Performance Evaluation Of Topology Based Routing Protocols In Vanet

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ABSTRACT

Vehicular Ad-hoc Networks (VANET) are formed between moving vehicles equipped with wireless interfaces, which are attracting a great deal of interest. VANET is a new communication paradigm that enables the communication between mobile nodes having dynamic topology on roads. There are still several areas of VANETS, such as congestion control, security, traffic engineering, traffic management, dissemination of emergency information to avoid hazardous situations and routing protocols, which lack large amounts of research. Here in this research we have to use OMNeT++ i.e. freely available simulator is used with traffic simulator (SUMO) that are uses the TraCI (Traffic control interface) module to couple the simulators which works in sync. It uses the UDP Basic Burst Notification application. In this paper basically to evaluate the proactive and reactive routing protocols that are commonly used in mobile ad-hoc networks, which will apply to VANETs. Optimized Link State Routing (OLSR), Dynamic Source Routing (DSR) and Dynamic MANET On-demand (DYMO) are initially simulated in a city, main road, and country environment in order to provide an overall evaluation.

Keywords: OLSR, DSR, DYMO, VANETs, OMNeT++, SUMO, IEEE 802.11b.

1. INTRODUCTION

A vehicular network is a kind of wireless networks that has emerged thanks to advances in wireless technologies and the automotive industry [1]. Vehicular networks are formed between moving vehicles equipped with wireless interfaces that could be of homogeneous or heterogeneous technologies. These networks, also known as VANETs (Vehicular Ad-hoc Networks) are considered as one of the ad-hoc network real-life applications, enabling communications among nearby vehicles as well as between vehicles and nearby fixed equipment (roadside equipment).

The development of communication networks was a significant step for mankind, undoubtedly facilitating everyday's tasks and improving the quality of life. Both telecommunication and computer networks began with a strong emphasis on wires, both for the communications infrastructure and for the last hop where the actual connection towards the users' terminals takes place [1]. In the last decade this trend has shifted towards wireless networks, especially at the user side.VANET (Vehicular Ad-hoc Network) is a new technology that has to be taken enormous attention in the recent years. Due to rapid change in topology and frequent disconnection makes it difficult to design an efficient routing protocol for routing data among vehicles, called V2V or vehicle to vehicle communication" [2]. VANET is a technology that uses moving cars as nodes in a network to create a mobile network. It turns every participating car into a wireless router or node, allowing cars approximately 100 to 300 meters of each other to connect and, in turn, create a network with a wide range. As cars fall out of the signal range and drop out of the network, other cars can join in, connecting vehicles to one another so that a Mobile Internet is created. It is estimated that the first systems that will integrate this technology are police and fire vehicles to communicate with each other for safety purposes. Other purposes include essential alerts and accessing comforts and entertainment. VANETs **are a kind of MANETs** provide vehicle to vehicle (V2V) and vehicle to roadside wireless communications, this means that every node can move freely within n/w coverage and stay connected. Vehicles are equipped with wireless transceivers and computerized control modules are used.

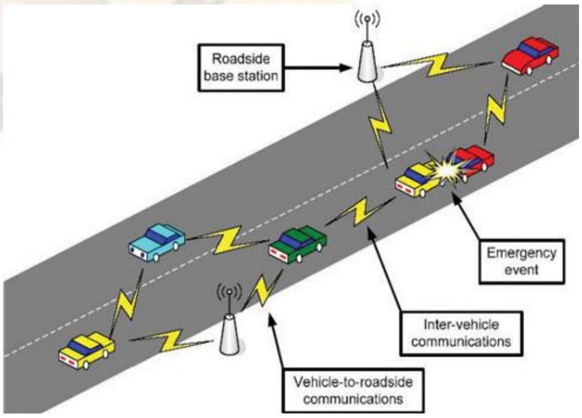


Figure 1: Vehicular Ad hoc Network [3]

VANETs integrates multiple Ad hoc networking technologies such as Wi-Fi IEEE 802.11 b/g, WiMAX 802.16, Bluetooth, IRA, ZigBee for easy, accurate, effective and simple communication between vehicles on dynamic mobility[3].

Vehicular networks consist of large no. of nodes, approximately no. of vehicles exceeding 750 million in the world today, these vehicles will require an authority to govern it, and each vehicle can communicate with other vehicles using short radio signals of 2.4 GHz at bit rate of 11Mbps. This communication is an Ad Hoc communication that means each connected node can move freely, no wires required, the routers used are called road side unit (RSU).

2. BACKGROUND

The growing mobility of people and goods incurs in high social costs: traffic congestion, fatalities and injuries. Around the globe each year about 1.2 million people die because of traffic accidents [4]. The traffic accidents place as the fourth cause of mortality by this statistics in the world. Also, this high number of fatalities and injuries high healthcare costs, more than any other type of injury or disease.

It is in this context that Vehicular Ad-hoc Networks (VANETs) have emerged. A VANET is based on smart cars and base-stations, which share information via wireless communications. This interchange of data may have a great impact on safety and driving, reducing the number of accidents and helping to optimize transport. While the original motivation for VANETs was to promote traffic safety, recently it has also become increasingly obvious that VANETs open new vistas for Internet access, distributed gaming, and the fast-growing mobile entertainment industry. The importance and potential impact of VANETs have been confirmed by the rapid proliferation of consortia involving car manufacturers.

2.1 Factors that affect communication in VANET

- ➢ High velocity of the vehicles.
- ➢ Environment factors: obstacles, tunnels, traffic jams, etc.
- ➢ Determined mobility patterns that depend on source to destination path and on traffic conditions.
- ➢ High congestion channels (e.g. due to high density of nodes).

2.2 Network requirements in VANETs applications

- ➢ **Mobility:** Wireless network technologies allow devices to move freely. In 802.11 transmissions the distance between the sender and receiver is an important factor; the more the distance, the smaller the probability of reception of packets. In infrastructure-based technologies, handoff between base stations is also relevant [5].
- ➢ **Permanent access:** Permanent access to the network is one of the main drawbacks of vehicular communications. In VANET designs, a physical infrastructure is not necessary, due to the inherent decentralized design.
- ➢ **Location Awareness:** Next generation vehicles are expected to exchange information not only beyond their immediate surroundings and line-of-sight with other vehicles, but also with the road infrastructure and Internet databases [6].
- ➢ **Time Awareness:** Vehicular applications often require a reliable communication channel that supports time-critical message transmissions.
- ➢ **Penetration rate dependency:** This rate is defined as the percentage of vehicles equipped with the necessary on board data unit (OBU) on the road.

3. ROUTING PROTOCOLS IN VANET

Routing is the act of moving information across an internetwork from a source to a destination. Along the way, at least one intermediate node typically is encountered. Routing occurs at Layer 3 (network layer) of the OSI model. The routing protocols are further divided into number of categories but here focus onto the **OLSR, DSR, DYMO** protocols mainly, that are evaluated on the behalf of throughput and latency.

The topology based routing protocols are further divided into two different categories for ad-hoc data networks, according to [7]: **Proactive and reactive.**

The first is a **proactive routing protocol**, which relies on the periodic broadcast of data network topology. Popular proactive protocol is OLSR (Optimized Link State Routing) and FSR (fisheye state routing). The second category, **reactive routing protocols**, can be viewed as a solution to proactive routing protocols because they only search for a route when one is needed. Some popular reactive protocols are DSR and DYMO.

3.1 Optimized Link State Routing (OLSR) Protocol

OLSR is the proactive routing protocol that is evaluated in this paper. OLSR achieved RFC status in 2003 (T. Clausen (Ed.), and P. Jacquet (Ed.) Oct. 2003) [8]. Basically OLSR is an optimization of the classical link state algorithm adapted for the use in wireless ad hoc networks. First, few nodes are selected as Multipoint Relays (MPRs) to broadcast the messages during the flooding process.

Second level of optimization is achieved by using only MPRs to generate link state information.

This results in minimizing the “number” of control messages flooded in the network. As a final level of optimization, an MPR can chose to report only links between itself and those nodes which have selected it as their MPR. MPRs play a major role in the functionality of the protocol[8].

OLSR is designed to support large and dense wireless networks. It is also suitable for scenarios, where the communicating pairs change over time. Once the communicating pair changes, a route to new pair is readily available, and no control traffic or route discovery process is needed as in the case of reactive protocols. This can be beneficial for situations where time critical or safety related data needs to be delivered with minimum possible delay.

3.2 Dynamic Source Routing

Dynamic Source Routing (DSR) is another routing protocol that was specifically designed for use in multi-hop mobile ad-hoc networks [9]. Like OLSR, DSR is a completely self organizing protocol.

It has two mechanisms:

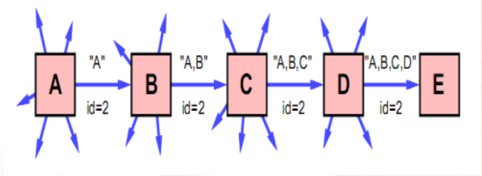


Figure 2: Route Discovery for DSR Routing Algorithm

- **Route Discovery:** The process of discovering a route from a source to a destination.
- **Route Maintenance:** Allows for the topology of the network to change and a nodes routing table to remain fresh. DSR does not use any type of periodic packets or messages at any level. The purely on demand behaviour of the DSR routing algorithm allows it to cut down network overhead that do use it [9].

Route discovery is the process that the DSR algorithm uses to find a route to send a packet from source to destination. When no route is present the source node transmits a route request (RREQ). Each node broadcasts the message until it reaches the destination. Once at the destination node, that node will send back a route reply (RREP) to the source. As shown in the Figure 2 node A wishes to send a packet to node E. Node A initiates a route discovery with an RREQ that contains node A as the initiator, an empty route record list, and a unique request ID. As each node broadcasts the request to all nodes within range, the route is built because each node appends itself to the route record in the RREQ.

Once the route request reaches the intended destination, the destination node will send a route reply back to the initiator. Node E request further, To avoid the possibility of infinite route discoveries, node E will piggyback the route reply on the new route request [9].

In the event that a node cannot successfully transmit a packet to the next hop, it needs to perform route maintenance. When forwarding packets along a source route, each node on the route is responsible for the successful transmission of the packet to the next hop. This reply can either be done by using an existing part of the MAC protocol in use or done passively [10]. In the Figure 2, node B can confirm the receipt of the packet to node C by listening to see if node C tries to forward the packet again. A route error message is sent out in the event that a node does not receive a successful transmission.

3.3 Dynamic MANET On-Demand Routing (DYMO)

The final routing protocol that was used for evaluation is the Dynamic MANET On-Demand (DYMO) routing protocol [11]. The DYMO routing protocol is another protocol that is designed for use in mobile wireless ad-hoc networks. Unlike the work in [12], this implementation will be integrated right into the network layer and not as part of the application layer. Just like DSR, DYMO consists of two main operations: Route Discovery and Route Maintenance.

DYMO route discovery is performed similar to the DSR routing algorithms. When a node needs to send out a packet to another node it will first search its route cache or routing table to see if an up to date route exists. If one does, the source node uses that route to send the packet to its destination. However, if a route does not exist the node must go through a process to find a path to the destination, called route discovery. The source node creates a route request (RREQ) message to send out to all neighbouring nodes. The RREQ contains the following information [13]:

- Destination Address
- Sequence Number
- Hope Count
- Next Hop
- Valid Timeout
- Delete Timeout

The source node will then send out the RREQ via broadcast to all of the surrounding nodes. The receiving node will look at the packet to make sure that it has not seen it before and if it has the packet will be discarded. If it has not been seen before, the node will then start to look at the information contained inside of the RREQ. Lastly, if the sequence number indicates there is new information in the RREQ then the data in the routing table is updated and the RREQ is passed on. Once the RREQ reaches the destination node, that node will then form a route reply (RREP) that contains the new route and is sent back along the reverse path.

4. IMPLIMENTATION FRAMEWORK

4.1 OMNeT++

OMNeT++ [14] is an open-source simulation environment. The primary simulation applications are Internet simulations, mobility, and ad-hoc simulations. This simulator has a component-based design, meaning that new features and protocols can be Performance evaluation of vehicular ad-hoc networks over high speed environment supported through modules.

In order to provide large scale simulations with reusable models, OMNet++ uses modules to develop the different components of the simulation. Simple modules are the most basic modules as they provide extremely basic functionality. Compound modules are created by grouping simple modules together to create an object with a complex functionality, such as a vehicle equipped with an IEEE802.11b radio. Modules in Omnet++ are connected to each other's input and output gates with the use of simple 'connection' modules. These connections are all defined in a file that uses the NED language. NED models are reusable and designed to work with other NED files to create much larger models. A nice feature of Omnet++ is that it uses a two way editor to create and modify the NED files that make up the environment.

We use a text editor or the IDE's graphical editor to create the network. Modules in the network contain a lot of unassigned parameters, which need to be assigned before the simulation can be run. The name of the network to be simulated, parameter values and other configuration option need to be specified in the omnetpp.ini file.

4.2 Traffic Simulation

Simulation of Urban Mobility (SUMO) is a C++ application developed to simulate the movement of objects along a road network. It is a free and open sourced simulator. Along with being able to model small areas, SUMO is also capable of modelling traffic in large networks, such as cities or highway networks, without any changes. SUMO simulations are considered to be multimodal, meaning that every object in the simulation is simulated [16].

4.3 Simulator Coupling

To accurately model a VANET, Omnet++ and SUMO are connected with a technique to synchronize node movement between two simulators. The Traffic Control Interface (TraCI) is used to couple the simulators. VANET simulation approaches used mobility traces that the network simulator read in [17, 18]. TraCI works in a client-server manner [17]. A wireless network, traffic map, and obstacles in the wireless environment were created in order to fully simulate a VANET. The wireless network was setup to be based on the IEEE802.11b standard, which is commonly used in VANET simulations [19]. The maps for the traffic simulation consisted of three different environments (city, main road, country). The purpose of using multiple traffic environments was to expose the routing protocols to a variety of topologies rather than just one. Figure 3 shows an example of how the client and server interact.

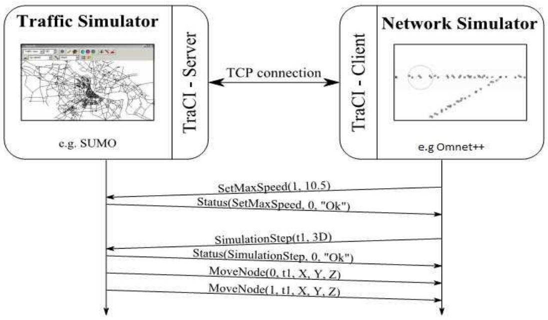


Figure 3: TraCI Connection Example

4.4 simulations

The simulations were run in different sets. For each set of simulation runs there was up to 10 TxRx pairs. The number of TxRx pairs was varied between one and ten sync pairs. Also, the traffic density change. The only difference between each set was the number of transmit and receive (TxRx) pairs that existed in the network. The reason to vary the number of TxRx pairs is to create more data network traffic that would have in impact on how quickly a message could get delivered between TxRx pairs. The final parameter that changes in the simulations was the density of the traffic, which varied from high density (460 vehicles) to medium density (250 vehicles) and to low density (165 vehicles).

From each simulation, the average throughput and latency were recorded for comparison of the protocols. This will allow for an in-depth analysis of the strengths and weaknesses of the routing protocols based on scenario and traffic density.

5. RESULTS AND ANALYSIS

The routing protocols used for evaluation are OLSR, DSR, and the DYMO protocols. All these protocols are designed by various technologies; however, they are all designed for mobile ad-hoc networks that have to play an important role within a VANET. Tables 1, 2, 3 consists the evaluated values of throughput using three different environments.

5.1 Throughput

The throughput is calculated by monitoring the channel that determines the speed at which the packets are successfully transmitted by the application. The results for each simulation scenario are shown in figures 4(A, B, C), 5(A, B, C) and 6.

High Traffic Density- Throughput (bits/sec)									
	OLSR			DSR			DYMO		
Tx Rx pair	City	Country	Main Road	City	Country	Main Road	City	Country	Main Road
1	2339.65	385.25	582.52	1851.23	380.55	671.95	1923.11	190.15	345.85
2	1999.36	365.15	665.59	2265.79	145.52	765.02	2015.55	156.46	366.55
3	1935.45	313.55	869.53	1815.31	399.77	1165.55	1365.65	137.28	577.37
4	1395.61	90.03	678.46	2219.78	189.18	465.45	1845.99	385.65	1235.56
5	1685.45	366.55	753.85	1745.3	458.95	1036.35	1322.15	165.23	712.98
6	1735.05	313.18	765.18	1901.43	201.28	936.99	1253.92	275.12	1120.35
7	1665.35	170.52	465.85	1463.21	414.65	935.65	1117.53	294.12	1288.12
8	1486.38	333.65	665.23	1835.25	309.65	1012.96	1267.56	308.35	1438.32
9	1681.89	232.68	823.84	1815.98	389.95	1055.11	1305.23	334.02	1585.05
10	1358.48	195.12	822.55	1780.91	320.31	1098.53	1385.99	344.32	1751.95

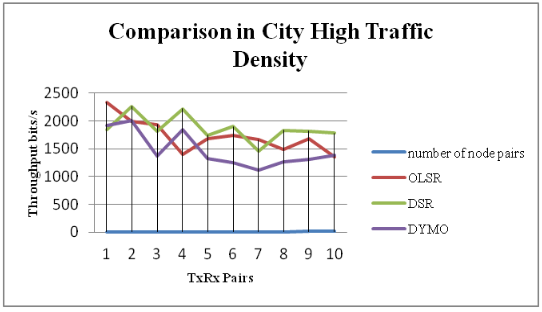
Table 1 Throughput results for high traffic density scenario

Medium Traffic Density- Throughput (bits/sec)									
	OLSR			DSR			DYMO		
Tx Rx pair	City	Country	Main Road	City	Country	Main Road	City	Country	Main Road
1	3338.23	0	502.95	2105.25	0	989.95	2054.41	0	731.99
2	3057.95	0	504.15	2715.31	0	492.55	2491.54	0	652.98
3	2550.42	0	735.15	2325.12	0	523.45	2145.74	0	905.15
4	2085.65	0	959.23	1791.26	0	475.65	1542.12	0	902.56
5	1754.12	0	665.55	1601.12	0	535.32	1556.25	0	882.11
6	1839.15	0	438.65	1139.21	0	423.54	1365.25	0	965.95
7	2061.01	0	545.46	1238.12	0	565.12	1169.24	0	1029.12
8	1598.56	0	602.45	1181.35	0	498.55	1288.65	0	1085.16
9	1405.35	0	695.34	1174.15	0	484.11	785.16	0	1135.46
10	1478.55	0	735.24	1358.14	0	512.56	575.53	0	1185.96

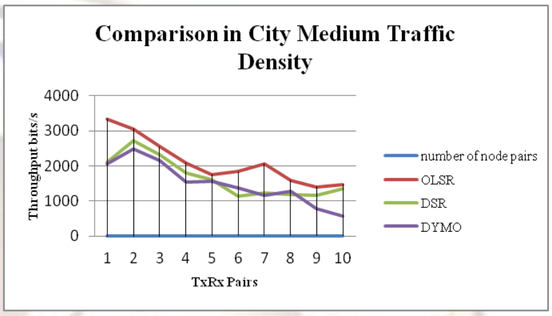
Table 2 Throughput results for Medium traffic density scenario

Low Traffic Density- Throughput (bits/sec)									
	OLSR			DSR			DYMO		
TxRx pair	City	Country	Main Road	City	Country	Main Road	City	Country	Main Road
1	1823.12	0	238.65	1785.16	0	445.13	1705.55	0	1235.74
2	1528.99	0	528.13	1528.99	0	977.23	1662.85	0	374.14
3	1185.15	0	618.65	2435.15	0	803.99	1155.15	0	905.65
4	1603.02	0	551.15	1345.29	0	462.12	2456.14	0	435.12
5	1112.05	0	706.99	1539.12	0	598.16	2312.02	0	668.65
6	1699.11	0	791.15	1523.14	0	592.44	2465.58	0	705.14
7	1485.99	0	875.11	1455.12	0	572.99	1863.64	0	716.25
8	1131.02	0	888.01	1735.61	0	555.72	1642.99	0	685.65
9	932.13	0	882.16	1321.12	0	523.96	1631.14	0	643.56
10	855.16	0	865.15	1253.14	0	512.13	1599.17	0	706.18

Table 3 Throughput results for Low traffic density scenario



(A)



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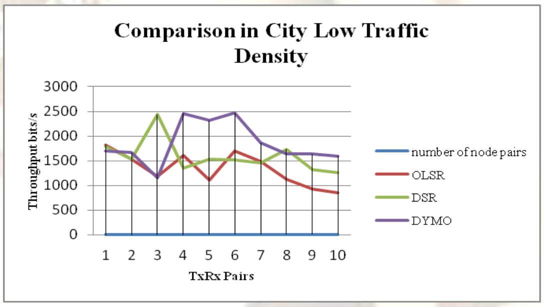
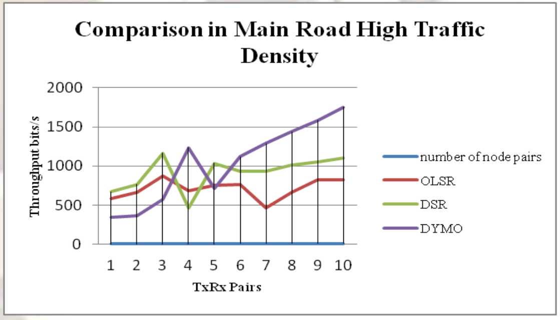
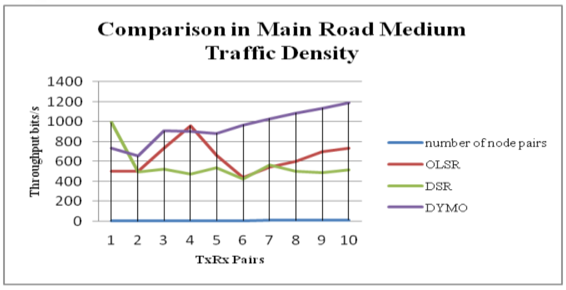


(C)

Figure 4(A, B, C): Throughput in bits/second for city environment



(A)



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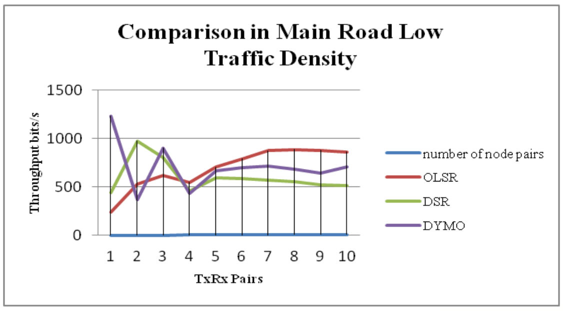


(C)

Figure 5(A, B, C): Throughput in bits/second for main road environment

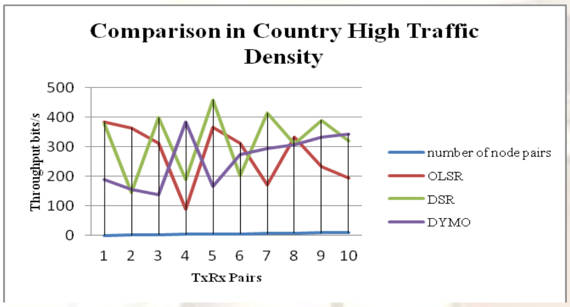


Figure 6: Throughput in bits/second for Country environment

The DSR routing protocol is to prove the higher throughput transmitting protocol in the city simulations of high traffic density. The high traffic density simulations in the country environment results in some communication between the nodes. The DYMO protocol remains the most stable throughout the all 10 TxRx pairs, rather the DSR routing protocol has the highest throughput with 5 TxRx pairs. OLSR do not remain as stable as DYMO because over the 10 simulations the throughput oscillations from high to low. The high traffic density city simulations, the all three routing protocols with only one transmit receive pair started with the throughput of 1850 bits/sec to 2350 bits/sec. The OLSR routing protocol had the most drastic change, about 100-150bits/s, as the number of TxRx pairs were increased. The DSR routing protocol remains stable with throughput between 1700 and 2250 bits/s. The DYMO protocol also shows the dip in throughput as on the OLSR that are of 900bits/sec drop. The similar effects show the medium traffic density environment for each of the routing protocols. In figure 4 look at the second line graph, each of the routing protocols with the single TxRx pair started at a high throughput between 2000bits/sec to 3500 bits/sec and finished with 10 TxRx pairs at a level that are between 400 and 1600 bit/s. DSR showed the lower loss in throughput for the 10 simulations. The DYMO protocol has an increase in throughput from six to seven TxRx pairs. However, the throughput drops to similar level as the number of TxRx pairs increased.

The graphs in figure 5(A, B, C) show the results obtained from the high, medium, and low density main road simulations. The DYMO protocol shows as the number of TxRx pairs increases the throughput is increases. As to increase in number of TxRx pairs that cause to increase the number of nodes communicate with each other, which cause to increase the chances to make the new routes. When the less dense spacing of the vehicles, OLSR actually gains throughput as the number of TxRx pairs increase.

5.2 Latency Results

The latency results are important for applications that are time sensitive, such as collision avoidance or emergency vehicle warning. These latency measurements are calculated by determining the time between the message send by the sender and to receive by the receive node. Tables 4, 5, 6 consist the values of latency by using three different environments.

High Traffic Density-Latency (s)									
	OLSR			DSR			DYMO		
TxRx pair	City	Country	Main Road	City	Country	Main Road	City	Country	Main Road
1	0.171	1.538	0.866	3.924	10.022	23.249	0.075	0.004	0.091
2	0.531	0.005	0.783	1.522	14.054	14.856	0.005	0.025	0.008
3	0.305	0.015	0.878	1.888	9.717	15.025	0.003	4.245	0.044
4	0.162	0.066	2.051	2.025	20.105	11.528	0.002	0.006	0.008
5	0.302	0.005	1.012	2.554	2.554	8.903	0.065	0.004	0.011
6	0.355	0.853	0.481	2.814	8.595	5.142	0.025	0.055	0.009

7	0.188	0.058	1.028	3.138	7.551	6.465	0.024	0.891	0.145
8	0.655	0.658	0.999	2.216	6.809	7.213	0.045	0.156	0.074
9	0.661	0.581	0.735	2.785	5.761	5.485	0.028	0.065	0.045
10	0.773	0.653	0.695	3.136	8.424	5.995	0.038	0.122	0.054

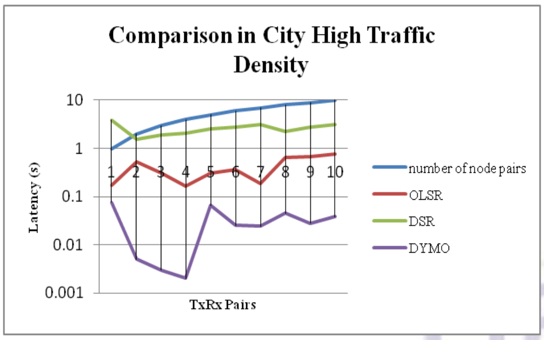
Table 4 Latency results for high traffic density scenario

Medium Traffic Density- Latency (s)									
	OLSR			DSR			DYMO		
Tx Rx pair	City	Country	Main Road	City	Country	Main Road	City	Country	Main Road
1	0.251	0	1.145	3.665	0	6.445	0.004	0	0.093
2	0.065	0	0.455	1.945	0	14.877	0.002	0	0.005
3	0.315	0	0.552	2.912	0	4.508	0.038	0	0.012
4	0.551	0	1.065	5.735	0	8.175	0.009	0	0.018
5	0.295	0	3.295	4.809	0	3.995	0.006	0	0.106
6	0.265	0	1.065	2.631	0	5.005	0.015	0	0.053
7	0.201	0	0.612	4.816	0	6.822	0.016	0	0.055
8	0.956	0	0.598	4.166	0	4.458	0.017	0	0.058
9	0.788	0	0.616	5.164	0	4.188	0.017	0	0.061
10	0.654	0	0.595	3.545	0	3.915	0.018	0	0.063

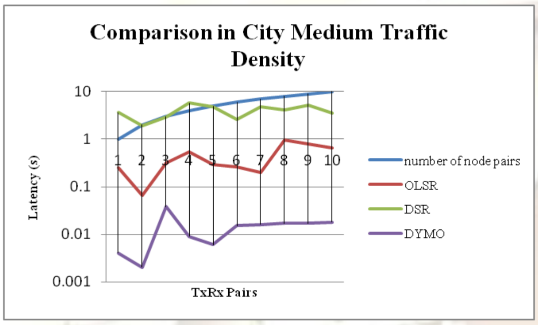
Table 5 Latency results for Medium traffic density scenario

Low Traffic Density-Latency (s)									
	OLSR			DSR			DYMO		
Tx Rx pair	City	Country	Main Road	City	Country	Main Road	City	Country	Main Road
1	0.06252	0	0.00581	3.62981	0	16.78001	0.00452	0	0.00225
2	0.34075	0	0.48891	3.75999	0	10.12163	0.00156	0	0.00689
3	0.67045	0	0.27882	3.45601	0	7.90605	0.00501	0	0.00428
4	0.53535	0	0.52415	3.06552	0	8.23601	0.00265	0	0.01352
5	0.35865	0	0.83295	3.21892	0	7.12552	0.00834	0	0.00428
6	0.465575	0	0.75761	2.96502	0	6.57812	0.00651	0	0.00955
7	0.28702	0	0.94595	2.08551	0	6.56714	0.00705	0	0.01056
8	0.280502	0	1.06599	2.65399	0	6.18642	0.00758	0	0.01157
9	0.428205	0	1.19100	2.45345	0	5.78786	0.00813	0	0.01267
10	0.439565	0	1.32156	2.32295	0	5.40702	0.00861	0	0.01375

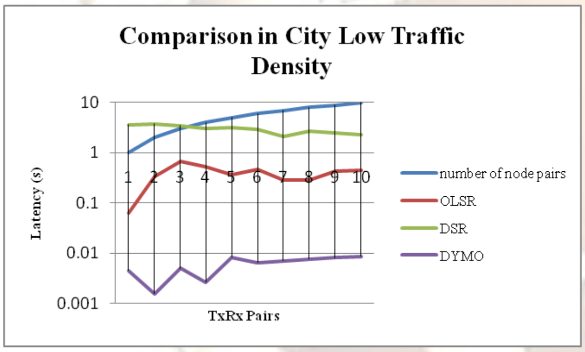
Table 6 Latency results for low traffic density scenarios



(a)

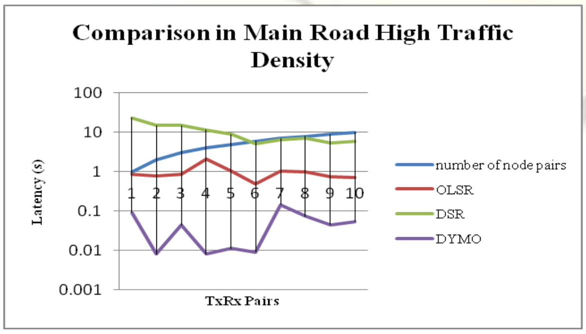


(b)

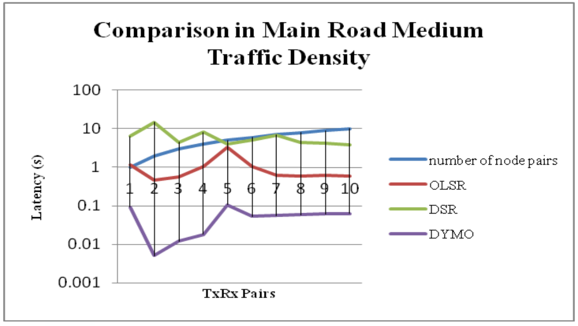


(c)

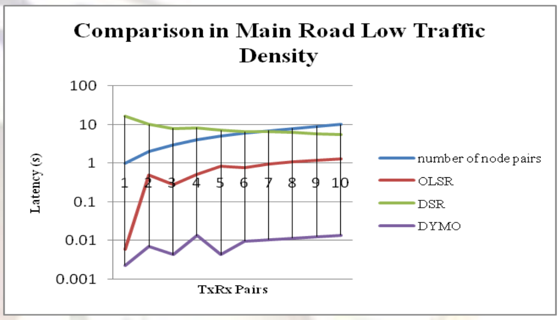
Figure 7(a, b, c): Latency in seconds for city environment



(a)



(b)



(c)

Figure 8(a, b, c): Latency in seconds for main road environment

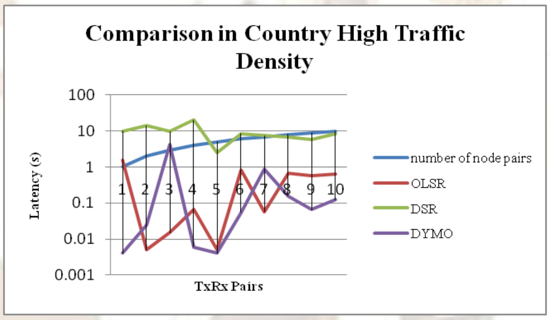


Figure 9: Latency in seconds for country environment

In figures 7(a, b, c), 8(a, b, c), and 9 shows the results of latency in different traffic environments with multiple TxRx pairs. The most noticeable thing in all plots the DSR routing protocol has the highest latency between 5 to 10 seconds in all simulations, and the DYMO having the lowest latency between 0.005 to 0.1 seconds. The city environment resulted in some of the lowest latencies for DSR that ranged between 2 seconds and 7 seconds. The main road and country scenarios are the environments that resulted in much higher latencies. For each of the main road environments, when the TxRx pair's remains low the DSR routing protocol has the highest latency. The OLSR is the second lowest latency protocol under 3 to 3.5.

6. CONCLUSION AND FUTURE WORK

In this conclusion, the DYMO routing protocol is to be the best choice for a routing protocol because of its very low latencies and throughput comparable to other protocols. The second choice is the OLSR routing protocol is also good because its average latency values are reasonable even though higher than DYMO but are the accepted range. In the end it is concluded that traditional approach of using proactive routing protocols in VANETs is not justifiable as reactive routing protocols have performed better than proactive routing protocols in variety of scenarios.

To create a wider variety of traffic environments for simulations is the other possibility for future work. Even though a city, a main road and a country environment are simulated, not all traffic environments are the same as defined for these simulations. Other future work could expand upon this research by constructing multiple VANET systems that could be placed into a vehicle and tested on real roads.

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