Analyzing MANETs Routing Protocols using VANETs Mobility Models

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In the name of ALMIGHTY ALLAH,
The most Beneficent, the most
Merciful.

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Final Approval

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Dedication

Dedicated to Almighty Allah and my Family who has supported me in all aspects throughout my life.

A dissertation submitted to the
Department of Computer Science,
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as a partial fulfillment of the requirements
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Declaration

We hereby declare that this research project, neither as a whole nor as a part thereof has been copied out from any source. It is further declared that we have developed this software entirely on the basis of our personal efforts made under the sincere guidance of our teachers. No portion of the work presented in this report has been submitted in support of any application for any other degree or qualification of this or any other university or institute of learning.

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Project In Brief

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Abstract

Vehicular Ad hoc Networks (VANETs) is a special type of Mobile Ad hoc Networks (MANETs) in which the nodes are vehicles and is based on vehicle to vehicle and vehicle to road side communications. There is an increase research interest in VANETs and its different areas have been targeted by different researchers from last decade. One of the most challenging characteristic of VANETs is high node mobility because due to high mobility the network may experience a more rapid and dynamic change in the topology. The high mobility will affect the availability and stability of wireless channel and hence the performance measurement results will be affected. So, it is crucial to reflect the affects of high mobility in simulations and to generate realistic mobility models for accurate results. Realistic mobility models are important tools to analyze the Performance of routing protocols for the ad-hoc networks because ad hoc routing does not depend on protocol only, the mobility model, the way model is generated, and performance factors on the basis of which the protocol is analyzed, also play a vital role in the overall performance measurements.

In this thesis, we have presented a simple framework which gives a detail about the entities and their characteristics, most important components, for the generation of realistic mobility models for vehicle ad hoc networks. Our framework also shows that how these components will affect each other. Furthermore, we have chosen some existing and our modified mobility models for evaluation of routing protocol. After conducting several simulation experiments each including several tests, we have presented our conclusions about the effect of different mobility models on protocols performance in VANETs.

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Introduction

Ad hoc network is a collection of nodes forming a temporary network with out the help of any pre-existing infrastructure and no centralized control. The nodes in an ad hoc network [7] may be mobile can be a laptop, PDA, or any other device capable of transmitting and receiving information. Nodes performs both the functions of transmission and receiving of data and also acts as router. Network is temporary as nodes are generally mobile and may go out of range of other nodes in the network. Routes between nodes may potentially contain multiple hopes as shown in Figure 1. Each node may traverse multiple nodes to reach its destination. When the nodes are mobile then this mobility causes a great change in the route from source to destination and thus causing the topology to be greatly affected.

The following variations exits in mobile ad hoc networks [44]

- Fully Symmetric Environment

The symmetric characteristic is that all nodes in an ad hoc network have similar capabilities.

- Asymmetric Capabilities

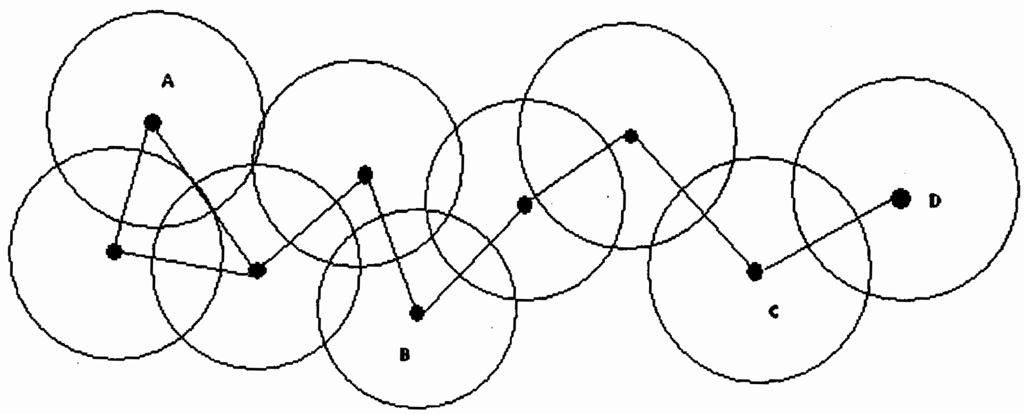
The Asymmetric Capabilities are that transmission ranges are different, battery life, processing capacity and speed may be different at different nodes.

- Asymmetric Responsibilities

Considering Asymmetric Responsibilities only some nodes may route packets and some nodes may act as leaders of nearby nodes e.g. cluster head.

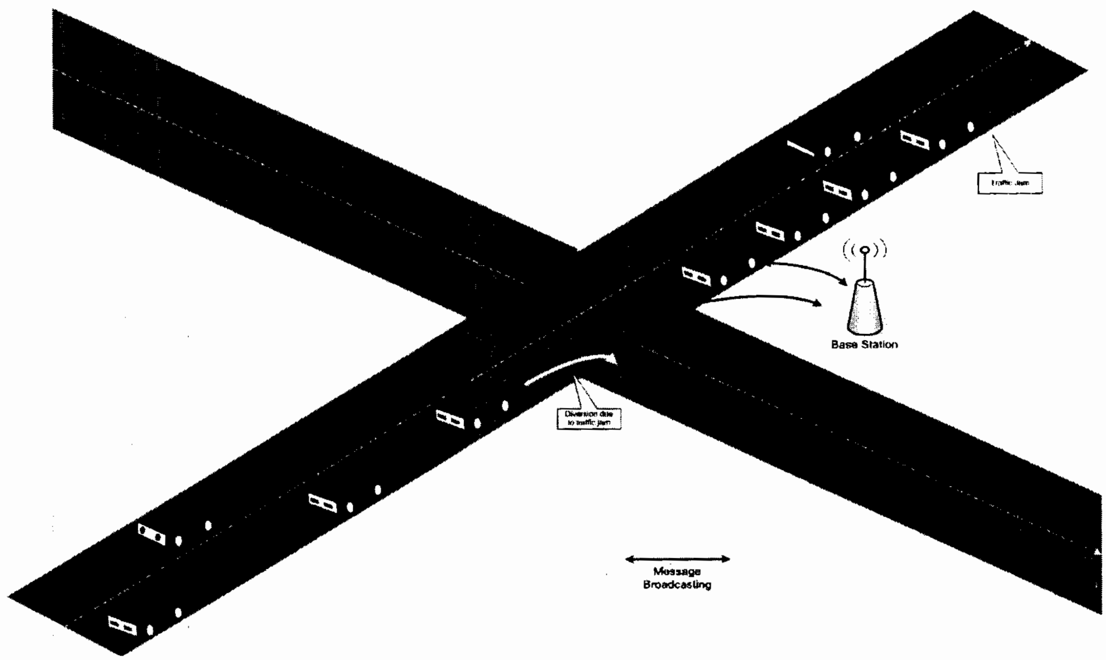
- Traffic characteristics

The traffic characteristics may differ in different ad hoc networks by bit rate, timeliness constraints, reliability requirements, unicast / multicast / geocast and host-based addressing / content-based addressing / capability-based addressing.



"Figure1 mobile nodes in MANETs"

A special type of mobile ad hoc networks is the vehicular ad hoc network in which the mobile nodes are vehicles and is based on vehicle to vehicle and vehicle to road side communications. Each vehicle is equipped with Wi-Fi hardware. One of the most challenging characteristic of VANETs is its high mobility which causes a rapid change in the topology of the network. The vehicles are restricted to their specified roads with specified directions it means that the vehicles have very limited degree of freedom as compared to the other ad hoc networks where the nodes randomly chose their directions. The inter vehicle communication can be grouped as safety related applications and non-safety applications . The safety related applications are developed for safe and accidents free traffic on roads. A number of applications have been developed for safety purposes that provide help in cooperative driving, vehicle collision warnings, road conditions warnings etc. The non safety applications include applications for using internet in the vehicles, entertainment support, file sharing, digital maps applications and congestion showing applications etc. Figure 2 shows a typical VANETs scenario in which the vehicles communicate with each other and with road side base stations.



"Figure 2 VANETs"

1.2 VANET Mobility Models

The mobility models provide the movement patterns for mobile nodes and are considered a key component in the simulation of mobile ad hoc networks. The mobility models also represent different characteristics that affect the wireless communication in real world. The mobility model should provide the characteristics of real world scenarios because in real world there exist different factors that do affect the wireless channel. Now the trend is towards the generation of realistic mobility models because for accurate and complete results there is no advantage of using a non realistic mobility model for simulation as they are not covering most of the needed parameters. Vehicular mobility models are usually considered microscopic or macroscopic [16]. In macroscopic point of view roads, streets, crossroads, and traffic lights, node density, initial position and speed is considered

[4]. On the other hand in microscopic point of view, the movement of each individual vehicle and its behavior with respect to other vehicles is determined [4]. The microscopic characteristics include the driver behavior, overtaking, braking, acceleration, road side obstacles, atmospheric factors and motion constraints etc.

The following mobility models have been chosen for the analysis.

1.2.1. Freeway Mobility Model.

The free way mobility model was first introduced in [4]. In freeway mobility model the nodes follow a certain path in a particular direction. Maps are used in freeway model which have a number of freeways and each freeway has a number of lanes for traffic in both directions. In freeway model the vehicles are restricted to their lanes on freeways so there is no random movement of the node because the nodes are now following a specific direction. The velocity of each vehicle is dependent upon its previous velocity.
There is safety distance between the two nodes that must be maintained while moving in the same lane and the velocity of following node can not exceed the preceding node. The freeway mobility model has high spatial and temporal depended and also applies strict geographic restrictions on nodes because the nodes are restricted to their lanes only[4]. The application of freeway mobility model are exchanging traffic status and tracking a vehicle on a freeway.

1.2.2. Manhattan Mobility Model

The Manhattan mobility model was first introduced in [4]. Maps are also used in Manhattan mobility model but these maps are different from that of freeway mobility model. The maps consist upon horizontal and vertical streets and their intersections representing urban areas. Each street has two lanes for each direction. Node moves on these horizontal and vertical streets. As in real life a node when reaching an intersection can turn to left , right or move in straight direction so in Manhattan model when the nodes reaches to the intersections they move with 0.5 probability on same street, 0.25 turning to left and 0.25 turning to right. In Manhattan model the velocity of the nodes is restricted to the lanes of streets and also there is a velocity dependency between to nodes. So Manhattan mobility model has high spatial and temporal dependencies and also impose geographic restrictions on nodes mobility but give some freedom by allowing the nodes to change its street. The Manhattan mobility model is useful in modeling movement in urban areas where persistent computing services are provided between portable devices. [4].

1.2.3. Fast Car Model

The topology of the VANET depends upon the mobility of the vehicles, with high velocities there would be a more rapid change in topology and ultimately the performance of the network will be greatly affected. This basic concept of high mobility by Fast car model was introduced in [2].In Fast car model [2] the nodes are highly mobile vehicles and moving on a pre defined paths or roads. The speed of the vehicle can be up to 150 km/hr. The vehicles in Fast car model is not always mobile but the may be stationary at certain place and wait for a while and then move on to the next specified destination [2]. For example, vehicles stop at certain break points and then moves to their specified destinations. In non realistic mobility models the vehicles moves with a pre-defined speed on velocity and there is no consideration of acceleration, increase in velocity, and deceleration, decrease in velocity. In Fast car model we have introduced the concept of acceleration and deceleration and presented its impact on performance of MANET protocols.

1.2.4 Slow Car Model

The idea of Slow car model [2] is similar to that of Fast car model with a slight difference and that is vehicle's velocity. In case of slow car model the vehicles move with slow velocities. Here the vehicles are assumed in busy streets or in rush hours so there is speed is reduced to 45 km/hr to 55 km/hr. In such case the traffic is dense and the whole burden is on wireless channel causing contention in channel. With slow velocities of vehicles the topology of the network will not be changing rapidly because with slow velocities the inter vehicle space is not changing very fast.

1.3 Mobile Ad hoc Networks Routing Protocols

In this section we will give a brief introduction of the chosen MANET protocols for analysis. Routing protocols is an active research area in ad hoc networks. So, a number of routing protocols have proposed and implemented for wireless ad hoc networks. The classification of protocols is very important for comparisons and analysis [11]. There are different classification methods available on the basses of which the protocols can be classified. But, most commonly the routing protocols are divided into unicast, multicast and broadcast [11]. In ad hoc networks the mobile node acquires and maintains the route information. On the basis of how a node acquires and maintain routing information, protocols can be divided into proactive routing, reactive routing and hybrid routing protocol.

Proactive Routing

Proactive routing protocols are also called “table driven” protocols [11]. In proactive routing node maintains up-to-date routing information about all reachable nodes. It means that all nodes maintains a consistent view of the network topology so when there is change in the topology then all nodes updates their information about the change and propagate the change to all other nodes in the topology. The nodes periodically update the information whether data traffic exists or not so in proactive protocols the over head to maintain the up-to-date information is high. The examples of proactive routing protocols are Wireless Routing Protocol (WRP), the Destination Sequence Distance Vector (DSDV) and the Fisheye State Routing (FSR).

Reactive Routing Protocols

In reactive routing the routing paths are searched only when needed that is why they are also called "on-demand" routing protocols. When a route is needed a route discovery operations is started and this discovery operation will continue till a route is found or no route is available to a particular destination. The reactive protocols have less controlled overhead over the proactive protocols. Thus reactive protocols have better scalability than proactive routing protocols in mobile ad hoc networks [11]. However, before data sending, the reactive routing protocols suffer from long delays. Examples are Dynamic Source Routing (DSR) [5] and Ad hoc On- demand Distance Vector routing (AODV) [10].

Hybrid Routing Protocols

This type of protocols combines the advantage of proactive and reactive routing and overcome there shortcomings. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. The main disadvantages of such algorithms are Advantage depends on amount of nodes activated and Reaction to traffic demand depends on gradient of traffic volume. Examples are Hybrid Routing Protocol for Large Scale Mobile Ad Hoc Networks with Mobile Backbones (HRPLS)[13], Hazy Sighted Link State routing protocol (HSLS) [14] ,Zone Routing Protocol (ZRP) [15].

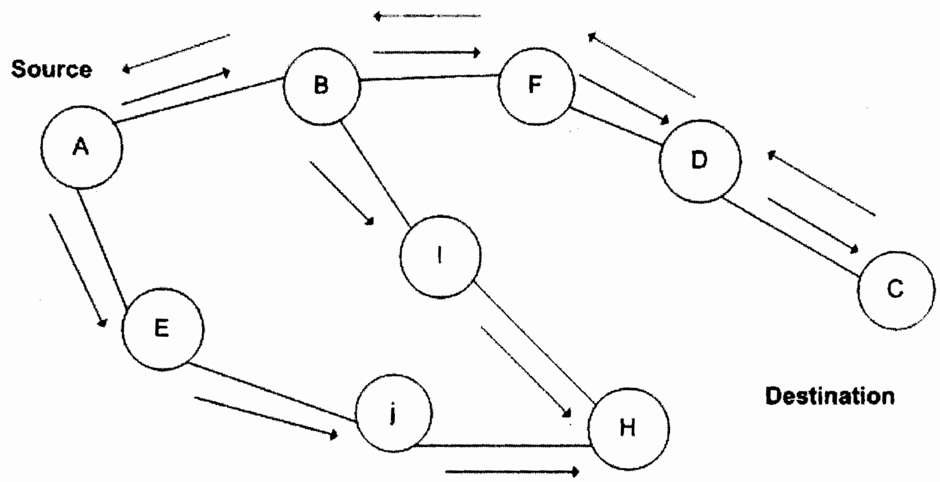
The following Protocols have chosen for analysis.

1.3.1 Ad Hoc On-demand Distance Vector Routing (AODV)

The AODV is a reactive unicast routing protocol for ad hoc networks [10, 11]. As it is a reactive routing protocol so only information about the active paths is maintained and this information about the active paths is maintained in tables at each node. The tables contains the information about the destination to which it has currently has a route. After a pre specified time the route table information expires.

In AODV, when a source node wants to send a packet to a destination it initiates a route discovery operation and broadcast route request packet (RREQ). A RREQ includes addresses of the source and the destination, the broadcast ID, the last seen sequence number of the destination as well as the source node's sequence number. Sequence numbers are important to ensure loop-free and up-to-date routes.

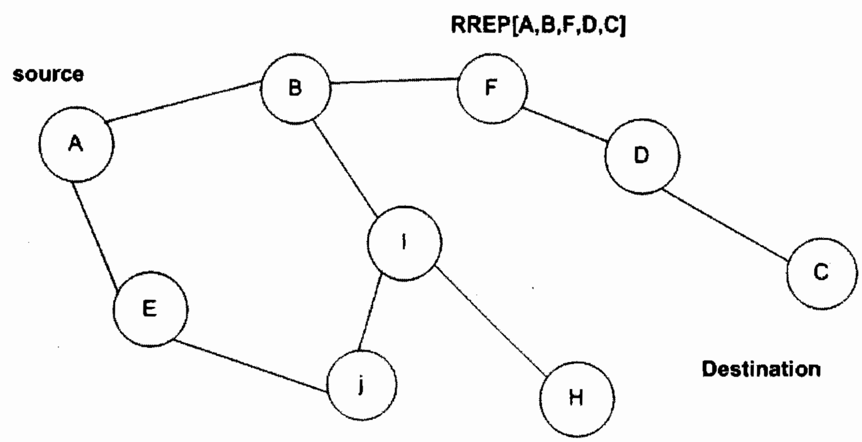
The RREQ starts with a small TTL (Time To Live) value but if destination is not found then the TTL value is increased. In AODV when a node receives a RREQ then it checks in its cache the destination number currently it has and the one that is specified in the RREQ. If the destination sequence number is greater or equal then a RRRP packet is created and forwarded back to source and follows the same path as that of RREQ. Upon receiving the RREP each node in the way updates its table entries with respect to the destination node. Each node drops the RREP with lower destination sequence number. Active links and the status of the neighbors can be checked by hello packets. On discovering a disconnection it broadcast a route error packet to neighbors which in turn broadcast the packet and in this way all the nodes updates its information. Figure 3 shows the route forwarding and route reply (red arrows) in AODV.



"Figure 3 Route Request and Route Reply in AODV"

1.3.2 Dynamic Source Routing (DSR)

DSR [5] is reactive unicate routing protocol that uses the source algorithm so each packet contains complete routing information. DSR works in two phases, the route discovery and the route maintenance. Each node has cache in which it maintains route information. When a source node wants to send a packet to a destination it first checks its own cache information if the route information is locally available then the source node includes the routing information before sending the packet. But, if the information is not available in the source cache then it initiates a route request operation by broadcasting a route request packets. This packet contains the source and destination addresses and also a unique number to identify the request. When a node receives a route request packet then it checks its cache for the information of the destination if it does not have, then it appends its own address and forward the packet to its neighbor and travels to the destination. Each intermediate node appends its own address to the route request packet. An intermediate node only processes the packet which it has not seen before. When the route request packet reaches the destination, or a node that it has information about the destination the route reply packet is generated to the source containing the whole information about the route to the destination. When the route reply packet is generated then it is route back to the source by either the existing route, or by the collected route information in the route record field. In case of unidirectional link the destination initiates a source finding operation. In case of route errors a ROUTE_ERROR packet is sent backward to the source. After receiving this packet the source initiates a new route discovery operation and all the broken links should be removed from the cache.



"Figure 4 Route Reply in DSR"

1.3.3 Optimized Link State Routing protocol (OLSR)

The Optimized Link State Routing protocol (OLSR) [6] is a proactive, table driven protocol. In OLSR fewer nodes are allowed to propagate the link state information. The only node selected for propagation of control massages is called multipoint relays (MPR). Each node selects its MPR. A node selects its MPRs from its one hop neighbors with bi-directional linkage. When a node broadcast a massage, this message will be broadcast by MPRs only so the overhead for message flooding can be greatly reduced. Nodes selected as MPRs announces their information periodically. The shortest routes information to all destinations is provided to all the nodes which have selected the MPR. The link state information received by each node is used in the construction of its routing tables. This table provides overall topology information to a node. The MRPs are used as intermediate node to a destination.

Using OLSR, each node periodically floods the link state information of its MPR set through the network. The frequency of link state updates is adjusted according to whether a change of the MPR set has been detected. If the MPR set has been changed, the period of link state exchange is set to a minimum value. If the MPR set remains stable, the period is increased until it reaches a refresh interval value. Each node obtains network topology information and constructs its routing table through link state messages. Routes used in OLSR only include multipoint relays as intermediate nodes.

1.4 Motivation

Vehicular ad hoc network is an active research area from last decade. Different areas of VANETs, as research, have been targeted by researchers. One of the challenging areas is mobility models development for the VANETs because the mobility model is a key tool for simulation. Most of the research in vehicular ad hoc networks is simulation based because the real life tests are too expensive or testing a large number of nodes is infeasible in real world. So, a number of mobility models have been proposed by the researchers for testing the performance of routing protocols. But, to the best of our knowledge, most of these models don't represent the actual realism exit in the real world. So there is a need to develop more realistic mobility models, although, some existing mobility models have included a few realistic components.

1.5 Problem Domain

VANETs have different challenging characteristics that differentiate it from other type of networks. One of the most challenging characteristic of VANETs is high node (vehicle) mobility. Mobility is challenging because it has many impacts on network performance. Due to high mobility network topology constantly changes at every moment. This topological change and its management is a key research area in VANETs. The topological changes and movement patterns are represented by mobility models which are considered a key component in the simulation of mobile ad hoc networks. So, the development of realistic mobility models, which truly represents the real life scenarios, for VANETs is very crucial because the real life tests are expensive and difficult to adopt.

1.6 Proposed Approach

In our proposed approach, we have first identified the necessary realistic and non realistic components for the development of a realistic mobility model for VANETs. On the basis of these identified components we have developed a simple entity framework for the development of mobility models. Furthermore, we have modified Manhattan mobility model, fast car and slow car models and included realistic components such as acceleration and deceleration, speed reduction during turning in the intersections in these mobility models. We have analyzed the effect of our modified mobility models, Manhattan and Freeway mobility models on the performance of MANETs routing protocols.

1.7 Thesis Structure

The thesis is further organized as follows. In chapter 2 we have presented the related work. In chapter 3 problem domain and proposed solution; and in chapter 4 system designs has been presented. In chapter 5 we have given a study about the implementation of the project. Chapter 6 deals with simulation and analysis results. Chapter 7 is about conclusions and future work.

2

Related Work

2.1 Introduction

There is a rich literature available on Vehicular Ad hoc Networks (VANET) and mobility models used for VANET and Mobile Ad hoc Networks (MANET) and also about the performance analysis of various routing protocols for MANET and VANET. In early research, only a few models like random waypoint, group mobility models and other random mobility based models were used for ad hoc networks and even for vehicular ad hoc networks. But, with the passage of time the research trends has changed and new dimensions were included in the mobility models generations for VANETs. The researchers have tried to include more and more realistic components in the mobility models to truly represent the real world scenarios. The related research community has used Congested urban scenarios, urban scenarios with traffic signs, lane changing models, city traffic scenarios, highways scenarios etc. for the detail analysis and study of the impact of these scenarios on the performance of inter-vehicle communications. On the basis of these analysis results different new mobility models and protocols have been proposed for the vehicular ad hoc network.

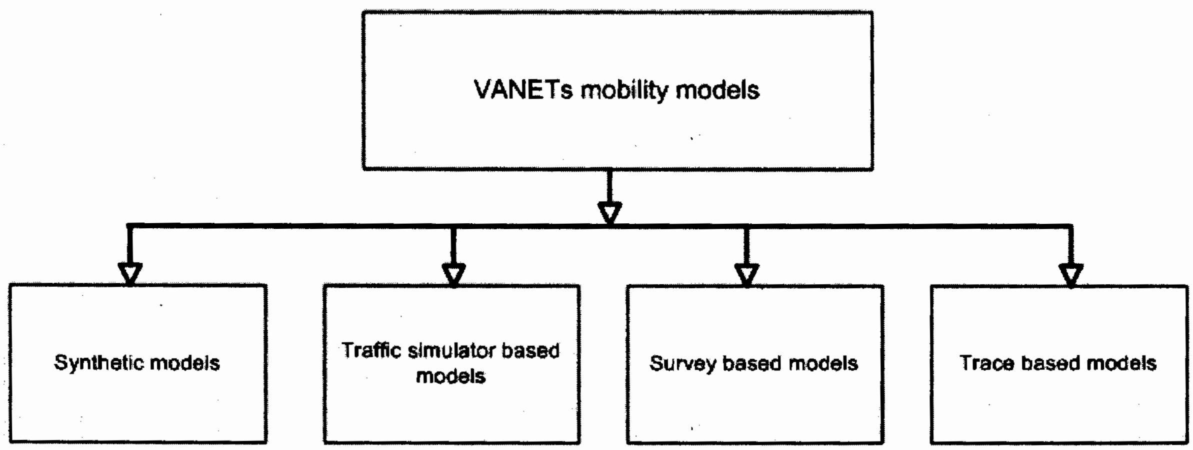
2.2 Related Research

The following papers, surveys and technical reports have been considered for related work for the Vehicular ad hoc networks and different mobility models that have been used for VANETs.

2.2.1 VANETs Mobility Models

Mobility models are key component for simulation, different researchers have proposed a number of mobility models and analyzed different mobile ad hoc networks protocols with a number of parameters. For this purpose different projects have been conducted.

A detail study about the vehicular ad hoc networks mobility model is presented in by J´erˆome H¨arri in [8]. They have classified the vehicular mobility models in the following four different classes:



"Figure 5 VANETs mobility models"

1-Synthetic Models wrapping all models based on mathematical models. Synthetic models may be further categorized in five classes by Fiore in [9]: stochastic models, traffic stream models, Car Following Models, Queue Models, and Behavioral Models.

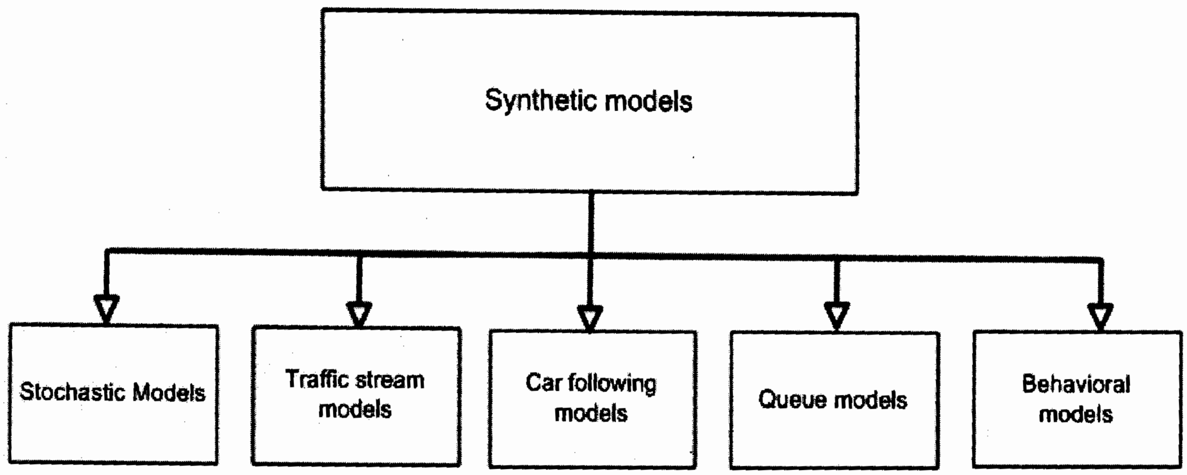
2-Traffic Simulators-based Models, here the vehicular mobility models are generated from a detailed traffic simulator. Different researchers have developed a number of traffic simulators for VANETs which are able to generate a mobility models with some realistic characteristics. In traffic simulator based a number of simulators have been developed e.g. PARAMICS [47], CORSIM [48], VISSIM [49] or TRANSIMS [50] are able to model urban microscopic traffic, energy consumption or even pollution or noise level monitoring.

3-Survey-based Models, in such models the mobility patterns are derived from surveys. The vehicle and human busy hours, working hours, arrival hours, mobility etc are taken into account and then on the basis of these survey mobility models generated. The survey based models includes UDel Mobility Model [39] and Agenda-based [40] mobility model.

4- Trace-based Models, where the mobility models are generated from real mobility traces. A mobility models based on WLAN Traces is presented by Groos in [41]. Using semi Markov process user mobility is modeled by J. Hou in [44]. Further example of Trace based mobility models are in [42, 43, 45, 46].

A detailed study of the inter-vehicular communication is also presented in technical report by Fiore [9]. The authors have given their classification about various vehicular mobility models. The vehicular mobility models have been classified in Stochastic models, Traffic Stream models, Car Following models, Queue models and Behavioral models as shown in figure.

The stochastic models show the random moment of nodes on a graph. In stochastic models the graphs represents the paths or roads that the vehicles follows. The City section [26] , Manhattan and Freeway [4] models, Real Track mobility model[27],Virtual Track model [28] are grouped as stochastic mobility models.



"Figure 6 Firoe's classification"

Traffic stream models look at vehicular mobility as a hydrodynamic phenomenon. These models try to relate the three fundamental variables of velocity, density and flow to vehicles. The simplest model of traffic stream model was proposed by Lighthill and Whitham [12], assuming the velocity to be a function of the density. For highway scenario a macroscopic approach is used by Rudack in [30].

In car following models, the relationship between the car in front and the following car is represented. These models describe the behavior between the cars in a microscopic manner. A detail survey and comparison of car following models is available in [31], [32], [33].

In Queue models the roads are considered as FIFO queues where the car comes as clients. Each queue is given a length and a maximum flow which is determined by the lanes. These models are introduced by Gawron. Queue models are employed by [34], [35] and present very large scale VANETs performance evaluations. They have used the vehicular traffic simulator from ETH [36].

In behavioral models the human mobility can be applied to vehicular mobility. This concept was introduced by Legendre in [37], [38]. In these models moments are determined by behavioral rules and are represented by attractive and repulsive forces.

A detail about several entity and group mobility models for ad hoc network is presented by T Camp in [1]. They have presented a survey of mobility models that are used in the simulations of ad hoc networks. The authors have described several mobility models that represent mobile nodes whose movements are independent of each other (i.e., entity mobility models) and several mobility models that represent mobile nodes whose movements are dependent on each other (i.e., group mobility models). The seven entity mobility models presented are Random Walk Mobility Model, Random Waypoint Mobility Model, Random Direction Mobility Model, A Boundless Simulation Area Mobility Model, Gauss-Markov Mobility Model, A Probabilistic Version of the Random Walk Mobility Model and City Section Mobility Model and the five group mobility models are Exponential Correlated Random Mobility Model, Column Mobility Model, Nomadic Community Mobility Model, Pursue Mobility Model and Reference Point Group Mobility Model. They have explained and simulated some of the above entity and group mobility models and then presented their results. They have used DSR as routing protocol and packet delivery ratio, end-to-end delay as performance metrics. In the end they have given their major conclusions about entity and group mobility models.

In [3] the author has presented a concept map for the generation of mobility models for VANETs. They also identified the basic components required for the development of a mobility model. They have presented the framework for the generation of vehicular mobility model. A simple description of the mobility model entities into microscopic and macroscopic characteristics is also presented. Their vehicular mobility model is composed of two main blocks Motion constraints and Traffic constraints. The Motion Constraints part describes how each vehicle moves (its respective degree of freedom) and is usually obtained from a topological map. The Traffic Generator, on the other hand, generates different kind of cars, and deals with their interactions according to their environment. The framework they presented has tree main components Motion Constraints, Time Patterns, and Traffic Generator. They have also described a general random limited mobility model that is fully compliant with the framework they presented. Likewise, they presented a simplified fully random mobility model that is compliant with parts of their framework but which does not implement all features they presented. They finally proposed to use Mobility Predictions in order to obtain realistic inter-vehicular interactions.

2.2.2 Impact of VANETs mobility models on routing protocols

The mobility models are widely used in simulations to test the performance of various routing protocols under different factors and conditions. The results that are generated from these analyses are used by various researchers in the development of new routing protocols and new mobility models. A number of projects have been conducted to find out the performance limitations of various routing protocols under different mobility models.

The Fleet Net project [61] is conducted by the German Ministry of Education and Research for building a communication platform for vehicular communication. A number of studies have been presented in this project. In a first study [62], authors compared AODV, DSR, FSR and TORA on highway scenarios, while in [63] the same protocols were compared for city traffic scenarios. They present that AODV and FSR are the two best suited protocols, and that TORA or DSR are completely unsuitable for VANET.
The platform deployed inside the FleetNet Project [64] [65] makes use of position-awareness of vehicles. Vehicles are equipped with GPS receivers to know their own positions and to exchange periodically their position information with their one-hop neighbors through beacon messages. So each vehicle knows the position of its immediate neighbors and message forwarding is based on on a hop-by-hop basis. Greedy Perimeter

Stateless Routing (GPSR) strategy has been investigated in the early stages of FleetNet. According to it, the next-hop node to choose for message forwarding should be the one-hop neighbor (w.r.t. the forwarder node) which is the nearest to the destination node of the message or, at least, the one whose direction is the nearest to the direction of the destination node. Reactive Location Service (RLS) introduction provides geographical position of the destination node. They have also presented that GPSR fail in city environment and are not suitable for in such scenarios. Geographic Source Routing (GSR) substitutes the forwarding strategies and use the city maps to select the forwarding direction that is best and nearest. The efficacy of this solution has been tested on the ns-2 simulator and is presented in [66], [67], and [68]. In city environment the vehicles mobility patterns have accurately represented. This will produce the realistic results. For this purpose FARSI a validated tool for simulation of driver's behavior has been used. A transmission rang of 500m has been used during simulation. Their results show that GSR routing protocol performs better than both DSR and AODV. They have also shown that connectivity between the source and destination car available up to three-hop distance and packets are discarded when no connectivity is available.

J. Härri and F. Filali have illustrated that how realistic motion patterns affect the velocity and how new parameters become necessary to evaluate the performance of routing protocols in VANETs in [7]. They have evaluated the performance of AODV with realistic urban scenarios to prove their statements. They have shown the significance of their new urban parameter and also described that how their new parameters will replace the non-urban parameters. They used the road segment lengths instead of average velocity and concluded that average velocity appears to be irrelevant in urban scenarios and should be replaced by road segment lengths. The authors have used the Vehicular Mobility Model (VMM) and simulated AODV in four different conditions velocity, road segment length and cluster effect. Studies related to the performance evaluation of VANETs in urban traffic are in [51,52,53].

Another work about the performance analysis of routing protocols under the VANETs mobility models is presented in [2]. The authors have used four Mobility Models namely Fast Car model (FCM), Slow Car Model (SCM), Human Run Model (HRM) and Human Walk Model (HWM). They have used four routing protocols namely Destination-Sequence Distance Vector (DSDV), Ad-hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Temporally Ordered Routing Algorithm (TORA). They have simulated these models using random way point model and presented their results. The have show that DSDV performs better than other protocols. AODV and DSR give identical throughput in all mobility models.

Impact of node mobility on routing protocols is presented by Bhavyesh Divecha in [54]. They have studied the effects of Random Waypoint, Group Mobility, Freeway and Manhattan models on the performance of two routing protocols Dynamic Source Routing (DSR) and Destination-Sequenced Distance-Vector (DSDV). The have shown that performance of routing protocols varies widely across different mobility models. They have given that DSR gives better performance under high node mobility than DSDV. DSR is fast in route finding mechanism because it has an efficient route repair mechanism while there is no route repair mechanism in DSDV. Packets are dropped if no route is found.

Importance of simulation results for VANETs and enhancements to the models for VANETs is elaborated in [55]. They have developed mobility models based on traffic lights and multilane roads etc. They have also compared their mobility models with models with Random waypoint model [56] and Rice university model [57]. Their results demonstrate that the delivery ratio and packet delays in VANETs are more sensitive to the clustering effect of vehicles waiting at intersections. They have also found that the simulation of multiple lanes and synchronization at traffic signals have only a low impact on the ad hoc routing performance.

AODV and OLSR performance in realistic urban scenarios is presented in [58]. They study these protocols under varying performance metrics such as node mobility and vehicle density, and with varying traffic rates. It shows that clustering effects created by cars aggregating at intersections have remarkable impacts on evaluation and performance metrics. The authors have used Packet Delivery Ratio (PDR), Routing Overhead (RO), Delay, and Hops count as performance metrics and vehicular mobility model (VMM) for MANETs routing simulations. The authors have presented the following results. They have tested OLSR and AODV against node density and data traffic rate. OLSR has better performance that AODV because it has smaller routing overhead, end-to-end delay and route lengths. And for the PDR the performance loss is limited to 10%. Based on these results they have stated that OLSR is more fitted to VANETs than AODV.

Vehicular mobility traces of downtown Portland, Oregon, have been introduced in [59]. The new mobility model is used to evaluate AODV [10] in flat and opportunistic infrastructure routing. To show the importance of a realistic mobility model for their evaluation, they compare these results with those obtained with CORSIM [60] traces. This work contributes in the introduction of efficient, opportunistic strategies for extending the AP infrastructure to use vehicle to vehicle paths and assessment of different mobility models - CORSIM traces and LANL's realistic vehicular traces - in the modeling of different routing strategies.

2.3 Concept Matrix

The following Table summarizes the concept matrix for the different works on VANETs mobility models and on ad hoc networks protocols.

Paper/Project	Concept	Findings/Results/Conclusions
FleetNet Project	1-Analysis of AODV, DSR, FSR and TORA under highway scenarios and city traffic scenarios 2-Testing Greedy Perimeter Stateless Routing (GPSR) under realistic city environment 3- The forwarding strategy of GPSR has been substituted by the Geographic Source Routing (GSR).	AODV and FSR are the two best suited protocols, and that TORA or DSR are completely unsuitable for VANET. GPSR approach is not suitable to realistic city environments and is likely to fail Results have shown that the GSR routing protocol outperforms both the DSR and AODV routing protocols (chosen as representative of topology-based routing protocols for ad hoc networks).
On Meaningful Parameters for Routing in VANETs Urban Environments under Realistic Mobility	Analysis of AODV under vehicular mobility model and to test the replacement of average acceleration with road segment length.	Average velocity has a minor impact on performance as it cannot reflect the real velocity in urban traffic. A more significant parameter is the road segment length, as this is the parameter controlling the real velocity.
Performance Evaluation of Routing Protocols in Vehicular Ad Hoc Networks	To analyze the performance of Position-based routing protocol (LORA), AODV and DSR.	AODV and DSR perform almost equally well under vehicular mobility, the location-based routing provides excellent performance.
A Survey of Mobility Models for Ad hoc Network Research	To present a detail of various routing protocols for ad hoc networks	Simple models like the Random Waypoint mobility model do not consider vehicles' specific motion patterns; they cannot be applied to simulation of vehicular networks.
A Framework for Mobility Models Generation and its Application to Inter-Vehicular Networks	To present a Framework to generate realistic mobility models for VANETs	A framework has been generated and VMM is compared with RWP.

Performance Comparison of AODV and OLSR in VANETs Urban Environments under Realistic Mobility	To compare the performance of AODV and OLSR in urban environment using VMM.	OLSR has smaller routing overhead, end-to-end delay and route lengths and thus performs better than AODV
Impact of Node Mobility on MANET Routing Protocols Models	To test DSR and DSDV for high node mobility under Random Waypoint, Group Mobility, Freeway and Manhattan models	DSR gives better performance for highly mobile networks than DSDV
Analysis of MANET Routing Protocols using Scenario Based Mobility Models	1- introduced Fast car and Slow car model 2- to analyze the impact of Fast Car Model (FCM), Slow Car Model (SCM), Human Run Model (HRM) and Human Walk Model (HWM) on DSDV, AODV, DSR and TORA routing protocols	DSDV has lower routing overhead and average end-to-end delay, which proves that DSDV performs better than other routing protocols.
Evaluating Vehicle Network Strategies for Downtown Portland: Opportunistic Infrastructure and the Importance of Realistic Mobility Models	1- To show the importance of realistic mobility models 2- To analyze the performance of AODV by using vehicular mobility traces of downtown Portland	Two main results are reported: (a) the motion model has an enormous impact on performance - the CORSIM simulation (b) The presence of APs and infrastructure make a big difference in performance but again this difference can be appreciated ONLY with the accurate motion model.
Survey of Mobility Models for Ad Hoc Network Research	1-To present detail study about the mobility model. 2-To present a study of the Impact of mobility models on the routing protocols	The performance of ad hoc network vary with different mobility models Using same mobility model with different parameters can also vary the results The selection of a mobility model may require a data traffic pattern which significantly influences protocol performance If the expected real-world scenario is unknown, then researchers should make an informed choice about the mobility model to use.

"Table 1 concept Matrix"

2.4 Mobility Models chosen by Researchers

From the literature survey it is clear that different researches have used the following mobility models for VANETs:

- Realistic mobility patterns
- Random walk
- City section
- Vehicular Mobility Model (VMM)
- Random Waypoint
- Group Mobility
- Freeway models
- Manhattan models
- Stop Sign Model(SSM)
- Probabilistic Traffic Sign Model (PTSM)
- Traffic Light Model (TLM).
- Rice University Model (RUM)
- Fast Car Model (FCM)
- Slow Car Model (SCM)
- Human Run Model (HRM)
- Human Walk Model (HWM)

2.5 Factors Affecting performance of VANETs

Following factors are affecting the performance of VANETs

- Street Layouts
- Block size
- Traffic control mechanisms
- Interdependent vehicular motion

- Average speed
- Acceleration
- Deceleration
- Road segment length
- Street layout
- Traffic rules
- Multilane roads
- RF attenuation due to obstacles
- Clustering effect of vehicles at intersections.
- Fast route convergence
- Freedom from loops
- Unidirectional link support
- Atmospheric factors

2.6 limitations

From the literature survey it is clear that some researcher have used mobility model to analyze different routing protocols but these mobility models do not consider the realistic mobility characteristics. For example Fast car and slow car has been used with random waypoint [2] which is totally impractical for vehicular communication because vehicles have a limited degree of freedom in mobility and they don't move randomly, rather, they follow a specified path [4]. In most of the mobility models e.g. Freeway mobility model [4] slow and Fast car mobility models [2] the vehicles are supposed to move with a predefined velocity and they will maintain this speed throughout the simulation time and the realistic characteristics such as acceleration and deceleration has been ignored in most of the mobility models. Furthermore, if the vehicles move with a constant speed then there will be no congestion at intersections which is against the real world scenarios. Also in Manhattan mobility model when the vehicle approaches the intersection they did not change their speed when turning to left or right and moves with the speed they are moving. Furthermore, limited study to specify the main entities for VANETs mobility model development is available; also a few frameworks for the development are available. Weather or atmospheric factors as obstacles have been ignored in the framework. From simulation point of view Fast car and slow car models has been tested for pause time only and few experiments with limited tests have been conducted [1]. Very few researchers have analyzed the effect of mobility models on OLSR [5].

2.7 Summary

In this chapter we have given a description of related work. Different researchers have presented different mobility models with different characteristics and tried to include more realism in their mobility models to find out more accurate results. The choice of mobility models and performance parameters also affects the overall results of simulations. At the end we have given the limitations of some of the existing mobility models which need some realistic mobility components to include.

3
Requirement Analysis

3.1 Problem Domain

A vehicular ad hoc network (VANETs) is a kind of Mobile ad hoc networks (MANETs) and is a hot research area from last decade. Different research areas such as security, routing protocols development, safety related applications development, entertainment on road, etc have been targeted by the researchers. VANETs have different challenging characteristics that differentiate it from other type of networks. One of the most challenging characteristic of VANETs is high node (vehicle) mobility. Mobility is challenging because it has many impacts on network performance. Due to high mobility network topology constantly changes at every moment. This topological change and its management is a key research area in VANETs. The topological changes and movement patterns are represented by mobility models which are considered a key component in the simulation of mobile ad hoc networks. So, the development of realistic mobility models, which truly represents the real life scenarios, for VANETs is very crucial because the real life tests are expensive and difficult to adopt.

3.2 Problem Statement

Based on the limitation and drawbacks of the existing work presented in chapter 2 we have developed our problem statement as follows.

As mobility is a challenging issue in VANETs and also real life tests for VANETs are expensive to adopt, so, there is a need for a mechanism that truly represents the actual world scenarios and to provide all the necessary components for simulations. Mobility models provide the necessary components for the simulations that is why a number of mobility models have been presented by the researchers. These mobility models try to present an environment that truly represents some of the components of real worlds. But from literature review it is clear that most of the mobility models don't truly represents the realistic components e.g. Freeway an Fast car and slow car models [2,4]. Now the trends are towards the development of realistic mobility models and the results obtained from the simulations of these realistic mobility models shows more accuracy compared to the others. So identification of necessary entities and their characteristics for the development of a Framework that truly considers all the entities and their characteristics for the development of a realistic mobility model for VANETs is required.

Further more, the existing mobility models such as Random way point, Freeway and a few others don't considers the realistic characteristics of mobile nodes and other entities so consequently simulation results are different from that of realistic mobility models. So there is need to develop more realistic mobility models or to include more realistic characteristics in the existing models.

3.3 Proposed Solution

Our proposed solution consists upon two phases:

Phase 1: To identify all the necessary entities and their characteristics for VANETs mobility model development and then to develop a Framework for the development of realistic VANETs mobility model.

Phase 2: To analyze the MANETs protocols using modified VANETs mobility models.

Phase 1

In this phase we have first identified the necessary entities and their characteristics for the development of realistic mobility model for VANETs. On the basis of these entities and their characteristics we have developed a simple realistic framework for the development of realistic mobility model for VANETs. The benefit of this Framework will be that it considers most of the macro and micro characteristics of the mobility models for VANETs and will provide an ease for the researchers to develop a new mobility model.

Phase 2

In phase 2 of project we have analyzed the MANETs routing protocols using VANET mobility models and presented our conclusions and findings. In this phase we have used some existing mobility models such as Manhattan mobility model and Freeway mobility model and also our modified Manhattan, Fast car and Slow car mobility models for the analysis MANETs routing protocols. We have modified the Manhattan mobility model and included the speed reduction when a car approaches to its intersection and starts to turn left of right. A number of experiments each with several tests have been conducted for this purpose. The main purpose of this phase is to find out the effect of different mobility patterns and other mobility model parameters e.g. node density, acceleration deceleration etc. on the performance of routing protocols.

3.4 Contribution

The main contributions of this thesis can be summarized as follows.

- A detail of important components for the development of realistic and non-realistic mobility model for VANETs.
- Framework showing the relationship between the main entities of mobility models for VANETs. The Framework also shows the micro and macro characteristics of these entities.

- Modified and implemented Manhattan mobility model, Fast Car Model (FCM) and Slow Car Model (SCM).
- Used different metrics to analyze the influence of different mobility models on performance of different routing protocols of MANETs.
- Evaluated results of simulations with different mobility models with some realistic parameters for vehicular ad-hoc networks.

3.5 Summary

A detail study about the problem domain, our problem statement and proposed solution is presented in this chapter. Mobility models development for Vehicular ad hoc networks is an active research area. The development of realistic mobility model is very important for VANETs because they represent the actual scenarios. Our proposed solution will be to identify the necessary components for VANETs mobility models, development of realistic framework for VANETs mobility models and also to analyze the impact of various existing and modified mobility models on the MANETs routing protocols.

4
System Design

4.1 Introduction

Mobility models are used for simulation of routing protocols because the real world tests are too expensive, difficult to deploy and also time consuming. But, if we want to use the mobility model in simulation the question arises whether the model represents the required components for analysis or not. For this purpose, a number of mobility models have been proposed for VANETs. The main focus of the mobility models are on the movement patterns of the vehicles which is accomplished by the introduction of road maps in the mobility models for VANETs. These road maps consist upon roads, streets and intersections etc. but if the mobility models only consists upon the roads and the vehicle moves on these roads with a predefined speed then most of the realistic components will be missing in such scenarios. For realistic design of mobility model, a number of meaningful parameters, that do exists in the real world, must be included in the architecture of the mobility models. So it is very important to use a mobility model that has most of the required components of the real world scenarios. For example, we can include traffic lights, traffic signs, and speed limitations at certain parts of the road etc. in the architecture of mobility models to have more realism in it. As real life tests are expensive to deploy and also simulations offer certain benefits over real life tests e.g. easy to implement, repeatable experiments etc. but, the results mainly depends upon the design and architecture of the mobility models. It means that, the accuracy of simulations results will mainly depends upon the realistic components included in the mobility model.

4.2 Design Requirements

From an architectural perspective of VANETs mobility model, the identification of most of the important realistic components for the development of a realistic mobility model is very important. We have identified most of the important components for the development of realistic mobility models for VANETs.

4.2.1Mobility models entities and its characteristics

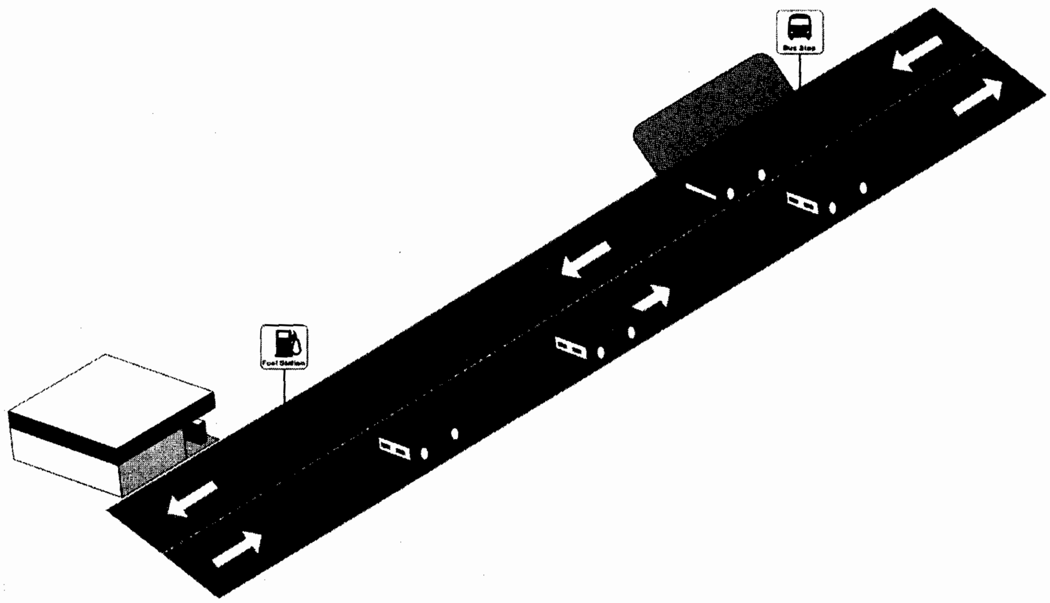
Following are the main entities along with their micro and macro characteristics.

4.2.1.1 Roads

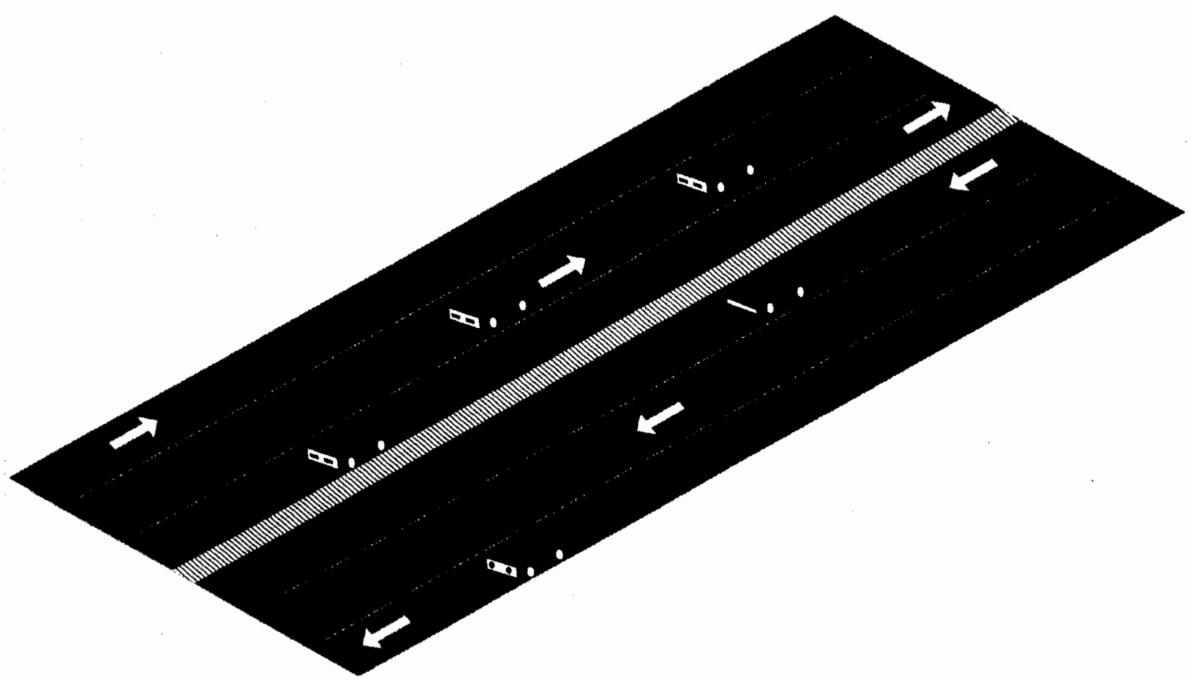
Road is the main entity for the development of mobility traces or maps for any mobility model used for VANET. Roads provide a specific path for the movement of the vehicles and remove the randomness in VANETs which exists in mobile ad hoc networks. Some of the characteristics of Roads and how they affect the mobility are as follows.

Number of Lanes

The roads may have single lane or multiple lanes as in figure.1. In single lane roads there is usually one lane for one direction of traffic it means that only one lane is available for the vehicles to move in a direction. The single lane roads also affect the driver's behavior because if the driver wants to vary his speed or wants to overtake a vehicle he will consider the vehicles that are coming in the opposite direction. On the other hand in multiple lanes roads there are multiple paths for vehicles to move on as in fig. 2. These vehicles have more freedom to change their lanes and vary their speed accordingly compared to the single lane roads. Also there an ease for the drivers to overtake the vehicles because there is no vehicles coming from the opposite direction only the driver has to consider the vehicle in front and the vehicles in lane he wants to join. These lanes have usually assigned certain speed limits so if a driver want to change a lane then he must change his speed according to the lane he want to move.



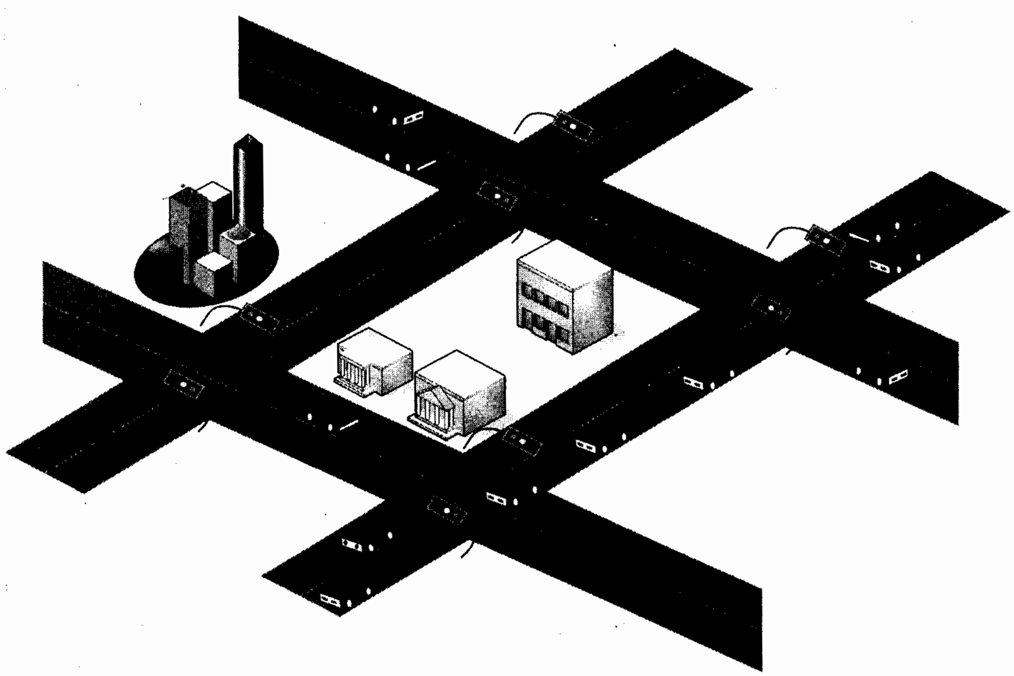
“Figure 7 Single LANE Road”



“Figure 8 multiple lane roads”

Number of Streets and Intersections

Multiple streets and intersections roads are represented in Manhattan mobility model [4].The number of streets and intersections in a road also affects the speed of vehicles and also the behavior of the drivers because in case of multiple streets as in figure.2 the drivers can choose the alternate route or shortest route or he can avoid the congested streets. The intersections are the junctions of two roads where they cross each other. In real world situations at intersections the drivers slow their speed because they can neither cross the road nor they can take a turn with the speed they are moving to the cross points e.g. if they are moving with a speed of 80 km/hr then they will reduce their speed to 20 to 30 km/hr. At intersection the vehicle density also increases so the vehicle speed reduces and the performance also greatly affects. This speed reduction causes deceleration which is not considered in most of the existing mobility models rather in these models vehicles moves with the pre given speed even at the cross points. Also, on reaching at cross points certain vehicles will move to their desired directions so certain probability must be assigned to these vehicles as given in Manhattan mobility model.



"Figure 9 multiple streets and cross points"

Traffic Sign and Traffic Lights

Traffic signs and lights on road sides, referred as Traffic Control Mechanism by some researchers; provide help and instructions to drivers for safe driving. These traffic signs include signs for speed limits, fuel stations, bus stops, bridges ahead signs, sharp turn signs etc. These signs restrict the drivers and the driver acts according to the instruction on the signs i.e. the driver may reduce his speed or stop at a fuel station or on a eating spot on the road side. The traffic signs, at the cross points or somewhere else on the road, has an impact on vehicle mobility because on these traffic lights the drivers will reduce their speed or stop for certain time interval. Also these signs cause traffic jams, increasing the number of vehicles and ultimately increasing the contention for channel so performance will affect. On the basis of these characteristics Stop Sign Model (SSM) and Traffic Sign Models (TSM) has been developed [6].

Other characteristics

There are certain other characteristics that should also be considered e.g. Bridges, road conditions, no of turns, road segments, location, road side buildings, trees, lane capacities etc. These characteristics affect the mobility in one way or the other e.g. if there is a bridge ahead on multiple lane road it may be possible that the number of lanes may reduce to one and the driver will reduce there speed accordingly and there may be traffic signs that points that a bridge is ahead and impose certain limitations on driver. The road conditions shows that whether the road is well metal or not and the location show where the road is e.g. in hilly areas, ruler areas, urban areas.

4.2.1.2 Vehicles

Vehicle is the main entity and its different characteristics must be considered while developing a Realistic Mobility Model. Some of the characteristics are given as follow.

Vehicle Velocity

The topology of the VANET depends upon the speed of the vehicles because there is no specific topology exists. Variations in velocities affects the topology and ultimately affects the performance because with high velocities packet delivery ratio will be reduced and the route breaking ratio will be high also with high mobility new routes will be established at a high rate. The velocity of a vehicle also affects the motion of other near by vehicles moving it in same lane or moving in side by lane. This relative velocity consideration is very important for over taking and affects driver behavior.

The speed of the vehicle in non realistic models are pre defined e.g. in Manhattan mobility model and Free Way Mobility model we assign a fix value to speed of the vehicles so these model can not reflect the actual speed of vehicles that vary during mobility.

Acceleration and Deceleration

Acceleration and Deceleration are considered as micro mobility characteristics [5]. The vehicles approaching to the intersections reduce their velocities and thus acceleration is produced considered in [7]. Acceleration and Deceleration must be considered in developing realistic mobility models because the speed and velocity of the vehicles can change at any instant of time.

Number of Vehicles

The number of vehicles or node density at certain parts of the road and at certain times is different e.g. at intersections the node density is high and low is in midway also in morning and after noon hours vehicles density is high and low in non working hours. The node density significantly increases overhead, increase contention in channel and thus network performance is affected.

Other vehicle characteristics

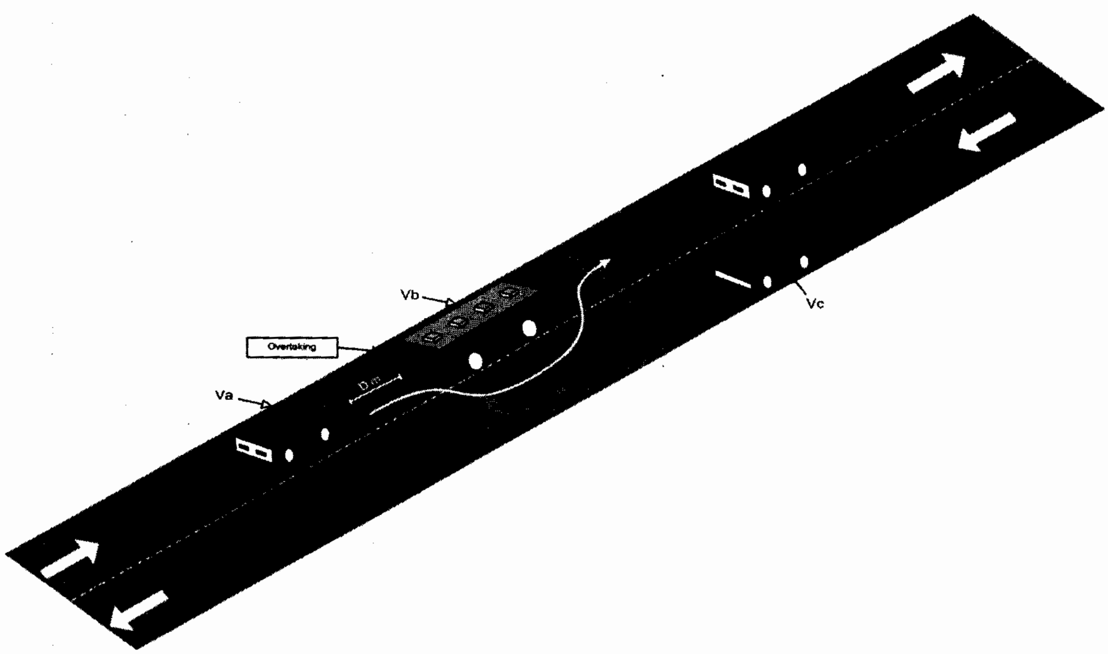
Vehicle size, vehicle type, safe relative distance between vehicle, initial position are some other characteristics that are now included in realistic mobility models e.g. vehicle size in [5].

4.2.1.3 Driver Behavior

Safe and accident free traffic really depends upon the driver behavior because he is the one who controls the vehicle and considers all the external stimuli that affects his behavior.

Overtaking

In most of the existing mobility models e.g. Manhattan mobility model, Freeway mobility model etc. Overtaking and other driver behavior characteristics are not considered. While overtaking the driver has to consider certain things in his mind e.g. the velocity of the his vehicle, the velocity of the immediate vehicle in front , the velocity of the vehicle coming in opposite direction, the distance between his vehicle and immediate vehicle in front ,his reaction time etc.



"Figure 10 Overtaking"

In the above figure the driver of the vehicle A must consider his velocity Va , velocity Vb of vehicle B and the velocity Vc of vehicle C coming in opposite direction. The velocity of vehicle A must be greater than vehicle B i.e.

$$Va > Vb$$

The driver must also consider the distance between his vehicles and up front vehicle e.g. distance dm between vehicle A and vehicle B in figure 4.

Lane changing

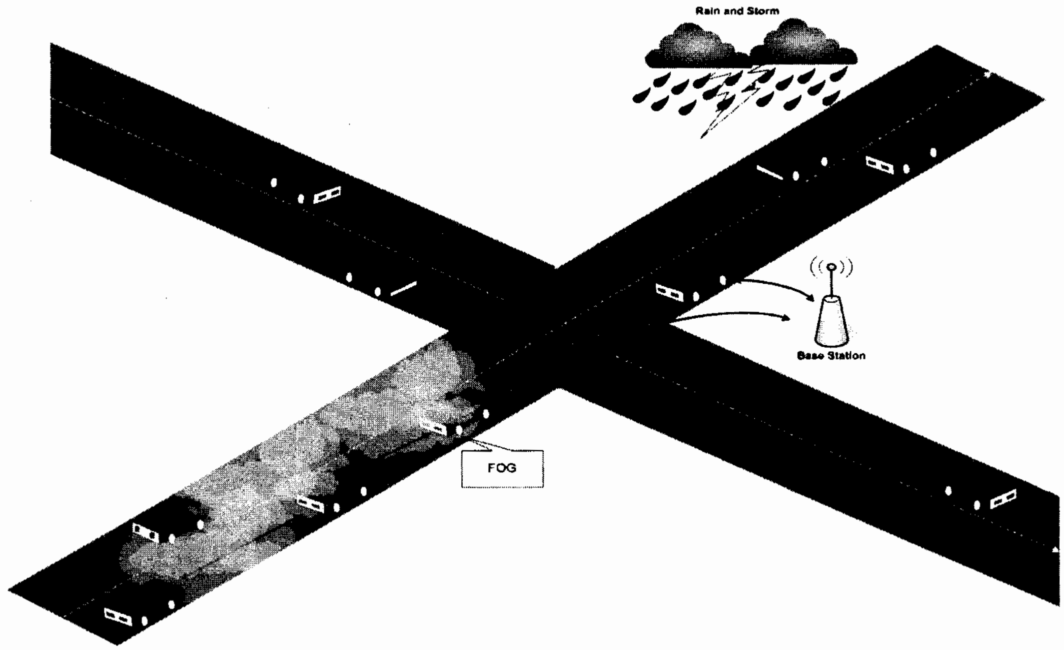
Lane changing is driver's behavior to change his lane, so vehicle velocity and network topology will change, and ultimately high velocity and topology change will affect network performance. As in certain mobility models different lanes have assigned their specific speed limits, so, the deriver must change the speed of his vehicle and will adopt the speed of that particular lane he has joined.

Other characteristics

keeping a safe inter vehicle distance , frustration due to traffic jam, alternate route selection , mobility prediction, social habits , age , reaction time in case of lane changing or overtaking are some of the other characteristics that should be in developing a realistic mobility model.

4.2.1.4 Obstacles

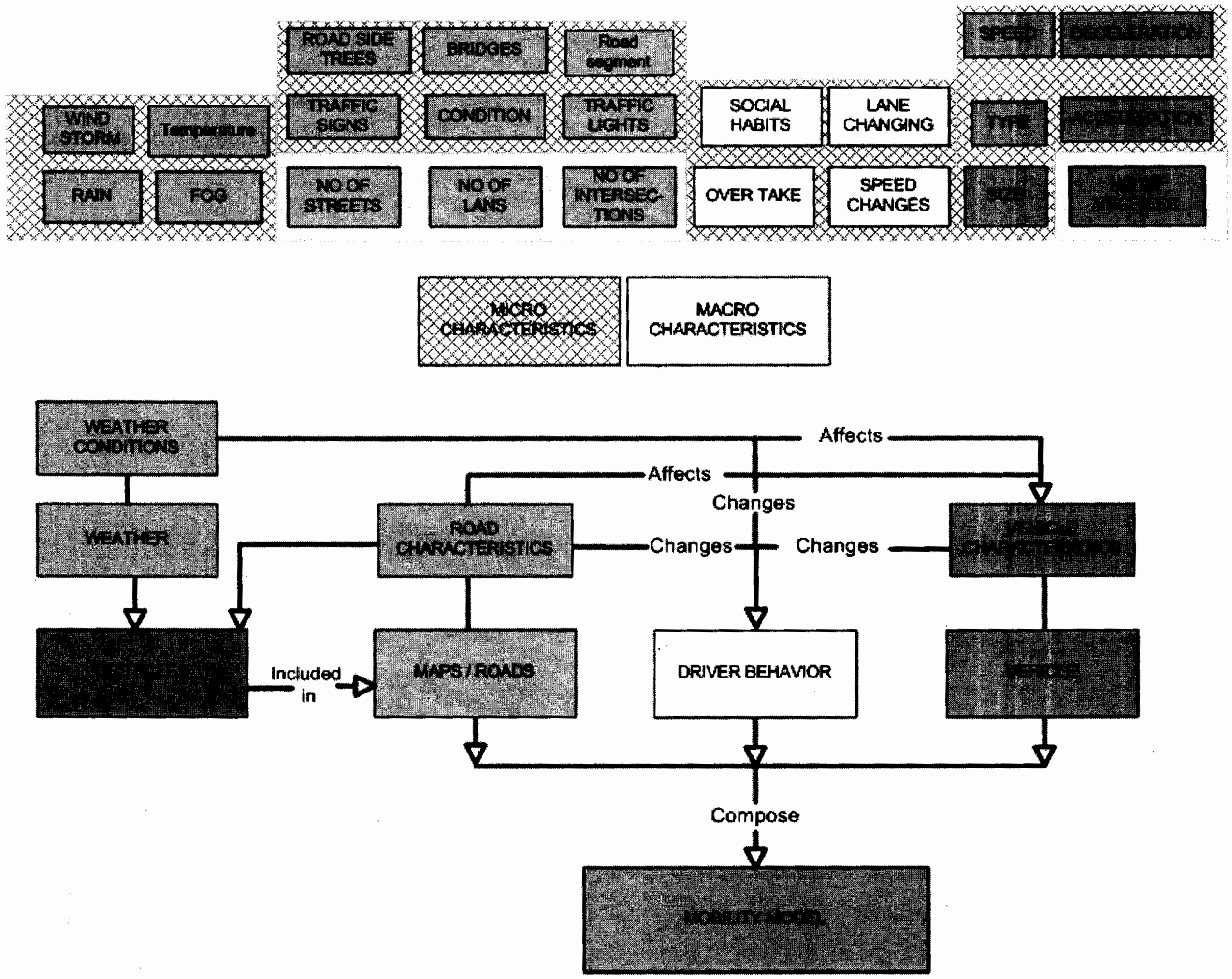
The consideration of obstacles in mobility models is very important because they affect all the main entities. The obstacles include road side buildings, trees, street poles, and also weather conditions. Weather condition e.g. Fog, rain, wind storm, snow fall, temperature as in figure 5 etc. affects the driver behavior and vehicle characteristics like variation in velocity, using alternate route etc so ultimately network performance will be affected.



"Figure 11 Weather as an Obstacle"

4.2.2 A simple Framework for VANETs mobility model

The mobility models present a scenario that represents components of real world. If the real world components are not represented then the results may not match with those of the real world performance measurement's results. The mobility models also represent different characteristics that affect the wireless communication in real world. So in order to develop realistic mobility models for VANETs that represents the real world components and its characteristics we presents our framework that considers, most of, the real world components and its characteristics for the generation of mobility models. The framework covers the important entities for the VANET mobility model and also classifies these characteristic into micro and macro characteristics. This framework also shows that how these entities and their characteristics affect each other.



"Figure 12 Framework for VANETs Mobility Model development"

4.2.2.1 Description of the Framework

Figure 10 shows the framework for the development of realistic mobility models. In this framework we have three, most important, components i.e. Roads or Maps, Vehicles and Drivers behavior for the development of mobility models.

From the framework it is clear that for the development of any mobility model we must include maps and vehicle, two main entities. To include more realism then micro characteristics of the above mentioned main entities and the driver behavior must also be considered. These entities are interdependent and its characteristics affect each other as show in figure 10. The vehicle characteristics affect the driver behavior e.g. the speed of a vehicle and the type of vehicle or number of vehicles etc. Similarly the roads or maps used have a large effect on both vehicles and driver behavior. Single lane streets, streets with traffic lights, traffic signs, roads with sharp turns, etc are all the road characteristic that can cause a change in the behavior of driver and also the in the characteristics of vehicles. In single lane roads with one way traffic or congested roads with high node densities or roads with more traffic signs the drivers are very careful regarding to overtaking and speed limits ,Similarly, such characteristics also limits the speed of vehicles and high accelerations and decelerations are produced. The streets and roads layout also compels the drivers to use the alternative routes and avoid the congested ones. One of the most important components is the obstacles that affect all the entities of the mobility model. The obstacles include weather obstacle and road side obstacles that affects the wireless communication among the vehicles. The weather obstacles include rain, wind storm, fog and high or low temperature etc. These obstacles affects driver's behavior and also vehicles characteristics e.g. if it is raining or fog then the driver will reduce the speed of his vehicle and will try to avoid overtaking in such situations. Other obstacles such as road side building and trees etc are barriers in wireless communication and affect the performance of the channel. As these obstacles do exist in real life world so its inclusion in the mobility model must be considered for true representation of real world scenarios.

4.2.2.2 Validation of the Framework

The simulation results in case of using a mobility model for VANET mainly depends upon the ingredient of the mobility model because a simple non realistic mobility model can not reflect the true real world situations. So, for performance analysis there is a need to have more realistic mobility models having some micro and macro characteristics of all the main entities of mobility models.

Taking one or a few characteristics of each entity from the framework one can generate a mobility model that can at least reflect some characteristics of real world. From the framework, if we want to develop Manhattan mobility model we take the number of vehicles (node density), velocity, acceleration and deceleration from vehicle characteristics and number of streets and intersections from the road characteristics to form a map; hence Manhattan mobility model is developed.

The Freeway mobility model is generated from the framework by taking the number of vehicles from vehicle's characteristics and number of lanes from road's characteristics for map generation and thus mobility model is developed.

In order to develop a realistic mobility model from the framework, we first take maps or roads layouts. We can consider many characteristics of the roads in the development of realistic mobility models e.g. how many lanes, streets, intersections, road segments etc we want to include. For more realistic behavior we can include the traffic lights, traffic signs, sharp turns, road side obstacles etc in the model. For urban areas more lanes and streets are included while for ruler areas, where traffic density is normally low, few streets and lanes are considered. After generating the maps, by choosing the appropriate characteristics for relevant scenario, vehicle characteristics are chosen. The vehicle characteristics mean how many vehicles, their speed, acceleration, size etc. Realistic characteristics related to driver such as overtaking, lane changing, speed variations etc are also included to have more realism. Simulation time is also a key consideration for the simulation because it will also affect the results.

4.3 Research Methodology

In this section we will describe the complete setup for the simulations. We conducted several experiments and several tests in each experiment. Two experiments were conducted for each mobility model one for the effect of node density and the other for the effect of high or low mobility. In each experiment we will analyze the effect of packet delivery ratio, end to end delay, and routing overhead. So on the basis of these simulations we will present our conclusions about each mobility model and its effect. We have performed the simulation experiments in open source network simulator NS

2.31[12], Fedora Core 6 operating system, Pentium 4 processor 2 GHz and 512 MB RAM. We have used omni directional antenna with 250m transmission range. UDP is used as transmission protocol with a packet size of 512 bytes. Table 2 shows the general parameters for the whole simulation.

Table 2 Simulation Parameters

Variables	Values
Simulation tool	NS2.31
Propagation model	TwoRayGround
Antenna Type	Omni directional
Topology size	1200m x 1200m
Simulation time	300 sec
Mobility models	Freeway, Manhattan, Fast car, Slow car
Transport protocol	UDP
Packet size	512 bytes
Traffic Type	CBR
Transmission Range	250 m

4.3.1 Experimental Setup

The details of complete experimental setup are given as follows.

4.3.1.1 Experimental Setup for Freeway mobility model

Besides the above general parameters in table 2 each mobility model is tested with their specific parameters. We have conducted two experiments for Freeway mobility model one for the effect of high mobility on performance and the other is for the effect of high node density. Maps with multiple lanes are used for freeway model. The details of both of these experiments are given in the following tables 3 and table 4. In experiment 1 we have kept constant the node density to 50 and performed tests for each velocity input. In experiment 2 we have changed the node density on freeways and eight tests were conducted for different node inputs. The velocity is kept constant to 20m/s for all nodes and in all tests.

Table 3 Parameters for Experiment No. 1

Variables	Values
Experiment	Effect of High mobility.
Model	Freeway
Velocity variations	10,20,30,40,50,60,70,80,90,100 m/s
Node Density	50 constant for all tests
Number of tests	10 tests. One test for each velocity with constant nodes.

Table 4 Parameters for Experiment No. 2

Variables	Values
Experiment	Effect of Node density.
Model	Freeway
Velocity variations	20 m/s constant for all tests.
Node Density	30,40,50,60,70,80,90,100 nodes
Number of tests	8 tests. One test for each node density with constant velocity.

4.3.1.2 Experimental Setup for Original and Modified Manhattan Mobility model

For Manhattan mobility model we have conducted two experiments and several tests in each experiment. We have used maps with multiple streets and intersections. Both for node density and high mobility with acceleration the experiments were performed. Besides the general parameters for the whole simulations the following tables summarizes the parameters for the Manhattan mobility model. In experiment 1 we have performed 5 tests in which we kept the velocity and node density constant and varied the acceleration form $2m/s^2$ to $10m/s^2$. Experiment 2 is conducted for the effect on node density in which the acceleration and average velocity is kept constant while the node density varies.

Table 5 Parameters for Experiment No. 3

Variables	Values
Experiment	Effect of Acceleration and deceleration.
Model	Original and Modified Manhattan mobility model
Average Velocity	20 m/s
Node Density	50
Acceleration	2,4,6,8,10 m/s^2
Number of tests	5 tests for Original and 5 tests for Modified Model

Table 6 Parameters for Experiment No. 4

Variables	Values
Experiment	Effect of node density.
Model	Manhattan mobility model
Average Velocity	20 m/s
Node Density	20,25,30,35,40
Acceleration	4 m/s^2
Number of tests	5 tests.

4.3.1.3 Experimental Setup for Fast Car Mobility model

For our modified Fast car model we have performed two experiments. One experiment is performed for node density and the other is performed for high node mobility. The vehicles moving on roads normally vary their speed and due to these variations in velocity acceleration is produced which we have included in the Fast Car model. In each experiment we have further performed 5 tests for each parameter of node density and high velocity with acceleration. In node density experiment we have taken the high velocity of vehicles constant to 20m/s and included acceleration variations up to 2 m/s^2.

In high mobility experiment we have taken the node density constant to 30 nodes and high acceleration variations up to 5 m/s^2. The details are given in the following tables.

Table 7 Parameters for Experiment No. 5

Variables	**Values**
Experiment	Effect of node density.
Model	Fast Car mobility model
Average Velocity	20 m/s
Node Density	20,24,28,32,36
Acceleration	2 m/s^2
Number of tests	5 tests.

Table 8 Parameters for Experiment No. 6

Variables	**Values**
Experiment	Effect of High mobility.
Model	Fast Car Mobility model
Velocity	110,120,130,140,150 km/h
Node Density	30 constant
Acceleration	5 m/s^2
Number of tests	5 tests.

4.3.1.4 Experimental Setup for Slow Car Mobility model

As clear form its name in slow car model the vehicle's velocity is slow compared to fast car model. Slow car model is tested for node density and low mobility of vehicles. We have modified the model and included the acceleration so that when the vehicles change its velocities, acceleration will be produced and this will affect the performance. The experimental details are given in the tables. The first experiment is performed for node density. In certain parts of road the vehicles density is high and the vehicle's mobility is low for example at intersections, so this experiment reflects such type of scenario. The second experiment is performed for low mobility. In case of low mobility we check out that whether low mobility affects the performance or not because with low mobility there will be little affect in the topology and hence the effect will be low.

Table 9 Parameters for Experiment No. 7

Variables	Values
Experiment	Effect of node density.
Model	Slow Car mobility model
Average Velocity	20 m/s
Node Density	20,24,28,32,36
Acceleration	2 m/s^2
Number of tests	5 tests.

Table 10 Parameters for Experiment No. 8

Variables	Values
Experiment	Effect of low mobility.
Model	Slow Car Mobility model
Velocity	30,36,42,48,54 km/h
Node Density	30 constant
Acceleration	5 m/s^2
Number of tests	5 tests.

4.4 Summary

In this chapter a detail study about the required entities and their characteristics for the generation of VANETs mobility models has been presented. On the basis of entities and their characteristics we have developed a simple framework for the mobility model generation. Further more, we have presented a detail study about the simulation and experimental setup for each mobility model.

5

Implementation

5.1 Introduction

As wireless ad hoc networks experience high variability in channel so real life test would be cost effective, time consuming compared to simulations but still they are crucial to be performed because they provides the actual factors that do affect the wireless channel. Real world test, no doubt, represent the actual scenarios but is it possible for a particular area to represent all the factors? e.g. high node density, speed restrictions, road side obstacles, atmospheric effects, alternate routes etc. There are areas that may have all the factors but the researcher may wait for a proper time in which there will be maximum factors available for testing e.g. for high node density the researchers have to wait for busy rush hours when node density is high on roads and for atmospheric effects he has to wait for certain weather conditions. On the other hand Simulation is an easy and repeatable way to analyze the performance under various factors. In simulation researchers can easily choose and find the effect of different parameters. Also the researcher can repeat simulations with different scenarios in a variety of ways and can present the results under repeatable tests. Due to these benefits the simulation has become a popular tool for ad hoc networks and that is why a variety of simulations tools are now available. Ns2 is popular network simulator which is event-based and is used for research in universities, research agencies and commercials companies. Other simulation tools include Qualnet [74] which is a commercial simulation tool. A number of models are available in qualnet and also offers graphical tools to generating a number of scenarios. Another popular commercial simulation tool is OPNET [75] which offers a variety of simulation analysis tools.

5.2 Implementation in Network simulator (Ns 2)

We have implemented and simulated the VANETs mobility models in NS 2.31 [12] simulator. As NS is open source, so it is widely used in network simulations. NS development begins in 1989 as REAL network simulator. Ns development was supported by DARPA trough VINT project at LBL, Xerox PARC, UCB and USC/ISI. NS is open source and a number of researchers have contributed in e.g. wireless code from UCB Daedelus and CMU Monarch projects.

NS is an object-oriented simulator, written in C++ and OTCL interpreter as front-end. NS uses C++ for detailed simulations of protocols requiring efficient manipulating bytes, packet headers, and implanting algorithms that run over large data sets. Because of performing these tasks the run time speed is important and turn around time is less important that is provided by C++. OTCL is used for varying parameters or configurations, or quickly exploring the number of scenarios [72].

Currently in ns-2 following ad hoc routing protocols are built in for wireless mobile nodes.

Destination Sequence Distance Vector (DSDV)

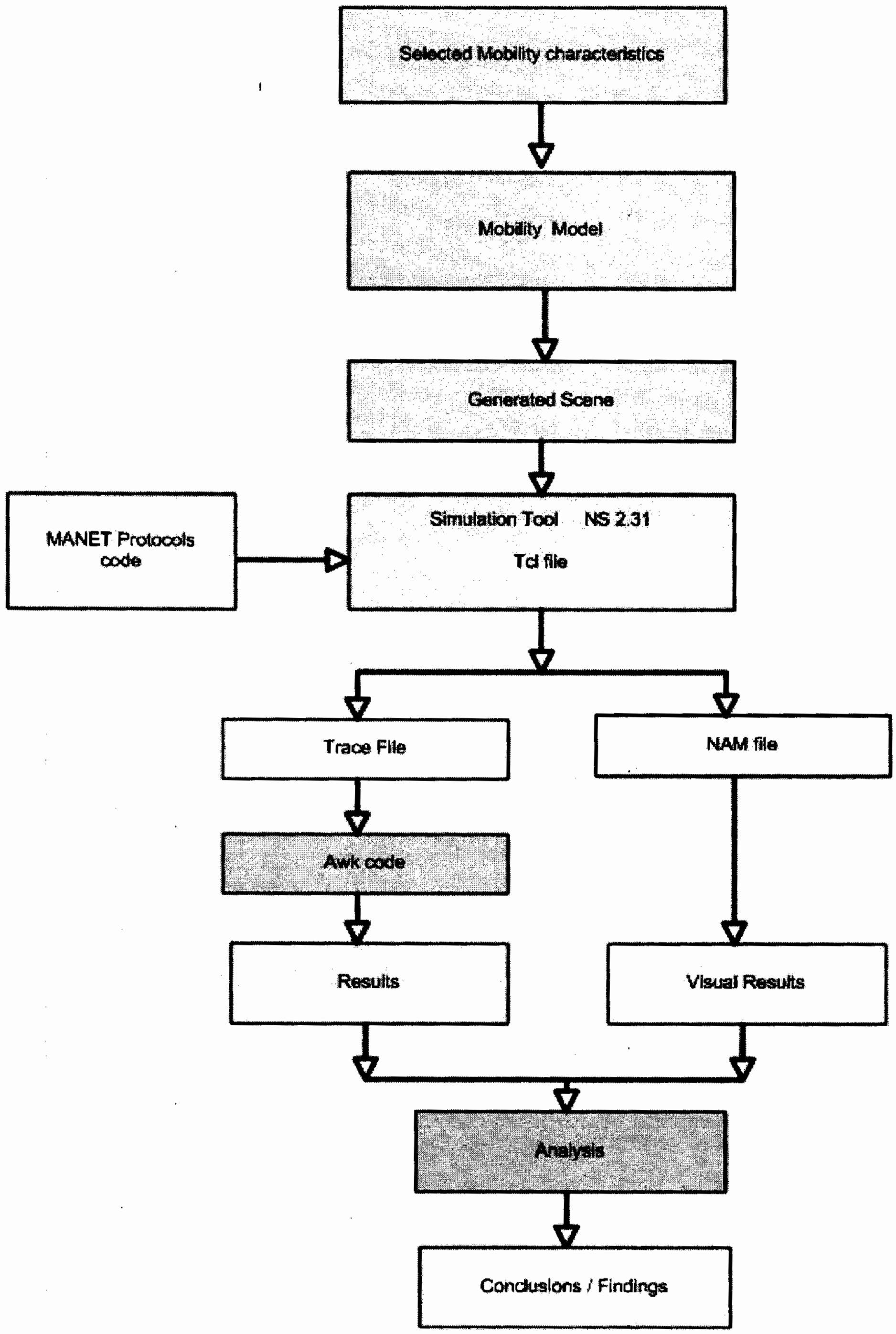
Dynamic Source Routing (DSR)

Temporally Ordered Routing Algorithm (TORA)

Ad hoc On demand Distance Vector (AODV)

NS can be used on UNIX, Linux, and Windows platforms. However, using windows as platform, Cygwin emulator is required for NS.

The following figure shows the implementations details of our project in NS 2.



"Figure 13 Implementation of mobility model in NS 2.31"

Figure 11 shows the implementation details. After generating the mobility model from the chosen mobility characteristics, we then generate the scene from the mobility model. The generated scene and the chosen MANET protocols are passed to the tcl file of the NS 2.31. The tcl file is run and it generates two file one is trace file and the other is nam file. The trace file is passed to an awk code which provides the text results while the nam file is run to show the visualization of the scenario. From the results generated by awk code we can also generate the graphs. Both text and visual results are analyzed and the conclusions and findings are presented.

5.3 Nam: Network Animator

The nam development effort was an ongoing collaboration with the VINT project. Nam began at LBL. Nam development has evolved substantially over the past few years. Currently, nam is being developed at ISI as part of the SAMAN and Conser projects [73].

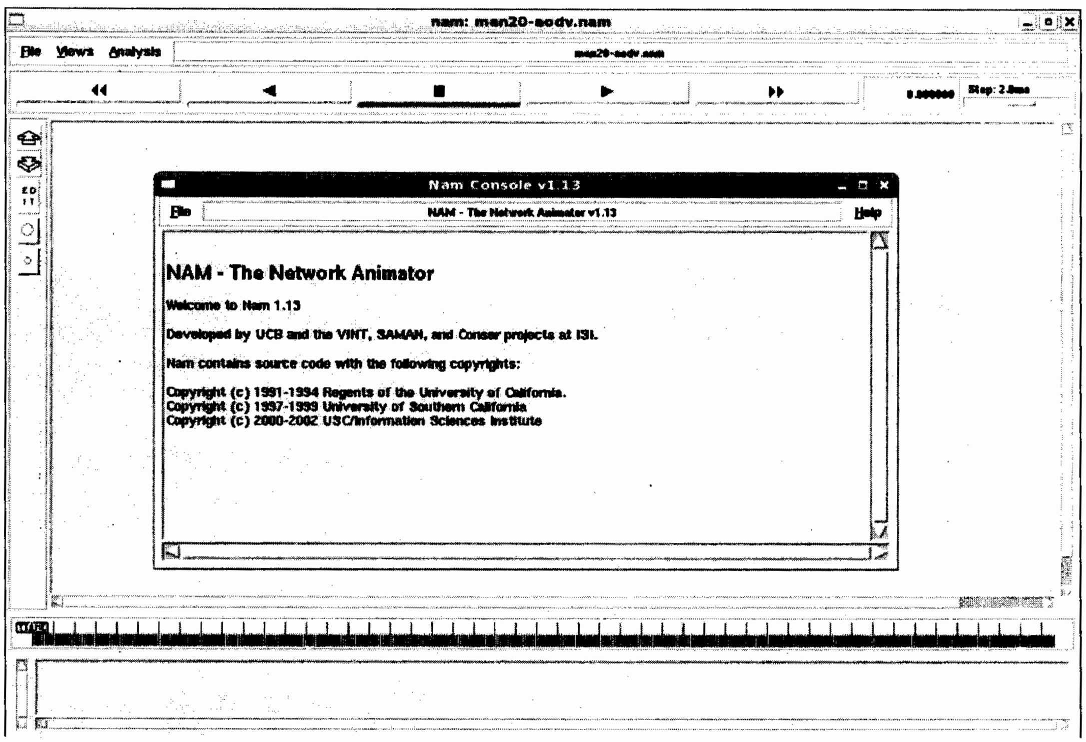
It is a Tcl/TK based animation tool which is used for viewing network simulation traces and also for real world packet traces. The design theory behind nam was to create an animator that is able to read large animation data sets and be extensible enough so that it could be used indifferent network visualization situations [72]. It shows the topology layout, packet animation, and also contains the various data inspection tools as shown in Figure 12. If want to use the nam we must first produce a trace file. The trace file contains the topology information e.g. node, link information and packet traces etc. The following command is used in Tcl file to create trace objects for ns and nam.

```
set tracefd     [open freeway.tr w]
set namtrace    [open freeway.nam w]

$ns_ trace-all $tracefd
$ns_ namtrace-all-wireless $namtrace $val(x) $val(y)
```

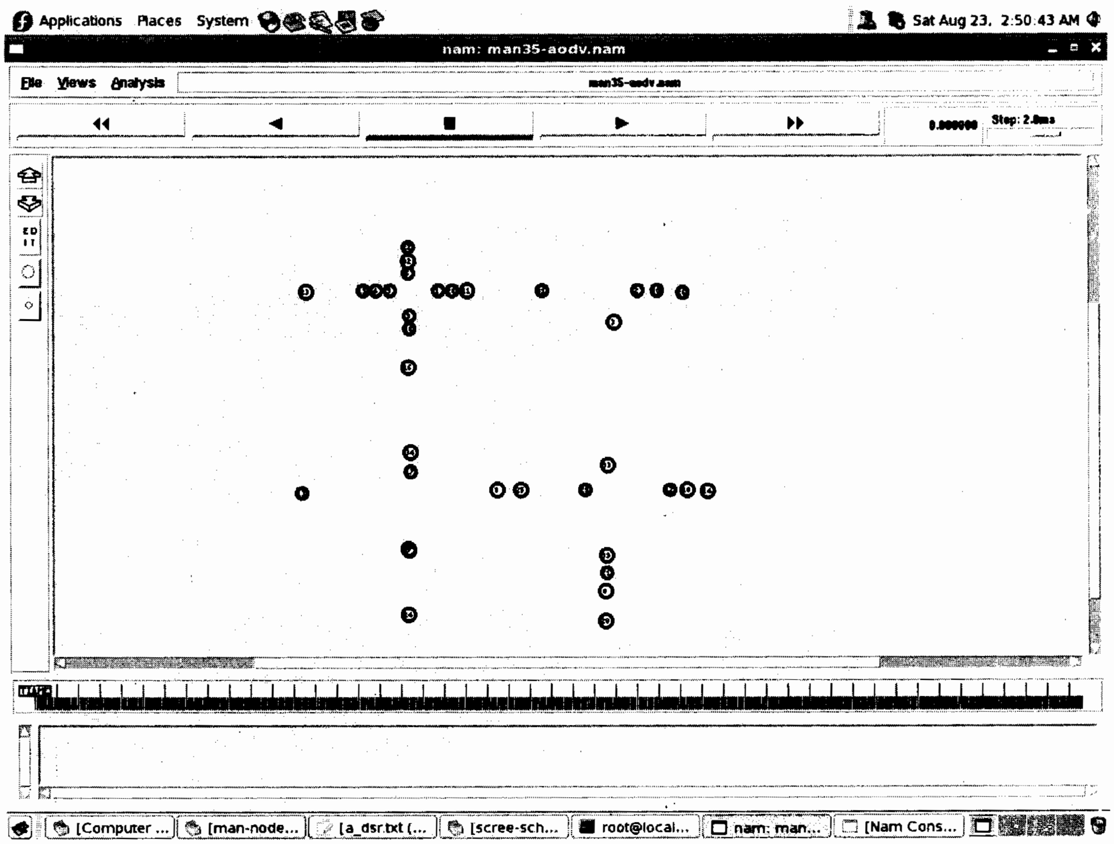
Here freeway.tr and freeway.nam are the names of trace files. When the trace file is created then it is animated by nam.

Starting up first create a name consol window. It contains only file and help menus. In file menu we have "new" for creating a new topology and "open" to open an existing trace file. Once a file is loaded to nam and the window appears it has a number of buttons for perfuming different tasks. It has stop, play, forward and rewind buttons.



"Figure 14 Network Animator"

As nam shows the visual results the following figure shows the output of Manhattan mobility model. It shows that at the upper left intersection the node density is high and low at the upper right intersection. Pressing the play button will start the simulation and the user can see the movement of the nodes and the transmission. The nodes will not go out of the specified range and will also restricted to the paths the have been assigned as we can see in figure that the vehicles are arranged in streets and moves on the roads they have been assigned.



"Figure 15 Congested intersections in Manhattan model"

5.4 Structure of tcl file

After generating the scene file and CBR (Constant Bit Rate) they are passed to the Tcl file which is then run and the trace and nam files are generated. The parameter of our tcl file is as follows.

1 set val(chanel)	Channel/WirelessChannel
2 set val(propag)	Propagation/TwoRayGround
3 set val(netif)	Phy/WirelessPhy
4 set val(mac)	Mac/802_11
5 set val(ifq)	Queue/DropTail/PriQueue
6 set val(ll)	LL
7 set val(ant)	Antenna/OmniAntenna
8 set val(x)	1200
9 set val(y)	1200
10 set val(ifqlen)	50
11 set val(adhocRouting)	AODV
12 set val(nn)	50

```
13 set val(cp)          "/root/project/cbr/cbr-acc"
14 set val(scne)          "/root/project/man/mana2"
15 set val(stop)         300.0
```

Line 1 and 2 shows that channel used is wireless channel and propagation method is two ray ground. Line 4 and 5 shows Mac layer protocol and the queue used. We have used the Omni Antenna. For the simulation we to set a simulation boundary in which the vehicles will move so we have to specify the x and y parameter. Line 11 shows the type of protocol used in simulation. Node density is shown by line 12. The node movement models, showing the nodes which will transmit packets and nodes which will be as intermediate nodes, the packet size and transition rate, is passed in line 13. The generated scene from the mobility model is passed to variable scene in line 14.

The topography object is created and then loaded by the following commands. The values passed to x and y is set here and new topology is created.

```
set topo        [new Topography]
$topo      load_flatgrid $val(x) $val(y)
```

The specified number of nodes is created by the following command

```
for {set i 0} {$i < $val(nn) } {incr i} {
        set node_($i) [$ns_ node]
        $node_($i) random-motion 0
```

As we have passed 50 to nn so it will create 50 nodes and will off the random movement of nodes.

The initial position of node in nam is shown by the following code

```
for {set i 0} {$i < $val(nn)} {incr i}
 {
   $ns_ initial_node_pos $node_($i) 20
}
```

The following code shows that when the simulation will ends and will generate the trace file.

```
for {set i 0} {$i < $val(nn) } {incr i} {
   $ns_ at $val(stop).0 "$node_($i) reset";
}

$ns_ at  $val(stop).0002 "puts \"NS EXITING...\" ; $ns_ halt"

puts $tracefd "M 0.0 nn $val(nn) x $val(x) y $val(y) rp $val(adhocRouting)"
puts $tracefd "M 0.0 sc $val(scne) cp $val(cp) seed $val(seed)"
puts $tracefd "M 0.0 prop $val(prop) ant $val(ant)"
```

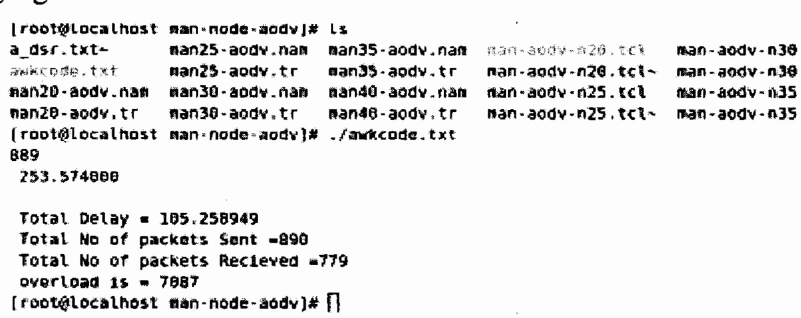
5.5 AWK code

The awk code is used to extract the results from the trace file. The name of trace and ad hoc routing protocol is passed to this awk code as in shown in the following awk code.

```
grep " dsr_fwy_50_30.tr | awk 'Begin
 { seqno =0; total_delay = 0 ; recv_count= 0; send_count=0;
}
{
if($1=="s" && $4== "AGT" && $7== "cbr")
{ seqno = $6; start_time[$6] = $2; send_seqn[$6] = $6; send_count= send_count + 1;
}
else
{
 if($1=="r" && $4== "AGT" && $7== "cbr")
{ end_time[$6] = $2; end_seqno[$6]= $6; recv_count= recv_count+1;}
} }
 END
{
printf("%d\n %f \n ", seqno, start_time[seqno]);
```

```
for (i=0; i<=seqno; i++)
{ if(end_time[i] != 0)
{
total_delay= total_delay + (end_time[i]- start_time[i]);  count=count+1;
}}
 printf("\n Total Delay = %f", total_delay);
printf("\n Total No of packets Sent =%d", send_count);
 printf("\n Total No of packets Recieved =%d", recv_count);
}
' grep " dsr_fwy_50_30.tr | awk 'Begin{rtng_pkts =0 ;
}
{
if (($1 == "s" || $1 == "D") && $4 == "RTR" && $7="DSR")
{ rtng_pkts++;
}}
END
{
printf("\n overload is = %d\n",rtng_pkts);
 }'
```

The above awk code outputs the total delay , total number of packet sent, totals number of packet received and routing overhead. The output of the above awk code is shown in the following figure.



```
[root@localhost man-node-aodv]# ls
a_dsr.txt~       man25-aodv.nam  man35-aodv.nam  man-aodv-n20.tcl   man-aodv-n30.
awkcode.txt      man25-aodv.tr   man35-aodv.tr   man-aodv-n20.tcl~  man-aodv-n30.
man20-aodv.nam   man30-aodv.nam  man40-aodv.nam  man-aodv-n25.tcl   man-aodv-n35.
man20-aodv.tr    man30-aodv.tr   man40-aodv.tr   man-aodv-n25.tcl~  man-aodv-n35.
[root@localhost man-node-aodv]# ./awkcode.txt
889
 253.574000

 Total Delay = 105.258949
 Total No of packets Sent =890
 Total No of packets Recieved =779
 overload is = 7087
[root@localhost man-node-aodv]#
```

"Figure 16 awk code result"

5.6 Summary

In this chapter the details of the implementation of our project are given. For implementation, a number of simulation tools are available. We have implemented this project in open source network simulation tool NS 2. Nam is another tool which provides the visual facility to users; the user can see the nodes, their movement patterns, the data packets and the simulation boundaries etc. the generated scene from the mobility model is passed to tcl file; in tcl file we set a number of parameter and then run it through ns. The ns generate the trace and nam files. The trace file is passed to awk code which gives the desired results and the nam file is run to see the visual results of scenario. The results of the awk code are analyzed and conclusions are presented.

6

Performance Evaluation

6.1 Introduction

In this chapter we analyzed the effect of different VANETs mobility models on the performance of MANETs routing protocols. After establishing a proper research and experimental methodology we have implemented our models. Further more, we have simulated and the results have been analyzed. The performance of routing protocols varies for different mobility models because each mobility model provides its own characteristics. The mobility model is the representation of the real world scenario, so if a mobility models represents the realistic parameters then the results will be more accurate compared to the non realistic mobility models. But the performance also depends upon some other factors as well e.g. the simulation time, performance metrics, etc.

6.2 Performance metrics

The results of the simulations not only depend upon the chosen mobility model but also depend upon the performance metrics chosen for simulations. In order to analyze the effect of mobility models we have chosen three performance metrics, namely Packet Delivery Ratio (PDR), Average End to End delay and Routing Overhead for both node density and velocity variations.

Packet Delivery Ratio

It is defined as the ratio of total number of packet received to total number of packet transmitted and is calculated as

Packet delivery ratio = n packet received / n packet transmitted

Average End to End Delay

It is defined as the time taken by a packet to reach its destination including route acquisition time and is calculated as.

Average Delay = Total delay / n packet received

Routing Overhead

It is defined as the number of routing packets transmitted per data packet delivered to the destination.

6.3 Simulation Results

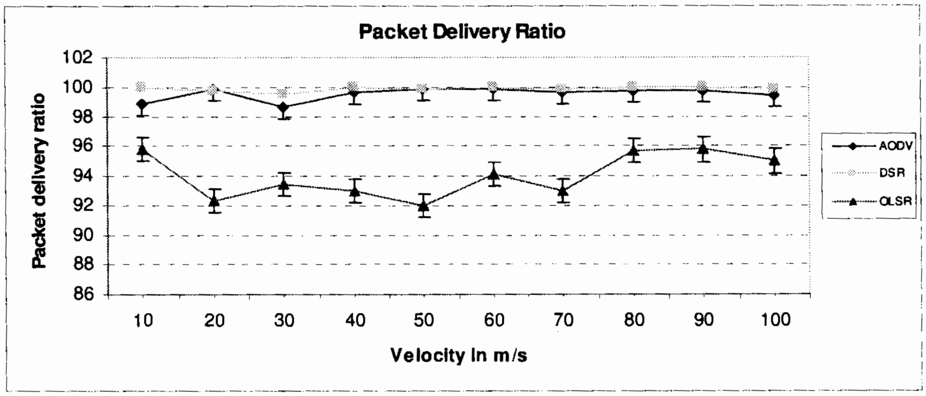
The simulation results of the mobility models is given is as follows.

6.3.1 Freeway mobility model Simulation results

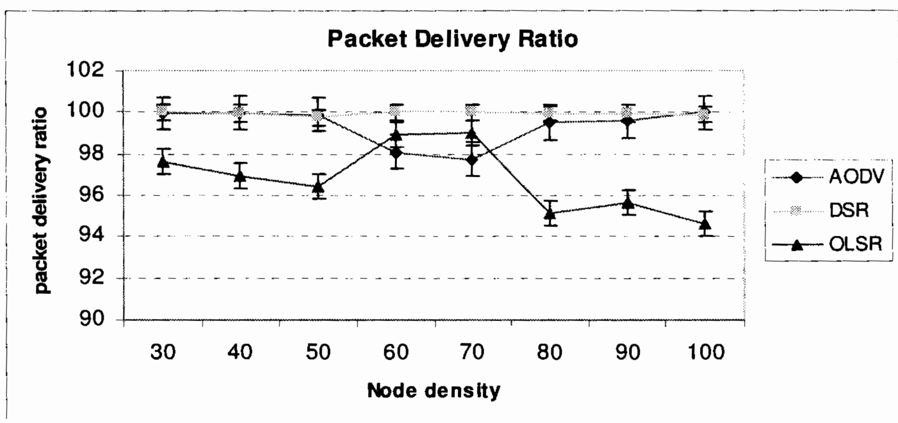
Packet Delivery Ratio (PDR)

Figure 14 shows the packet delivery ratio of MANET routing protocols under Freeway mobility model. The PDR of AODV and DSR is not very much affected by high mobility and remains high and constant while the PDR of OLSR is not that much high but it also remains almost constant with changing speed.

In figure 15 the velocity of the vehicle is kept constant and the node density is varied form 30 to 100 nodes so the PDR of the protocols is affected. There is a decrease in PDR of OLSR and AODV with changing node density while the PDR of DSR almost remains constant.



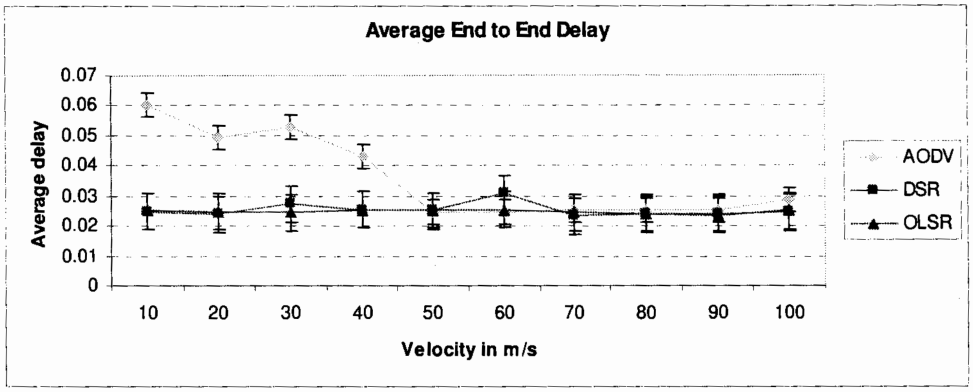
"Figure 17 Freeway packet delivery ratios with changing velocity"



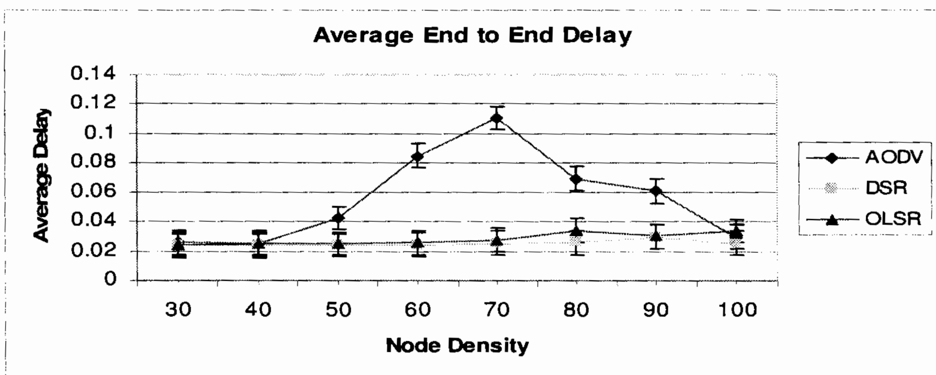
"Figure 18 Freeway packet delivery ratio with node density"

Average End to End Delay

Figure 16 shows that the average end to end delay of AODV is initially high but with increase in speed the average delay is decreases. There is a slight increase of average delay in DSR with change in speed. The average delay of OLSR remains constant and show very little variations with increased velocity. Figure 17 shows the effect of node density on average end to end delay. There is rapid increase and then decrease in average delay of AODV with increase in node density and a slight increase in average delay of DSR and OLSR.



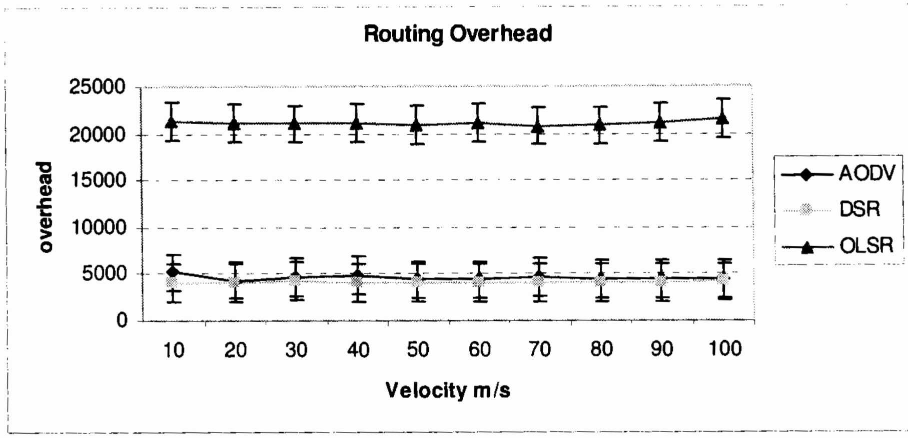
"Figure 19 Freeway Average End to End Delay with change in velocity"



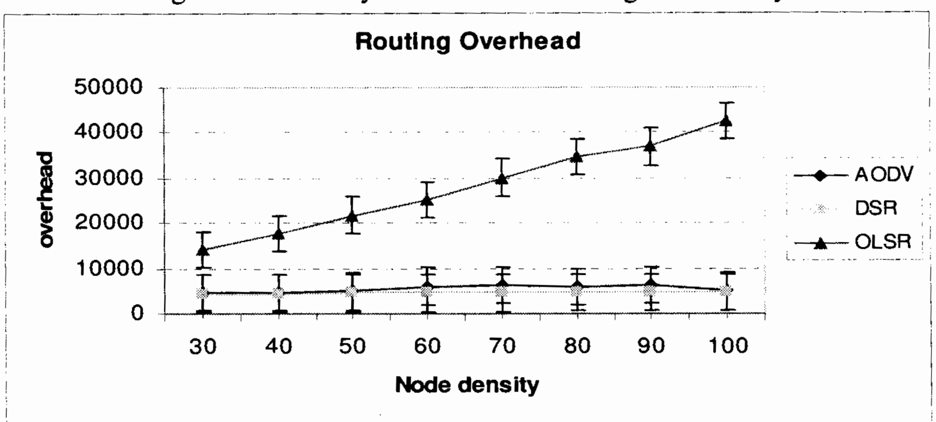
"Figure 20 Freeway Average End to End Delay with node density"

Routing Over head

Figure 18 shows the routing over head of routing protocols with change in speed of the nodes. The figure shows that the over head of OSLR is very high and remains at this high value for the variations in velocities. The routing over head of AODV and DSR is almost remains constant and low compared to OLSR. In case of increase in node density there is an increase in the overhead of OLSR while the over head of AODV and DSR remains low and constant compared to OLSR as shown in figure 19.



"Figure 21 Freeway Overhead with change in velocity"

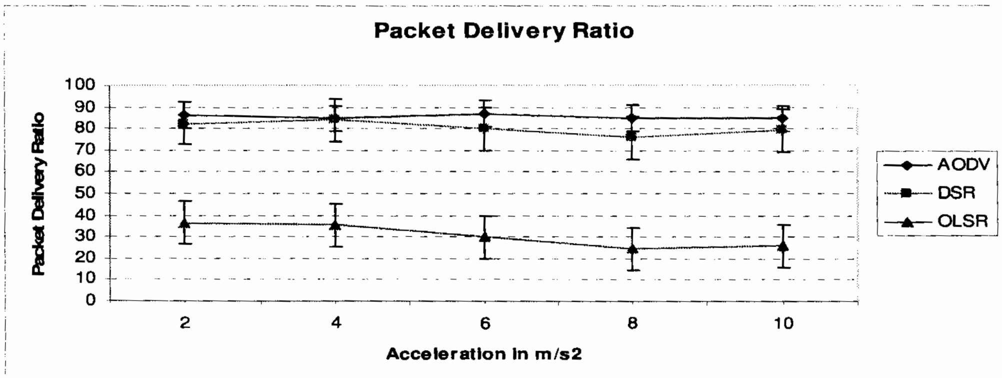


"Figure 22 Freeway Overhead with node density"

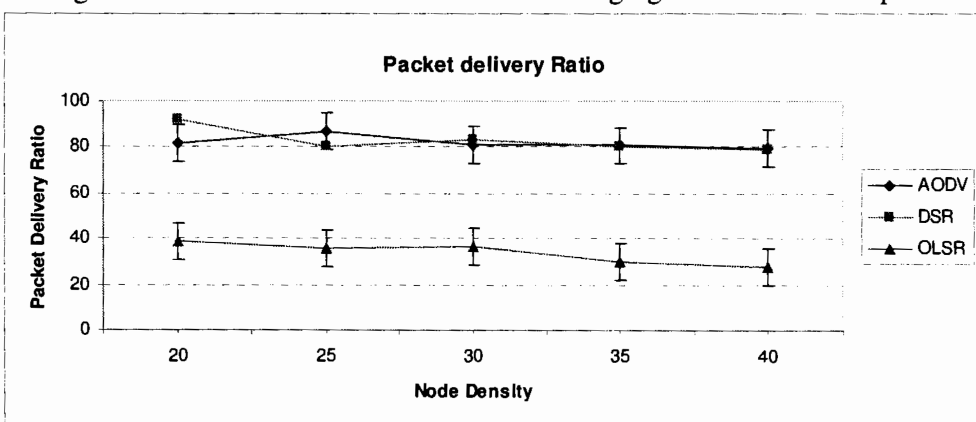
6.3.2 Manhattan mobility model Simulation results

Packet Delivery Ratio (PDR)

The PDR of the Manhattan mobility model for changing acceleration is show in Figure 20.The PDR of AODV is high and about 85% and remains constant with changing in acceleration. The PDR of DSR is also high but a slight decrease in PDR with changing the acceleration from 2 m/s^2 to 10 m/s^2. The PDR of OLSR is low and further decreases with increasing the acceleration speed. In case of changing node density the PDR of DSR and AODV is initially high but there is a slight decrease with increase in number of nodes while the PDR of OLSR is 38% at 20 node but when the node density increases to 40 the its PDR decreases to 27%.



"Figure 23 PDR of Manhattan model with changing the acceleration speed"

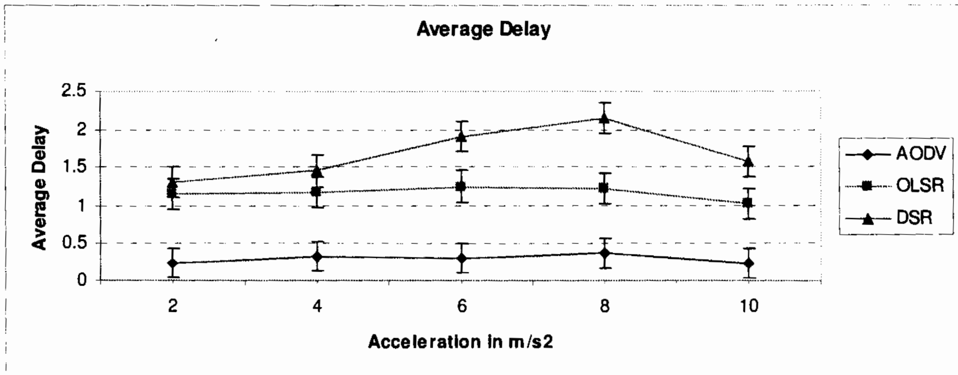


"Figure 24 PDR of Manhattan model with changing node density"

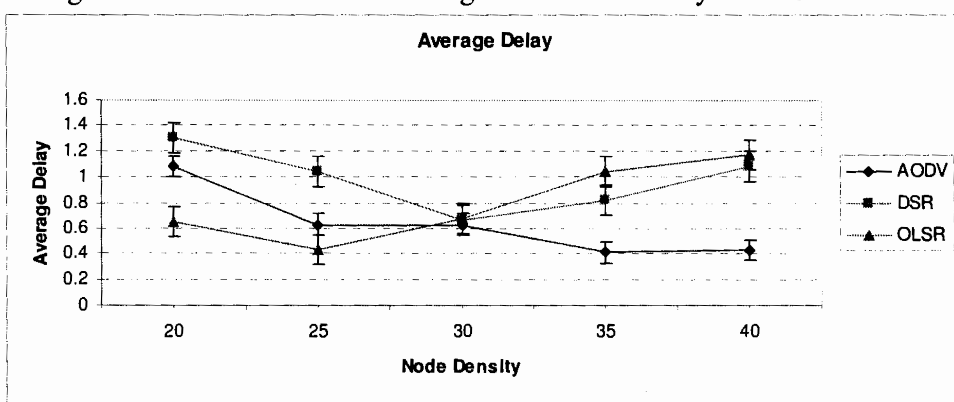
Average End to End Delay

Figure 22 shows the End to End delay of Manhattan model for changing the acceleration. The end to end delay of AODV is low compared to DSR and OLSR. There is a slight increase in the average delay of OLSR and AODV with changing the acceleration. The average end to end delay of DSR is high and further increases with increase in acceleration from 2 m/s^2 to 8 m/s^2 and then starts decreasing for 8 m/s^2 to 10m/s^2.

The figure 23 shows the average end to end delay of Manhattan mobility with node density. If we see that the delay of AODV is decreasing with increase in the density of traffic (nodes) while in contrast the average delay of OLSR increases with the increase in traffic density or with high node density. The average delay of DSR first decreases and then increases with node density.



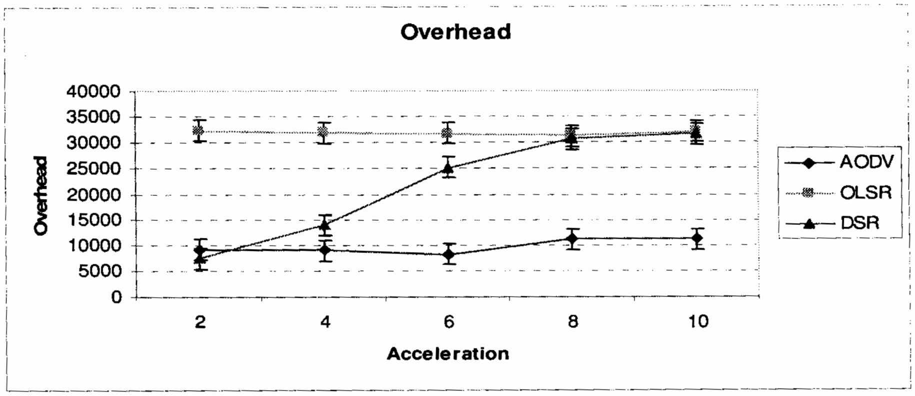
"Figure 25 Manhattan model Average End to End Delay with acceleration"



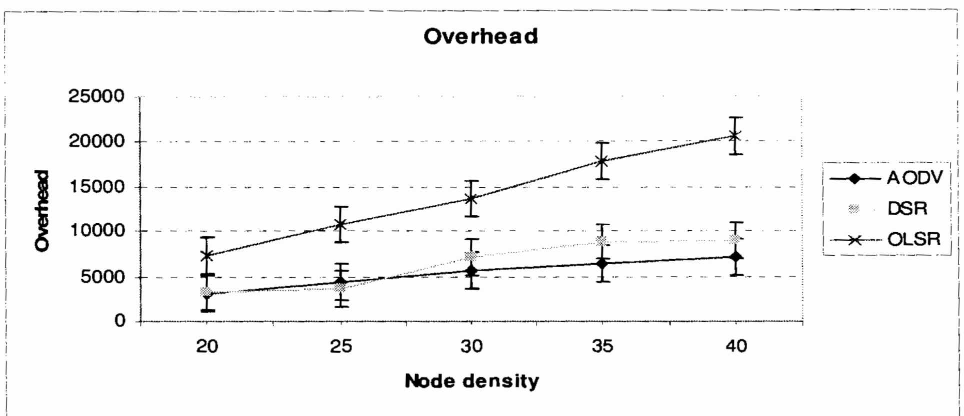
"Figure 26 Manhattan model Average End to End Delay with node density"

Routing Over head

The overhead of OLSR remains almost constant with change changing accelerations. There is slight increase of overhead in AODV while the overhead of DSR constantly increases with increase in acceleration from 2 to 10 m/s^2. Figure 25 shows that there is a constant increase in the overhead of OLSR, AODV and DSR with increase in node density.



"Figure 27 Manhattan model overhead with acceleration"

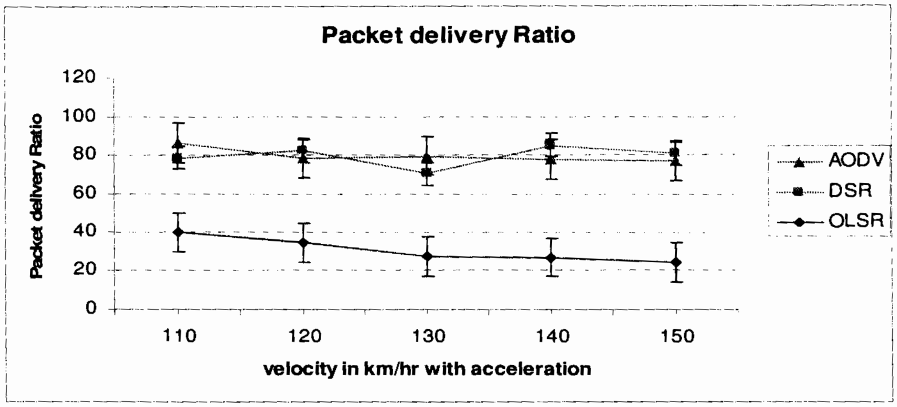


"Figure 28 Manhattan model overhead with node density"

6.3.3 Fast Car Model simulation results

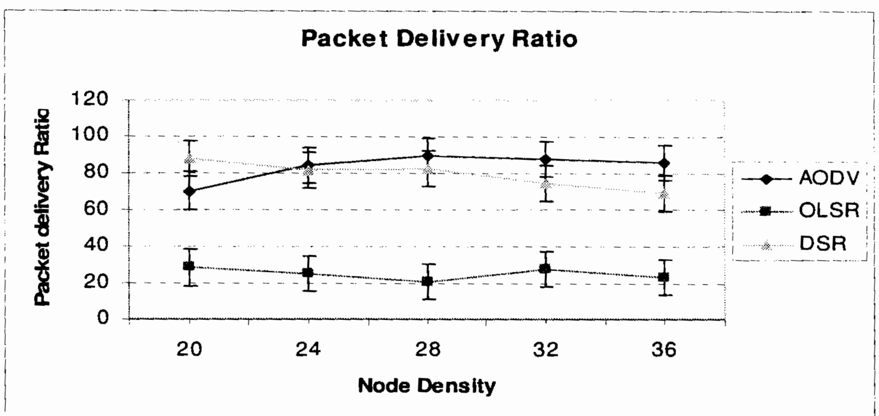
Packet Delivery Ratio (PDR)

Figure 26 shows the PDR of Fast car model with high velocities ranging from 110 km/h to 150 km/h. The PDR of AODV is high and with increase in velocity it gradually decreases. The PDR of DSR is almost remains constant while the PDR of OLSR is 40% at 110 km/h and then gradually decreases to 25% at high speed of 150 km/h.



"Figure 29 PDR of Fast Car model with changing the velocity"

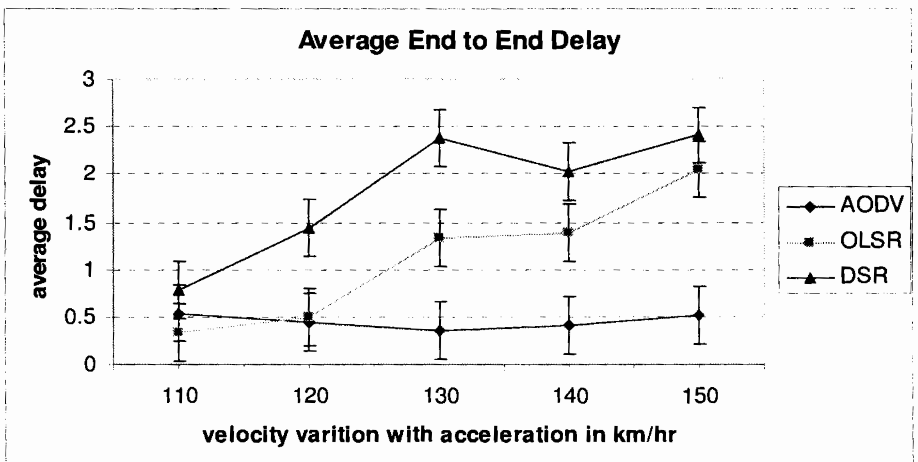
Figure 27 shows the effect of node density. With changing node density from 20 to 36 the PDR of AODV changes from 70% to 86% while the PDR of DSR decreases from 87% to 69% and that of OLSR from 28% to 23%. It means that the PDR of OLSR and DSR is decreased with high node density.



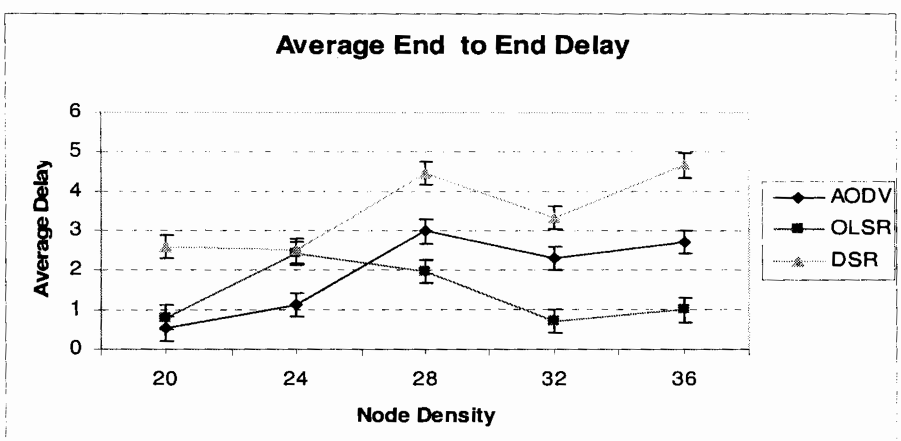
"Figure 30 PDR of Fast Car model with changing node density"

Average End to End Delay

Figure 28 shows the average End to End delay with changing speed from 110 km/h to 150 km/h. The average End to End delay of DSR and OLSR increases with high speeds while that of AODV almost remains constant. Figure 29 shows the effect of node density on average delay. The average End to End to delay of AODV and DSR increases with increases node density and that of OLSR first increases and then decreases.



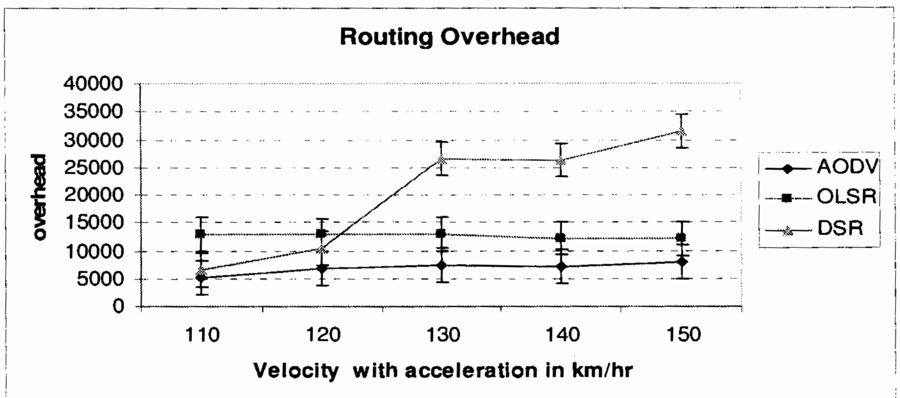
"Figure 31 Fast car model Average End to End Delay with change in velocity"



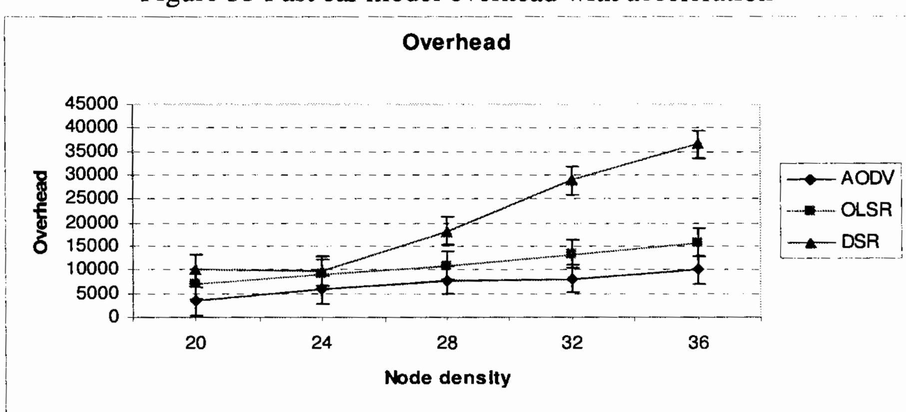
"Figure 32 Fast car model Average End to End Delay with node density"

Routing Overhead

Figure 30 shows the overhead of Fast car model with increase in acceleration from 110 km/h to 150 km/h. the over head of DSR increases very highly with high velocities and there is a slight increase in the over head of AODV while the overhead of OLSR almost remains constant. Figure 31 shows the overhead with changing node density there is slight increase in the overhead of OLSR and AODV with increase in node density but there is a rapid increase in the over DSR with changing node density from 20 to 36 nodes.



"Figure 33 Fast car model overhead with acceleration"

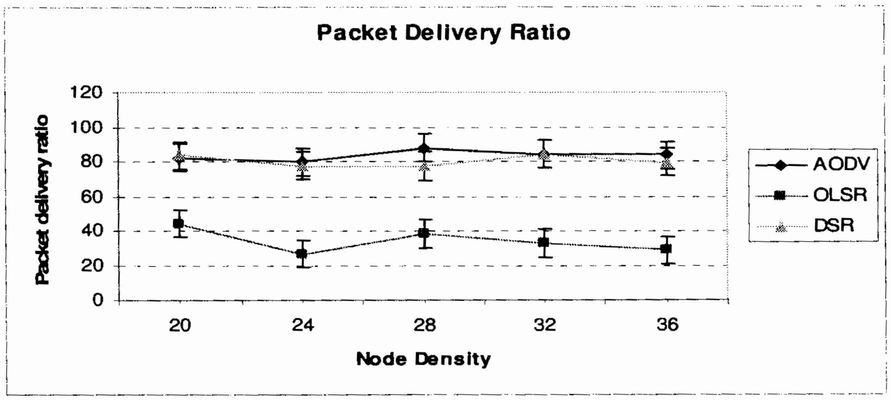


"Figure 34 Fast car model overhead with node density"

6.3.4 Slow Car model simulations results

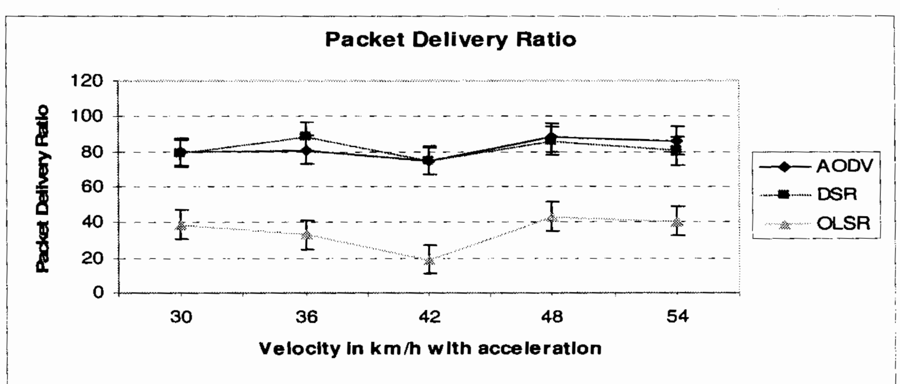
Packet Delivery Ratio (PDR)

The PDR of slow car model with node density is shown in the figure 32. The node density has a little effect on the PDR of AODV while the PDR of DSR decreases from 83% to 79%. The PDR of OLSR is greatly affected by node density and decreases form 44% to 28%.



"Figure 35 PDR of Slow Car model with changing node density"

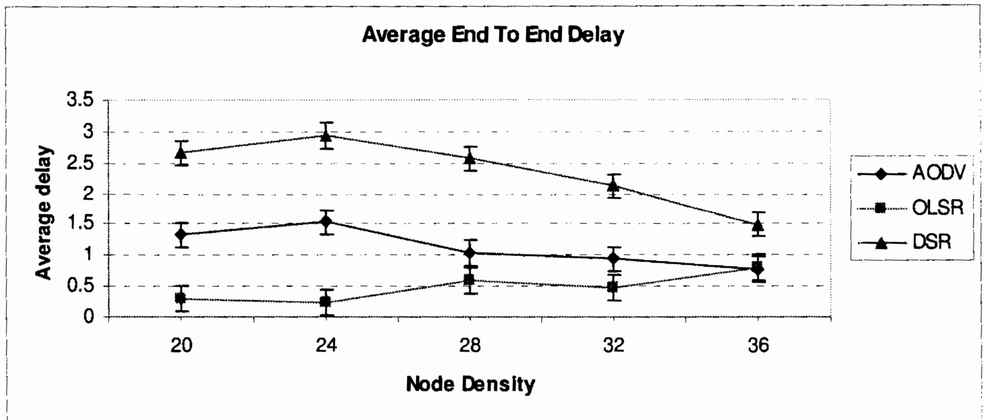
The figure 33 shows the PDR of slow car model with changing speed from 30km/h to 54km/h as this speed variations are very limited so the effect on performance is also very minor. The PDR of AODV increase from 79 % to 89% While that of DSR increase from 79 % to 80%. The PDR of OLSR first decreases and then increases with change in speed.



"Figure 36 PDR of Slow Car model with changing speed"

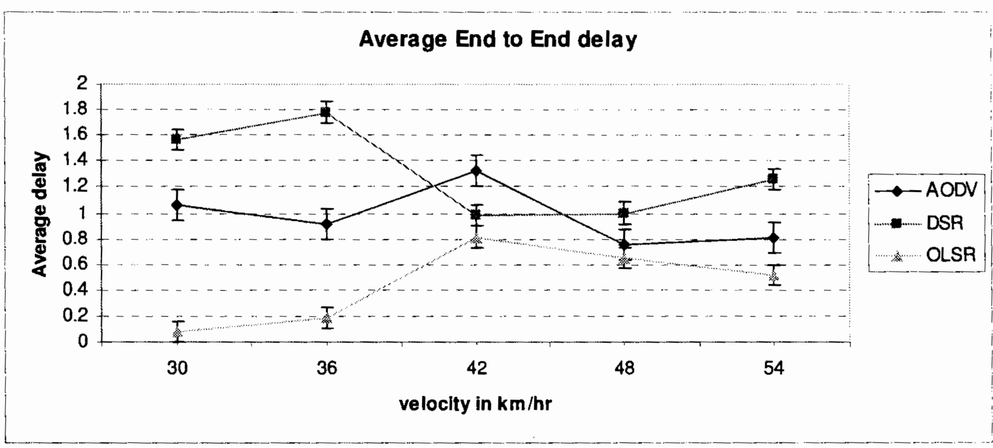
Average End to End Delay

The average End to End delay of DSR and AODV decrease with increase in node density and there is a slight increase in the average delay of OLSR as shown in figure 34.



"Figure 37 Slow car model Average End to End Delay with node density"

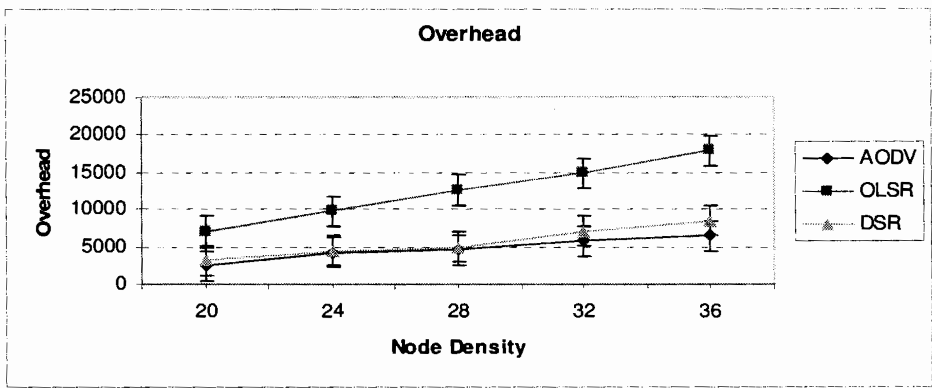
Figure 35 shows the average delay in case of changing velocities. The average delay of DSR is initially high but decrease with a slight increase in speed. Similarly the average delay of AODV is initially high but with increase in speed it decreases a little. The average delay of OLSR increases with increase in the speed from 30 km/hr to 54 km/hr.



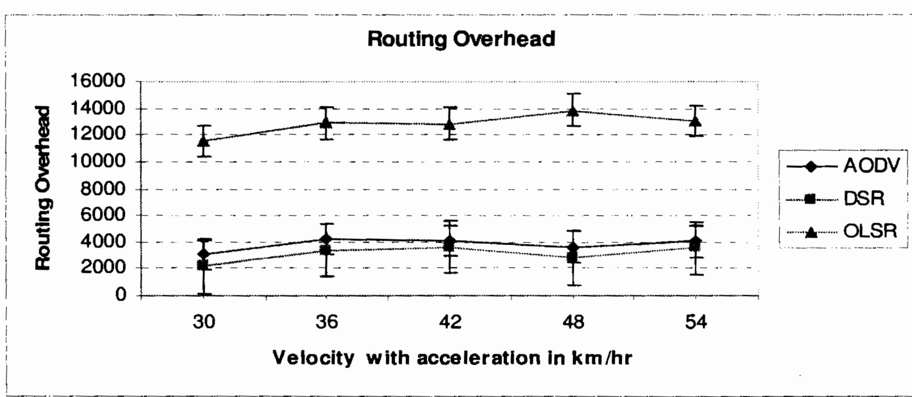
"Figure 38 slow car model Average End to End Delay with change in velocity"

Routing Overhead

Figure 36 shows the routing overhead of slow car model with node density. The overhead of DSR and AODV increases, less sharply, with high node density while the overhead of OLSR increases very rapidly with increase in the node density. Figure 37 shows the overhead with increase in speed. The overhead of OLSR is very high and further increases with changing the speed of nodes. The overhead of DSR and AODV compare to OLSR is less and slightly increases with changing the node speed as shown in figure 37.



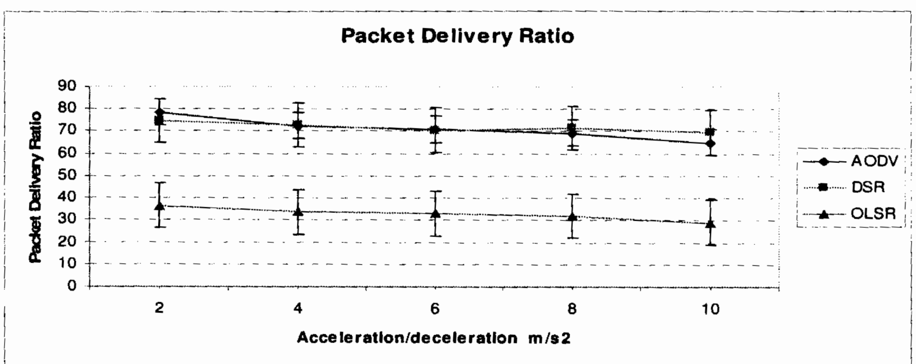
"Figure 39 Slow car model overhead with node density"



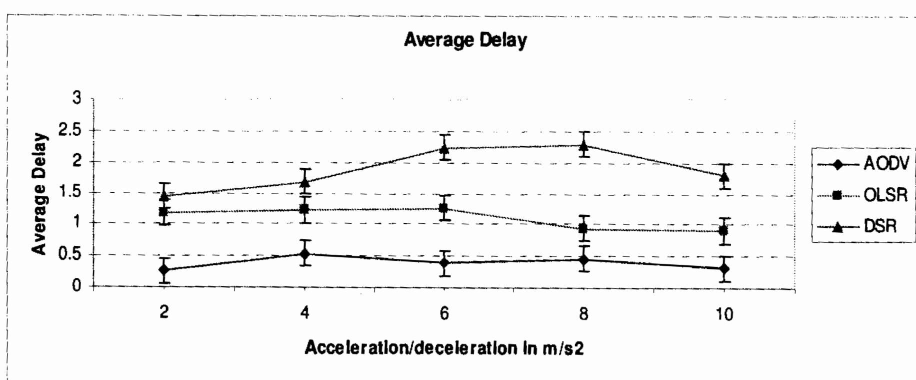
"Figure 40 Slow car model overhead with speed"

6.3.5 Modified *Manhattan mobility model Simulation results*

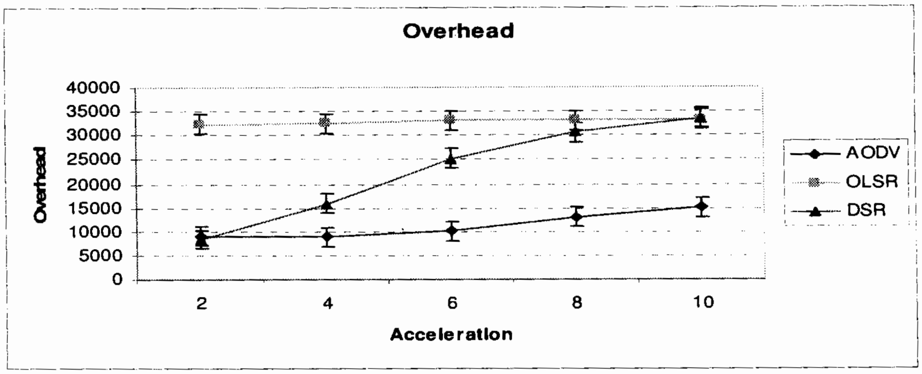
We have modified the Manhattan mobility model in which the cars, when approaches to the intersections starts to turn, will reduce the speed as in real world scenario. In such cases when the speed of the vehicles reduces at the intersections then the number of vehicles will be increased at intersections means resulting high density of vehicles so the performance will affects. When the speed of the cars reduces at the intersection this will cause deceleration. We have shown the results of these effects in the following figures which shows that the PDR of the modified Manhattan is affected and low compared to the original Manhattan mobility model.



"Figure 41 PDR of Modified Manhattan model with changing the acceleration speed"



"Figure 42 modified Manhattan model Avg End to End Delay with acceleration"



"Figure 43 Modified Manhattan model overhead with acceleration"

6.4 Major Conclusions about the impact of mobility models

from the graphs It is clear that routing protocol's performance varies with changing the mobility model and also with the route finding mechanism of ad hoc routing protocols. Different mobility models provide different characteristics that cause an affects in one way or the other on the ad hoc network's performance. The layout of lanes, streets, intersections, and other characteristics like including obstacles affects the performance. Also the route finding mechanism of each protocol is different from the other so it is also a factor that must be considered for performance evaluations.

Impact of Freeway mobility model: In freeway mobility model the vehicle moves on a predefined freeway with a predefined velocity. All the vehicles are assigned same velocity which is constant during the simulation time. There are two things about the freeway model one is that the vehicle follows a straight path and they don't moves to left or right directions it means it provides less topological changes to the vehicles and as a result the performance is not much affected. The second thing about the freeway model is that the vehicles are moving with a predefined speed with no acceleration or deceleration as a result the links that have been created at start remains in tact for longer duration. Due to these two characteristic the PDR of DSR, AODV and OLSR is high as shown in figures 17, 18.

Impact of Manhattan mobility model: In contrast, the Manhattan mobility model offers more topological changes by using multiple streets and intersections. In Manhattan mobility model the vehicles on reaching the intersections moves to left and right directions with 0.25 probability and goes straight with a probability0.5. So when vehicles moves to the left or right the topology change and the chances of breaking the old links become high because the vehicles may move out of range from each other. When the vehicles changes its streets at intersection new link formation will start up so more effort will be needed. As there is an acceleration or deceleration then the inter vehicle distance don't remains constant for long, as a results, the probability of link breakage is high in such cases and thus the performance results may affects. Also when the cars approaches to the intersections they reduce their speed which causes the deceleration and also the node density becomes high at intersection so it also affects the performance. Due to these characteristics of Manhattan mobility model the packet delivery ratio of DSR and AODV and OLSR is low as shown in figures 23, 24 compared to the freeway mobility model. Also the overhead in case of Manhattan model is high and further increases with high mobility and node density as shown in figures 27, 28.

Impact of Fast and slow car models: In case of fast car model the vehicles moves with high velocities and accelerations. As we expect that high velocities will cause a more rapid change in the topology resulting in high link failures so ultimately the performance will be affected. Like Manhattan model the packet delivery ratio of the routing protocols is low compared to the freeway mobility model as in figures 29, 30. The slow car model is similar to the fast car except the speed of the vehicles are slow compared to the fast car model so less topological changes are expected with high performance but the results shown in figures 35, 36 shows that the effect of the low mobility and high mobility are almost the same the only factor that affects the performance in case of fast car and slow car model is the node density. With high node density there is more burden on the wireless channel and causes contention resulting high packet loss ratios and low performance as for fast car is shown in figure 30 and for slow car model shown in 36. In nut shell high mobility is not the only factor that affects the performance of routing protocols but other factors like high node density, acceleration and deceleration also affects the performance of routing protocols.

6.5 Summary

In this chapter a detail about the performances metrics and the simulations results have been presented. We have chosen packet delivery ratio, end to end delay and routing overhead as performance metrics. Each mobility models is tested for both node mobility and high node density and the effect of it on the MANETs routing protocols is analyzed then we have presented our results and conclusions.

7

Conclusion and Future work

In this chapter we will summarize our conclusions about the thesis and will present the future dimensions of this work.

7.1 Achievements

The main achievements of this project can be summarized as follows.

- We have presented a detail of important components for the development of realistic and non- realistic mobility model for VANETs.
- On the basis of important entities and their characteristics for mobility models, we presented a Framework showing the relationship between the main entities of mobility models for VANETs. The Framework also shows the micro and macro characteristics of these entities.
- We have modified and implemented Manhattan mobility model, Fast Car Model (FCM) and Slow Car Model (SCM).
- We have used different metrics to analyze the influence of different mobility models on performance of different routing protocols of MANETs and got a number of meaningful results about the impact of mobility models.

7.2 Conclusion

Realistic mobility models are important tool for simulations because they represent the meaningful parameters and consequently the performance results shows more accuracy. In this thesis we have tried to identify the important entities and their characteristics for the development of realistic mobility models. Furthermore, we have presented our Framework that covers most of the important components of VANETs mobility models and also shows the inter-relation of these entities. In last, we have performed a rich set of experiments to analyze the effect of our modified and existing VANETs mobility models on the performance of MANETs routing protocols. In each of these experiments we have conducted several tests that we have used to find out the effect of high mobility and high node density on routing protocols. Normally we expect that high mobility will cause a more rapid change in network topology as compared to the increase number of nodes and ultimately the network performance will be greatly affected. But the results show that high velocity causes very little affects unless we consider the acceleration or decelerations. On the other hand high node density will always affect the network performance.

7.3 Future work

The future dimensions of this work is that the researchers should build more realistic mobility models based on micro mobility characteristics that reflects the real world scenarios for the simulation and analysis of routing protocols. The atmosphere factor such as high temperature, low temperature also affects the wireless channel, so, these factors should also be considered in overall simulation parameters for accurate results generations. Weather characteristics, considered as obstacles, such as rain, wind storm, fog etc. should also be included in the development of realistic mobility models for VANETs because in real life these characteristics do exits. In short, only realistic mobility models for VANETs will generate accurate results.

7.4 Summary

In this chapter we have concluded our work and the future dimensions of our work. The performance of MANETs protocols is affected by the mobility models used because each mobility models has its own characteristics. There is a need to develop more realistic mobility model and to include more realistic components such as weather conditions.

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VANETs Mobility Model Entities and Its Impact

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Abstract

Mobility Models plays a vital role in the performance evaluation of routing protocols. Research trends are now towards the development of realistic mobility models for vehicle ad hoc networks. In this paper we have given the entities and their characteristics, most important components, for the development of realistic mobility models for vehicle ad hoc networks. We have also described how these components will affect each other and network performance. In addition , we evaluated various routing protocols including DSR , AODV and OLSR using Fast Car Model (FCM), Slow Car Model (SCM) and Freeway mobility model and concluded that high mobility alone causes little affect on performance.

1. Introduction

A Mobile Ad hoc NETworks (MANETs) is collection of mobile node communicating each other in the absence of any infrastructure [4] while Vehicular Ad hoc Networks (VANETs) represents a class of MANET. In VANETs the nodes are vehicles which are distributed and highly mobile and with limited degree of freedom. In VANETs the high node mobility causes frequent topology change which greatly affects the network performance. The movement of the nodes and its position in the topology is represented by Mobility Models which is key components of simulation for MANETs and VANETs routing protocol [11].

As mobility models represents a key component for the analysis of protocols but in VANET the nodes moves with high velocities and will affect performance so the models with unrealistic movements and performance parameters may not reflect the true performance of the protocols[11]. Most of the existing mobility models are unrealistic and don't cover the necessary performance parameter exits in the real world scenarios but the trend has now shifted from unrealistic to realistic mobility models generations.

The rest of this paper is organized as follows. In section 2, we present a brief description of related work, in section 3 mobility models entities and their characteristics, in section 4 Analysis of Routing protocols using VANET mobility models and in section 5 Conclusions and Future work.

2. Related Work

There is a rich literature available on mobility models and the analysis of routing protocols on mobility models. A detail study about several entity and group mobility models for ad hoc network is presented in [1]. The authors have discussed and simulated different ad hoc mobility models and also explained the importance of choosing a mobility model by simulating. Four mobility models namely Fast Car Model (FCM), Slow Car Model (SCM), Human Run Model (HRM) and Human Walk Model (HWM) have been used in [2].They have analyzed the performance of routing protocols AODV, DSR, DSDV and TORA against the given mobility models. Necessary requirements and key components for the generation of mobility models for VANETs have been given in [3]. The framework presented covers most of the required entities and their characteristics for the generation of realistic mobility models for VANETs. The impact of different mobility models on the performance of MANETs routing protocols is given in [4]. They have proposed spatial and temporal dependencies and geographic restrictions. They analyzed DSR, AODV and DSDV under Random Waypoint, Reference Group Mobility Model, Free

Way and Manhattan models. Necessity of new realistic parameters for the performance evaluation of routing protocols has been considered and used in [5]. They have used the Vehicle Mobility Model (VVM) for the evaluation.

3. Mobility Model Entities and their characteristics

Mobility models are used for simulation of routing protocols because the real world tests are too expensive, difficult to deploy and also time consuming. So, it is very important to use a mobility model that has most of the required components of the real world scenarios.

3.1 ROADS

Road is the main entity for the development of mobility traces or maps for any mobility model used for VANETs. Some of the characteristics of Roads and how they affect the mobility are as follows.

3.1.1 Number of Lanes

The roads may have single lane or multiple lanes. In single lane roads there is usually one lane for one direction of traffic. These roads restricts the vehicles speeds and also affect the driver's behavior because if the driver wants to vary his speed or wants to overtake a vehicle he will consider the vehicles that are coming in the opposite direction. On the other hand, in multiple lane roads there are multiple paths for vehicles to move on. These vehicles have more freedom to change their lanes and vary their speed accordingly. Also there is an ease for the drivers to overtake the vehicles because there is no vehicles coming from the opposite direction. These lanes have usually assigned certain speed limits so if driver want to change a lane then he must change his speed according to the lane he wants to join.

3.1.2 Number of Streets and Intersections

Multiple street and intersection roads are represented in Manhattan mobility model [4].The number of streets and intersections in a road also affects the speed of vehicles and the behavior of the drivers. As there are multiple paths available so the drivers can choose the alternate route or shortest route or he can avoid the congested streets. The intersections are the junctions of two roads where they cross each other. In real world situations at intersections the drivers reduces the speed of his vehicle so he can neither cross the road nor he can take a turn with the speed he is moving to the cross points. At intersection the vehicle density (node density) is high so there is more burden on the channel and the performance also greatly affects. Also, on reaching at cross points certain vehicles will move to their desired directions so certain probability must be assigned to these vehicles.

3.1.3 Traffic Sign and Traffic Lights

Traffic signs and lights on road sides, referred as Traffic Control Mechanism by some researchers; provide help and instructions to drivers for safe driving. These traffic signs include signs for speed limits, fuel stations, bus stops, bridges ahead signs, sharp turn signs etc. These signs affect the driver and vehicle's characteristics e.g. the driver may reduce his speed or stops according to the instruction on signs. At certain spots, these signs cause traffic jams, increasing the number of vehicles and ultimately increasing the contention for channel so performance will affect. On the basis of these characteristics Stop Sign Model (SSM) and Traffic Sign Models (TSM) have been developed [6].

3.1.4 Other characteristics

Other characteristics like, Bridges, road conditions, number of turns, road segments, location, road side buildings, trees, lane capacities etc affects the mobility in one way or the other.

3.2. Vehicles

Like road, vehicle is also a main entity and its different characteristics are considered while developing mobility model. Some of the characteristics are given as follow.

3.2.1 Vehicle Velocity

The topology of the VANET depends upon the speed of the vehicles because there is no specific topology exists. Variations in velocities affects the topology and ultimately affects the performance because with high velocities packet delivery ratio will be reduced and the route breaking ratio will be high also with high mobility new routes will be established at a high rate. The velocity of a vehicle also affects the motion of other near by vehicles moving in same lane or moving in side-by lane. This relative velocity consideration is very important for overtaking and affects driver behavior.

3.2.2 Acceleration and Deceleration

Acceleration and Deceleration are considered as micro mobility characteristics [5]. The vehicles approaching to the intersections reduce their velocities and thus deceleration is produced considered in [7]. Acceleration and Deceleration must be considered in developing realistic mobility models because the speed and velocity of the vehicles can change at any instant of time.

3.2.3 Number of Vehicles

The number of vehicles or node density at certain parts of road and at certain times is different e.g. node density at intersections is high and is low in midway also in morning and after noon hours vehicles density is high and low in non working hours. Node density significantly increases overhead, increase contention in channel and thus network performance is affected.

3.2.4 Other vehicle characteristics

Vehicle size, vehicle type, safe relative distance between vehicle, initial position are some other characteristics that are now included in realistic mobility models e.g. vehicle size in [5].

3.3 Driver Behavior

Safe and accident free traffic really depends upon the driver behavior because he is the one who controls the vehicle and considers all the external stimuli that affects his behavior.

3.3.1 Overtaking

In most of the existing mobility models e.g. Manhattan mobility model, Freeway mobility model etc. Overtaking and other driver behavior characteristics are not considered. While overtaking the driver has to consider certain things in his mind e.g. the velocity of the his vehicle, the velocity of the immediate vehicle in front , the velocity of the vehicle coming in opposite direction, the distance between his vehicle and immediate vehicle in front , reaction time etc. As in Fig. 1 the driver of the vehicle **A** must consider his velocity **Va** , velocity **Vb** of vehicle **B** and the velocity **Vc** of vehicle **C** coming in opposite direction and distance **dm** between **A** and **B**. The velocity of vehicle **A** must be greater than vehicle **B** i.e.

$$Va > Vb$$

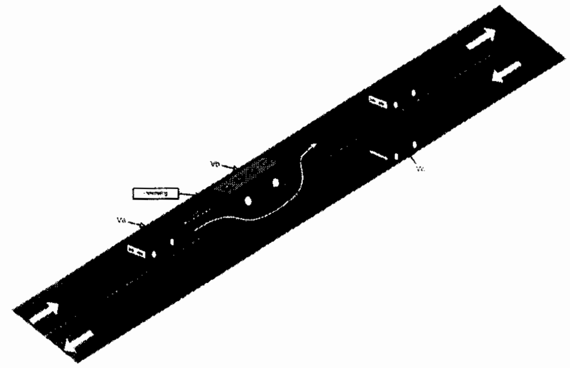

Figure 1. Overtaking

3.3.2 Lane changing

Lane changing is driver's behavior to change his lane, so vehicle velocity and network topology will change, and ultimately high velocity and topology change will affect network performance.

3.3.3 Other characteristics

keeping a safe inter vehicle distance , frustration due to traffic jam, alternate route selection , mobility prediction, social habits, reaction time are some of the other characteristics that should be considered in developing realistic mobility models.

3.4 Obstacles

The consideration of obstacles in the development of mobility models is very important because they affect all the main entities. The obstacles include road side buildings, trees, street poles, and weather conditions. Weather condition e.g. Fog, rain, wind storm, snow fall affects the driver behavior and vehicle characteristics.

4. Analysis of Routing protocols using mobility models

In this section we have analyzed OLSR, DSR and AODV routing protocols using VANETs mobility models but first we will give a brief introduction of these mobility models and routing protocols.

4.1 Mobility Models

The freeway mobility model consists upon several freeways or roads [4]. These roads or freeways in freeway model are single or multilane and bidirectional. Each node is restricted to is lane and direction and moves with certain rules. The velocities of the vehicles are high and normally each lane is assigned a pre defined velocity limits.

In Fast car model [2] the nodes are highly mobile vehicles and moving on a pre defined path or roads as in Freeway model with certain mobility constraints e.g. acceleration and deceleration. The velocity of vehicle may reach to 150 km/hr. The idea of the Slow car model [2] is similar to that of Fast car model but here vehicles moves with slow velocity and thus offer less topology change.

4.2 MANET routing protocols

In Ad Hoc on Demand Routing (AODV) [9] the source node first initiates a route discovery process and broadcast a Route Request (RREQ) packet and this packet is forwarded until an active route is found when a node knows a route to destination node it sends a Route Reply (RREP) packet to source node and source node opens the route when it receives the RREP packet.

Optimized Link State Routing (OLSR)[8] uses Multi Point Relays (MRP). Each node periodically maintains information about 1-hop and 2-hops neighbors. A source node selects MRP and this MRP sends packets. OLSR builds a routing table which is periodically updated about the link state information. This information about the link state is send and maintained on MRPs.

Destination Sequence Routing (DSR)[10] works in two phase route discovery and route maintenance. In route discovery each node first checks its cache and if route not found here then it initiates a route discovery process by broadcasting route request packets containing both source and destination addresses. Each node when receiving the packet when sees its id then packet is discarded otherwise broadcasted and the process continues till destination is located. Route maintenance is the process of detecting a change in network topology by source. When a route error packet is received by the source it removes the error from cache.

4.3 Simulation Parameters and Results

Table1 summarizes all the parameters that have been used in simulation.

In order to analyze these mentioned mobility models we have chosen three performance metrics, namely Packet Delivery Ratio (PDR), Average end to end delay and Routing Overhead for both node density and velocity variations. We have performed the simulation in open source network simulator NS 2.31 on Fedora Core 6.

Table 1. Simulation Parameters

Variables	Values
Simulation tool	NS-2.31
Topology size	1200m x 1200m
Simulation time	300 sec
Mobility model	Freeway, Fast car, Slow car
Packet size	512 bytes
Nodes density	30-100 for Freeway 30 for Fast car and slow car
Velocity Variations	10 -100 m/s for Freeway 100-150 km/hr for Fast car model 30,36,42,48,54 for Slow car model
Traffic Type	CBR
Transmission Range	250 m

4.3.1 Packet Delivery Ratio

It is defined as the ratio of total number of packet received to total number of packet transmitted.

The PDR of freeway way mobility model under node density and velocity variations is shown in Fig. 2 and Fig. 3 respectively. In Fig. 2 the velocity of the vehicle is kept constant and the node density is varied form 30 to 100 nodes so as results there is a decrease in PDR of OLSR and AODV while the PDR of DSR almost remains constant. The PDR of OLSR varies with change in velocity and remains low as compared to DSR and AODV as shown in Fig 3. The PDR of AODV and DSR is not much affect by high mobility of vehicles.

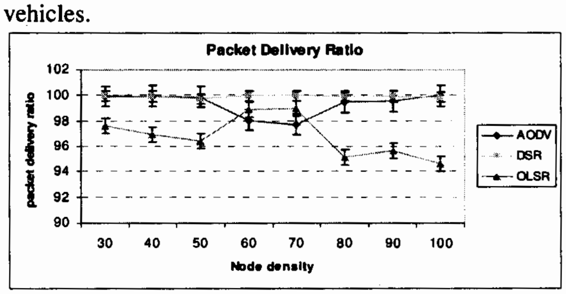

Figure 2. Freeway PDR under node density

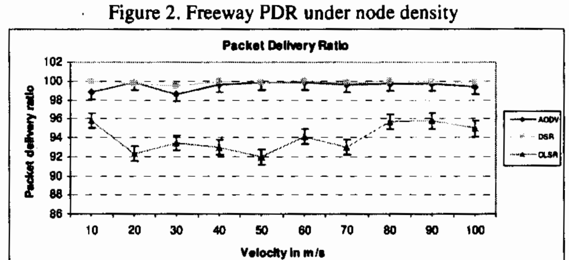

Figure 3. Freeway PDR with change in velocity

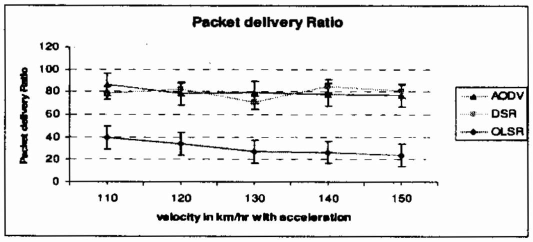

Figure 4. FCM PDR with change in velocity

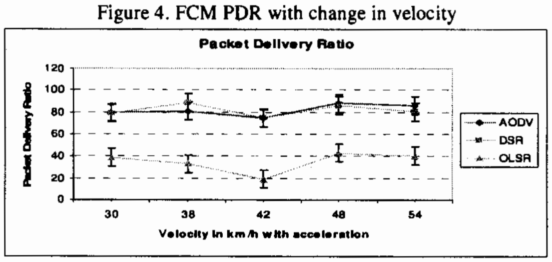

Figure 5. SCM PDR under with change in velocity

In Fast car model the vehicle moves with a speed 110 km/hr to 150 km/hr so with this high mobility the PDR of DSR and AODV on average remains at 80 % and OLSR at 30 % which means that the packet lose ratio of OLSR under high mobility is high shown in Fig. 4. Fig. 5 shows the PDR of Slow car model here the cars are moving with a slow speed but the results remain almost the same as in Fast car model.

4.3.2 Average End to End Delay

It is defined as the time taken by a packet to reach its destination including route acquisition time.

The average delay in milliseconds of Freeway model with node density and with change in velocity is shown in Fig. 6 and Fig. 7.

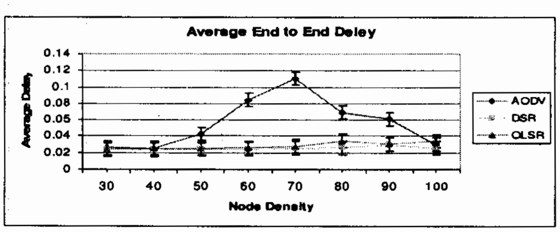

Figure 6. Freeway End to End Delay with node density"

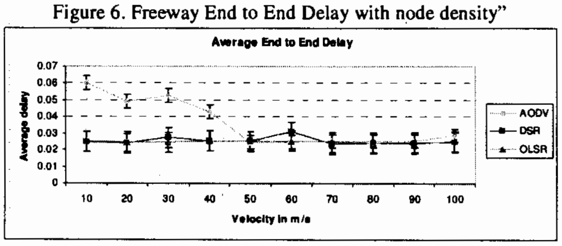

Figure 7. Freeway End to End Delay with change in velocity"

Fig.6 shows that there is a rapid increase and then decrease in average delay of AODV with increase in node density and a slight increase in average delay of DSR and OLSR. In case of velocity variations the average delay of OLSR and DSR remains almost constant while the average delay of AODV decrease with high velocities.

Average delay is not much affected with high speeds but when there is an acceleration and declaration then it affects the average delay for Fast and Slow car models as shown in Fig. 8 and Fig. 9. There is a rapid increase in the average delay with increase in velocity for OLSR and DSR but AODV average delay almost remains constant as in Fig. 8.In case of Slow Car Model the average delay of OLSR and AODV increases with change in velocity but then remains constant while that of DSR decreases and then remains constant shown in Fig. 9.

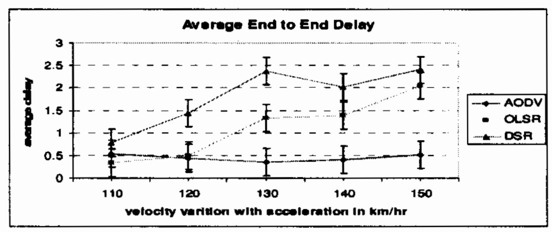

Figure 8. FCM End to End Delay with change in velocity

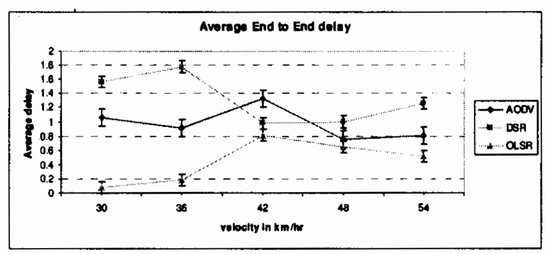

Figure 9. SCM End to End Delay with change in velocity

4.3.3 Routing Overhead

It is defined as the number of routing packets transmitted per data packet delivered to the destination.

Fig.10, 11, 12, and 13 show the routing overhead of Freeway model, Fast Car Model and Slow Car Model respectively. These figures show that the routing overhead of OLSR is very high and increases with increase in node density and velocity as in Fig. 10, and Fig. 11. There are slight variations in the routing over head of AODV and DSR and remains almost constant with both node density and high mobility.

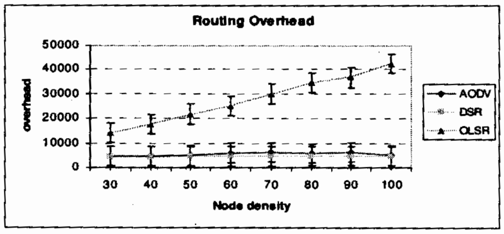

Figure 10. Freeway Overhead with node density

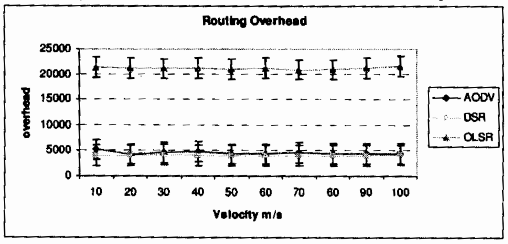

Figure 11. Freeway Overhead with change in velocity

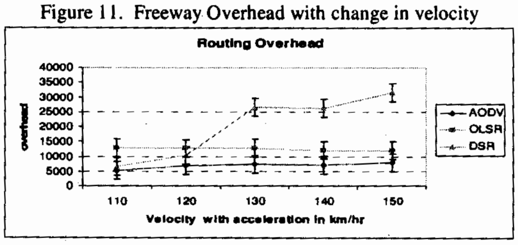

Figure12. FCM Overhead with change in velocity

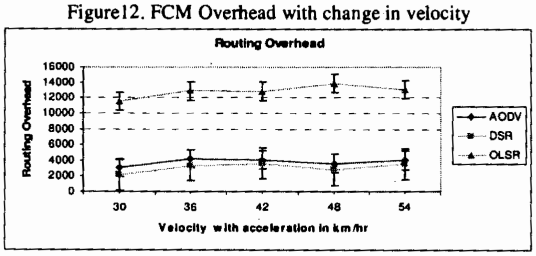

Figure 13. SCM Overhead with change in velocity

4.3.4 Simulation Results Conclusions

Normally we expect that high mobility will cause a more rapid change in network topology as compared to the high node density and ultimately the network performance will be greatly affected. But the results shows that high velocity causes very little affects alone, unless, we consider the acceleration or decelerations with it, compared to high node density.

5. Conclusions and Future work

As mobility model is an important tool for simulation and analysis so, in this paper we have tried to present the main entities and their characteristics for VANETs mobility models development. We have also analyzed some routing protocols on mobility models and give our results and conclusions. The future dimensions of this work is that the researchers should build more realistic mobility models based on micro mobility characteristics that reflects the real world scenarios for the simulation and analysis of routing protocols.

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