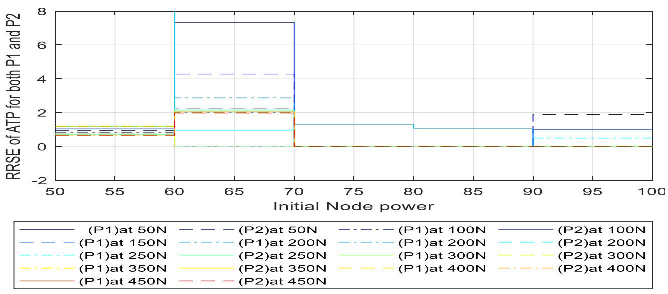

Fig.1 (e): scenario (1) case (5), the RRSE of ATP of AODV AND AOMDV at different initial node energy and certain network size (N).

2. The Effect of Network Density Change at Certain Initial Node Energy.

The simulation cases of scenario (2) are calculated from Eqn. (5) and are summarized in Table (8). It lists five cases studies with X-axis is the Network size (50,100, 150, 200, 250, 300, 350, 400, and 450 Nodes) and Y-axis is the performance parameter (i.e. SP, DPR, NRL, AETED, and ATP) at certain initial node energy (50, 60, 70, 80, 90 and 100 joules).

Table (8) Simulation Parameters of Scenario (2)

Case study	Network size (X)	Parameter RRSE (Y)	Initial Node Energy
Case 1	(50,100, 150, 200, 250, 300, 350, 400, and 450 Nodes)	SP	This performed at different initial node energy from 50 to 100 joules with a step of 10 joules.
Case 2		PDR	
Case 3		NRL	
Case 4		AETED	
Case 5		ATP	

Scenario (2) Case (1):

For scenario (2) case (1) Table (9) shows the RRSE values for sent packets (SP). The results are plotted in Fig.2 (a) where the X-axis is the network size density (50,100…450) and the Y-axis is the sent packets at different initial node energy. For network size between 50 and 250 nodes and initial node energy of 50, 60 and 70 joules, the RRSE values of AODV are better than AOMDV and both protocols have similar RRSE values between 100 and 150 at 60 joules and between 50 and 150 at 70 joules. At initial node energy 50 joules and network sizes between 250 and 400 nodes, the RRSE values of AODV are better than AOMDV, also at network sizes between 350 and 400 nodes at 60 and 70 joules and for network size at 400 to 450 nodes at 70 joules. For network sizes, between 250 and 450 nodes, and with the initial node energy between 80, and 100 joules the AODV protocol has better RRSE values.

Table (9): Scenario (2) Case (1), the effect of changing network density for the Sent Packets (SP) at different initial node energy.

RRSE of Sent Packets at different initial node energy for AODV						
Nodes	50	60	70	80	90	100
50-100	0.13	0.13	0.15	0.16	0.17	0.17
100-150	0.36	0.36	0.34	0.38	0.40	0.40
150-200	0.52	0.55	0.57	1.02	1.87	1.88
200-250	0.90	0.94	1.04	1.10	1.11	1.11
250-300	8.44	15.16	23.31	2.08	1.51	1.50
300-350	1.11	1.14	1.10	0.77	0.69	0.69
350-400	1.04	0.87	0.86	0.71	0.67	0.67
400-450	0.51	0.45	0.41	0.37	0.36	0.36
RRSE of Sent Packets at different initial node energy for AOMDV						
50-100	0.15	0.16	0.15	0.15	0.15	0.15
100-150	0.38	0.36	0.34	0.34	0.34	0.33
150-200	0.60	0.61	0.59	0.59	0.59	0.59
200-250	1.02	1.07	1.07	1.07	1.07	1.07
250-300	34.48	11.78	11.93	11.93	11.93	11.64
300-350	1.24	1.12	1.06	1.06	1.06	1.06
350-400	1.16	0.93	0.88	0.88	0.88	0.88
400-450	0.45	0.43	0.43	0.43	0.43	0.43

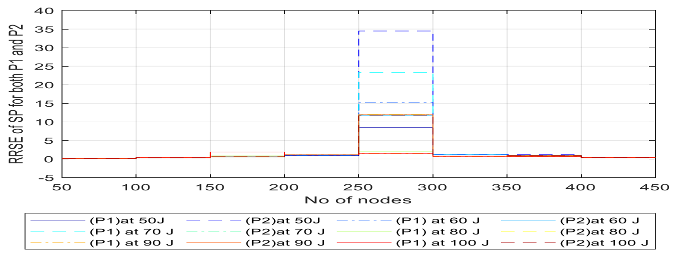

Fig.2 (a): scenario (2) case (1), the RRSE of the SP of AODV (p1) and AOMDV (p2) and certain network size (n) and different initial node energy.

Scenario (2) Case (2):

For scenario (2) case (2) Table (10) illustrates the RRSE values of Packet Delivery Ratio (PDR) for AODV and AOMDV at different network density at certain initial node energy. In general, the RRSE of Packet Delivery Ratio (PDR) for AODV is better than that of AOMDV except for network size between 350 and 400 nodes at different initial node energy, for network size between 100 and 150 nodes at 70 joules. For network size between 150 and 200 nodes at initial node energy between 60 and 90 joules. Also for network size between 350 and 400 nodes at all initial node energy.

Table (10): scenario (2) case (2), the effect of change network size on the PDR at certain initial node energy.

RRSE of PDR at different initial node energy for AODV						
Nodes	50	60	70	80	90	100
50-100	0.39	0.43	0.57	0.52	0.52	0.52
100-150	0.55	0.74	0.88	0.73	0.72	0.72
150-200	2.52	8.10	28.36	5.57	4.60	4.32
200-250	1.47	1.40	1.35	1.51	1.55	1.56
250-300	0.10	0.14	0.09	0.10	0.11	0.11
300-350	0.38	0.31	0.21	0.25	0.26	0.26
350-400	0.28	0.22	0.19	0.22	0.22	0.22
400-450	0.03	0.03	0.02	0.02	0.02	0.02
RRSE of PDR at different initial node energy for AOMDV						
50-100	9.46	1.62	1.14	1.14	1.14	0.74
100-150	0.66	0.90	0.80	0.80	0.80	1.14
150-200	4.84	2.24	0.58	0.58	0.58	9.46
200-250	0.71	1.22	1.48	1.48	1.48	1.32
250-300	2.96	5.80	2.05	2.05	2.05	2.75
300-350	0.62	0.40	0.28	0.28	0.28	0.30
350-400	0.12	0.13	0.08	0.08	0.08	0.09
400-450	3.10	1.00	0.75	0.75	0.75	0.84

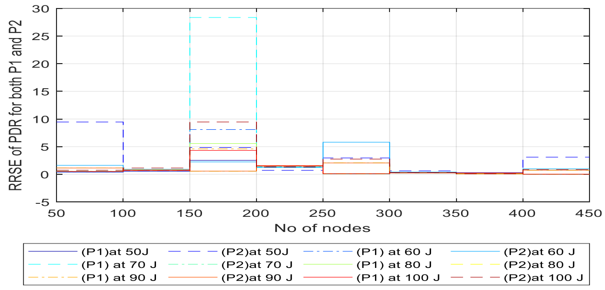

Fig.2 (b): scenario (2) case (2), the RRSE of the PDR of AODV and AOMDV and different network size (n) the initial node energy.

Scenario (2) Case (3):

For scenario (2) case (3) Table (11) figure, 2 (c) concludes the RRSE values of Normalized Routing Load (NRL) at different network sizes and the selected initial node energy. In general, the RRSE values of AODV is better than AOMDV excluding the network size between 200 and 250 nodes also between 350 and 400 nodes and between 150 and 200 nodes at 50, and between 70 and 90 joules.

Table (11): scenario (2) case (3), the RRSE of NRL of AODV and AOMDV at different network size and certain initial node energy.

RRSE of NRL at different initial node energy for AODV						
Nodes	50	60	70	80	90	100
50-100	0.05	0.05	0.05	0.05	0.06	0.06
100-150	0.05	0.05	0.05	0.05	0.06	0.06
150-200	2.58	2.46	2.46	1.88	1.13	1.16
200-250	1.33	1.29	1.30	1.44	3.54	3.01
250-300	0.20	0.44	0.34	0.42	0.56	0.55
300-350	0.76	0.85	0.81	0.95	1.15	1.14
350-400	12.90	20.10	16.59	65.78	29.68	31.60
400-450	0.38	0.39	0.33	0.31	0.30	0.30
RRSE of NRL at different initial node energy for AOMDV						
50-100	0.13	0.12	0.23	0.23	0.23	0.20
100-150	0.73	1.11	1.28	1.28	1.28	0.82
150-200	1.92	3.88	1.05	1.05	1.05	4.55
200-250	0.98	0.26	0.19	0.19	0.19	0.17
250-300	61.30	0.51	0.81	0.81	0.81	0.72
300-350	1.24	2.42	6.49	6.49	6.49	3.91
350-400	0.50	0.53	0.54	0.54	0.54	0.50
400-450	0.97	1.40	1.07	1.07	1.07	0.90

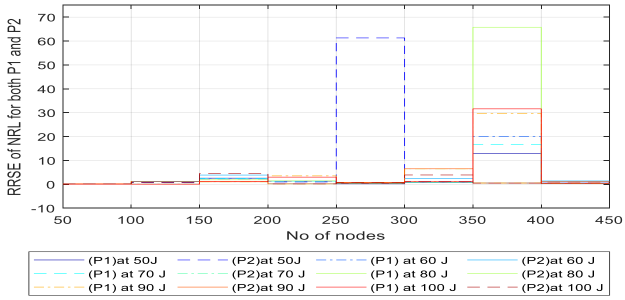

FIG.2 (C): SCENARIO (1) CASE (3), THE RRSE OF THE NRL OF AODV AND AOMDV and network size (N) for different initial node energy.

Scenario (2) Case (4):

For scenario (2) case (4) Table (12) and figure 2 (d) present the RRSE values of average End-to-End Delay (AETED) at variable network size each time at certain initial node energy. The RRSE values of AOMDV are better than AODV excluding network size densities between 50 and 100 nodes at 50 and 100 joules. Also at network sizes between 100 and 150 nodes at 50 joules, at network size densities between 350 and 400 nodes at 60 joules. In addition to, for network size densities between 200 and 250 nodes and 300 and 350 nodes at all initial node energies.

Table (12): scenario (2) case (4), the RRSE of AETED of AODV and AOMDV at different network size and certain initial node energy.

RRSE of AETED at different initial node energy for AODV						
Nodes	50	60	70	80	90	100
50-100	0.37	0.63	0.59	0.59	0.59	0.59
100-150	0.40	1.44	0.90	0.90	0.90	0.90
150-200	1.08	0.92	1.47	1.47	1.47	1.47
200-250	1.13	1.10	1.06	1.06	1.06	1.06
250-300	1.73	3.33	5.92	5.92	5.92	5.92
300-350	0.03	0.84	0.77	0.77	0.77	0.77
350-400	2.23	0.15	4.84	4.84	4.84	4.84
400-450	0.69	0.23	0.72	0.72	0.72	0.72
RRSE of AETED at different initial node energy for AOMDV						
50-100	0.95	0.00	0.00	0.00	0.00	4.50
100-150	0.73	0.60	0.58	0.58	0.58	0.16
150-200	0.84	0.75	0.73	0.73	0.73	0.84
200-250	1.80	1.50	1.38	1.38	1.38	1.80
250-300	1.13	1.50	1.80	1.80	1.80	1.13
300-350	18.00	6.00	6.75	6.75	6.75	27.00
350-400	2.12	2.40	1.17	1.17	1.17	1.04
400-450	0.00	0.00	0.00	0.00	0.00	0.00

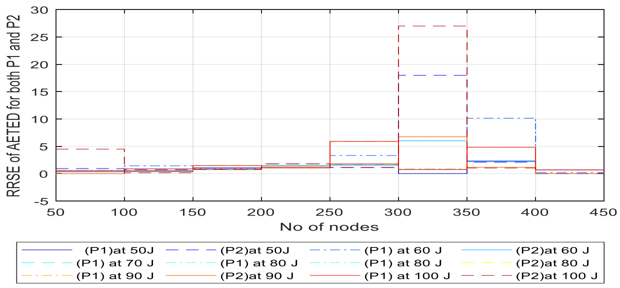

Fig.2 (d): scenario (2) CASE (4), THE RRSE of the AETED of AODV and AOMDV and different network size (N) and initial node energy.

Scenario (2) Case (5):

For scenario (2) case (5) is illustrated in Table (13) and figure 2 (e). It presents the RRSE values of average throughput (ATP) at variable network densities at certain initial node energy. The Average throughput of AODV is better than AOMDV for all network densities, the RRSE values are equal to zero for AODV at network densities between 50 and 150 nodes and between 250 and 450 nodes. In addition to between 200 and 250 nodes. On the other side, the RRSE values of AOMDV is better between 150 to 200 nodes at initial node energy at 50, 70, 80, 90, and 100 joules.

Table (13): scenario (2) case (5), the RRSE of the ATP of AODV and AOMDV at different network size and certain initial node energy.

RRSE of ATP at different initial node energy for AODV						
Nodes	50	60	70	80	90	100
50-100	0.00	0.00	0.00	0.00	0.00	0.00
100-150	0.00	0.00	0.00	0.00	0.00	0.00
150-200	9.00	9.00	9.00	9.00	9.02	9.02
200-250	1.13	1.13	1.13	1.13	1.13	1.13
250-300	0.00	0.00	0.00	0.00	0.00	0.00
300-350	0.00	0.00	0.00	0.00	0.00	0.00
350-400	0.00	0.00	0.00	0.00	0.00	0.00
400-450	0.00	0.00	0.00	0.00	0.00	0.00
RRSE of ATP at different initial node energy for AOMDV						
50-100	0.20	0.29	0.24	0.24	0.24	0.10
100-150	0.39	0.28	0.31	0.31	0.31	0.32
150-200	0.96	0.84	0.77	0.77	0.77	0.81
200-250	5.10	1.67	1.30	1.30	1.30	1.40
250-300	0.03	0.82	3.00	3.00	3.00	2.39
300-350	3.28	3.08	1.96	1.96	1.96	1.85
350-400	1.17	0.97	0.93	0.93	0.93	0.91
400-450	0.16	0.22	0.27	0.27	0.27	0.27

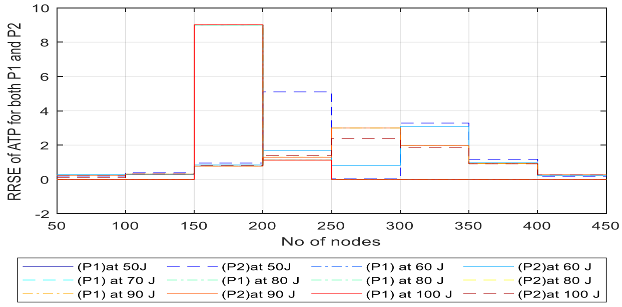

Fig.2 (e): scenario (1) CASE (5), THE RRSE of the ATP of AODV and AOMDV and different network size (N) and certain initial node energy (J).

The list of symbols and abbreviations, used in this paper are listed in Table (14).

I. CONCLUSION

The intelligent transportation system (ITS) key element is the autonomous vehicles, that their growth in the network size drives the researchers to develop an efficient and fast routing protocol, in addition improve road safety. In this paper, two different reactive routing protocols, AODV and AOMDV, have been investigated for communications among autonomous vehicles. They have been simulated using NS-2.34. The simulation results have been obtained for different performance parameters such as sent packets, packet delivery ratio, normalized routing load, average end-to-end delay, and average throughput. These parameters have been evaluated using the RRSE concept. Two different experiments have been presented: the first examines the effect of initial node energy changes at a certain network size. The RRSE values are similar and are equal to zero for AODV and AOMDV when initial node energy is greater than 70 Joules and for network sizes. The RRSE values of sent packets, packet delivery ratio, normalized routing load for AOMDV are better than those of AODV for initial node energies, which lies between 50, and 70 joules and network sizes are greater than 200 nodes. The RRSE values of AETED of AODV are better than AOMDV for initial node energy between 50 and 60 joules and network densities are less than 400 nodes.

The RRSE values of ATP are better of AOMDV for initial node energy, which is located between 50, 60 joules, and network sizes greater than 150 nodes. The second experiment studies the effect of network density changes at a considerable node initial energy. Generally, the RRSE values for AODV are better than AOMDV for sent packets; packet delivery ratio normalized routing load, and average throughput. The RRSE values of AETED for AOMDV are better than those of AODV. In the future work new metrics will be evaluated for these protocols using a variation of transmission range and a speed change with other parameters such as packet loss and residual energy. In addition, the effect of the combination of AODV and AOMDV on the same environment will be validated. More over the security of VANET protocols will be enhanced.

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List of symbols and abbreviations, used in this paper are listed in Table 14.

Table 14 List of symbols and abbreviation.

Symbols	Abbreviations
AETED	Average End To End Delay
AODV	Ad-hoc On-demand Distance Vector (P1) protocol
AOMDV	Ad-hoc On-demand Multipath Distance Vector (P2) protocol
ASTAR	Anchor based Street and Traffic Aware Routing
ATP	Average Throughput
CBF	contention-based forwarding
DSDV	Destination Sequence Destination Vector
DYMO	Dynamic MANET On-demand
GPCR	Greedy Perimeter Coordinator Routing
GPSR	Greedy Perimeter Stateless Routing
MANET	Mobile ad-hoc network
OLSR	Optimized Link State Routing
PDR	Packet Delivery Ratio
RERR Message	Rout Error message
RREQ Message	Route Request message
RRSE	Root Relative Squared Error
SP	Sent Packet
TIL	Time Interval Length
VANET	vehicular ad-hoc network
ZRP	Zone Routing Protocol

Figures

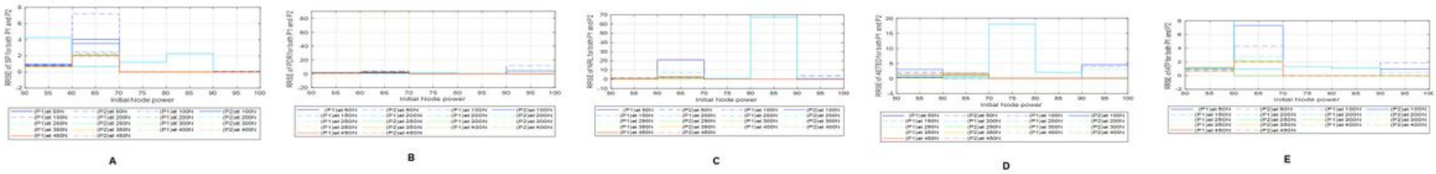

Figure 1

(a): Scenario (1) case (1), the RRSE of sent packets of AODV (P1) and AOMDV (P2) at different initial node energy and certain network density size (N). (b): scenario (1) case (2), the RRSE of the PDR of AODV (P1) and AOMDV (P2) at different initial node energy and certain network size (N). (c): scenario (1) case (3), the RRSE of NRL of AODV (P1) AND AOMDV (P2) at different initial node energy and certain network size (N). (d): scenario (1) case (4), the RRSE of AETED of AODV AND AOMDV at different initial node energy and certain network size (N). (e): scenario (1) case (5), the RRSE of ATP of AODV AND AOMDV at different initial node energy and certain network size (N).

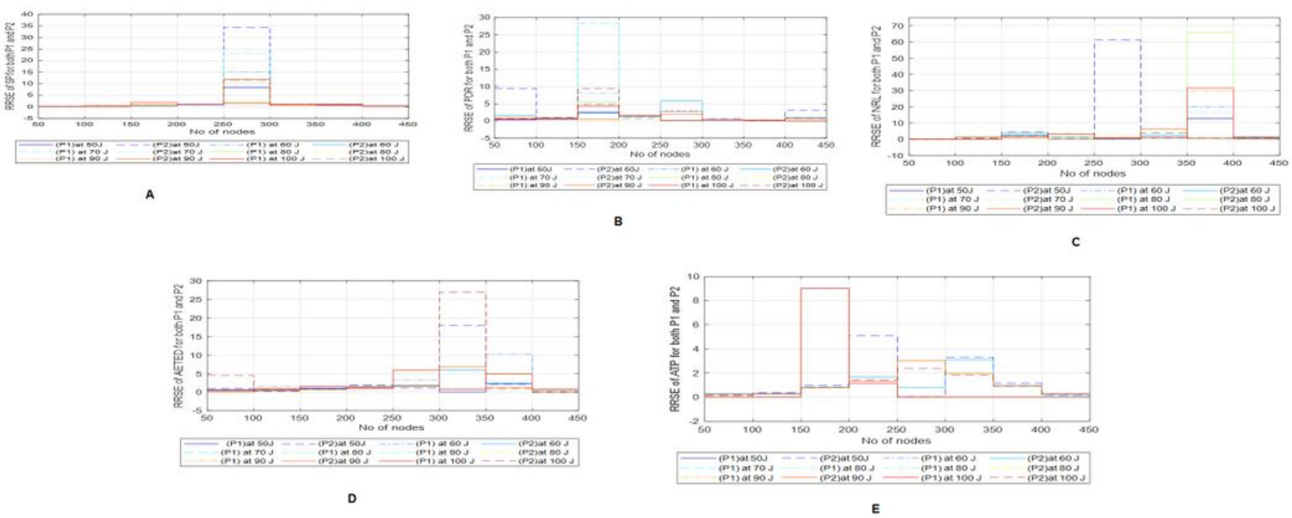

Figure 2

(a): scenario (2) case (1), the RRSE of the SP of AODV (p1) and AOMDV (p2) and certain network size (n) and different initial node energy (b): scenario (2) case (2), the RRSE of the PDR of AODV and AOMDV and different network size (n) the initial node energy. (C): SCENARIO (1) CASE (3), THE RRSE OF THE NRL OF AODV AND AOMDV and network size (N) for different initial node energy. (d): scenario (2) CASE (4), THE RRSE of the AETED of AODV and AOMDV and different network size (N) and initial node energy. (e): scenario (1) CASE (5), THE RRSE of the ATP of AODV and AOMDV and different network size (N) and certain initial node energy (J).