Vehicular Ad hoc Network Paradigm and Evaluation of IEEE 802.11a and IEEE 802.11p using Realistic Vehicular Traces

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***Abstract*— In recent years, the vehicular communication has become an innovative and sophisticated way to provide necessary information to the rural or urban travellers in roads and motorways. Through the idea of multi-hop ad hoc networking, it is possible to efficiently disseminate traffic related information to the drivers and utilise the information collected from on-board sensors from neighbouring vehicles to provide more safe travel to the passengers. This paper presents an evaluation of two proposed wireless standards for vehicular network communication – IEEE 802.11a and IEEE 802.11p using TCP and UDP data transmission. This paper also investigates various vehicular mobility models and traffic generators for simulations and several well-known routing protocols for inter-vehicular communication. The simulation uses AODV and DSR routing protocols in a realistic vehicular environment using a real-world topological map extracted from TIGER data set. VanetMobiSim is used to generate realistic mobility model and the wireless network is simulated using the dominant network simulator ns-2. From the simulations it is found that IEEE 802.11p performs better than IEEE 802.11a in case of TCP transmission while performs almost similarly in UDP transmission.**

I. INTRODUCTION

NOWADAYS travel, traffic and transportations have become an integral part of our daily life. Real-time traffic data collection and dissemination is able to provide backend support to the end users' applications and services e.g. active navigation. Again with the increasing number of vehicles on roads government organisations and vehicle manufacturers need to provide sufficient measures in both planning and development on traffic management and ensuring public safety. The main concern is the traffic data dissemination in a more appropriate and precise way which can be used for real-time decision making. Intelligent Transportation Systems (ITS) addresses the challenges faced in traffic information collection and dissemination, advanced highway signalling, real-time traffic monitoring and surveillance, mobility data mining and knowledge discovery and a large number of internet-based applications providing entertainment and multimedia services. All of these ITS technologies depend on the efficiency of the communication techniques between vehicles and roadside infrastructures. Vehicular Ad hoc Network (VANET) is nowadays in a more focused stage through real-life implementations and academic researches. Although the primary reason of interest behind VANET research only emphasises the traffic and road safety but it has opened new windows for internet access, distributed computing, delay-tolerant networking, e-commerce etc. Although many promising applications e.g. congestion avoidance, emergency road maintenance notifications etc. are seen today to use the single-hop point-to-point VANET but it is still a challenge to implement real-life applications that will utilise multi-hop ad hoc networking technique. This paper investigates the latest vehicular communication technology paradigm, mobility models and mobility generators, routing protocols, simulation tools and major performance criteria. The rest of the paper is organised as follows: section II gives the background insight of VANET architecture. Section III presents mobility models and vehicular traffic simulators which are widely used to simulate and measure the performance of VANET. Section IV discusses different VANET routing protocols and their characteristics. Finally section V presents a simulation work which uses two well-known VANET simulation tools VanetMobiSim [1] and ns-2 [2] to evaluate the performance of IEEE 802.11a and 802.11p using two popular MANET routing protocols (Ad hoc On-demand Distance Vector (AODV) [3] and Dynamic Source Routing (DSR) [4]) with realistic vehicular traffic traces. Section VI includes some conclusions, challenges and future work directions.

II. BACKGROUND

The IEEE 802.11p draft amendment to the popular IEEE 802.11 standard focuses on the enhancements of physical medium and medium access techniques to ensure inter-vehicular and roadside communications. It includes the 5.9 GHz licensed ITS band and enables Dedicated Short Rage Communications (DSRC) channels which is specially designed for one-way or two-way vehicular communications [45]. Recently multi-hop ad hoc networking opened a new era in inter-vehicular communications (IVC), vehicle-to-vehicle (V2V) and infrastructure-to-vehicle (I2V) communications. VANET architecture can be described in three different categories: pure WLAN/Cellular, pure ad hoc and hybrid. In the pure WLAN/Cellular architecture, access points or base stations are able to provide connectivity to the vehicles.

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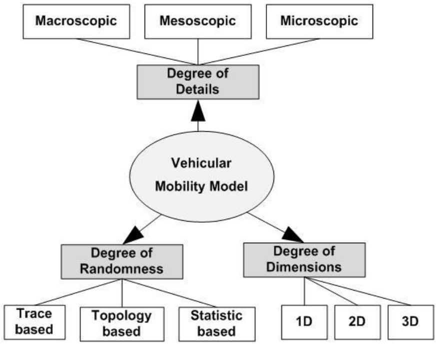


Fig. 1. Different aspects of vehicular mobility model generation

In pure ad hoc network all vehicles are responsible to construct and maintain the network without any network infrastructure. In hybrid architecture, vehicle which has both WLAN and Cellular networking capabilities act as the gateways or routers for other vehicular nodes. As vehicles can move at high speed, it is much harder to construct and maintain the communication network. Thus vehicular nodes frequently experience node disconnection, lost route and re-discovery problems. Delay tolerant and opportunistic routing therefore seems to be a better choice for VANET. Energy and power management which is a major concern for many ad hoc network types is not a challenging issue for VANET because of the onboard vehicle battery power supply. Similarly processing and storage capability obstacles can also be handled if vehicles are equipped with on-board computing devices. The availability of the computing devices also ensures on-demand, multimedia and roadside business applications. Another important characteristic of VANET is that it can be used for vehicular traffic mobility prediction. As in most of the big cities and highways, the vehicle mobility patterns are fixed through lane separation, traffic lights, speed cameras etc. it is convenient to use mobility data mining techniques to provide improved traffic management services. Mobility data mining could provide valuable knowledge about predictive movement, future positions based on daily, weekly and monthly movement patterns of vehicles.

III. MOBILITY MODELS FOR VEHICULAR AD HOC NETWORK

To design, model and simulate any VANET architecture it is necessary to have realistic network model and traffic data or mobility pattern taken from real scenarios in daily life. As conducting real-life experiments is not always possible due to proper environment, safety, setup cost, equipments etc., simulation is the only feasible way to test and evaluate network protocols for VANET. Fig. 1 shows different aspects of a mobility model. Macro and micro mobility features are the two main categories for vehicular mobility attributes. The *macro-mobility* features include road topology, road structure, lane formation, speed limits, restrictions, traffic signs etc. It also considers the effects of points of interests which exhibit particular mobility patterns for vehicles. The *micro-mobility* features include individual vehicle, driver behaviours based on sex, age and mental conditions; driver's interactions with other drivers, with the traffic signs and various driving conditions; vehicle acceleration, deceleration, overtaking criteria etc. *mesoscopic-mobility* feature [9] describes the traffic flows from an intermediate level between the macro and microscopic features. Fig.1 shows a breakdown of various degrees and levels of categorisation for vehicular mobility model generation. A comprehensive discussion on VANET mobility models can be found in [5]-[8].

The multilayer description of vehicular mobility patterns consist of trip modelling, path modelling and flow modelling [9] and based on these criteria the authors categorise the mobility models as random models, flow models, traffic models, behavioural models and trace-based models. A concept map is presented in [5] which states two primary building blocks – Motion Constraints and Traffic Generator which are linked together with time patterns. Motion Constraint also employs Topological Maps which also includes Speed Constraints, Attraction Points and Obstacles. On the other hand, Traffic Generator is further decomposed into Car Generation Engine and Driver Behaviour Engine. These decompositions also include car's type and particulars, centres of interest, social habits, mobility predictions and driver's danger assessments.

Random models e.g. Random Waypoint (RWP) model, Random Walk model (RWalk), Reference Point Group model (RPGM), node following model and Gauss-Markov model are popular choices of many research works for both (Mobile Ad-hoc Network) MANET and VANET. Although these random models are widely used within the research community, these are not able to generate realistic traffic data for vehicular network simulations [5]. The few first attempts to make a realistic mobility model are through the introduction of Simple Freeway model and Manhattan (or Grid mobility) model. Simple Freeway model restricts vehicle's movement into several bi-directional multi-lane freeways while the Manhattan Grid mobility model restricts the movement on urban grids [5]. But these models do not consider the macro and micro mobility features [5]. Many recent traffic generation tools are capable of generating realistic traffic and mobility data for vehicles.

IMPORTANT [10] and Java based BonnMotion [11] tools implement several variations of random mobility models while considering only the macro-mobility features. IMPORTANT only features the Car Following model which features car-to-car inter-distance control a specific type of micro-mobility attribute. The generated scenarios can also be exported into several well-known network simulators like ns-2 [2], GloMoSim [12], QualNet [13] etc. Mobility Model Generator of Vehicular Networks (MOVE) [14] adds the TIGER/Line (Topologically Integrated Geographic Encoding and Referencing system) [15] map (available from U.S. Census Bureau) extraction capability as well as random and manual mobility traces generation. This map parsing and mobility trace generation schemes also add improved capability into SUMO [16] vehicular mobility simulator. Both the Street Random Waypoint (STRAW) [17] tool and GrooveSim [18] are capable of parsing TIGER data files. STRAW implements an intersection management scheme using traffic signs and traffic lights. GrooveSim mainly introduces non-uniform distribution of vehicles speed on the roads considering motion constraints and speed limitations. Therefore, vehicles are not able to maintain the initial velocity set by the model.

MobiREAL [19] mainly focuses on pedestrian mobility showing a guideline and direction for future vehicular mobility model design. UDel model [20] is a set of tools for generating urban mobility along with the calculation of radio propagation. It works based on the statistical data obtained from the U.S. Department of Labour and is capable of parsing Geographical Information System (GIS) data which makes it more realistic while producing radio signal propagation information. SHIFT [21] traffic simulator, developed within the PATH [30] project, is a complete microscopic tool which generates mobility traces according to validated mobility models. Voronoi Model [22] is based on the voronoi graphs which utilises voronoi channels to represent roads and other spatial area based on Voronoi Tessellation algorithm [22]. It introduces global moving direction and local direction patterns for vehicular mobility thus it mainly improves the motion constraints mentioned previously. The obstacle mobility model [23] utilises random building corners and voronoi tessellations in order to identify the movement path between buildings. It also includes a radio propagation model; wireless communication and movements are restricted using the paths identified by the voronoi graph which is based on the presence of individual obstacles.

The CanuMobiSim [24] is a Java-based flexible user mobility modelling tool which is able to generate mobility traces for ns-2, QualNet, GloMoSim. While most of the mobility trace generation tools only consider macro-mobility attributes CanuMobiSim considers micro-mobility attributes which enables it to generate more realistic mobility traces. It implements several car-to-car interaction models like Fluid Traffic model [24], Intelligent Driver Model (IDM) [24] etc. The tool also includes a complex traffic generator that can utilise source-destination based path calculation using Dijkstra's shortest path algorithms or can also model trips between attraction points. It also identifies a separate class of users or drivers and their individual motion patterns. Extractions of spatial information from Geographical Data Files (GDF) or TIGER data sets are also possible.

CanuMobiSim is primarily focused on general purpose MANET. To extend its capability towards the VANET VanetMobiSim [25] is introduced as an extension of it. The model is the pioneer to consider the mobility patterns of a vehicle through a driver's point of view. To define road topology, VanetMobiSim introduces user-defined graph and spatial data extraction from GDF map, TIGER map and clustered voronoi map. Road topology is characterised by introducing multiple lanes in both directions, physical separation of traffic flows for opposite directions, traffic signs or traffic lights and speed limits. Trip generation is based on either random motion or activities sequencing which consists of multiple sets of “start” and “start and stop” points. VanetMobiSim introduces three categories of micro-mobility models like considering mobility behaviour in a deterministic way or a function of nearby vehicles in either a single lane or multiple traffic flows. The Graph-Based Mobility Model (GBMM), the Constant Speed Motion (CSM) and the Smooth Motion Model (SMM) originally introduced by CanuMobiSim fall under the deterministic categorisation. The Fluid Traffic Model (FTM) and Intelligent Driver Model (IDM) falls under the single lane or multiple traffic flows categorisation. To model realistic vehicular mobility patterns, a tight relationship is maintained between the traffic generation mechanism and topological map. Therefore, while a driver approaches towards a traffic signal it slows down and acts as per the traffic light's indication. Again a close relationship is maintained according to the traffic signs and state of the traffic lights and other neighbouring vehicles activities. To model intersection management schemes VanetMobiSim introduces Advance Intelligent Driver Model (AIDM) which introduces acceleration and deceleration mechanism in the road intersection points. The Intelligent Driver Model with Intersection Management (IDM-IM) and Intelligent Driver Model with Lane Changes (IDM-LC) are the inherent models from AIDM. Furthermore, the IDM-LC model is actually extends the IDM-IM model through introducing lane changing model. Minimising Overall Breaking deceleration Induced by Lane changes (MOBIL) model, which is another interesting feature in this tool to model lane changes and maintain compatibility with AIDM also. More details on VanetMobiSim and its features and a comprehensive validation can be found in [7].

IV. ROUTING PROTOCOLS FOR VEHICULAR AD HOC NETWORK

Unicast routing protocols for vehicular ad hoc networks could be categorised broadly into two categories; topological and geographical as shown in Fig. 2. Proactive and reactive protocols maintain link state routing tables or discover route on-demand. Geographic routing mechanisms use location of the source node and its neighbouring nodes to make routing decisions by utilising neighbourhood discovery process. In [26] the authors classified geographic routing protocols into three categories; non-Delay Tolerant Network (non-DTN), Delay Tolerant Network (DTN) and hybrid. The non-DTN does not consider network partitioning or disconnectivity while the DTN type routing protocols consider this issue and act accordingly. Hybrid protocols use both kinds of measures to handle partial network connectivity and temporally disconnectivity.

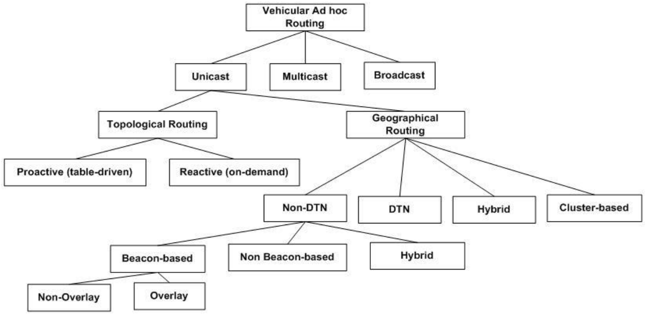


Fig. 2. Classification of Vehicular Ad hoc Networks Routing Protocols

Greedy Perimeter Stateless Routing (GPSR) [27] is one of the widely discussed geographic routing protocols in literature. A node greedily forwards network packets to a neighbouring node that is geographically close to it. A local maxima is reached when there is no direct communication path between the source and forwarding nodes due to the presence of obstacles e.g. buildings and trees or there is no other neighbour node which is closer to the destination node. If such a situation is encountered, GPSR uses face routing and right hand rule to go around and again trying to resume in greedy mode. As GPSR uses planer graph to build the network, therefore routing loops can occur. Again, mobility introduces a great performance impact on GPSR because of frequent network partitions and disconnectivity. GPSR with Advanced Greedy Forwarding (AGF) [28] is an improvement over GPSR which solves two problems. By increasing the frequency of beaconing it solves the problem of having outdated information at each node. And by introducing speed, direction and total time to travel into the beacon packet, every node computes the deviation of the destination node's estimated current position from its previous position.

Greedy Perimeter Coordinating Routing (GPCR) [29], a beacon-based overlay routing protocol, utilises nodes at the junctions or intersections of roads which follow a natural planer graph. It represents the planer graph using underlying roads and nodes using both greedy and perimeter routing along the edge. Upon reaching the junction (J) a coordinating node guides the packets to the next edge of the planer graph using the right hand rule. In a realistic network simulation in ns-2, it has been shown that GPCR performs better than GPSR with high packet delivery rate [29]. Geographic Source Routing (GSR) [29] assumes to have static city map information which will provide global topological knowledge about the total network. Source node can determine the junction nodes using the map information and directly forwards packets to them in the road intersections. Therefore, GSR performs more accurately in the city areas and has better packet delivery rate with low bandwidth consumption comparing to two well-known topological routing protocols AODV and DSR [30]. Similarly like GSR, Anchor-based Street and Traffic Aware Routing (A-STAR) [31] also utilises city street map information to compute a series of junction points in advance. But A-STAR selects the anchor points based on the traffic flow along the street. It chooses two types of paths – one is along the bus routes which indicate the static path for traffic and another one is dynamically rated path with latest traffic information. When nodes fall into local maxima it computes another anchor path immediately while marking that region as "out-of-service" for other network packets. It remains in "operational" state after a timeout period.

Street Topology Based Routing (STBR) [32] is a beacon-based overlay routing scheme which computes the road connectivity at the junction nodes selecting a junction node as a master. The master nodes exchange information with each other. Thus these are able to sense either the next junction node for a packet delivery is up or down. Unlike GSR or A-STAR, STBR computes its route based on geographic distance. Another overlay routing mechanism is Greedy Traffic Aware Routing (GyTAR) [33] where a junction node receives a packet and will decide which will be the best junction node to forward to it. It also assumes the number of cars on a road from the roadside units and thus determines the connectivity, traffic density and physical distances from each other. Based on this information GyTAR marks the neighbouring junction nodes with weights and in time of making a packet forwarding decision it utilise these weight values accordingly.

Landmark Overlays for Urban Routing Environments (LOUVRE) [34] is a geo-proactive beacon-based overlay routing technique which determines the sequence of overlaid junction nodes in advance. Considering a threshold of vehicular density on a road it chooses a connected link thus not taking the spatial information of the road into account. Thus it decreases the delay of computing overlay routes and increases the global route optimality while fails to scale as much as is expected. Topology-assist Geo-Opportunistic Routing (TO-GO) [35] is non-DTN hybrid routing which acquires 2-hop neighbour information to select the best target node based on the greedy mechanism to forward network packets and introduces opportunistic forwarding. The protocol always chooses the target node instead of the destination node. It is unlikely that the destination is in the same street as the forwarding node or the source node. As the packet is expected to travel through several junctions, network packets are opportunistically forwarded to the target nodes and those are constantly making progress towards the destination node.

Based on the predictable vehicular mobility, Vehicle Assisted Data Delivery (VADD) [36] employs opportunistic delay tolerant networking. At a junction point each node makes its decision to forward packets to the next node based on the smallest packet delivery delay. This delay is computed based on road density and distance, vehicle velocity etc. Several variations are also available which choose the forwarding node after the forwarding path is selected. Location First Probe (L-VADD), Direction First Probe (D-VADD), Multi-path Direction First Probe (MD-VADD) and Hybrid Probe (H-VADD) are some of the mentionable variations. Geographical Opportunistic Routing (GeOpps) [37] is another similar type of routing protocol that utilises vehicle's onboard navigation systems to greedily find out the next forwarding node which is close to the destination. It computes the shortest distance from the packet's destination to the nearest point (*NP*) of vehicle's moving path and the estimated arrival time to the destination. If another neighbour vehicle is found which has lower arrival time for packets towards the destination the packets are forwarded to that vehicle and repeats until it reaches the destination. GeoDTN+Nav [38] is a hybrid approach which includes both greedy, perimeter and DTN mode of operations. The greedy and perimeter mode operation is same as previously mentioned for others routing mechanism. Based on the network connectivity (by measuring the number of hops the packet has passed so far), neighbour node's packet delivery quality and neighbours moving direction, a vehicular node can determine possible delay tolerance capabilities on different paths. It can also switch back and forth between the DTN and Non-DTM mode to utilise both its delay tolerant and greedy routing capability.

Cluster-based routing protocols can be also used for VANET. A cluster is consisting of a cluster-head and other members. A cluster-head is responsible for maintaining the member information dissemination and inter-cluster communication. The main drawback is the instability of the lifetime of a cluster-head. Clustering for Open IVC Networks (COIN) [39] is a cluster-based VANET routing protocol where a cluster-head is elected estimating the vehicular dynamics and driver intentions rather than traditional cluster-head election procedure. Thus it provides a more stable virtual cluster infrastructure, increases the lifetime of a cluster-head and decreases the frequency of cluster membership changes.

Broadcast routing is essential for vehicular network communication in the case of dissemination of traffic data, emergency, congestion, weather forecast, roadside business promotion and advertisements etc. Although simple flooding technique works well in simple stable network topology, in the case of a highly dynamic VANET, more efficient broadcast mechanisms are required. BROADCOMM [41] is stated as an emergency broadcast routing protocol which utilises hierarchical network topology considering a group of vehicles as a virtual cell. These types of small virtual cells follow the moving direction of the vehicles consisting of them. There are also cell-reflectors which are the nodes located close to the geographical boundary of the virtual cells. Cell reflectors behave as a cluster-head or base station for a certain period of time. It also handles emergency messages within its own cell and the neighbouring cells and act as intermediate routers for neighbouring cells. These simple mechanisms work well in motorways. Urban Multi-hop Broadcast (UMB) [41] is another broadcast routing protocol which handles issues related to interference, collision, hidden node problem etc. during multi-hop message dissemination. The mechanism always selects the furthest nodes in the broadcast direction for forwarding and acknowledging packets without any prior information.

Geocast routing is basically location-based multicast routing. Thus in geocast routing information is delivered to a group of network nodes identified by their geographical locations and service region. Therefore, simplified multicasting techniques can be used by defining multicast groups for specific service regions. In [42] a simple geocast technique is described for inter-vehicular communications which uses selective rebroadcast technique with waiting time to see whether it receives the same message from any other nodes or not. If it receives the same information from other neighbouring nodes before the expiry of the waiting time it will not rebroadcast the packet. A similar type of idea is also used in Inter-Vehicles Geocast (IVG) [43] protocol. In [44] another specialised geocast routing mechanism is described which will broadcast packets to the nodes which stay in the geocast service region for a certain period of time within its lifetime. It is more like a client-server based communication technique used for service oriented applications like location based services (LBS), advertising and publish-and-subscribe. This idea of periodic retransmission of geocast message is called abiding or stored geocast. Table I shows a summary of the routing protocols.

TABLE I

SUMMARY OF VEHICULAR ROUTING PROTOCOLS

Routing Protocol	**Type**	**Unique Properties**
GPSR	Unicast	Non-DTN, Beacon-based, Non-Overlay, greedy forwarding, perimeter and face routing
GPSR with AGF	Unicast	Non-DTN, Beacon-based, Non-Overlay, solves the problem of routing loops in GPSR
GPCR	Unicast	Non-DTN, Beacon-based, Overlay, Junction Points
GSR	Unicast	Non-DTN, Beacon-based, Overlay, Static City Maps
A-STAR	Unicast	Non-DTN, Beacon-based, Overlay, Static City Maps with dynamic traffic rating
STBR	Unicast	Non-DTN, Beacon-based, Overlay, Junction Points as Master Nodes
GyTAR	Unicast	Non-DTN, Beacon-based, Overlay, consider traffic density, connectivity and distance
LOUVRE	Unicast	Non-DTN, Beacon-based, Overlay, assumes the sequence of overlaid junction nodes in advance
TO-GO	Unicast	Non-DTN, Hybrid, greedy forwarding and opportunistic routing
VAAD	Unicast	DTN, smallest packet delivery delay based on road density and delay
GeOpps	Unicast	DTN, calculates the Nearest Points in the moving path from the destination point
GeoDTN+ Nav	Unicast	Hybrid, combining greedy, perimeter mode and DTN routing mechanism
COIN	Cluster-based	Clustered, elect cluster head based on vehicular dynamics and driver intention (Unicast)
BROADCOMM	Broadcast	Hierarchical topology, virtual cells of vehicles
UMB	Broadcast	Consider interference, packet collision and hidden node problem
Geocast	Multicast	Selective rebroadcast (Simple)
IVG	Multicast	Selective rebroadcast
Geocast	Multicast	Consider location based services (Specialised)

V. EVALUATION OF IEEE 802.11A AND IEEE 802.11P STANDARDS

IEEE 802.11p draft standard and IEEE 1609 WAVE (Wireless Access for Vehicular Environment) standards are an emerging technology for vehicular communications and ad hoc networking operating in the 5.9 GHz frequency bands. It uses OFDM-based physical layer construction with recommended 3 Mbps data rate. While IEEE 802.11a standard which is amended in IEEE 802.11-2007 standards also use OFDM-based technology in the 5 GHz frequency band with 54 Mbps data rate. Both of these technologies utilise short range communication facility having a larger operational frequency than other popular wireless technologies in 2.4 GHz range e.g. IEEE 802.11b and IEEE 802.11n.

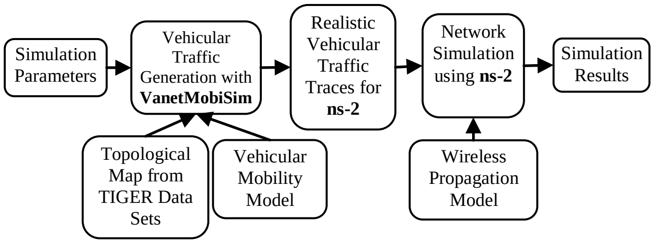


Fig. 3. Overall simulation procedure using VanetMobiSim and ns-2

TABLE II

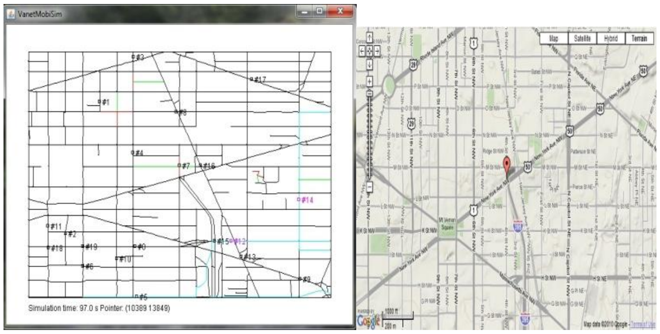
VANETMOBISIM PARAMETERS FOR VEHICULAR MOBILITY DATA GENERATION

Parameters	Values
Region	District of Columbia, Washington, USA
Data Set	TIGER/Line files 2006 Second Edition
Dimension of Area	2000 X 2000 m^2
Maximum Traffic Lights	Maximum 5 in an intersection
Number of Lanes	Maximum 4, minimum 2
Trip Generator	Random trip generator with minimum stay of 5 sec and maximum stay of 30 sec
Path Selection	Dijkstra's shortest path algorithm - default
Position Generator	Random initial position generation every time
Mobility Model	Intelligent Driver Model with Lane Changes (IDM-LC)
Lane Changing Model	Minimizing Overall Breaking deceleration Induced by Lane changes (MOBIL)
Vehicle Movement Speed	Minimum 8.33 m/s (30 km/h) and maximum 13.89 m/s (50 km/h)
Vehicle's Length (l)	5 m (Default)
Maximal Acceleration (a)	0.5 m/sec^2 [0.6 m/sec^2 (Default)]
Comfortable Deceleration (b)	0.5 m/sec^2 [0.9 m/sec^2 (Default)]
Jam Distance (s0)	1 m (Min. distance to a standing vehicle)
Recalculation time of movement parameters	0.5 s (step)
Maximum Safe Deceleration	4 m/sec^2 (Default)
Driver's Politeness Factor (p)	0.7 [0.5 (Default)]
Threshold acceleration (athr)	0.2 m/sec^2 (Default)
Number of Vehicles	20
Simulation Time	100 sec

TABLE III

NS-2 PARAMETERS FOR NETWORK SIMULATION

Parameters	Values	
ns-2 Version	2.34	
PHY and MAC	IEEE 802.11a and 802.11p with 80211 PHYEXT	
Propagation	Shadowing model with path loss	
	IEEE 802.11a	***IEEE 802.11p***
Sensitivity	-82 dBm	-85 dBm
Frequency	5.18 GHz	5.9 GHz
Bandwidth	-96 dBm for 10 MHz bandwidth	-99 dBm for 10 MHz bandwidth
Power Monitor Sensitivity	-99 dBm	-102 dBm
Header Duration	20 µs	40 µs
Antenna Type	Omni-directional	
Transmission	150 m	
Packet Size	1000 with packet sending interval 0.005 sec	
TCP Packet Size	1460 with window size 32	
Routing	AODV, DSR	
Time	100 sec	



(a). VanetMobiSim Screenshot (b) Google Map Screenshot

Fig. 4. Street Map of District of Columbia, Washington, USA in (a). VanetMobiSim (based on TIGER/Line 2006 Second Edition Data Set) (b). Google Map Screenshot (Year 2010)

DSRC radio technology also fits well in IEEE 802.11a based mechanism. Therefore, an effort has been carried out since 2004 to include DSRC into IEEE 802.11a standard which resulting IEEE 802.11p draft standard [46]. Again, IEEE 802.11p includes the enhancement stated in IEEE802.11e Enhanced Distributed Channel Access (EDCA) mechanism therefore it is designed to support multiple channel access and message prioritisation using Access Categories (AC). So, IEEE 802.11p can be used for reliable data transmission e.g. TCP more efficiently [48]. Although IEEE 802.11a is a legacy standard but due to its efficiency in short range communication it is useful to make performance comparisons with IEEE 802.11p. Therefore, for short range vehicular communication both of these specifications are quite suitable in nature.

In this paper, a vehicular ad hoc network simulation has been designed using the popular network simulator ns-2 and realistic mobility traffic generator VanetMobiSim. Intelligent Driver Model (IDM) with Lane Changes is applied as the driver model and a real life topological map of the District of Columbia; USA extracted from the TIGER/Line 2006 Edition data sets is used. A 2000 x 2000 m^2 area is chosen for the simulation. Fig. 4(a) and 4(b) exhibit the VanetMobiSim screenshot and corresponding Google Map, respectively to show the similarity of the simulated area with real-life. In Table II, a list of key parameters is given which have been used in VanetMobiSim to generate realistic traffic data and produce mobility traces for ns-2. These traces are applied on two well known topological routing protocols AODV and DSR. IEEE 802.11a and IEEE 802.11p are used respectively using TCP and UDP data transmission between a source and destination node for 100 seconds. Note that, the simulation results shown in this paper are only based on IEEE 802.11a and 802.11p PHY and MAC layer enhancement available in ns-2. The IEEE 1609/WAVE specifications are not considered here. Table III shows the list of related parameters that are used in ns-2. In all cases node 0 is designated as the packet source and node 1 as the destination. For TCP data transmission, CBR traffic over TCP is used while FTP over UDP is used in another case.

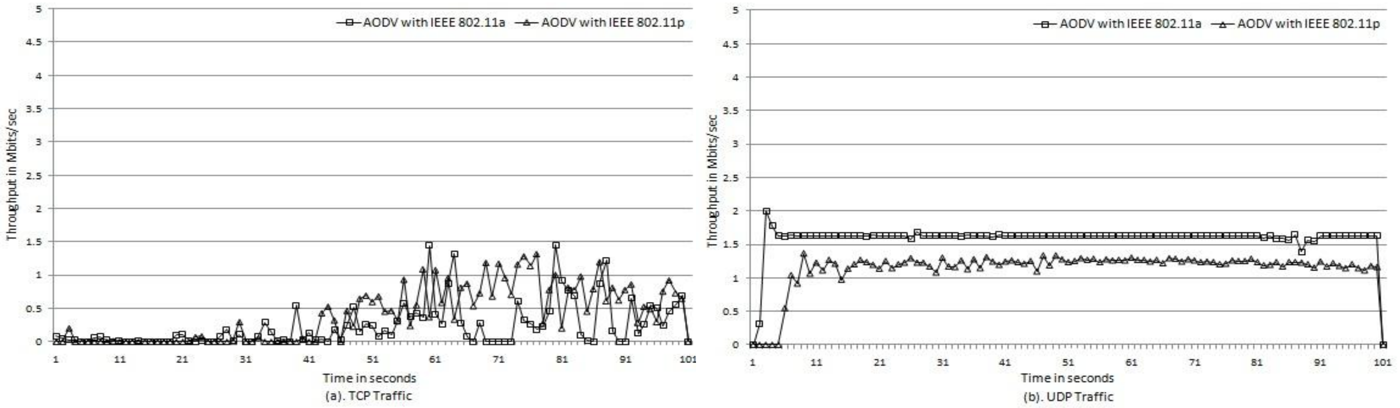
A block diagram is shown in Fig. 3 to describe the overall simulation procedure using VanetMobiSim and ns-2. Fig. 5 shows the performance throughput graphs of AODV routing protocol for both IEEE 802.11a and IEEE 802.11p standards. From Fig. 5(a) it is seen that for TCP traffic though there is a late start for both protocols, at later stage IEEE 802.11p shows more stable throughput than IEEE 802.11a. Again Fig. 5(b) shows that for UDP, traffic IEEE 802.11a produces better throughput when comparing to IEEE 802.11p which carries out with a slow start but maintains a reasonable throughput performance for the entire simulation. Fig. 6 shows the throughput performance of DSR protocol. Fig. 6(a) shows that for TCP traffic IEEE 802.11p performs better than IEEE 802.11a. However, from Fig. 6(b) it is hard to compare the performances of the two standards for UDP traffic as both of them show a constant throughput performance throughout the total simulation period.

For TCP transmission, AODV routing protocol suffers from frequent packet drops and low packet delivery ratio but DSR routing shows more stable throughput. In case of UDP transmission, DSR also performs better than AODV routing in terms of throughput measurement. IEEE 802.11p uses OFDM-based radio technology in the physical layer while FDMA/TDMA based techniques in MAC layer for link bandwidth management. It also uses dedicated control channels to exchange network control packets. On the other hand, IEEE 802.11a uses back-off periods to avoid collision detected in the MAC layer which delays the estimated packet transmission time [47].

According to the WAVE standards, the communicating nodes need to perform the authentication and association process therefore can start actual data transmission right away. These features make IEEE 802.11p draft standard suitable for vehicular communications rather than IEEE 802.11a standard. In this simulation, it is seen that TCP traffic suffers less while using IEEE 802.11p specifications. As TCP produces higher control packets and ensures reliable end-to-end communication therefore IEEE 802.11a adds extra overhead over the data transmission phase. But in unreliable UDP transmission both of these wireless standards perform similarly in AODV and DSR routings. DSR performs better due to its reactive nature of utilising source routing rather than proactive routing table management in AODV. Therefore, it might be beneficial to choose IEEE 802.11p as the wireless standard for vehicular ad hoc networking and WAVE systems as in today’s Internet world a big portion of data traffic is carried out by TCP. A more deep investigation is needed to clearly understand TCP and UDP performance behaviour over ad hoc networks.

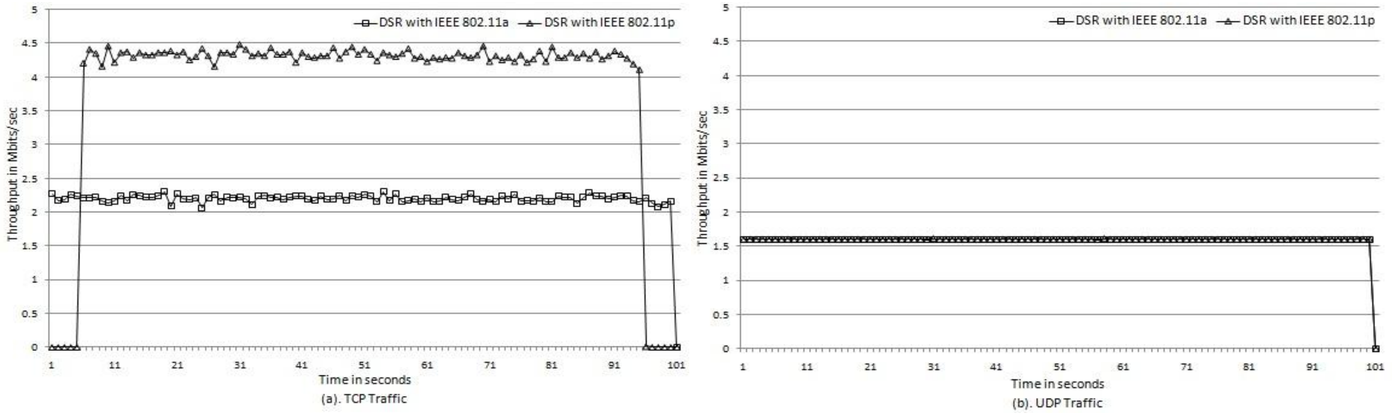
VI. CONCLUSION

This paper presents an ns-2 simulation using a realistic vehicular traffic generator VanetMobiSim to observe the performance of two proposed IEEE standards IEEE 802.11a 802.11p. It is found that DSR routing performs better than AODV and IEEE 802.11p draft standard shows a more stabilised nature with both AODV and DSR protocols in TCP and UDP transmissions. It is seen that the enhanced quality of service features in IEEE 802.11p makes it more suitable for reliable data transmission like TCP although a simulation with full WAVE architecture can able to produce more clear aspects. Large scale simulations are needed to observe the scalability of other topological and geographical routing protocols within these two IEEE standards. A comprehensive discussion has also made on vehicular mobility models and recognized routing protocols. Our future work will extend towards a more large scale network simulation with more emphasis on evaluating the performance of reliable data transportation using IEEE 802.11p/IEEE 1609 WAVE network architecture.



(a). TCP Traffic (b). UDP Traffic

Fig. 5. AODV throughput using IEEE 802.11a and IEEE 802.11p



(a). TCP Traffic (b). UDP Traffic

Fig. 6. DSR throughput using IEEE 802.11a and IEEE 802.11p

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