CHAPTER 1

INTRODUCTION

1.1 GENERAL

The Next Generation Wireless Networks (NGWN)/4G are envisioned to be a combination of diverse but complimentary access technologies, like Universal Mobile Telecommunication Systems (UMTS), Wireless Interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE), Wireless Local Area Network (WLAN), etc. Mobile devices with multiple access interfaces are reaching the market, enabling users to gain access to all these networks. These devices need to have multi-access mobility to enable users to benefit from different technologies. As multimode terminal moves across a heterogeneous network, the choice of a particular network should be cost efficient and provide good quality of service (QoS) to the end-user.

Conceptually, a typical Next Generation Wireless Networks (NGWN)/4G architecture can be viewed as many overlapping wireless access domains. This architecture is called wireless overlay network. The main goal of the NGWN is to allow subscribers to seamlessly access services anytime and anywhere, which is known as Always Best Connected (ABC).

Future generation wireless networks are expected to support heterogeneous access technologies rather than homogeneous wireless networks. The present trend towards ubiquitous network, global mobility and
network accesses are provided by a large diversity of technologies with coverage overlaps. Mobile users can thereby move freely from one network to another without having to reconnect, change settings or terminate connection at any point. Users must remain always connected while moving between networks of different access technologies. This is not easy when it comes to data sessions because of intersystem handovers, e.g., 2G→3G/4G networks.

The most important process in wireless networks is handoff or handover. In cellular telecommunications, the term handover or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another. This handoff technology is needed for seamless mobility and to get the connection without any interruption. A handoff between base stations using the same type of wireless network interface is called homogeneous handover. The heterogeneous handover uses interfaces of different wireless networks. There are two variants in each category namely “hard handover” and “soft handover”. Hard handover follows “break before make” principle for making the connection between interface and base station, whereas soft handover follows “make before break” principle for making the connection.

1.2 INTRODUCTION TO 4G NETWORKS

The cellular mobile telecommunication has crossed many generation standards such as 1G, 2G, 2.5G, 3G, 3.5G, etc, towards Fourth Generation (4G) networks. Cellular mobile communication generations are given in Table 1.1. The current wireless systems provide only limited services. Over 3G it is possible to watch streaming videoconferencing, VoIP, web-browsing and multimedia services. 3G technology supports both packet and circuit switched data transmission, and a single set of standards are used worldwide providing compatibility over a variety of mobile devices. UMTS delivers services at moderate data rates in indoor, small and highly populated
areas. The next level 3G networks like HSPA, HSUPA, EDGE, etc, have still not gained maturity in the market. Despite of all the supported features of 3G, the potential access to internet from any location at any time is trivial for many users even today. Also 3G technologies lack standard multi-interfaces for global roaming across different networks. These pitfalls necessitated the designing and defining of a new standard called the Fourth Generation (4G) wireless networks.

Table 1.1 Cellular Mobile Communication Generations

<table>
<thead>
<tr>
<th>Technology</th>
<th>1G</th>
<th>2G</th>
<th>2.5G</th>
<th>3G</th>
<th>4G</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example</strong></td>
<td>AMPS</td>
<td>GSM</td>
<td>GPRS</td>
<td>UMTS, HSDPA</td>
<td>802.16m / LTE-A</td>
</tr>
<tr>
<td><strong>Type of Service</strong></td>
<td>Voice only</td>
<td>Voice and data</td>
<td>Data (packed switched)</td>
<td>Videoconferencing, VoIP, Multimedia etc</td>
<td>Always Best Connected</td>
</tr>
<tr>
<td><strong>Data rate</strong></td>
<td>9.6kbps</td>
<td>14.4 kbps</td>
<td>384 kbps</td>
<td>2 Mbps</td>
<td>200 Mbps</td>
</tr>
</tbody>
</table>

4G wireless networks will be heterogeneous networks supporting multiple radio access technologies of wireless network such Wireless LAN (WLAN) (e.g., 802.11b, 802.11g, 802.11p, etc.), HiperLAN, Wireless Metropolitan Area Networks (WMAN) (802.16d, 802.16e, 802.16m, etc).
area. Hence 4G standards ideally support data rates of 1Gbps (static) and 100-
300 Mbps (mobility).

1.2.1 Features of 4G Networks

Fourth Generation (4G) or next generation wireless networks will be a heterogeneous network consisting of different access networks which may overlap with one another (i.e., wireless overlay networks). In this environment, a mobile node will typically be equipped with multiple interfaces (or multi-face node). It will provide any service, anytime, anywhere with seamless connectivity by ensuring service continuity at low cost (Kim et al 2003).

- **Anytime, anywhere availability** – In 4G systems, mobile networks must be available to the user, anytime, anywhere. To accomplish this objective, services and technologies must be standardized on a worldwide scale.

- **Pure Data Network** - The current 3G mobile network handles both voice and data separately. One of the most significant changes to the 4G network is that, it is a data network, transferring Internet Protocol (IP) data packets. A completely data based network provides larger bandwidth. High Speed 4G systems should offer speeds in the hundreds of Mbps.
of a 10-Mbyte file to one second on 4G, from 200 seconds on 3G, enabling high-definition video to stream in phones and create a virtual reality experience on high-resolution handset screens.

- **Fast/Seamless Handover across multiple Networks** – Though current 3G networks do have the ability to transfer data, when a user moves from a 3G coverage area to another, the data transfer may be halted or stopped due to compatibility issues. The improved 4G network standards will eliminate this, enabling a smooth handoff from one coverage area to another without interruption to any ongoing data transfers. This results in smooth streaming of data for the user.

- **Next-Generation Multimedia support** – The goal of 4G is to replace the current proliferation of core mobile networks with a single worldwide core network standard, based on IP for control, video, packet data, and voice. This will provide uniform video, voice, and data services to the mobile host, based entirely on IP. The objective is to offer seamless multimedia services to users accessing all IP based infrastructure through heterogeneous access technologies. The goal is to merge data/voice/multimedia network.

- **Devices and Applications** - 4G network devices can take advantage of the higher bandwidth to robustly deliver data heavy applications at high data rates. One of the most anticipated uses of the 4G network is to be able to deliver high definition, digital television to a handheld device. Other anticipated applications include portable online gaming, improved GPS and telemedicine.
1.2.2 Heterogeneous Networks

4G wireless networks must allow the coexistence of different access technologies and provide the differentiated services to end users. However, the provisioning of differentiated services over heterogeneous networks poses several challenges. Each heterogeneous networks namely IEEE 802.11g (WiFi), IEEE 802.16d/e (WiMAX) and 3GPP2 LTE have their own advantages in terms of characteristic such as coverage, data rate and broadband. The network system architecture of WiFi, WiMAX and LTE are as shown in Figure 1.1 Figure 1.2 and Figure 1.3 respectively.

1.2.2.1 IEEE 802.11 Wi-Fi (Wireless Fidelity)

![Figure 1.1 IEEE 802.11 WiFi](image)

Wi-Fi (Wireless Fidelity) has standardized from IEEE 802.11 a, b, and g. Wi-Fi is the first widely deployed fixed broadband wireless networks with a maximum data rate of 54Mbps. The Wi-Fi architecture consists of a base station to which wireless hosts connect in order to access the network resources. As long as the users remain within 300 feet of the fixed wireless access point, they can maintain broadband wireless connectivity. It has short range of coverage and hence suitable only for indoor services.
1.2.2.2 IEEE 802.16 WiMAX (Worldwide Interoperability for Microwave Access)

WiMAX eliminates the constraints of Wi-Fi. Unlike Wi-Fi, WiMAX is intended to work outdoors over long distances. It is a more complex technology and has to handle critical issues such as QoS guarantee, carrier-class reliability, NLOS, etc. WiMAX is not intended to replace Wi-Fi. Instead, the two technologies complement each other. WiMAX covers 50 km radius with speed up to 70 Mbps. The objectives of WiMAX are superior performance, flexibility, advanced IP-Based architecture, attractive economics. WiMAX can provide at-home or mobile Internet access across whole cities or countries.

Figure 1.2 IEEE 802.16 WiMAX

1.2.2.3 3GPP Release-8 LTE (Long Term Evolution)

LTE (Long Term Evolution) is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM / EDGE and UMTS / HSPA network technologies, that
increases the capacity and speed by using new modulation techniques. The standard is developed by the 3GPP (3rd Generation Partnership Project). The goal of LTE is to increase the capacity and speed of wireless data networks. The data type is all packet switched data for both voice and data. The applications of LTE are voice, SMS, instant messaging, internet browsing, video streaming, social networking, online navigation, email, health surveillance, vehicle tracking, positioning and tracking.

![Figure 1.3 Long Term Evolution (LTE)](image)

Figure 1.4 shows the LTE network architecture in detail. It supports the data rate of 300 Mbps (DL)/75 Mbps (UL) with less than 5ms latency. Mobility Management Entity (MME) has functionalities such as identification, authentication, attach and detach procedures. Home Subscriber System (HSS) maintains the subscribers fixed information. Serving Gateway handles policy and charging rule functions. PDN Gateway bridges the user (UE) and different external IP networks. eNodeB - Evolved NodeB is similar to nodeB in UMTS network functioning as base station. Evolved Packet Core or System (EPC)/EPC handles the network side responsibilities.
1.3 NEED FOR HANDOVER

The Future generation wireless networks are expected to support heterogeneous access technologies such as WiFi, WiMAX, LTE, etc., than homogeneous wireless networks. The present trend towards ubiquity of network, global mobility and network access is provided by a large diversity of technologies with coverage overlaps. The new mobile devices will provide the user with great flexibility for network access and connectivity but also creates a challenging problem of mobility support among different networks. Users will expect their connections to be without any disruption when they move from one network to another.

In heterogeneous wireless network environment, the always best connected (ABC) service requires dynamic selection of the best network and access technologies when multiple options are available simultaneously. An important process in wireless networks is referred to as handoff or handover. In cellular telecommunications, the term handover or handoff refers to the process of transferring an ongoing call or data session from one channel
connected to the core network to another. Handover refers to the automatic switching from one technology to another in order to maintain communication. This handoff technology is needed for seamless mobility and uninterrupted connectivity.

1.3.1 Types of Handover

Figure 1.5 shows the different basic handover scenarios. The handover takes place under two different situations, when user moves from one location to location i.e. mobility and the other situation is heavy network load condition.

![Figure 1.5 Horizontal and Vertical Handover Scenarios](image)

The process of transferring an ongoing call or data session from one base station to another base station without loss or disruption of service is known as handoff or handover. The basic two different types of handovers are horizontal and vertical handovers are explained as follows:

- **Horizontal handover** - the users use the same network access technology and the mobility is performed on the same layers. In horizontal handover the on-going calls are to be maintained
in spite the change of IP address because of the mobile node movement.

- **Vertical handover** - the user can move across different network access technologies. The change is not only in the IP address but also in the network interface, QoS characteristics etc.

### 1.3.2 Multi-Access Seamless Mobility

Multi-access seamless mobility solution enables mobile operators to tie their networks, such as wireless LANs and GPRS, together (Bhebhe 2008). Mobile users can therefore move freely from one network to another without having to reconnect, change settings or terminate connection at any point. Users need to stay connected while moving across networks of different access technologies. This is not easy when it comes to data sessions because during intersystem handovers, eg., 2G→3G the data session is terminated and resumed after the mobile station has camped on the target cell.

Future generation networks are envisioned to be a combination of diverse but complimentary access technologies, like General Packet Radio Service (GPRS), Wideband Code Division Multiple Access (WCDMA), Long Term Evolution (LTE), Wireless Local Area Network (WLAN), etc. Mobile devices with multiple access interfaces are reaching the market, enabling users to gain access to all of these networks. These devices are setting a requirement for multi-access mobility to enable users to benefit from different technologies (Bhebhe 2008). As multimode terminal moves across a heterogeneous network, the choice of a particular network should be cost efficient and provide good quality of end-user experience (QoE).
Conceptually, a typical NGWN architecture can be viewed as many overlapping wireless access domains and is called a wireless overlay network. The main goal of NGWN is to allow subscribers to profit services anytime and anywhere, which is known as always best connected. Hence, current trends in communication network evolution are directed towards all-IP principle to hide heterogeneities and achieve convergence of various networks (Makaya & Pierre 2008).

The integration of the heterogeneous technologies mainly 3G and IEEE 802.x networks by combining the advantages of each namely high coverage of 3G and the high bandwidth of IEEE 802.x networks. Thus building what is named as 4G networks. In this integrated network a new concept is introduced aka ABC (Always Best Connected) where many issues have to be addressed mainly mobility management, QoS, security, integration level, and business model. The thesis addresses the mobility management issue and hence proposes the seamless handover business model for 4G networks.

1.3.3 Handover Management

In 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 involves the transfer of a connection between a BS and an AP. The comparison between vertical and horizontal schemes is shown in Table 1.2.
Table 1.2 Vertical Vs Horizontal Handovers

<table>
<thead>
<tr>
<th></th>
<th>Vertical Handover</th>
<th>Horizontal Handover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Technology</td>
<td>Changed</td>
<td>Not changed</td>
</tr>
<tr>
<td>QoS Parameters</td>
<td>May be changed</td>
<td>Not changed</td>
</tr>
<tr>
<td>IP Address</td>
<td>Changed</td>
<td>Changed</td>
</tr>
<tr>
<td>Network Interface</td>
<td>May be changed</td>
<td>Not changed</td>
</tr>
<tr>
<td>Network connection</td>
<td>More than one connections</td>
<td>Single connection</td>
</tr>
</tbody>
</table>

During the handoff decision phase, the mobile device determines the network to which it should connect. During the handoff execution phase, connections are re-routed 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.

Figure 1.6 Handover Management Systems
The handoff or handover management system modules are shown in Figure 1.6. The basic idea of handoff is to effectively use the network bandwidth and provide improvised QoS to real-time applications. Some of these 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. This approach is called cross-layered handover.

Figure 1.7 Basic Horizontal and Vertical Handoffs

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 network and QoS estimation which including RSS, channel utilization, link delay, jitter, etc. Based on the output of the handoff decision algorithm, the system will choose either the VHO routine or the HHO routine to hold the current connection.
The basic WiMAX to WiMAX or horizontal handover (HHO) and WiMAX to UMTS or vertical handover (VHO) scenarios are shown in Figure 1.7. 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, RSS comparison alone is not sufficient to make a vertical handoff decision. The mobile user's option which mainly consists of application options, monetary cost, network conditions, mobile node conditions, user preferences, etc must also be considered.

1.4 NEED FOR REAL-TIME MOBILITY MODELS IN VANETS

Vehicular Ad-Hoc Networks (VANETs) 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. The widely used mobility model for vehicular ad hoc network is Random waypoint mobility model. This mobility model for vehicular ad-hoc networks does 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 chooses a random destination and a speed that is uniformly distributed between \([\text{minspeed}, \text{maxspeed}]\). The vehicular node then travels toward the newly chosen destination at the selected speed.

![Figure 1.8 VANETs Scenario](image)
Figure 1.8 shows the VANETs scenario. Multi-face node has I1 and I2 which indicate the IEEE 802.11p (WAVE) and the WiMAX network interfaces respectively. BS indicates WiMAX base station as tower on the road-side unit. Vehicular networks consists of WiMAX / or LTE base station as Road-Side Unit (RSU or infrastructure) and IEEE 802.11p (WAVE) as On-board Unit (OU or vehicle). The vehicle-to-infrastructure (V2I) and vehicle-to-vehicle communication (V2V) formulates the heterogeneous network environment. Hence the heterogeneous handover has great impact in providing effective and efficient communication towards building intelligent transportation systems. Hence building the real-time mobility model for VANETs is highly challenging.

1.4.1 Vehicular Networks

In vehicular networks, VANETS are the technology that uses moving vehicles as nodes in a network to create mobile network. It turns every participating car into a node or router, allowing cars approximately 100 to 300 metres in range to connect and in turn, create a network with wide range.

1.4.2 Safe Distance

Every vehicle is equipped with activated electronic emergency braking lights (EEBL) or intelligent driver model (IDM) component which follows a certain distance called as Safe Distance. It varies with the speed of the vehicle. It indicates the distance within which no other vehicle must be present in order to avoid crash.

1.4.3 Deceleration

The rate at which the speed of the vehicle decreases, here the
deceleration component is calculated using the speed of the vehicle, speed of
the vehicle which is behind the decelerating vehicle, the distance between
them and the safe distance of the decelerating vehicle.

1.5 HANDOVER AND MOBILITY MANAGEMENT
CHALLENGES

4G wireless and mobile communication networks have the ability
to integrate heterogeneous wireless access technologies by combining their
mutual advantages and thus offering a variety of services to end users. This
maximizes the satisfaction of end users on the one hand and the network and
service providers’ profit on the other hand. However, this seamless integration
is not possible without challenges.

The crucial challenges that necessitated 4G heterogeneous wireless
networks are as follows:

- **Lack of Scalability** – Roaming is available between a Limited
  set of Networks and Operators.

- **Lack of Standard Handover Interfaces** – No standard
  interoperability between networks and different vendor
  equipments.

- **Limited QoS guarantees during Handover** – disruption to
  user traffic, Significant latency, high signaling message
  overhead, significant resources & route setup delay, High
  handover failures & Packet loss-rate.

- **No Security** – hard to maintain the same level of security
  when roaming across multiple access networks.
- **Non-existence of Real-time Mobility Model** – Mobility model has not considered more real-time constraints like congestion-free mobility in the narrow roads or high density roads for implementing vehicular communication. Safety and emergency reporting messages must be delivered on time with higher priority.

### 1.6 RESEARCH OBJECTIVES AND OPPORTUNITIES

In order to resolve the challenges discussed in the previous section 1.5, the following objectives have been proposed.

- **Vertical Handover Decision framework** provides seamless connectivity between access networks with different link-layer technologies, which will involve the transfer of a connection between 3GPP / 3GPP2 networks like UMTS, WiMAX, LTE etc and Non-3GPP networks like WLAN. Also the multi-interface per-application based vertical handover system is to be designed using IEEE 802.21 media independent handover function (MIHF). Centralized handover decision model is suggested and has to be implemented. Also the congestion and load factor of the existing load have to be considered while performing the seamless handover decision.

- **Adaptive Bandwidth Allocation (ABA) and Call Admission Control (CAC)** module controls the optimal utilization of bandwidth for the existing users which translates into more revenue for the service provider. It also gives priority to admit the handoff calls than new calls which in turn reduces the handoff blocking probability. Also care must be taken to
reduce the new call blocking probability by tuning the bandwidth allocation effectively.

- **Multi-Player Game-Theoretic and Ranking framework** provides the optimal decision based on Bayesian equilibrium. When choosing the network, if any tie happens then go for a sub-optimal solution using ranking approach. IEEE 802.21 based network scanning; it has the great impact on obtaining the reduced handoff latency.

- **Real-Time Mobility Model framework** includes the priority of lane-changes for emergency vehicle, emergency braking, traffic rules and speed limits while intersection of streets are included in order to design a VANETs based intelligent transportation systems.

Based on the above mentioned achievable research objectives, the research opportunities are presented as follows:

Multi-access seamless mobility solution enables mobile operators to tie their networks, such as wireless LANs, GSM/GPRS, UMTS/HSPA and LTE together. Hence, mobile users can move freely from one network to another without having to reconnect, change settings or lose connection at any point. Users need to stay connected while moving and roaming between networks of different access technologies. This approach enables the user to get service continuity by having seamless connectivity without interruption. Hence users get more Quality of Experience (QoE) which in turn gives more revenue to the service providers.

The intelligent transportation model would be constructed using VANETs. V2V and V2I communications handle the heterogeneous handover management and the real-time mobility model which includes intelligent
driver model (IDM) with emergency braking, lane-changes for priority vehicles, speed limits during intersection points, etc are incorporated with this system.

1.7 ORGANIZATION OF THE THESIS

The Thesis is organized as follows:

Chapter 2 presents the literature survey pertaining to seamless vertical handover decision and the limitations. The QoS based vertical handover decision using IEEE 802.21 MIHF has been represented to design a cross-layered solution. It also presents the survey related to cross-layered handover, Multi-attribute decision making like Analytic Hierarchy Process (AHP) and game-theoretic approaches. The existing issues and its performance metrics related to vertical handover are listed out in this chapter.

Chapter 3 describes the various vertical handover decision solutions proposed by this thesis. A simple handover management process based on mobile-terminals and network controlled inputs are described. The various seamless vertical handover decision techniques such as application-oriented, QoS-centric and congestion-aware techniques are presented for 4G networks. Also the Game-theoretic and MDP approaches are applied to vertical handover decision for vehicular networks.

Chapter 4 presents the general framework for seamless handover decision in 4G heterogeneous networks and VANETs based vehicular communications. IEEE 80.21 MIHF based centralized media independent soft handover decision (CMISHD) framework with Quality Metric Score (QMS) calculator module and its functionalities are demonstrated. Nash-equilibrium and ranking approach for media independent soft handover decision (NRMISHD) framework for vehicular networks is presented. The system
Chapter 5 presents the research contributions relating to the implementations of Vertical Handover Decision over 3GPP and non-3GPP networks. The different soft handover implementations such as per-application aware handover, QoS-centric handover decision and congestion-aware handover approaches are implemented and demonstrated. Also the adaptive bandwidth algorithm and call admission control approaches are incorporated along with handover decision model which in turn provides effective utilization of bandwidth.

Chapter 6 describes the implementations of various vertical handover decision techniques for 4G networks. The policy based handover, MIHF based QoS-centric handover, seamless media independent vertical handover (SMIVH) and congestion-aware handover approaches are implemented and demonstrated.

Chapter 7 presents the implementations of various vertical handover decision approaches for vehicular networks. The game-theory based network selection and the extended-constrained Markov Decision Process (ECMDP) are modelled and described. Intelligent Driver Model (IDM) with electronic emergency braking lights (EEBL) implementation details are provided. Also the speed limits and lane-changes are included in the proposed real-time mobility model.

Chapter 8 describes the vertical handover decision supported real-time mobility model framework for VANETs communication. It also demonstrates the Nash-equilibrium with MDP based decision for target network selection. The ranking method is used when sub-optimal level is reached in the Nash-equilibrium matrix. The implementations of this work on
network simulator-3.10 (NS-3.10) with SUMO are explained. The implementation considered the traffic map with real-time mobility model for vehicular communications.

Chapter 9 gives the conclusion of the thesis and the future research in this area.