

PERFORMANCE EVALUATION OF VANETS ROUTING PROTOCOLS

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ABSTRACT

Lately, the concept of VANETs (Vehicular Ad hoc Networks) has gotten a huge attention as more wireless communication technologies becoming available. Such networks are expected to be one of the most valuable technologies for improving efficiency and safety of the future transportation. Vehicular networks are characterized by high mobility nodes which pose many communication challenging problems. In vehicular networks, routing Collision Avoidance Messages (CAMs) among vehicles is a key communication problem. Failure in routing CAMs to their intended destination within the time constraint can render these messages useless. Many routing protocols have been adapted for VANETs, such as DSDV (Destination Sequenced Distance Vector), AODV (Ad-hoc On demand Distance Vector), and DSR (Dynamic Source Routing). This work compares the performance of those routing protocols at different driving environments and scenarios created by using the mobility generator (VanetMobiSim) and network simulator (NS2). The obtained results at different vehicular densities, speeds, road obstacles, lanes, traffic lights, and transmission ranges showed that on average AODV protocol outperforms DSR and DSDV protocols in packet delivery ratio and end-to-end delay. However, at certain circumstances (e.g., at shorter transmission ranges) DSR tends to have better performance than AODV and DSDV protocols.

KEYWORDS

VANETs, MANETs, Routing protocols, ITS

1. INTRODUCTION

The World Health Organization (WHO) presented a report on road safety covers 182 countries which account for almost 99 % of the world's population. The report indicated that worldwide the total number of road traffic deaths remains unacceptably high at 1.24 million per year [?]. The advances in many technologies have helped many countries around the world implement plans to reduce the road traffic fatalities. Vehicular Ad hoc Networks (VANETs) is very promising that plays an important role in Intelligent Transportation System (ITS). VANETs assist vehicle drivers to communicate (through enabling Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications) to avoid many critical driving situations. VANETs supports variety of safety applications such as co-operative traffic monitoring, control of traffic flows, blind crossing, prevention of collisions, nearby information services, and real-time detour routes computation. VANETs consist of two entities: access points, called Road Side Units (RSUs), and vehicles,

called On Board Unit(OBUs). RSUs are fixed and can act as a distribution point for vehicle networks. Figure ?? shows VANETs communication model of VANETs system.

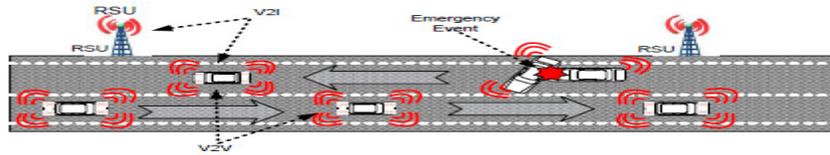


Fig. 1: VANETs Connection topology

In addition to road safety applications, VANETs provide Internet connectivity to vehicles while on the move, so passengers can download music, send emails, book restaurants and/or play games.

Due to vehicle's high speed, vehicular networks are characterized by rapid topology changes. The latter makes designing an efficient routing protocols for vehicular environment very difficult. Designing an adaptive routing protocols to such rapidly changing network typologies is very critical to many vehicular safety applications as failing to route collision avoidance messages to their intended vehicles can render these messages to be useless.

Considerable effort has been spent in performance comparison of VANETs routing protocols: the authors in [?] evaluated the performance of Ad hoc On demand Distance Vector (AODV) and Optimized Link State Routing Protocol (OLSR) for VANETs in city environment, in their study all the characteristics are handled through the vehicle mobility model. Their study showed that OLSR has better performance than AODV in the VANETs, as the AODV protocol has higher routing overhead compared to OLSR. The performance analyses of traditional ad-hoc routing protocols like AODV, Destination Sequenced Distance Vector (DSDV), and Dynamic Source Routing (DSR) for some highway scenarios have been presented in [?]. The authors argued that these routing protocols are not suitable for VANETs. Their simulation results showed that these conventional routing protocols have higher routing overhead which cause less packet delivery ratio. The work in [?] compared AODV and DSR with SWARMIntelligence based routing protocol by varying mobility, load, and size of the network. Their results showed that AODV and DSR have less performance than swarm intelligence routing algorithm in VANET environments. The authors in [?], [?] compared the performance of the routing protocols: AODV, DSR, Fisheye State Routing (FSR) and Temporally-Ordered Routing Algorithm (TORA), in city traffic scenarios. Their results showed that both protocols AODV and DSR have the lowest routing overheads and deliver packets quite fast.

Most previous studies on VANETs routing protocols focused on single driving environment. Therefore, in our study we focus on evaluating these protocol at different environments, i.e., downtown, residential, and suburban. Moreover, the performance of different routing protocols have not been well measured since each researcher used different simulator and performance metrics for performance evaluation. Due to aforementioned problems, there is continuous need to study various ad hoc routing protocols in order to select appropriate routing protocols for different driving environments of VANETs. In this work we evaluate the performance of DSDV, AODV, and DSR in different driving scenarios using the mobility generator (VanetMobiSim) and network simulator (NS2) to model all the driving environment and networking details of the vehicular ad hoc networks.

The remaining of this work is organized as follows: in Section ?? we give background about the objectives behind VANETs and how the standard work is produced. Section ?? classifies the routing protocols and shows their scope and structure. Mobility generator and network simulator tools which used to create different driving environments and scenarios are explained in Section ??. Section ?? defines the scope and structure of the simulation model framework. The obtained results are presented and analyzed in Section ??. Finally our concluding remarks are presented in our conclusion in Section ??.

2. VEHICLE ADHOC NETWORKS (VANETS)

Vehicles independently produce and analyze large amount of data such as time, heading angle, speed, acceleration, position, brake status, steering angle, headlight status, turn signal status, vehicle length, vehicle width, vehicle mass, and even the number of occupants in the vehicle. This data is selfcontained within a single vehicle. VANETs enable vehicles to share this data among themselves and with the road infrastructure. This shared driving information can then be used to implement many road safety applications that help to avoid many critical driving situations such as road side accidents, traffic jams, speed control, free passage of emergency vehicles and unseen obstacles and etc. In October 1999, the United States Federal Communications Commission (FCC) allocated 75 MHz of spectrum in the 5.9 GHz band to Dedicated Short Range Communications (DSRC). As shown in Figure ?? two standards are primarily involved: the IEEE 1609 standards (which defines the communications services and also known as Wireless Access in Vehicular Environment (WAVE)) and IEEE 802.11 p (which defines the physical and medium Application Layer access layer details). The IEEE 1609 standard breaks down into the following components: 1609.1 (WAVE resource manager), 1609.2 (WAVE security services for applications and management messages), 1609.3 (WAVE networking services), and 1609.4 (WAVE multi-channel operations). The IEEE task group "P" has approved the IEEE 802.11p amendment of IEEE 802.11 standard to support VANETs applications. The main enhancements include short latency and higher ranges, up to 1000 meters.

Application Layer	IEEE P1609 WAVE
Presentation Layer	
Session Layer	
Transportation Layer	
Network Layer	IEEE 802.11p DSRC
Data Link Layer	
Physical Layer	

Fig. 2: protocol Stack

3. ROUTING PROTOCOLS FOR VANETS

The main goal of routing protocols is to provide optimal paths between network nodes at minimum overhead possible. Figure ?? classifies the routing protocols into: topologybased and position-based routing protocols. In topology-based routing, each node should be aware of the

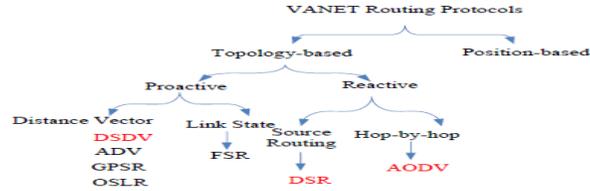


Fig. 3: Routing Protocols hierarchy

Network layout also be able to forward packets using information about available nodes and links in the networks. Topology-based routing protocols use link's information which stored in the routing table as a basis to forward packets from source to destination node; they are commonly classified into two categories (based on their underlying architecture): Proactive (periodic) and Reactive (on-demand) routing protocols.

Proactive protocols (also called table driven protocols) allow a network node to use the routing table to store routes information for all other nodes in the network, each entry in the table contains the next hop used in the path to the destination, regardless of whether the route is actually needed or not. To reflect the network topology changes, the proactive protocols frequently update their routing table. The topology changes are broadcasted periodically to all neighbors. In proactive routing protocols routes to destinations are always available when needed. Proactive protocols usually depend on shortest path algorithms to determine which route is chosen. They generally use two routing strategies: Link State (LS) strategy and Distance Vector (DV) strategy. The most representative are DSDV [?], ADV (Adaptive Distance Vector) [?], GPSR (Greedy Perimeter Stateless Routing) [?] and OLSR [?].

Reactive routing protocols (also called on-demand) reduce the network overhead by maintaining routes only when needed. The source node starts a route discovery process if it needs a non-existing route to a destination. It does this process by flooding the network by a route request message. After the message reaches the destination node or to the node that has a route to the destination, the receiving node sends a route reply message back to the source node using unicast communication. Depending on how the routing method is implemented, reactive routing protocols can be divided into source routing protocols and hop-by-hop or point-to-point protocols.

In source routing protocols every data packet carries the whole path information in its header. Before a source node sends data packets, it must know the total path to the destination, that is, all addresses of intermediate nodes which compose the path from source to destination. There is no need that intermediate nodes update their routing tables, since they only forward data packets according to the header information. The most representative source routing protocol is DSR [?].

On the other hand, hop-by-hop routing protocols try to improve the performance by keeping the routing information in each node. Every data packet does not include the whole path information any more. They only include the address of the following node where data packet must be forwarded to get the destination as well as the destination address. Every intermediate node, along the path, must look up its own routing table to forward the data packets to the intended destination, so that the route is calculated hop-by-hop. The most representative hop-by-hop routing protocol is AODV [?].

4. VEHICULAR SCENARIOS AND ENVIRONMENTS MODEL

In this work we used VanetMobiSim simulator which models all the VANETs traffic and environment details. The Vanet- MobiSim framework includes a number of mobility modules, parsers for geographic data sources in various formats, as well as visualization module. The framework is based on the concept of pluggable modules so that it is easily extend the model to cover many traffic and environment details. The chosen scenario is based on random street configurations. While vehicles are distributed randomly and move in a random direction. Roads in different driving environments are configured with single-lane as well as multi-lane.

The simulated scenario also includes different traffic flows and traffic lights located in different places. Several speeds have been selected as well as level of congestion. The selected mobility pattern is Random Waypoint mobility (RWP) with obstacles avoidance [?], in which vehicles move randomly and freely without restrictions. In addition, vehicles motion is enhanced with IntelligentDriving Model (IDM) which incorporates intersection management and lane changing mechanism [?]. IDM with Intersection Management (IDM-IM) module describes perfectly vehicle-to-vehicle and intersection managements. This module allows vehicles to adjust their speed based on the movements of neighboring vehicles (e.g., if a vehicle in frontbrakes, the succeeding vehicles also slow down and stop at intersections, or act according to traffic lights). IDM with Lane Changing (IDM-LC) is an overtaking module which interacts with IDM-IM to manage lane changes, vehicle accelerations, and deceleration. Based on IDM-LC module, vehicles are able to change lane and perform over takings in presence of multilane roads. Continuous bit rate (CBR) traffic sources are used in vehicles. The source-destination pairs are spread randomly over the simulation area. The number of source-destination pairs and the packet sending rate in each pair is varied to change the offered load in the network. 32-byte data packets are used. Table ?? lists the mobility model parameters and their values used in the simulation.

TABLE I: Mobility modele parameters

Parameter	Value
Number of roads managed by traffic lights	6 roads
Maximum number of roads with multi-lane	4 roads
Number of lanes in multi-lane roads	2 lanes
Time interval between traffic light changes	10000 <i>ms</i>
Minimum initial stay duration of the vehicle	5 Seconds
Maximum stay duration of the vehicle	30 Seconds
Step for recalculating movement of the vehicle	0.1 Seconds
The length of vehicle	5 Meter
Vehicle acceleration	0.6 (<i>m/s²</i>)
Vehicle deceleration	0.5 (<i>m/s²</i>)
Minimal distance to a standing vehicle (i.e., Jam distance)	2 Meters
Safe time headway	1.5 Seconds

To model the vehicular driving environment as close as possible to the real world environment, in our created model we divide the simulation area into three clusters: downtown, residential, and suburban. Clustering in VanetMobiSim tool are used to create different simulation areas with different driving environment and obstacles. Figure ??depict the different simulation areas: downtown, residential, and suburban. The clustering density parameter describes how many clusters per squared area (i.e., clusters/m²). In this model we set the cluster density to be 4 clusters per 1000000 m² which is 250000 m² per cluster area. Based on the simulated area which is

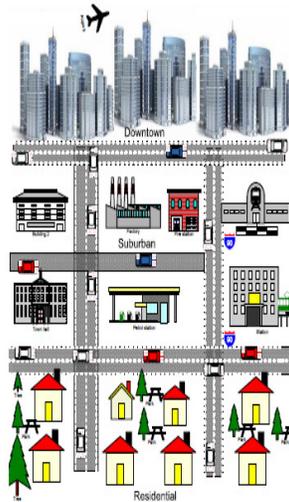


Fig. 4: Different driving environments

TABLE II: simulation area configurations

Cluster description	Number clusters	obstacles
Downtown	1	50
Residential	5	62
Suburban	16	15
Total	12	127

3000000 m² we have 12 clusters in our simulation model. Table ??lists the number clusters and obstacles configured in each simulation area.

5. SIMULATION MODEL FRAMEWORK

Figure ?? depicts the simulation process framework which is divided into three stages: stage 1, 2, and 3. In stage 1, we first define the scenario by writing all the vehicle mobility and environment details using XML file. Next we run the VanetMobiSim simulator to generate vehicular traffic trace file which contain all the details related to vehicular network including environment details such as node identifier, time, position, speed and etc. Figure ?? depicts a snapshot of the created model using VanetMobiSim at one instance time. The generated trace file is going to be the input to NS2 simulator in stage 2. In stage 2 we writing the details related to communications and network configuration using script Tcl programming language. The scripting files from stage 1 and 2 are used to run NS2 simulator. At stage 3, after running the NS2 simulator, the NS2 tool generates two files: Network Animator (NAM) file (*.nam) and a trace file (*.tr) as the outputs. The NAM file records all the positioning and graphical information performed during the simulation time. The trace file (.tr) (generated by NS2) contains all of the information about the simulation, e.g. packets sent, received, dropped, attached sequence number, protocol type, packet sizes, and etc. The trace file is simply available in a text format and could be called as a log file of the simulation.

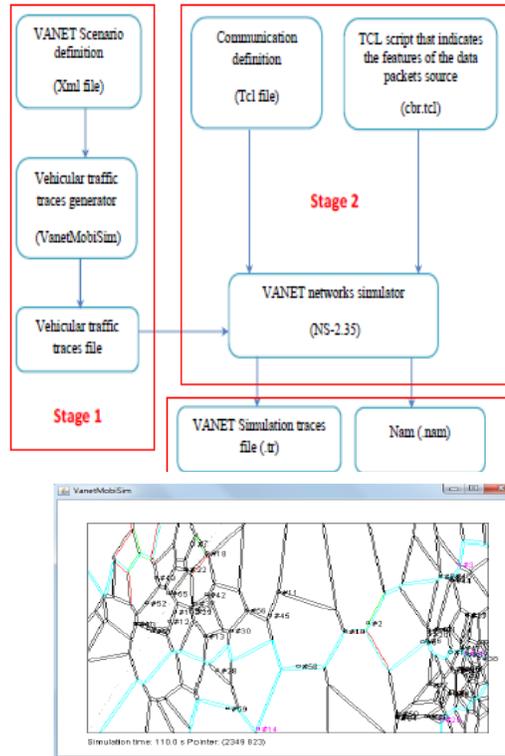


Fig. 6: Simulated vehicular environment snapshot

To extract the statistics (such as transmitted/received bytes and packet loss) from the generated file of NS2, we utilize AWK tool.

6. PERFORMANCE EVALUATION

The results obtained from modeled traffic and environment of vehicular networks using VanetMobisim and NS2 simulators are presented and analyzed in this section. We evaluate the scenarios using global metrics such as packet delivery ratio and end-to-end delay. The results are studied at different driving environment parameters such as node's density, speed and/or transmission range. We used different node densities (i.e., 20 to 45 nodes/km²) while the speed of the nodes are configured randomly between 30 to 50 km/h.

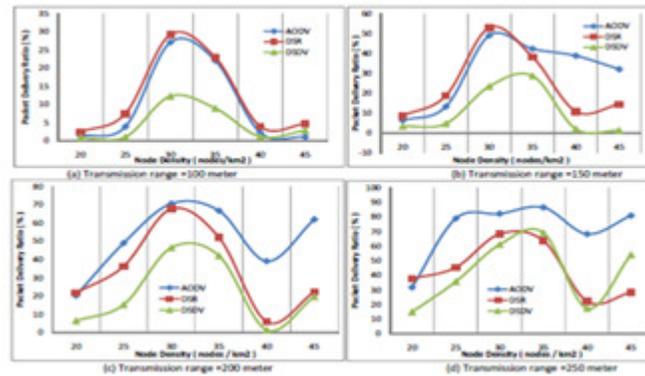


Fig. 7: Average packet delivery ratio vs node densities

Figure 7 shows the average packet delivery ratio versus node densities at different transmission ranges. The adaptability of reactive protocols to the rapid network topology changes of VANETs networks, make AODV and DSR outperform DSDV protocol, the latter protocol is belong to proactive protocols category. We notice that at different node density levels, the performance of three protocols produce the bell shape during the middle values of network node densities. That is because for small node densities (i.e., at sparse networks) only few nodes are available for routing functions. This shortage in forwarding nodes reduces the probability of finding multiple paths between the sources and the destinations. As the vehicular network density increases (e.g., from 30 to 35 nodes/km²), the probability of finding multiple paths through multiple intermediate nodes increases which can result in higher packet delivery ratio. However, as vehicular network density increases (i.e., beyond the optimum range) the performance decreases. That is because higher node densities make more intermediate nodes available for routing, this can produce higher number of paths characterized by higher number of hops compared with small density nodes. Higher number of hop count increases the probability of packet collision and loss as for each hop there is a chance of packet loss introduced by medium access or any other channel related parameters such as fading. Figure 7 shows that at different transmission ranges, the evaluated routing protocols tend to have slightly different performance. For example, when we increase the transmission range (as in Figure 7(c) and 7(d)), the AODV protocol achieve higher packet delivery ratio compared to DSDV and DSR protocols. That is because in AODV protocol all the intermediate nodes share the routing load, i.e., every node along the path uses fresh and updated routing information to forward the packets. However, DSDV and DSR protocols do not seem to gain a substantial improvement at higher transmission ranges. The poor performance of DSDV protocol is resulted from the protocol trying to maintain network connectivity by flooding the network for any topology change. Higher number of paths can cause DSDV protocol to produce higher network overload which turn to overall poor performance. Being source routing protocol, packets in DSR protocol carries the whole path routing information. Intermediate nodes only forward the packets based on the loaded information in the header. For any path break the source node has to use another path stored for the same destination or flood route request if none is available. Higher number of paths and/or hops per each path can also result in network performance degradation in DSR protocol.

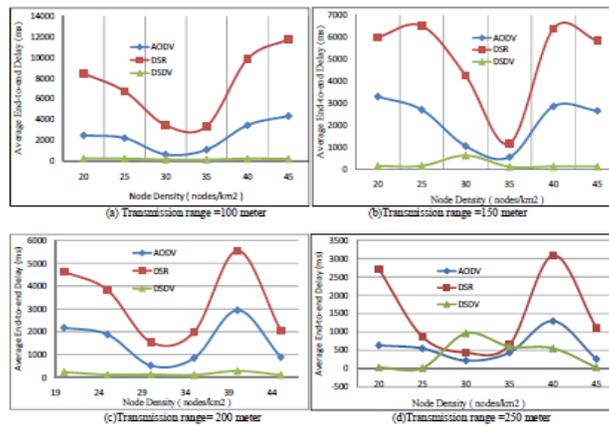


Fig. 8: End-to-End delay vs node density

Figure ?? shows the average end-to-end delay at different node densities and transmission ranges. At all ranges and network densities used, DSDV protocol tends to have the lowest end-to-end delay compared to AODV and DSR protocols. Comparing these results to the packet delivery ratio in Figure ??, we observe that DSDV also has the lowest packet delivery ratio. As explained above, DSDV is proactive protocol where every node in the network stores routing path for every node in the network. Due to the fast topology change of VANETs environment, DSDV can not maintain valid paths to the other destinations specially paths with multiple hops. The stale routing table entry of DSDV protocol, make the latter protocol forwards packets toward broken links. Due to this, the successfully delivered packets are only those of few number of hops which then can result in small end-to-end delay. It is apparent from Figure ?? that AODV outperforms DSR in terms of end-to-end delay at all network densities and transmission ranges. That is because in AODV protocol all nodes along the path share the routing load, where in DSR protocol only the source node is responsible for maintaining the whole path information. Larger header size of DSR (because of routing information stored in the header) consumes higher network capacity which then can result in higher network delay compared to AODV. As shown in Figure ??, the three evaluated protocols tend to have higher packet delivery ratio at the density range of 30-35 nodes/km². They similarly tend to have lower end-to-end delay for the same density range as shown in Figure ?. That is because higher packet delivery ratio means more packets have made it cross the network to the destination, this, as result, indicates the optimum availability of number of routing paths and network congestion during these values of node densities. As we increase the transmission range, the end-to-end delay is decreasing for all the evaluated protocols.

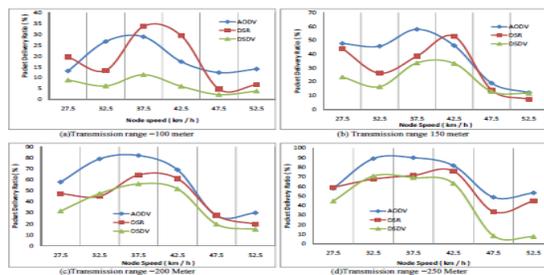


Fig. 9: Packet delivery ratio vs speed

Next we evaluate the performance the routing protocols at different vehicle speed ranges. In this scenario, the number of nodes is fixed to 100 nodes (i.e., 33.33 nodes/km²) and the average node speed increases from (25-30) km/h to (50- 55) km/h. Figure ??shows the average packet delivery ratio at different average node speed and transmission ranges (i.e., 100, 150, 200, and 250 meters).

It is apparent that, on average, all the evaluated protocols tend to perform better as the transmission range is increased. However, at different vehicle speeds the protocols start having different performance. For example, the performance of all protocols is degrading during high speed ranges. However, the adaptability of AODV protocol to higher network topology changes caused by high node speed, improve the performance of AODV compared to DSR and DSDV protocols in terms packet delivery ratio. Reactive source routing protocol (i.e., DSR) slightly perform better than AODV protocol at small transmission range and medium node speed. We think short transmission range can be the cause of higher link failures. Link failures trigger new route discoveries in AODV since it has at most one route per destination in its routing table. Thus, the frequency of route discoveries in AODV is directly proportional to the number of route breaks. The reaction of DSR to link failures in comparison is mild and causes route discovery less often. The reason is the abundance of cached routes at each node. Thus, the packet delivery ratio seems to be better for DSR during short transmission range and mild node speed.

7. CONCLUSION

VANETs is a mile stone enabling technology for ITS applications. VANET system supports many collision avoidance applications. Due to the high mobility of vehicular networks, many challenging problems are still open and requires more focus research. Routing collision avoidance messages in vehicular networks is a vital function for vehicular ad hoc networks. Failure to route these critical message to their desired destinations can make vehicles end up in road crashes. In this work we have studied three routing protocols: AODV, DSR, and DSDV. We used different clusters in VanetMobiSim simulator to create different vehicular driving environments: downtown, residential, and suburban areas. Each created area is characterized by different driving environment parameters: different road obstacles, road lanes, and/or traffic light. The obtained results showed that the routing protocols perform differently at different combination of transmission ranges, vehicular densities, and vehicle speeds. On average, the adaptability and the network load sharing of AODV protocol improved its performance compared to DSR and DSDV protocols. Although DSR protocol showed better performance, at certain values of simulation parameters, than AODV and DSDV protocols, these combination of parameters only represent vehicular environment for only certain cases of transmission range, vehicular density, and/or vehicle speeds.

REFERENCES

- [1] Xiong Wei, Li Qing-Quan, "Global status report on road safety," Decade of Action for Road Safety 2011-2020, Declared by the UN General Assembly, 2013.
- [2] Haerri, J., Filali, F., and Bonnet, C., "Performance Comparison of AODV and OLSR in VANETs Urban Environments under Realistic Mobility Patterns," Proceedings of the 5th IFIP Mediterranean Ad-Hoc Networking Workshop, pp. 14–17, June 2006.
- [3] Xiong Wei and Li Qing-Quan, "Performance Evaluation of Data Disseminations for Vehicular Ad hoc Networks in Highway Scenarios," The International Archives of the Photogrammetry, Remote Sensing, and Spatial Information Sciences, pp. 21–25, April 2008.

- [4] Manvi, S.S., Kakkasageri, M.S., and Mahapurush, C.V., "Performance Analysis of AODV, DSR, and Swarm Intelligence Routing Protocols In Vehicular Ad hoc Network Environment," In International Conference on Future Computer and Communication, pp. 21–25, April 2009.
- [5] Iwata A. et al., "Scalable Routing Strategies for Ad-hoc Wireless Networks," IEEE Journal on Selected Areas in Communications, pp.1369–79, Aug 1999.
- [6] Sven J., Marc B., and Lars W., "Evaluation of Routing Protocols for Vehicular Ad Hoc Networks in City Traffic Scenarios," in Proc of the 11th EUNICE Open European Summer School on Networked Applications, Colmenarejo, pp. 584–602, April 2005.
- [7] Perkins C.E. and Bhagwat P., "Highly Dynamic Destination-Sequenced Distance Vector Routing (DSDV) for Mobile Computers," SIGCOMM '94 Proceedings of the Conference on Communications Architectures, Protocols and Applications , pp. 234–244, Sep 1994.
- [8] Boppana R.V. and Konduru P., "An Adaptive Distance Vector Routing Algorithm for Mobile Ad Hoc Network," Proceedings of the Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies, pp. 1753–1762, Oct 2001.
- [9] Brad K. and Kung H. T., "Greedy Perimeter Stateless Routing for Wireless Networks," Proceedings of the 6th Annual International Conference on Mobile Computing and Networking , pp. 243–254, Oct 2000.
- [10] Clausen, T. and Jacquet, P., "Optimized Link State Routing Protocol (OLSR)," RFC Editor, vol. OLS:RFC3626, pp. 195–206, 2003.
- [11] D. Maltz D. Johnson, and Y. Hu., "The Dynamic Source Routing (DSR) Protocol for Mobile Ad hoc Networks for IPv4," URL <http://tools.ietf.org/html/rfc4728>, February 2007.
- [12] Perkins C., Belding-Royer E., and Das E., "Ad-hoc On-demand Distance Vector Routing," Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA '99, pp. 90–100, Feb 1999.
- [13] Johanson P., Larsson T., Hedman N., Mielczarek B., and Degermark M., "Scenario-based Performance Analysis of Routing Protocols for Mobile Ad-hoc Networks," Proceedings of ACM/IEEE MOBICOM'99, pp. 195–206, Aug 1999.
- [14] Helbing, D., Hennecke, A., Shvetsov, V., and Treiber, M, "MicroandMacrosimulation of Freeway Traffic," Mathematical and Computer Modelling Journal, vol. 35, pp. 517–547, 2002.