# A Multi-Constraint Real-time Vehicular (MCRV) Mobility Framework for 4G Heterogeneous Vehicular Ad-Hoc Networks

P.Vetrivelan, P.Narayanasamy, and J.C.John Charlas

***Abstract*— A Vehicular Ad-Hoc Network or VANET is a technology for implementing Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications. The present Vehicular mobility framework is not considering realtime constraints such as vehicle' priority, lane-changes, speed-limit etc. The proposed Multi-Constraint Realtime Vehicular (MCRV) mobility framework is equipped with important criterion like collision avoidance between vehicles and traffic reports. Also certain vehicles such as ambulance, fire service vans, police patrols need to be given a high priority in our envisioned network architecture, as their requirements are crucial during emergency situations. Hence, enabling QoS for differentiating the services according to vehicular priorities and providing group communications, alongside vehicular collision avoidance, will be implemented using NS3 and SUMO.**

***Index Terms*— WAVE, WiMAX, UMTS, Long Term Evolution (LTE), VANET, SUMO, NS3.**

## I. Introduction

The Recent advances in wireless networks have led to the introduction of a new type of networks called Vehicular Networks. Vehicular Ad Hoc Network (VANET) is a form of Mobile Ad Hoc Networks (MANET). VANETs provide us with the infrastructure for developing new systems to enhance drivers' and passengers' safety and comfort. VANETs are distributed self-organizing networks formed between moving vehicles equipped with wireless communication devices. This type of networks is developed as part of the Intelligent Transportation Systems (ITS) to bring significant improvement to the transportation systems performance.

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Each Vehicle Node is equipped with WAVE (IEEE 802.11p) protocol known as OBUs (On Board Unit). There are mainly two types of communications scenarios in vehicular networks: Vehicle-to-Vehicle (V2V) and Vehicle-to-RSU (V2R or V2I). The RSUs can also communicate with each other and with other networks. Vehicular Networks are expected to employ variety of advanced wireless technologies such as Dedicated Short Range Communications (DSRC), which is an enhanced version of the WAVE (IEEE802.11p) technology suitable for VANET environments. The DSRC is developed to support the data transfer in rapidly changing communication environments. The basic VANET communication scenario is shown in Fig.1.

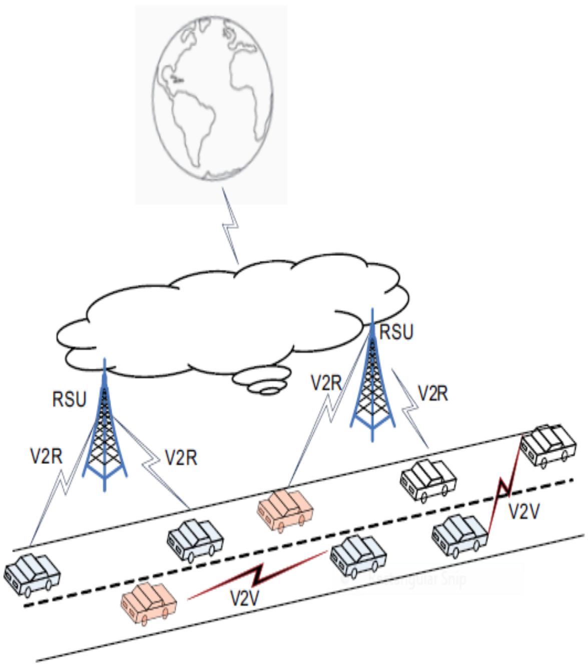


Fig. 1. Basic VANET Communication Scenario

VANET applications are Safety applications, Cooperative Collision Avoidance (CCA), Emergency Warning Messages (EWM), Cooperative Intersection Collision Avoidance (CICA), Traffic Managements, Advertisements, entertainment and comfort applications like Electronic toll collection.

A new MAC protocol known as the IEEE 802.11p is used by the WAVE stack. The IEEE 802.11p basic MAC protocol is the same as IEEE 802.11 Distributed Coordination Function (DCF), which uses the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) method for accessing the shared medium. The IEEE 802.11p MAC extension layer is based on the IEEE 802.11e (IEEE, 2003) that uses the Enhanced Distributed Channel Access (EDCA)

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like Access Category (AC), virtual station, and Arbitration Inter-Frame Space (AIFS). Using EDCA, the Quality of Service (QoS) in the IEEE 802.11p can be obtained by classifying the data traffic into different classes with different priorities. The basic communication modes in the IEEE 802.11p can be implemented either using broadcast, where the control channel (CCH) is used to broadcast safety critical and control messages to neighboring vehicles, or using the multi-channel operation mode where the service channel (SCH) and the CCH are used. The later mode is called the WAVE Basic Service Set (WBSS).

In the WBSS mode, stations (STAs) become members of the WBSS in one of two ways, a WBSS provider or a WBSS user. Stations in the WAVE move very fast and it's very important that these stations establish communications and start transmitting data very fast. Therefore, the WBSSs don't require MAC sub-layer authentication and association. The provider forms a WBSS by broadcasting a WAVE Service advertisement (WSA) on the CCH. The Protocol architecture of IEEE802.11p DSRC is shown in Fig.2.

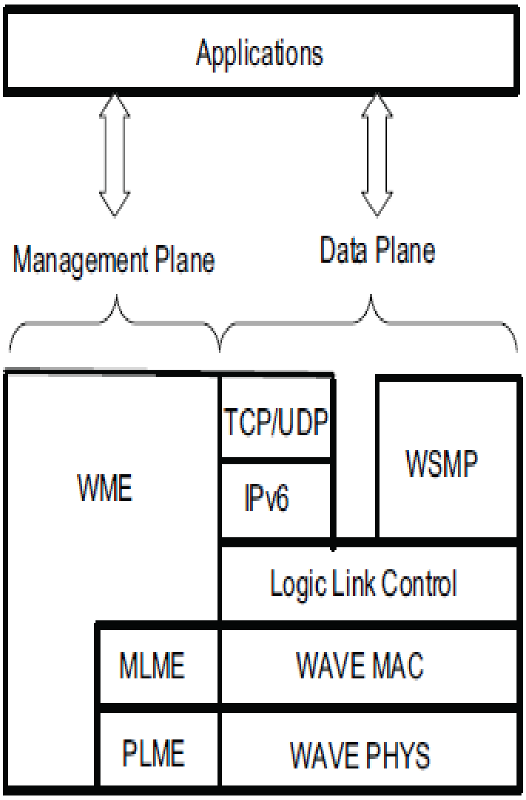


Fig.2. Protocol architecture of IEEE802.11p DSRC

V2V uses DSRC based WAVE protocol for collision avoidance messages and V2I uses WiMAX or UMTS/LTE networks for lane-changes /assigning vehicle priorities.

The remainder of this paper is organized as follows: Section II offers an overview of VANETs vehicular mobility issues. Then MCRV mobility framework shows the interworking of between WAVE-WAVE for V2V and WiMAX/UMTS for V2I communications in Section III. The handoff management module and the vertical handoff decision scheme are presented in Section IV. The MCRT Vehicular Mobility Algorithm and its functions were presented in Section V and VI deals about performance evaluation. Finally, concluding remarks and future work are stated in Section VII.

## II. VEHICULAR MOBILITY ISSUES

The survey contains information about VANET mobility models, several architectures for mobility management, integration of network and traffic simulator, performance issues in VANET. Several issues and parameters were considered.

Vaishali D. Khairnar et al [1] has analyzed mobility models for vehicular adhoc network. Mobility model is important characteristic of vehicular networks. Mobility models can be commonly classified into macroscopic models, mesoscopic models, and microscopic models. The Random way-point model evaluates its effect in VANETs by ns-2 simulations. Ricardo Fernandes et al [2] presents a tool for simulating heterogeneous vehicular networks. The existing microscopic traffic simulator, DIVERT, has been extended by adding NS-3 support resulting in a very tightly integrated simulator. Hybrid approaches provide a fully integrated framework with the ability to simulate both the mobility and network components.

Salman Durrani et al [3] propose a new equivalent speed parameter and develop an analytical model to explain the effect of vehicle mobility on the connectivity of highway segments in a VANET. They prove that the equivalent speed is different from the average vehicle speed and it decreases as the standard deviation of the vehicle speed increases. Jens Mittag et al [4] addresses the network simulators typically abstract physical layer details (coding, modulation, radio channels, receiver algorithms, etc.) while physical layer ones do not consider overall network characteristics (topology, network traffic types, and so on). In particular, network simulators view a transmitted frame as an indivisible unit, which leads to several limitations.

Hadi Arbabi et al [5] proposed highway mobility in vehicular network and they described the first implementation of a vehicular mobility model integrated with the networking functions in ns-3. Mate Boban el at [6] studied about vehicle as obstacle in vehicular network. The impact of vehicles as obstacles on vehicle-to-vehicle (V2V) communication has been largely neglected in VANET research, especially in simulations. Useful models accounting for vehicles as obstacles must satisfy a number of requirements, most notably accurate positioning, realistic mobility patterns, realistic propagation characteristics, and manageable complexity.

Evjola Spaho et al [7] present a simulation system for VANET called CAVENET (Cellular Automaton based VEhicular NETwork). In CAVENET, the mobility patterns of nodes are generated by a 1-dimensional cellular automaton. Claudia Campolo el at [8] investigated the feasibility of V2R communications, by considering the 802.11p/WAVE features and capabilities. In order to increase the number of vehicles able to make the best of a short-lived RSU coverage, the proposed a solution that exploits both the repetition of BSS advertisements during the CCH interval and the piggybacking over beacons to spread the BSSs parameters.

Valery Naumov et al [9] report on a investigation of the effectiveness of AODV and GPRS in an inner city environment and on a highway segment. This evaluation is based on traces obtained from a microscopic vehicle traffic simulation on the real road maps of Switzerland.

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David R. Choffnes Fabi ´an E. Bustamante et al [10] analyzes ad-hoc wireless network performance in a vehicular network in which nodes move according to a simplified vehicular traffic model on roads defined by real map data.

This research work indicate that the packet delivery ratio for common topology-based ad-hoc routing algorithms varies significantly between an environment using a model of vehicular movement confined to real roads and one using the random waypoint model.

## III. MULTI-CONSTAINT REALTIME VEHICULAR (MCRV) MOBILTY FRAMEWORK

Vehicular Ad-Hoc Network (VANET) communication has recently become an increasingly popular research topic in the area of wireless networking as well as the automotive industries. The goal of VANET research is to develop a vehicular communication system to enable quick and cost-efficient distribution of data for the benefit of passengers' safety and comfort. While it is crucial to test and evaluate protocol implementations in a real world environment, simulations are still commonly used as a first step in the protocol development for VANET research. Several communication networking simulation tools already exist to provide a platform to test and evaluate network protocols, such ns-3, ns-2, OPNET and Qualnet.

One of the most important parameters in simulating ad-hoc networks is the node mobility. It is important to use a realistic mobility model so that results from the simulation correctly reflect the real-world performance of a VANET. For example, a vehicle node is typically constrained to streets which are separated by building, trees or other objects. Such obstructions often increase the average distance between nodes as compared to an open-field environment. Many prior studies have shown that a realistic mobility model with sufficient level of details is critical for accurate network simulation results.

Vehicular node mobility is represented by mobility model Mobility models represent the movement of mobile users, and how their location, velocity and acceleration change over time. Such models are frequently used for simulation purposes when new communication or navigation techniques are investigated. Mobility of vehicular nodes is crucial issue in VANET. Mobility of vehicular node represented by mobility models. The widely used mobility model for vehicular adhoc network is Random waypoint mobility model. This mobility models for vehicular ad-hoc networks do not provide realistic vehicular node movement scenarios. The Random Waypoint Mobility Model includes pause times between changes in direction and/or speed. A vehicular node begins by staying in one location for a certain period of time (i.e., a pause time). In Random waypoint mobility model, Once this time expires, vehicular node the chooses a random destination and a speed that is uniformly distributed between [minspeed, maxspeed].

The vehicular node then travels toward the newly chosen destination at the selected speed. Upon arrival, the vehicular node pauses for a specified time period before starting the process again. This mobility model ignore many real time constrains such as traffic signal, speed limit and so on. The proposed solution for this problem is resolved by introducing new real-time mobility framework. Real-time mobility framework include real world constraints such as traffic signal, speed limit, number of lanes (whether interstate highway, national high way), speed will increasing/ decreasing, while intersection of street vehicular node turn left/right/go straight, vehicle over taking behavior and also it support bidirectional highway. Vertical and Horizontal Handover parameters were tabulated in Table I.

TABLE I
VERTICAL AND HORIZONTAL HANDOVERS

| Parameters | Horizontal Handover | Vertical Handover |
|---|---|---|
| Access Technology | Not Changed | Changed |
| QoS Parameters | Not Changed | May be Changed |
| IP Address | Changed | Changed |
| Network Interface | Not Changed | May be Changed |
| Network Connection | Single Connection | More than one Connection |

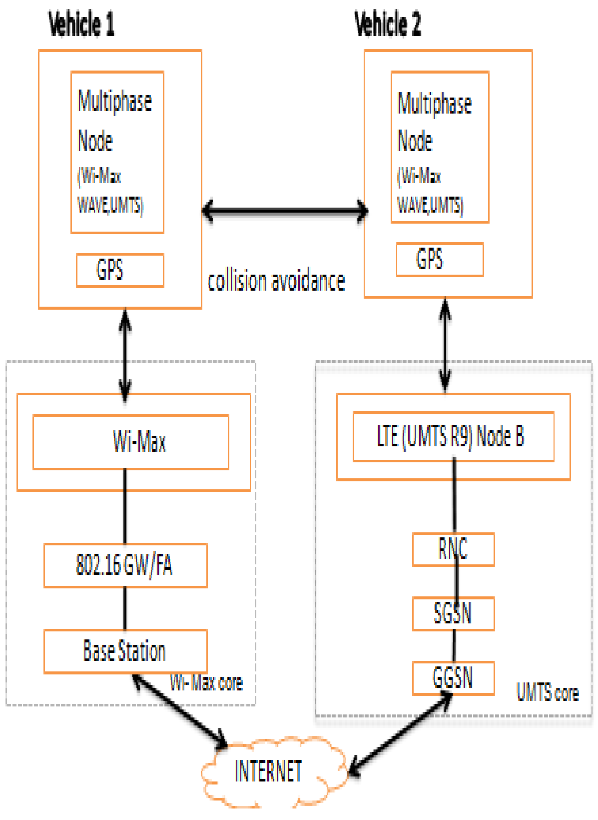


Fig. 3. MCRV Mobility Framework for VANET

The Multi-Constraint Realtime Vehicular (MCRV) mobility framework is shown in Fig.3. Each vehicle is equipped with 802.11p based DSRC unit. Vehicles communicate with neighbor vehicle for collision avoidance / warning, safety like applications using WAVE protocol. Also vehicles information communicated to Infrastructures (WiMAX or UMTS/LTE) for assigning vehicle priorities and lane-changes applications.

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The module description as follows:

- Cluster formation: This module forms small clusters within a specific area with four to five vehicles in each cluster.
- Selection of cluster head: The vehicle which has the closest proximity to all the vehicles in the cluster will be selected as the cluster head.
- Vehicle to vehicle communication: This kind of communication takes place mainly to avoid collisions between vehicles. It sends timely alerts.
- Vehicle to infrastructure communication: This kind of communication takes place when the vehicle needs to obtain any traffic information and routing information.

*A. Mobility between WAVE-WAVE and WAVE-RSU*

There has been a huge development in wireless communication technologies such as GPRS, EGPRS, WCDMA, HSPA and WLAN. Currently Mobile wireless technologies such as GPRS, EGPRS, WCDMA, and HSPA provide users high mobility but with low rates, i.e. 12kbit/s, 200kbit/s, 2Mbit/s, 3.6 Mbit/s respectively while WLAN systems offer higher bandwidth such as 11Mbit/s, 54Mbit/s and more but the mobility is low. The variant of WLAN is WAVE protocol which gives 27Mbps based on IEEE802.11p with the coverage 1Km. The RSU unit is equipped with the Infrastructure based cellular Networks (UMTS/LTE or WiMAX) which gives 75Mbs based on IEEE802.16e with the coverage of 50Km.

*B. Media Independent Handoff Framework (MIHF)*

The MIHF framework which is used to perform Vertical handover in Heterogeneous Wireless Networks like WLAN, WiMAX and UMT or/LTE. It has the following signals.

- Media Independent Event Service (MIES)
- Media Independent Information Service (MIIS)
- Media Independent Command Service (MICS)

Using IEEE 802.21 MIHF each MN can perform handover without service interruption.

## IV. VANET HANDOFF MANAGEMENT SYSTEM

In VANETs heterogeneous wireless networks, handoff can be separated into two parts: horizontal handoff (HHO) and Vertical Handoff (VHO). A horizontal handoff is made between different access points within the same link-layer technology such as when transferring a connection from one BS to another or from one AP to another. A vertical handoff is a handoff between access networks with different link-layer technologies, which will involve the transfer of a connection between a BS and an AP.

During the handoff decision phase, the mobile device determines which network it should connect to. During the handoff execution phase, connections need to be rerouted from the existing network to the new network in a seamless manner. During the VHO procedure, the handoff decision is the most important step that affects mobile host's communication. An incorrect handoff decision may degrade the QoS of traffic and even break off current communication. The factors of 3G-4G Access Technologies were tabulated in Table II.

TABLE II
3G-4G ACCESS TECHNOLOGIES

| Factors | 802.11p/ WAVE | WiMAX | LTE |
|---|---|---|---|
| Peak Data Rate | 802.11p= 6-27 Mbps | DL=70 Mbps UL=70 Mbps | DL=100 Mbps UL=50 Mbps |
| Bandwidth | 5.9 GHz | 5-6 GHz | 20 MHz |
| Multiple Access | DSRC / TDMA | OFDM / OFDMA | W-CDMA |
| Coverage | 1000 meters | 16 Km | Wider Area |
| Mobility | Low | Medium | Higher |

Handoff algorithms in heterogeneous wireless networks should support both HHO and VHO and can trigger HHO or VHO based on the network condition. What should be noted is that, because of the uncertainty of the network distribution and the randomness of mobile host's mobility, it is impossible to forecast the type of the next handoff in advance. Thus, handoff algorithms in heterogeneous wireless networks must make the appropriate handoff decision based on the network metrics in a related short time scale.

*A. Modules of Handoff management system*

The basic idea of handoff is to make use of network bandwidth and also to provide improvised QoS to real-time applications. The modules collect the link-layer and network-layer information useful for handoff management, and other modules use this information to decide on the appropriate time to initiate handoff and execute the handoff procedures.

If there are multiple network choices, and the current access network cannot satisfy the QoS requirements of the existing applications, the handoff decision module will be started. It will determine the destination network based on the staying time of the MH in the candidate networks and these networks' QoS estimation, including RSS, channel utilization, link delay/jitter, etc. Based on the output of the handoff decision algorithm, the system will choose to enter the VHO routine or the HHO routine or keep the current connection.

*B. Vertical Handoff Decision scheme*

The Handoff metrics are the values that are measured to give an indication of whether or not a handoff is needed. In the traditional handoffs, such as policy-based vertical handoff algorithms, only Received Signal Strength (RSS) and channel availability are considered, however, this RSS comparisons are not sufficient to make a vertical handoff decision, as they do not take into account the mobile user's option, which mainly consist of application options, including monetary cost, network conditions, mobile node conditions, user preferences etc.

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*Steps for Seamless Communication in V2I (OBU-RSU)*

- RSU1 (UMTS / LTE) broadcasts TB (timing beacons) to OBUs (WAVE) at Vehicle Nodes.
- OBU send coordination request to RSU1.
- RSU1 broadcasts the revised TB.
- Communication takes place between OBUs and RSU1.
- Vehicle Node (OBU) sends WAVE HO_Request to RSU1.
- RSU1 sends HO_Confirm to Distributed HO_Controller.
- HO_Controller send HO_Request to RSU2.
- RSU2 broadcasts the TB.
- OBU respond with coordination request to RSU2.
- RSU2 sends HO_Confirm to HO_Controller.
- A New TB is send to OBU and messages are communicated.

## V. MCRT VEHICULAR MOBILITY FRAMEWORK

The dual-mode mobile stations (Vehicle Nodes) which roam between wireless local area network (ie. WAVE) and WAVE. The Vehicles moving at vehicular speeds. The act of transitioning from WAVE to cellular (ie. UMTS or WiMAX) is commonly referred to as a vertical handoff (VHO).

*MCRV Mobility Framework Algorithm*

The MCRV mobility framework algorithm handles both horizontal and vertical handovers. The detailed procedures were given below:

- Step 1: Discover the available networks based on RSS
- Step 2: Calculate quality of network i,
  $Q_i = W1*B_i + W2*(1/D_i) + W3*(1/C_i) + W4*T_i$
  Where $B_i$ -> Bandwidth, $D_i$ -> Delay, $C_i$ -> Cost, $T_i$-> Throughput
- Step 3: Select the network with highest $Q_i$
- Step 4: Trigger the handover (V2V: Horizontal Handover and V2I: Vertical Handover)
- Step 5: Perform make-before-break connection

1. *V2V: Horizontal Handover*

   Each Vehicle node discovers the network for neighbor Vehicle communicating collision avoidance using WAVE to WAVE.

2. *V2I: Vertical Handover*

   - Each vehicle runs at vehicular speed in the range of 40 Kmph to 60 Kmph. If the vehicle information (Speed, position, Status-Emergency) has notified to Infrastructure or RSU.
   - And also decision like lane-changes and reporting messages has be communicated to each vehicles from Infrastructure or RSU (WiMAX or UMTS/LTE).

## VI. EXPERIMENTS AND EVALUATION

The VANETs integration of SUMO with NS3-11. The road map was generated using Merkaartor map tool.

### *A. Network Simulator-3.11 (NS-3.11)*

NS-3.11 is a discrete-event network simulator, targeted primarily for research and educational use. The NS-3.11 is free software, licensed under the GNU GPLv2 license, and is publicly available for research, development, and use. The ns-3 simulation core supports research on both IP and non-IP based networks. However, the large majority of its users focus on wireless/IP simulations which involve models for Wi-Fi, WiMAX, or LTE for layers 1 and 2 and a variety of static or dynamic routing protocols such as OLSR and AODV for IP-based applications.

### *B. SUMO*

"**S**imulation of **U**rban **MO**bility", or "SUMO" for short, is an open source, microscopic, multi-modal traffic simulation. It allows to simulate how a given traffic demand which consists of single vehicles moves through a given road network. The simulation allows addressing a large set of traffic management topics. It is purely microscopic: each vehicle is modeled explicitly, has an own route, and moves individually through the network.

### *C. Integration of NS-3.11 and SUMO*

The traffic generated in SUMO and the VANET scenarios simulated using NS-3.11 shown in fig.4.

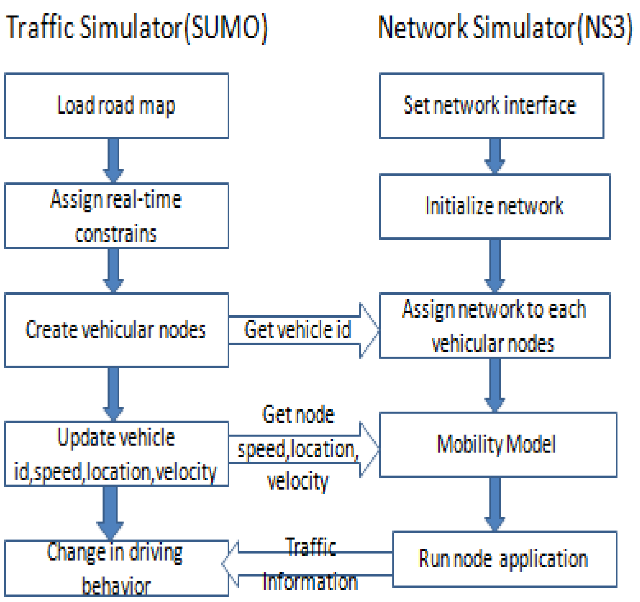


Fig.4. Integration of NS-3.11 and SUMO

### *D. Open Street Map (OSM)*

**OpenStreetMap** (**OSM**) is a collaborative project to create a free editable map of the world. The maps are created using data from portable GPS devices, aerial photography, other free sources or simply from local

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knowledge. Both rendered images and the vector dataset are available for download under a Creative Commons Attribution-ShareAlike 2.0 license. Merkaartor - Multi-platform Qt-based map editor which was shown in fig.5. Import to osm file to sumo using net convert tool in sumo package. The city road map can be generated by using Merkaartor tool and which could be used in NS-3.11 simulator.

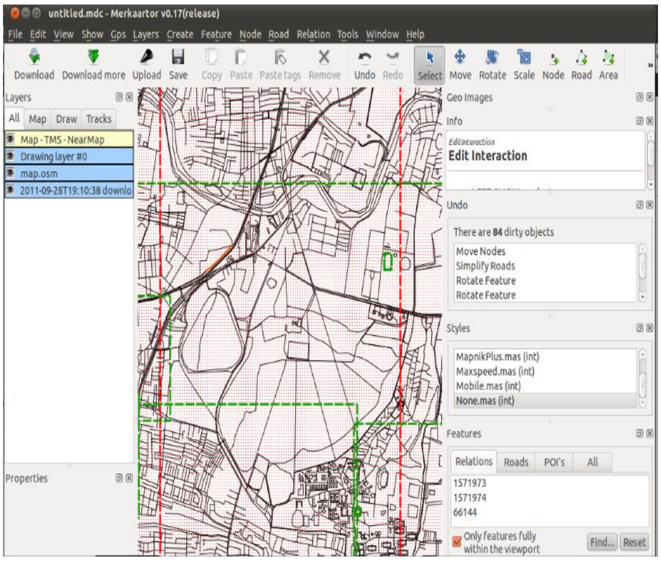


Fig.5. Merkaartor Map

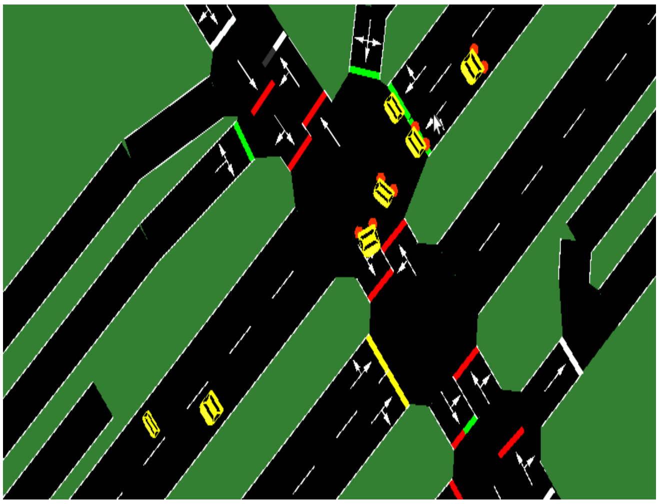

Fig. 6. SUMO with NS-3.10 Output

The Output scenarios for VANETs are shown in fig.6. The SUMO-12.3 front end tool is integrated with NS-3.11 simulator. The control signal coordinates the ongoing vehicles and also in turn gets controlled by RSUs. The OBUs are short range communication and also forms the clustering in a particular region. Then chooses the CH (Cluster Head) among OBUs for communicating to RSU with minimal overhead.

## VII. CONCLUSION AND FUTURE WORK

The vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications were done using WAVE and WiMAX/UMTS heterogeneous networks respectively. The horizontal and vertical handovers were chosen at appropriate rite decision for their communications.

In future, Enhanced systems like automatic toll-gate collection, Unmanned Vehicle driving, post-crash intelligent reporting system etc were to be made available with considering more real-time constraints like congestion-free mobility in the narrow roads or high density roads for implementing Vehicular mobility models. Safety and emergency reporting messages must be delivered on time with higher priority.

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