[UCI]I804:24011-200000490985

August 2021
Master’s Degree Thesis

Comparison of vehicular communication protocols using OMNET++ and NS-2

Graduate School of Chosun University

Department of Electronic Engineering

Mariama Soumah

Comparison of vehicular communication protocols using OMNET++ and NS-2

OMNET++와 NS-2를 이용한 차량통신 프로토콜 비교

August 27, 2021

Graduate School of Chosun University

Department of Electronic Engineering

Mariama Soumah

Comparison of vehicular communication protocols using OMNET++ and NS-2

Advisor: Chung Ghiu Lee

This thesis is submitted to Graduate School of Chosun University in partial fulfillment of the requirements for the degree of a Master's Degree

April, 2021

Graduate School of Chosun University

Department of Electronic Engineering

Mariama Soumah

수마 마리아마의 석사학위논문을 인준함

위원장 조선대학교 교 수 황 석 승 (인)

위 원 조선대학교 교 수 강 문 수 (인)

위 원 조선대학교 교 수 이 충 규 (인)

2021년 5월

조선대학교 대학원

contents

Table of Figures

List of Tables

List of Acronyms

AODV Ad-hoc On-demand Distance Vector
DREAM Distance Routing Effect Algorithm for Mobility
DSRC Dedicated Short-Range Communication
DSR Dynamic Source Routing
DSDV Destination Sequenced Distance Vector
GPS Global Positioning System
GPSR Greedy Perimeter Stateless Routing
GUI Graphical User Interface
IDE Integrated Development Environment
IVC Inter-Vehicle Communications
LAR Location Aided Routing
LOTOCOR LOcation-based TOpology COntrol Routing
MANet Mobile Ad-hoc Network
MFR Most Forwarded within Distance
NED Network Description
NS-2 Network Simulator 2
NS-3 Network Simulator 3
OLSR Optimized Link State Routing
OMNeT++ Objective Modular Network Testbed in C++
PDR Packet Delivery Ratio
PSID Provider Service ID
RHR Right Hand Rule
SUMO Simulation of Urban Mobility
TCP Transmission Control Protocol
TORA Temporally-Ordered Routing Algorithm
TraCI Traffic Control Interface
UAV Unmanned Aerial Vehicles
UDP User Datagram Protocol
VANET Vehicular Ad-hoc Network
VEINS Vehicles in Network Simulation
V2I Vehicle to Infrastructure
V2V Vehicle to Vehicle
WAVE Wireless Access in Vehicular Environment
WSA WAVE Service Advertisement
WSM WAVE Short Message
WSMP WAVE Short Message Protocol
XML eXtensible Mark-up Language
AP Access PointBS Base Station
BSC Base Switching Center
IDE ntegrated Development Enviroment
IEEE Institiute of Electrical and Electronic Engineers
IP Internet Protocol

MAC Media Access Control
MANET Mobile Ad Hoc Network
MID Multiple Interface Declaration
MIG Mobile Inetrnet Gateway
MPR Multi Point Relaying
MS Mobile Station
MSC Mobile Switching Center
NED Network Description
PDR Packet Delivery Ratio
QoS Quality of Service
RFC Request for Commnet
RIP Routing Information Protoco
lTC Topology Control
TIB Topology Information Base
UDP User datagram Protocol
VANET Vehicular Ad-Ho Network
WLAN Wireless local area network

ABSTRACT

"Comparison of vehicular communication protocols using OMNET++and NS-2"

SOUMAH MARIAMA
Advisor : Prof. Lee, Chung Ghiu, Ph.D.
Dept. of Electronic Engineering,
Graduate School of Chosun University

The network technology which is used to form a communication network by the use of cars as mobile nodes is known as vehicular communication network. In VANET (vehicular ad-hoc network), one of the vehicular communication network, there is a significant role of routing protocols. Since the routing protocols play basic roles for communications to be possible, it is important that the performances of the various protocols are compared. Then, we are able to understand the advantages and disadvantages of a specific protocols over other ones.

In this comparison study, I perform modeling and simulation using OMNET++ and NS-2. I evaluate the performance of a set of well-known three routing protocols used in VANET, namely, AODV (ad-hoc on demand distance vector) protocol, DSR (dynamic source routing) protocol, and DSDV (destination-sequenced distance vector) protocol in terms of packet delivery ratio (PDR), throughput, and normalized routing load (NRL).

I try to find out the suitable routing protocol for a example city of high density traffic area, Casablanca. The real map of Casablanca is edited by Open Street Map (OSM), and the "Simulation of Urban Mobility (SUMO)" tool is used to create the mobility model, while the traffic model generation and the simulations are carried out using Network Simulator 2 (NS-2).

Keywords: OMNET++, NS-2, Simulation, VANET, ITS, AODV, DSR, DSDV, OSM, SUMO

요약

OMNET++와 NS-2를 이용한 차량통신 프로토콜 비교

수마 마리아마
지도교수 : 공학박사 이충규
조선대학교 대학원 전자공학과

자동차를 모바일 노드로 사용하여 통신망을 형성하는 네트워크 기술은 차량 네트워크로 알려져 있다. 차량 네트워크 기술 중 하나인 vehicular ad-hoc network (VANET)에서 라우팅 프로토콜의 매우 중요한 역할이 있다. 라우팅 프로토콜들은 통신이 수행되기 위한 역할을 수행하기 때문에, 성능 비교는 중요하며, 해당 프로토콜의 장단점을 이해할 수 있게 된다.

본 비교 연구는 VANET에서 사용되는 라우팅 프로토콜 집합들, 즉 AODV (ad-hoc on demand distance vector) 프로토콜, DSR (dynamic source routing) 프로토콜, 및 DSDV (destination-sequenced distance vector) 프로토콜의 성능을 PDR (packet delivery ratio), 처리량(throughput) 및 NRL (normalized routing load) 측면에서 평가한다.

카사블랑카와 같은 고밀도 트래픽 영역에 적합한 라우팅 프로토콜을 찾기 위해, 카사블랑카의 실제지도를 Open StreetMap (OSM)으로 편집하고 “Simulation of Urban Mobility”(SUMO) 도구를 사용하여 모빌리티 모델을 생성하고 트래픽 모델 생성 및 시뮬레이션은 NS-2를 사용하여 수행한다.

Chapter 1

1.1 Intelligent Transportation Systems (ITS)

1.1.1 What are ITS?

Intelligent transport systems can be explained as the technology that is currently applied to transport infrastructure (traffic and transit systems, road networks) to:

1 Manage traffic
2 Reduce congestion
3 Improve mobility and safety
4 Increase the efficiency of existing transport infrastructure
5 Allow users to make informed decisions
6 Integrate technologies and knowledge to create innovative services

Intelligent transport systems (ITS) apply to transport technologies of information and communication. Computers, satellites and sensors are playing an always increasingly big role in our very complex transport systems. ITS as such are instruments that can be smartly used under different conditions for different purposes. ITS can be applied in every transport modality (road, rail, air, water) and can be used by both passenger and freight transport. Examples of ITS are as follow:

- Traffic and Transit Management
- Commercial Vehicle Electronic Clearance
- Global Positioning Systems
- Weather Information System
- Real Time Traveler Information
- Traffic Signal Systems

1.1.2 Importance of Intelligent Transportation Systems

The importance of ITS relies on the communication link that it provides among the infrastructure the vehicles and the people, for reducing the accidents and get better communication among the elements of this system. This is done by communicating among other things the direction and speed of each vehicle. Additionally ITS betters the safety, convenience and productivity of the infrastructure that already exists, for example by communicating traffic jams, road reparation and most broadly speaking any unexpected situation that could cause safety or productivity issues.

With worldwide population increasing congestion is also increasing, and available funding and territory for new roads is also diminishing, this could be addressed with the implementation of ITS.

The following diagram illustrates the components of ITS:

Fig. 1-1. Components of ITS

Usually Intelligent Transportation Systems (ITS) are introduced as tools to manage urban high congestion and balanced travel demands by improving safety, operational capabilities and transportation efficiency. ITS technologies strongly improve transportation safety and mobility, reduce the impact on the

environment, and enhance productivity by integrating into the transportation infrastructure and vehicles advanced communications-based information and electronic technologies.
The ITS systems collect and process data to analyze, regulate and track vehicle movement on roads in an effective way, to enforce traffic rules for safety and security of all.

ITS applications are quite ample and variegated, some of the applications of ITS can be on cars (intelligent vehicles), and on infrastructure (intelligent infrastructure).

We can better understand how ITS works by analyzing the following image that includes various kinds of vehicles, infrastructure and environment, in the image we can notice that intelligent vehicles share information among each other.

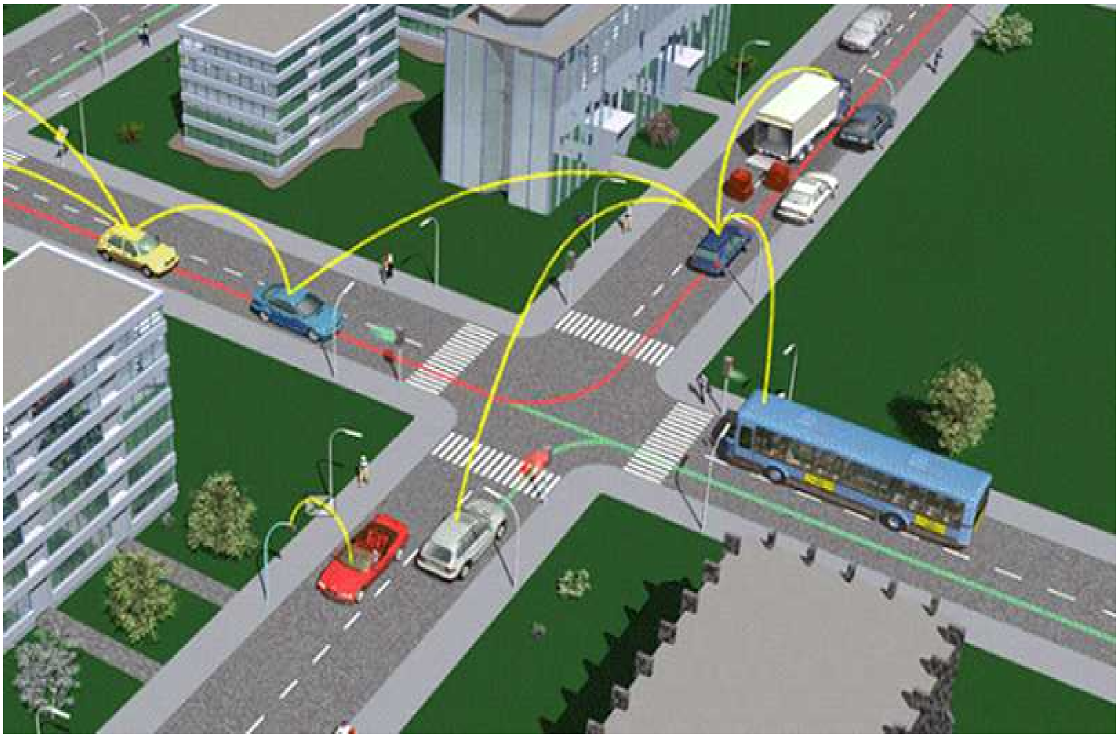

Fig. 1-2. ITS Application on cars (Intelligent vehicles) [1-1]

1.1.3 Traffic enforcement systems in ITS.

Traffic enforcement systems in ITS detect vehicles that are breaking traffic rules and regulations and are able to automatically send traffic tickets to the offenders. These systems require of specific cameras to monitor the vehicle behaviour [1-2].

The devices needed to put in place a traffic enforcement system include: Speed cameras that have radars to detect a vehicle's speed or electromagnetic loops that are buried under the lanes of the road, to detect vehicles that cross a stop line red light cameras can be used. Many cities have exclusive bus lines and also high-occupancy lanes that can be enforced with the use of special cameras as double white line crossing can also be enforced with the use of ITS and specific cameras that detect the rule violation and later on, through mail will send a ticket to the vehicle that has been identified by its licence plate [1-3].

The following figure illustrates Traffic enforcement systems in ITS:

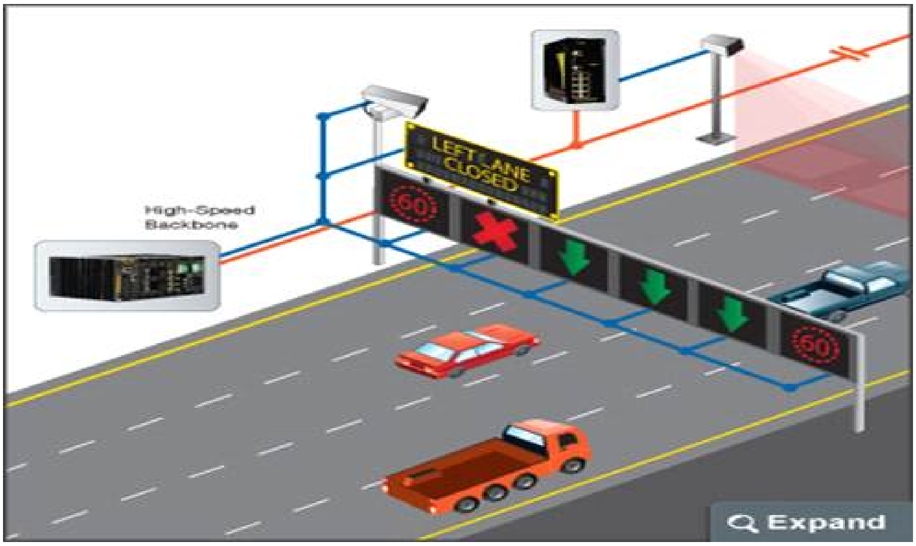

Fig. 1-3. Intelligent Transportation System [1-3]

1.2 Vehicle-To-Vehicle Communication (V2V)

1.2.1 What is V2V?

V2V communication is based on DSRC (Dedicated Short Range Communication). DSRCs are wireless communication channels very secure, which cover short to medium range, high-speed, that allow vehicles to connect among them for short periods of time and interchange information. Through DSRC, two or more vehicles can exchange data regarding their direction, distance, speed and acceleration. This can notify in real time all vehicle drivers about things like relative speed of the other vehicles, lane change and approaching vehicle trajectory [1-4].

To enable vehicular communications, when vehicles are in transit on highways and major roads, it is necessary a branch of telecommunications with information and communications technology. GPSs track and monitor locations, movements, status and behavior of the vehicles. Vehicular communication systems comprise of GPS module which communicates with "On board units" (OBU) to generate safety messages, which are later transmitted and received by RF transceiver modules. In order to have complete communication between two vehicles, we need to comply with the following two conditions.

First, an accurate and trusted safety message has to be transmitted.

Second, receiving & interpreting of the same message by another vehicle has to be confirmed [1-5].

The safety messages that are received are displayed on the display panel.

The following figure illustrates Vehicle-to-Vehicle Communication:

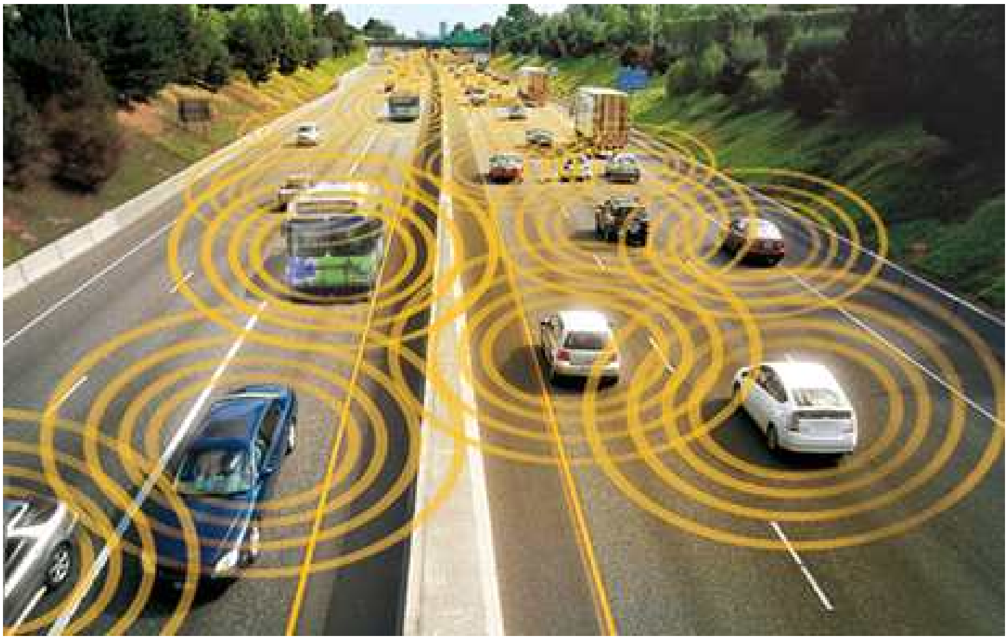

Fig. 1-4. Vehicle to Vehicle communication [1-6]

V2V communications utilizes many forms of wireless components and form a vehicular ad hoc network on the road. The "Wireless Access for Vehicular Environments" V2V standard works on the lower-level and uses 5.9 GHz band. The area in which ITS communication is usually used is 300m which is about the area thata a vehicle can cover travelling at highway speed for 10s [1-7].

1.2.2 V2V communication system

V2V, which means vehicle to vehicle communication system can be explained using the figure below, as we see in the figure 1.5, the orange vehicle receives the messages that are transmitted by the surrounding vehicles in an area of 300 meters with a 360 degrees radius, to allow the safety and to detect the threats of accidents [1-8].

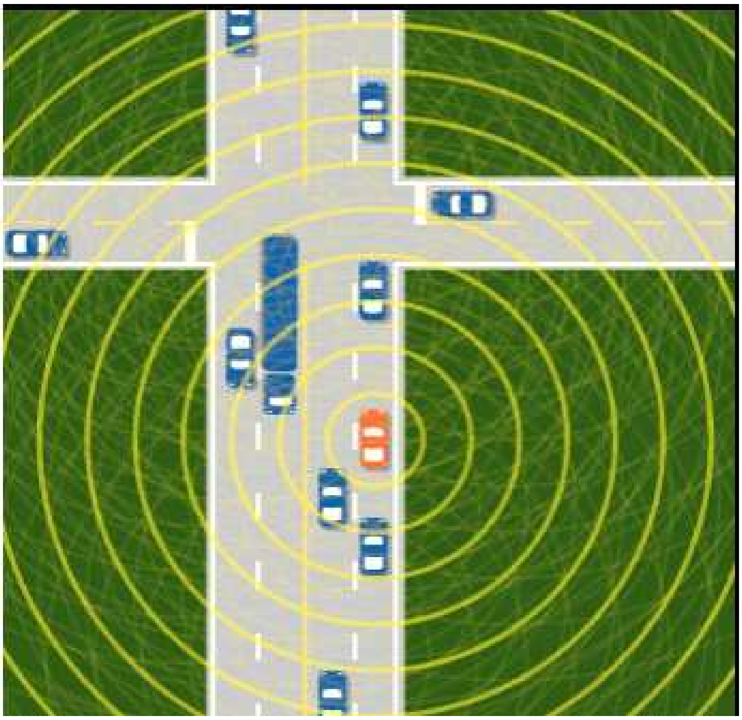

Fig. 1-5. V2V System [1-9]

In contrast to the V2V communication system, we can analyze the conventional system. It is an system that includes a camera for each corner in the back of the orange vehicle and a long range camera for the front view of the vehicle. With these cameras the orange vehicle can detect the vehicles present in front of it or in the rear blind side where the driver can not clearly see. The blue shadow in Figure 1.6 shows the area that is covered by the blind side cameras, with the sensors shown, the conventional system can only detect and reliably monitor only two of the vehicles shown, the vehicle directly ahead and the vehicle in the blind area to the left rear of the orange vehicle.

The latter is much less detailed than the V2V system using a single GPS sensor and DSRC communications that can warn of threats from any direction

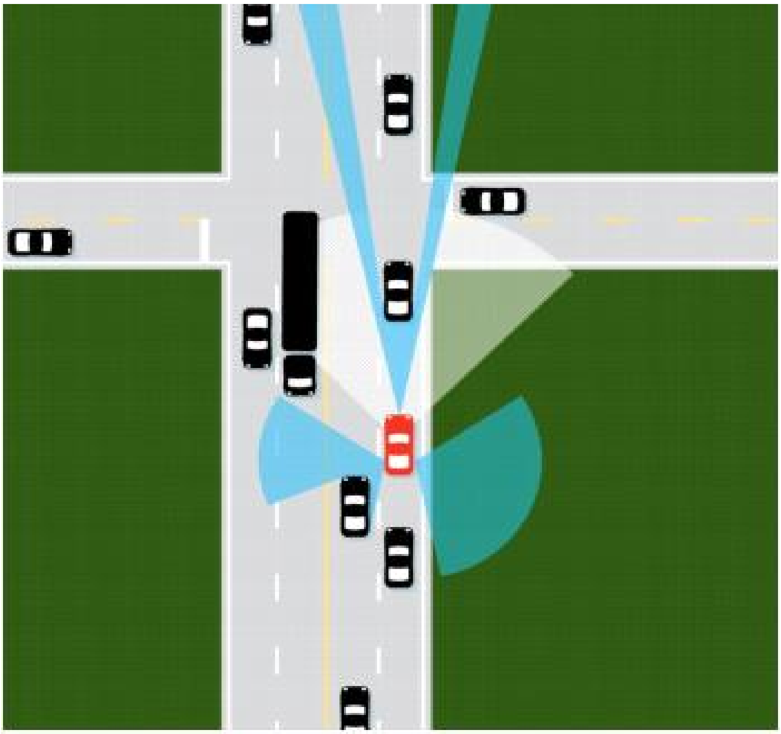
Fig. 1-6. Conventional System [1-10]

Chapter 2 Introduction to OMNET++ and NS-2

2 Description of OMNET++

2.1.1 What is OMNET++?

OMNET++ is a modular, component-based C++ simulation library and framework. The use of OMNET++ is to simulate, model and make various kinds of networks. OMNET++ provides a component structure for models. Components (modules) are programmed in C++, then combined into bigger components and models using a high level language (NED). OMNET++ works as a simulation framework it provides the infrastructure for writing simulations [2-1].

2.1.2 Model a simulation

A simulation in OMNeT ++ is like a structure of modules which are independent among each others but also closely related, these modules communicate with messages and together form an OMNeT ++ model. These modules are considered as building blocks, that can be put together; Modules can be single modules or compound modules, where compound modules are various simple modules combined together. This is illustrated in Figure 1.1 [2-2].

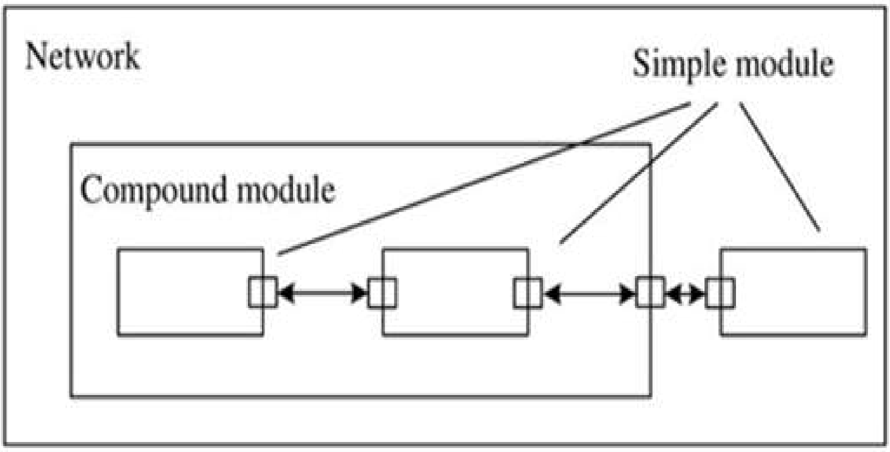

Fig. 2-1. Model Structure in OMNeT++ (from OMNET++ manual [2-3])

2.1.2 Network Description (NED) File

The NED file is a language that describes the resources that we use to create the Topology in OMNET++, it helps to simulate the Nodes, and also to connect the nodes. This is done through an graphic and text interface. The NED file is made of various modules, for example: the module for the management of connections, the module to collect the results, the module to manage the structure of the nodes.

The NED file uses graphical interfaces to manage the positioning function and to define the area in which the simulation will be run [2-4].

2.1.4 INI File

The INI file is a file that contains the values of the parameters that we utilize when we start the simulation, it contains the initial value of the modules. Through the INI file we do the configuration of the details of the scenario. Additionally through the INI file we can also make the changes required in the scenario.

2.1.5 Result Analysis

One of the features of OMNeT++ is the graphical interface it has, wich can be used to analyze the results. OMNET++ allows us to see the results in various types of graphs that can best suit the user. These graphs can also be formatted according to the preference of the user. Additionally the results can be extracted to be filtered or sorted more easily and hence help the analysis according to the needs of the user [2-5].

2.2 Example simulation OMNET++

As previously mentioned the structure of the simulation should be defined by the NED language. If the User wants to create simple modules and/or connect them this should be also done with the NED file. In the example below we can see a network, which is defined as the connection of tow or various simple modules.

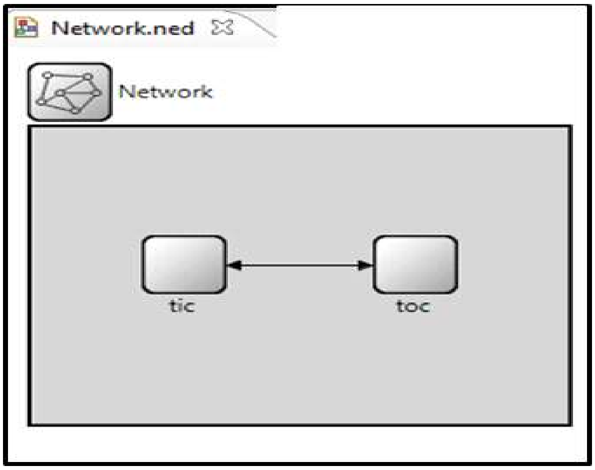

Fig. 2-2. NED File (from OMNET++ simulation)

The edition of the NED file can be done either graphically or by text, this makes it particularly easy to manage. In the following image we can see an example of the NED file text editor:

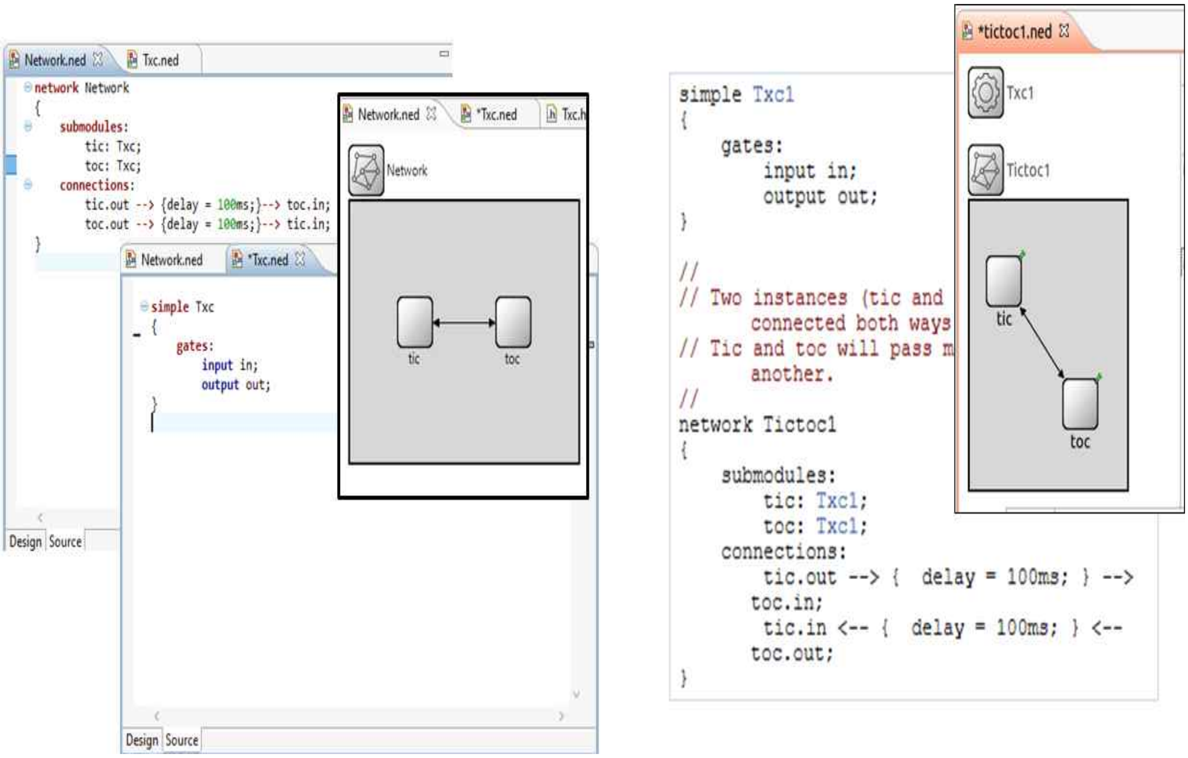

Fig. 2-3 NED File (from OMNET++ simulation)

2.2.1 Create the configuration ini file

By creating the ini file we do the configuration of the simulation environment. It utilizes the standard interface of the execution of the simulation and allows control over the execution of simulations. It is written in C++ and compiled into libraries. The figure below is a picture of the execution environment.

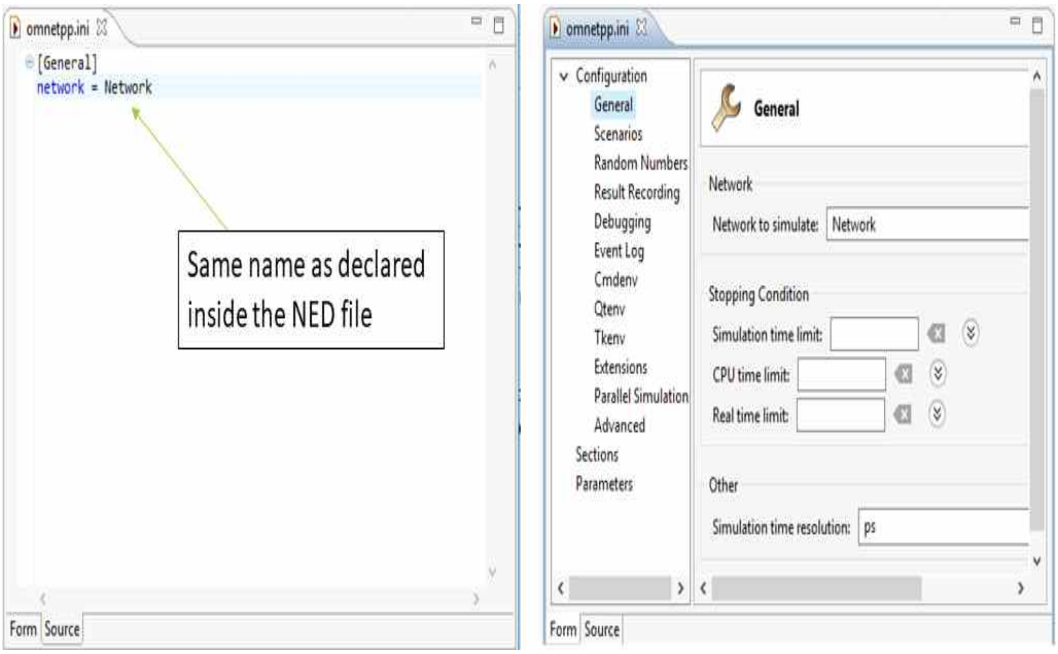

Fig. 2-4. NED File (from OMNET++ simulation)

2.2.2 Launching the simulation

When we plan to start the simulation this will happen in the OMNeT++ IDE, this makes it possible to run simulations from the integrated environment. The simulation is run in C++. The user can also run the simulation as a single simulation or run group simulations that require much more variables and parameter settings than the single simulation.

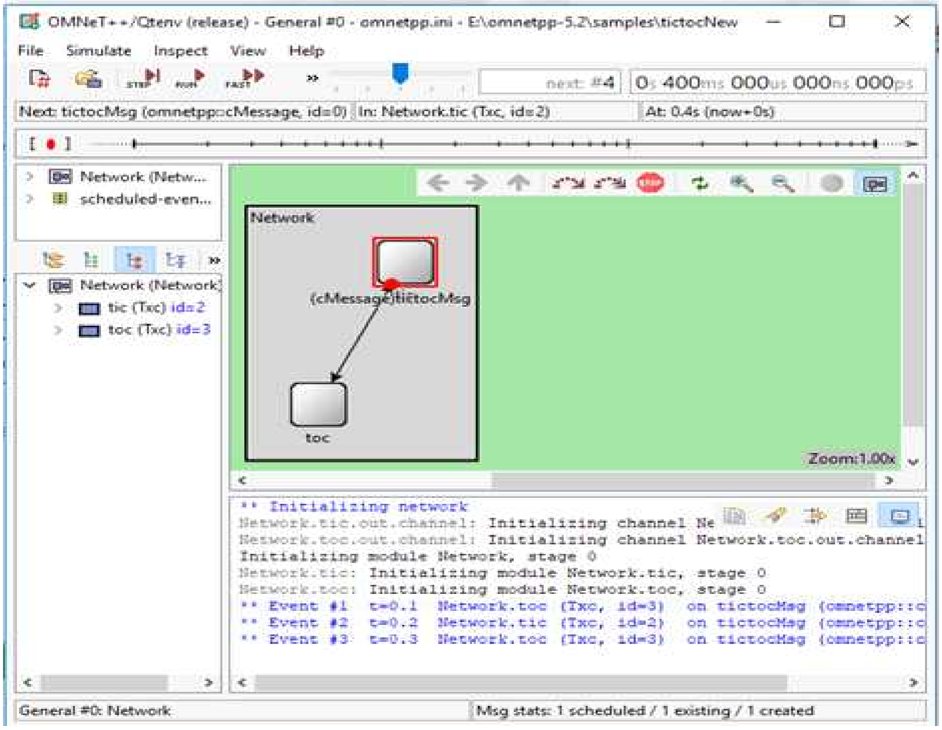

Fig 2-5. Launching the simulation program (from OMNET++ simulation)

2.2.3 Visualizing on a sequence chart

For visualizing the results of the simulation we enter the Omnet ini file and extract the results in a chart, as shown below. The image below shows the results related to the simulation parameters that were originally recorded for the simulation.

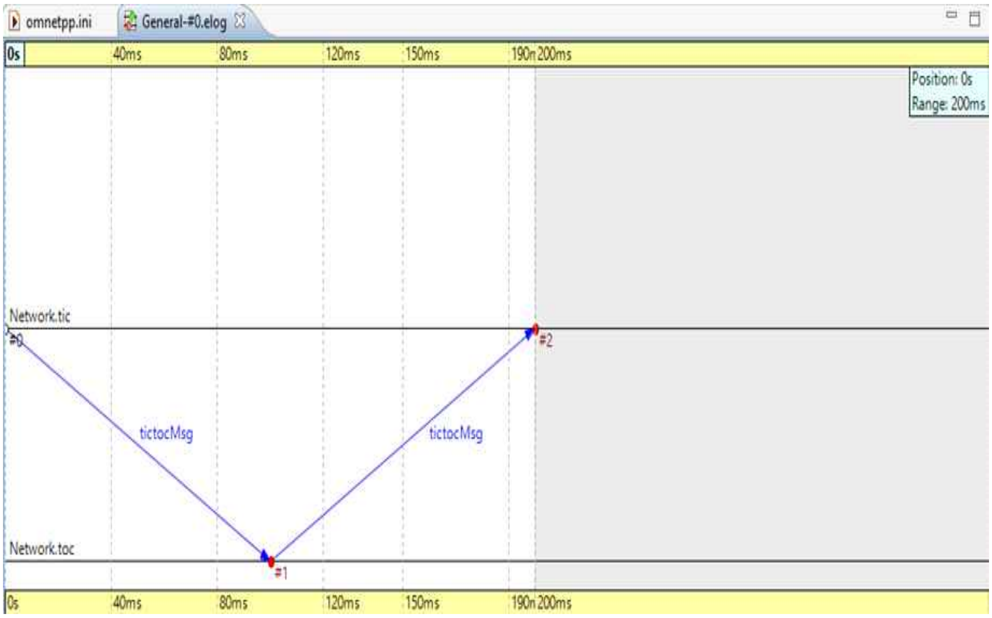

Fig. 2-6. Visualizing on a sequence chart (from OMNET++ simulation)

2.3 Description of SUMO

2.3.1 What is SUMO (Simulation of Urban MObility)?

SUMO is an open sourced fast road traffic simulator developed using standard C++ for Transportation Systems. SUMO models the mobility of the vehicles in a microscopic manner, this means that every vehicle in the simulation is modeled independently and has its own route. The other characteristics specific to the vehicle such as acceleration, deceleration and length vary between types of vehicle. Additionally some of the applications that are listed below are used in this thesis work:

• Sumo-GUI : allows to have a Graphical User Interface for the simulation.

• Netgenerate : Allows the user to generate three types of abstract networks; grid, spider and random.

• Netconvert : It allows to import the road network from different format files like maps from OpenStreetMaps and generate a road network that conforms with SUMO's format [2-6].

• Polyconvert : Enables the import of other components such as buildings. This is an important feature because it will allow to make a simulation more similar to the real world [2-7].

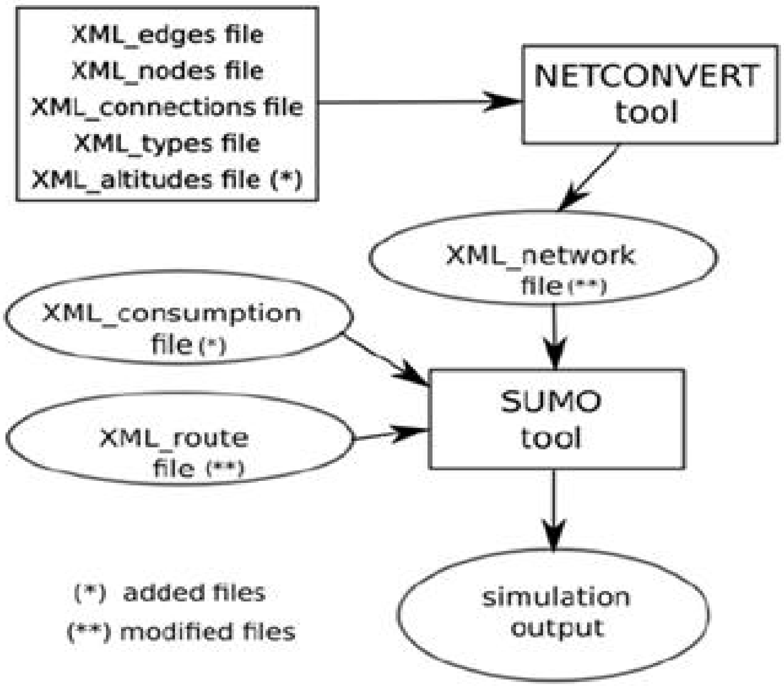

Fig. 2-7. Simulation process with SUMO [2-8]

2.4 NS-2

2.4.1 What is NS-2?

The Network Simulator Version 2 is the software simulator that we used to do the protocol simulation in this thesis, it is open source, and it is specialized in research on computer communication networks. NS2 can be used for wireless and wired networks and it is relatively simple to use [2-9].

2.4.2 Features of NS-2

Two languages make the NS2: C++ and Object-oriented Tool Command Language (OTcl). One language is used for the Internal mechanism of simulation, the C++ defines the internal mechanism of the simulation objects, and the other language, the OTcl, makes the external mechanisms of the simulation [2-10].

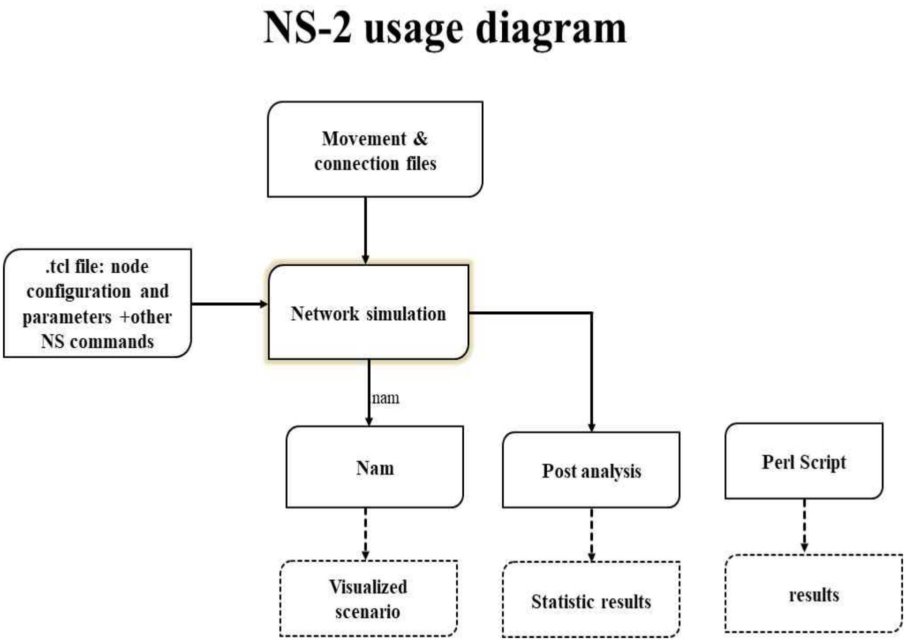

Fig. 2-8. NS-2 simulation diagram

Chapter 3 Simulation Model and Setup

3.1 Simulation Setup

3.1.1 Objective

In this thesis we plan to do a simulation and do a performance comparison of two types of routing protocols, reactive routing protocols (AODV, DSR) and proactive routing protocols (DSDV). With the use of these protocols, we do a comparative analysis to understand the quality of communication between the different nodes communicating, to reach this goal we will use the following variables: **packet delivery ratio (PDR)**, **throughput** and **normalized routing load (NRL)**. Network Simulator (NS2) will be used for the topology. The simulation results show that the network using routing protocols can provide quality status changes with low control overheads [3-1].

3.1.2 Random Waypoint Mobility Model

The Random Way Point Mobility Model changes speed and direction of the vehicles by including a pause time for the vehicles.

3.1.3 SIMULATION SCENARIOS

To define the most efficient model to perform the simulations, three different traffic protocols are taken into consideration.

• Real world, a famous intersection in the town of Casablanca is extracted using an Open Street Map (OSM) which is then imported into SUMO. The vehicle speed is defined to be the maximum speed authorized by each routing protocol.

• Motorway scenario, a multi-lane motorway for traffic is considered.

• The map, a 1000 × 1000 map is a mobility model that consists of vertical and horizontal roads for this road network structure. The vehicles in the scenario move at maximum speed.

as shown in the map network scenario in SUMO.

In Fig. 3.1 we can see the result of the model:

Fig. 3-1. Traffic mobility model file in SUMO (from OMNET++ SUMO simulation)

The commands used in SUMO for this simulation to generate the targeted model are:

Netconvert: generates roads net-works

Polyconvert: imports geometrical shapes (polygons–buildings)

Ramdomtrips.Py: is used to generate random routes

.traceExporter.py: to generate the following three files: activity.tcl, mobility.tcl and config.tcl.

3.1.4 PROPOSED METHODOLOGY

1) Design the Simulation using DSDV, DSR and AODV routing protocols.
2) Use different mobility models for each of the routing protocols.
3) Analyze the results using the following performance metrics: PDR, Throughput, Network Routing Load.
4) Define Decide in what scenario which routing protocol gives better performance.

3.1.5 PERFORMANCE METRICS

1) Packet Delivery Ratio (PDR)

This indicator is calculated by dividing the number of packets received by the number of packets initiated. It defines the packet loss rate [3-2].

2) Throughput

Throughput is calculated as the percentage of the initiated messages that are effectively received by the destination. It is measured in bits per second [3-3].

3) Normalized Routing Load

Represents the effectively received number of routing packets at the destination over the totally sent packets [3-3].

3.1.6 Parameters of Simulation

In this work we used the NS-2 network. We have simulated three routing protocols AODV, DSR and DSDV. We used 150 nodes and the layout topology for the nodes is a grid topology, ie 1000m × 1000m. The simulation time is 200s.

Table 1. Parameters of simulation

Parameter	Value
Network simulator	NS-2, 2.25.3 version
Mobility simulator	SUMOv.0.26.0
Map model	OSM(city Casablanca)
Routing protocol	AODV, DSR and DSDV
Type of traffic/routing agent	CBR/UDP
Rate	8k
Number of vehicles	25,50,100,150
network size	1000x1000
Mobility model	Random trip model (RTM)
Propagation model	Two ray ground
Simulation time	200ms
Channel type	Wireless channel
Antenna type	Omni antenna
Mac protocol	IEEE 802.11

3.1.7 Simulation of Traffic Generation Model

In this protocol comparison analysis, we used the NS2 simulator which is open sourced. For creating CBR traffic connections between wireless nodes, we used script ‘cbr-gen.tcl’. In Fig. 4.6 we can see the NAM file that was generated.

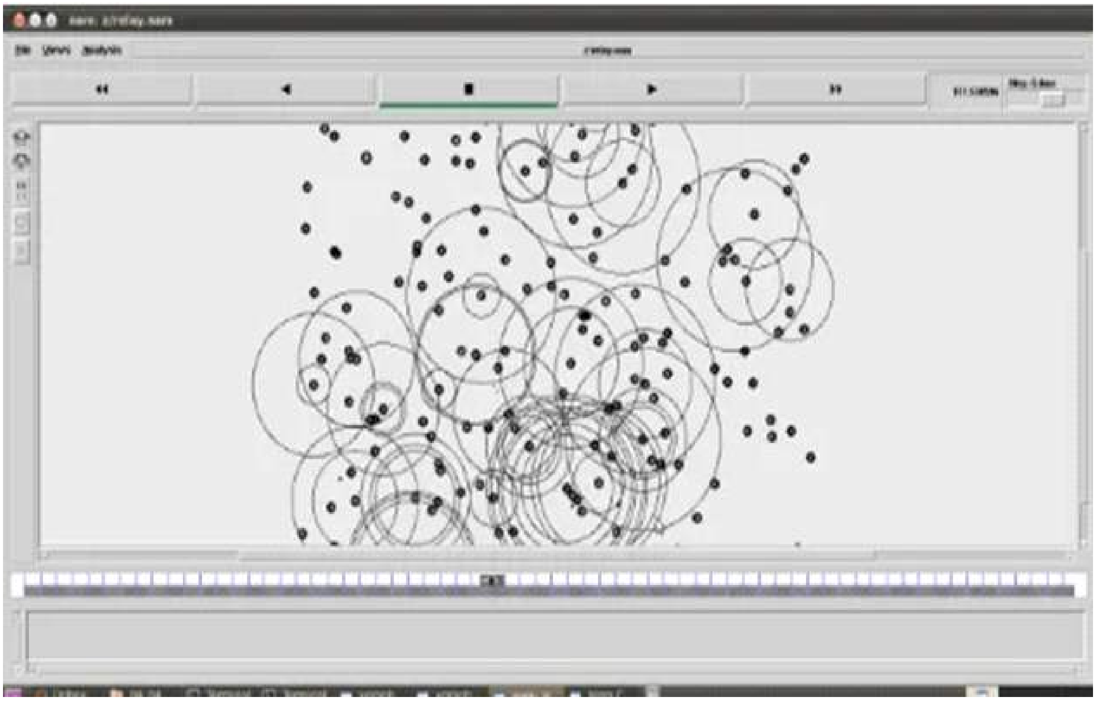

Fig. 3-2. NAM file General Simulation AODV

Chapter 4 Protocol simulation

4.1 Protocols and simulation

4.1.1 What are Routing Protocols?

Routing protocols define how routers communicate among each other to share information that allows them to select routes between nodes on a computer network. Routers direct traffic on the Internet; data packets go to their destination thorough the internet. Routing Algorithms determine the routes of the packets. Internet has high availability and fault tolerance because it allows to modify connections and components and route data around obstructions.

Among the ad hoc routing protocols we can find proactive and reactive protocols:

Proactive routing protocols keep routing information consistent and up-to-date with periodic routing exchanges between neighboring nodes. DSDV is a proactive routing protocol.

Reactive protocols do not require to keep the routing information updated for improving the use of resources. Nodes start exchanging information once a reply is received. AODV and DSR are reactive routing protocols.

In reactive routing protocols, analysis is done in two main stages:

- ✓ Discovery of extinguishing
- ✓ Route maintenance

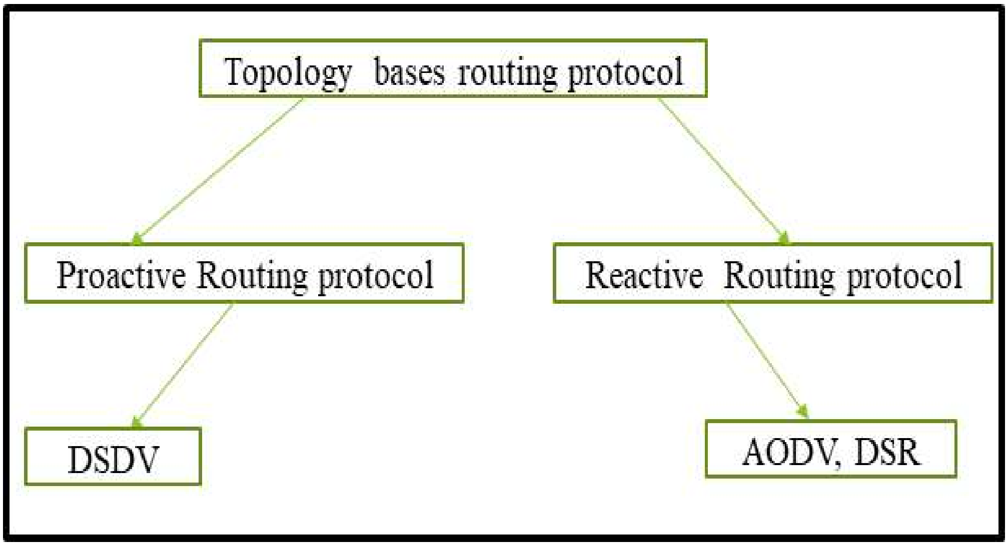

Fig. 4-1. Classification of routing protocols based on topology

4.1.2 AODV Protocol

AODV uses the destination sequence number. Mobile nodes respond to any change in network topology and link failures on time. AODV uses various types of messages to find the route from source to destination. AODV does two operations: route maintenance and route discovery. [4-1]

4.1.3 Route discovery

In AODV routing, whenever a source has any data to transmit to a new destination, it sends an RREQ message for that specific destination. The node of a neighbor receiving the message verifies, with the ROUTE-ID message if it previously received the same request before. If it is not the intended destination and has no current route to the destination, it resends the RREQ and at the same time a return route to the source is created.

4.1.4 Route maintenance

After the exit has been established, a route maintenance protocol provides feedback on the route links and allows route modification, maintenance of the established, discovered route is necessary for two main advantages: the network and to reduce the excessive overhead required for new discoveries [4-2].

4.1.5 Advantages

1. Generation of routes on request or on demand.
2. Sequence number of destinations helps to search the recent destination.
3. Low delay in connection start.
4. Route maintenance is supported by the HELLO message.

4.1.6 Disadvantages

1. In-between nodes causes inconsistent route due to inactiveness source sequence number.
2. Route reply packets response through single route request packet generates high control overhead.

4.1.7 Feature

1. On demand generation of routes with little delay.
2. Meaningfully recovering of link add/remove in operating routes.
3. Independent from loop with the help of sequence number.
4. Tracing appropriateness of information with use of sequence number.
5. Storing only tracing of next hop information rather than whole route information.

4.2 AODV Simulation

The NED files represent a node that has received messages and show the nodes are within the other range of transmission.

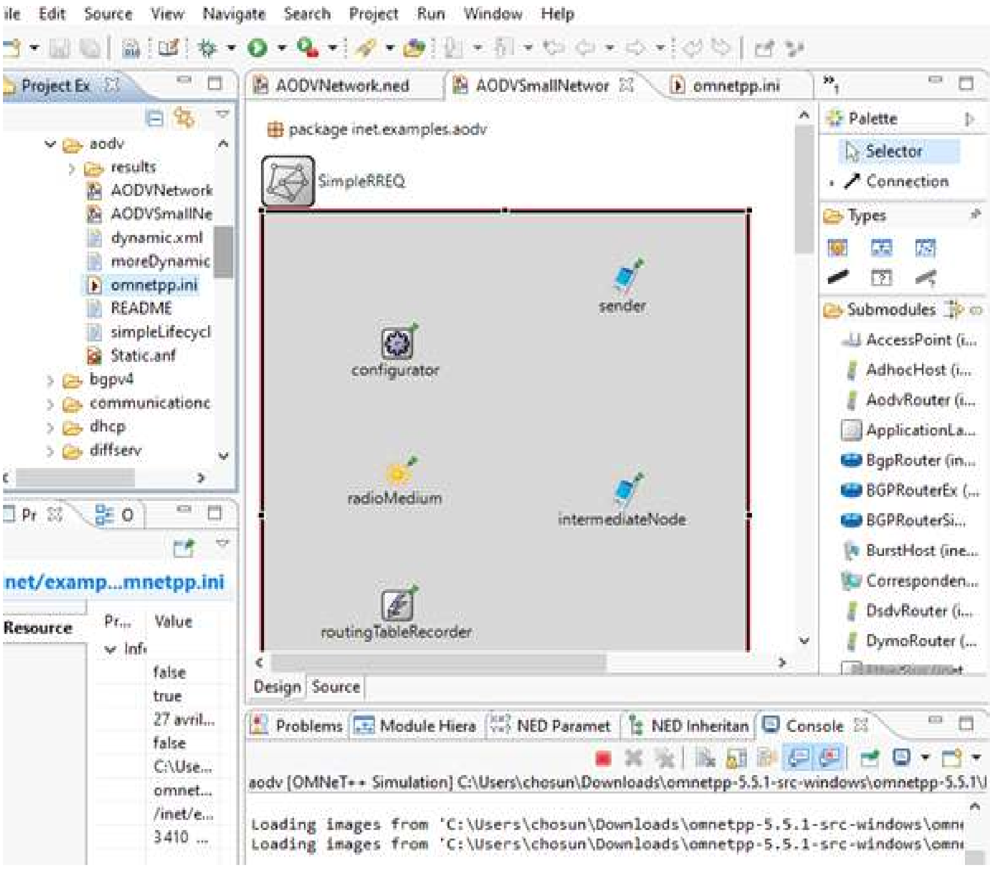

Fig. 4-2. AODV NED language Description

Fig. 4.2 is illustrations of the progression of the network simulation using the Tcl / knev graphical environment.

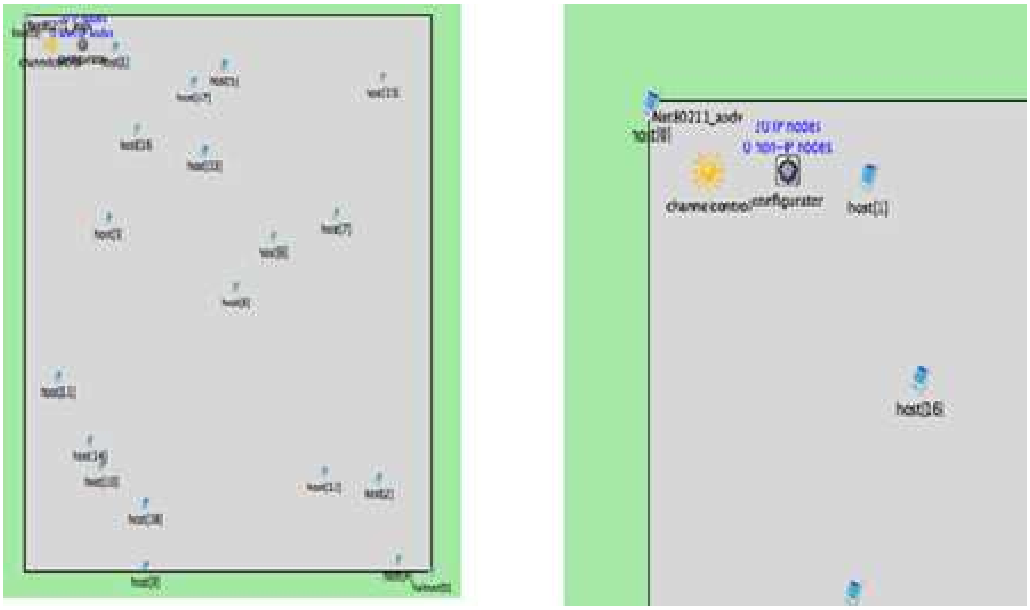

Fig. 4-3. AODV Screnshot

Figure 4.4 shows Wireless Hosts contains routing, mobility, and battery components. This is a typical mobile node that can participate in ad-hoc routing.

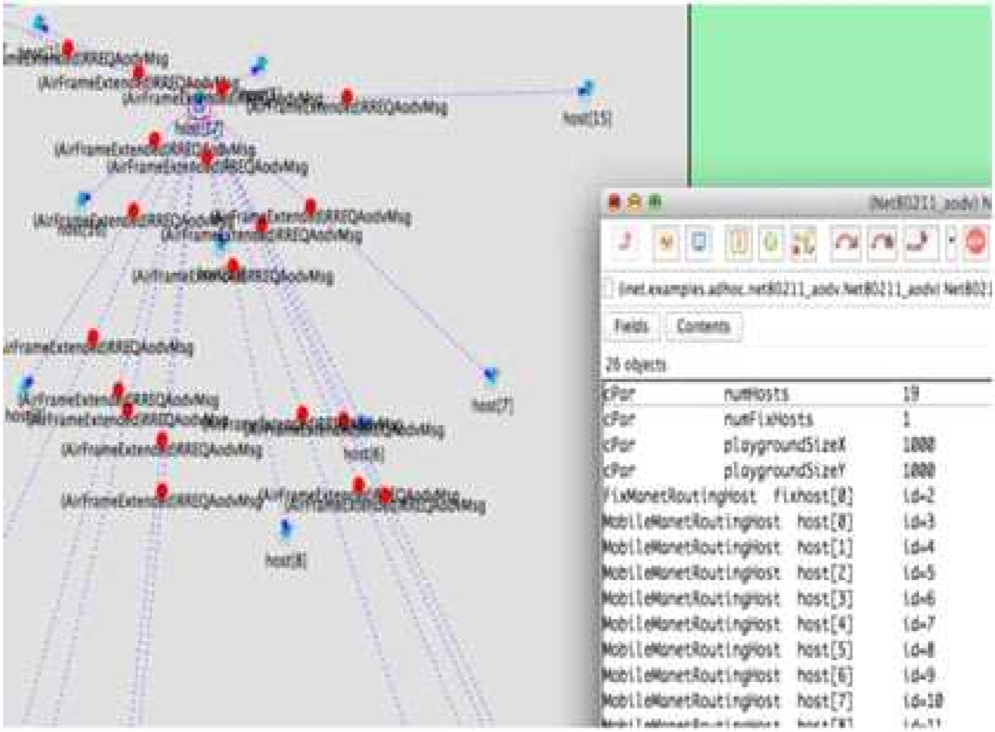

Fig. 4-4. The network activity shows the AODV overhead

Fig. 4.5 shows the sub modules in ad hoc networks, Hosts are clearly organized as the layers of TCP/IP protocol and some sub modules are compound modules. The components on the left side of the image facilitate communication between sub modules as well as communication with the other modules.

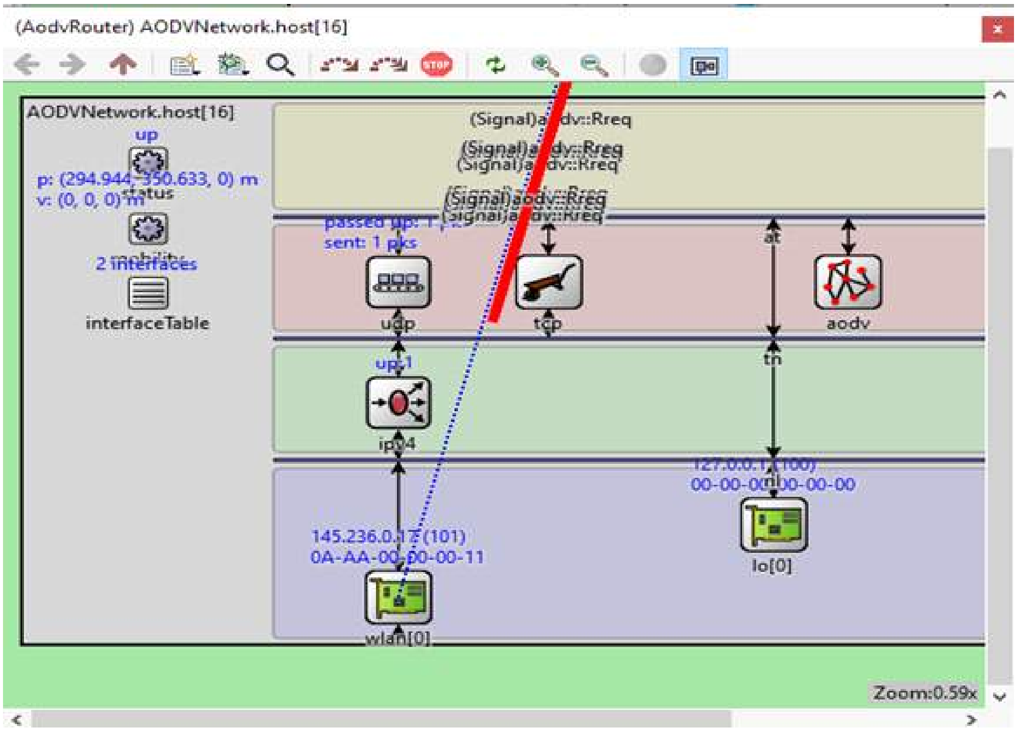

Fig. 4-5 The internal structure of AODV

4.3 Dynamic Source Routing (DSR)

The DSR determines and maintains routes dynamically and ensures quick response by delivering data packets successfully. When data is sent from the source node, a route discovery mechanism works and the PREQ message is transmitted to all nodes in its neighbour. All of these nodes add each unique identifier to the PREQ message. When the data reaches its destination a PREP message is generated. When a route failure happens, the nodes create a PEER message and the buffer is updated.

4.3.1 Advantages

1. It does not create routing loops because a single node determines the complete route.

2. It does not need to store or update routing information of the packets because all the routing information is already contained in the packets.

3. The intermediate nodes don't need to discover other routes because they already have all this information in the route cache and they utilize it efficiently.

4.3.2 Disadvantages

2. The overhead is carried by every packet.

3. Broken link does not repaired through route maintenance mechanisms

4. The connection start up delay is higher than AODV protocols.

5. Increase of motion causes the the performance to decrease.

6. Routing overhead is directly proportional to the length of the path.

4.3.3 Features

1. Establishing of route with less delay.

2. Repairing of broken link in active/ working routes.

3. Sequence numbers allow for loop free activity and are used to ensure the accuracy of information.

4. Only carry trace of next hop for a single route rather than full/ whole route [4-3].

4.4 Sequenced destination distance vector (DSDV)

The Sequenced Destination Distance Vector (DSDV), is a table-driven routing scheme based on the Bellman-ford algorithm. The improvement to the Bellman-Ford algorithm includes the absence of loops in the routing table using sequence numbers. In this protocol a periodically updated routing table is kept in each node, even though routes are not needed. A sequence number is associated with each route to avoid routing loops. The new external broadcasts have a unique sequence number as well as all the message required information. The most recent sequence numbered route is used. The mobiles also keep good track of the route setting time, or the weighted average time that the routes take before receiving the route with the best metric. [4]

4.4.1 Advantages

1. It is simple same as distance vector.
2. Independent from loop with the help of sequence number of destinations
3. Free from latency.
4. Less delay.

4.4.2 Disadvantages

1. No unconscious nodes/ activeness node.
2. Suffer from overhead.
3. Update Needed regularly.
4. Consumes more power and bandwidth is less.
5. Not supported dynamic networks.

4.4.3 Features

1. No worldwide change of topology
2. Maintaining of information of routing for all popular destinations.

3. Periodically manipulation of routing information.
4. Overhead related to traffic
5. Maintenance of unused routes.

Chapter 5. Results and Analyses

The experimentation of this research work was implemented using the NS2 network simulator. In total, 150 nodes are given to find the performance metrics of PDR (Packet Delivery Report), Throughput and Network Routing Load Consumption (NRL). The simulation were done with the following protocols: AODV, DSR, and DSDV.[5-1],
In this chapter we will analyze the performances of the mentioned protocols. On the basis of the performance comparison an efficient routing protocol is selected which support the small and the large network efficiently with less resource consumption.[5-2]

A simulation using NS2 simulator is presented and with the increasing traffic in network the performance is computed using the trace files. For this simulation we selected until 150 mobile nodes, with a simulation time of 200s, the nodes move in a 1000-meter x1000-meter square region. . In this work we perform simulations using different number of nodes 25, 50, 100, and 150. The following graphs show the comparison between the protocols, two mobility and non-mobility scenarios based on the metrics mentioned before.

5.1.1 Packet Delivery Ratio (PDR)

In Fig. 5.1 we have observed a slight advantage in DSDV when the number of nodes is higher than 150 nodes in mobile network.
When the number of vehicles is 25 AODV and DSR have the higher PDR %.
We can notice that when the number of vehicles increases all the analyzed protocols' PDR % decrease but the DSDV's PDR% decreases at a lower rate than the AODV and DSR's.

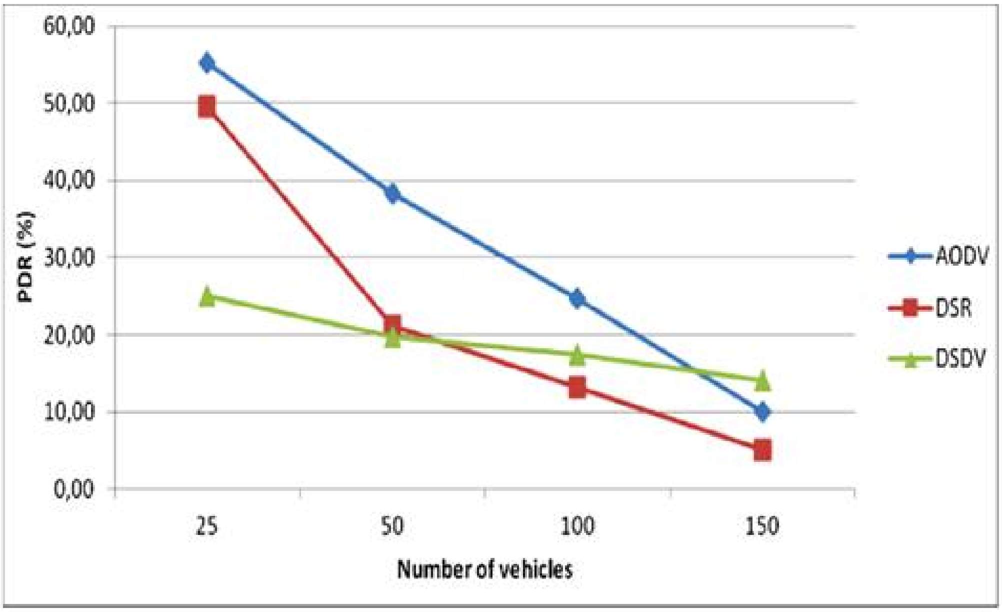

Fig. 5-1. Number of vehicles versus packet delivery ratio

5.1.2 Throughput

Fig. 5.2 is measured in bits per seconds, measures the number of packets delivered per second. DSDV protocol gives a better Throughput after 150 nodes if compared with AODV and DSR. DSDV performs with a more stable path if compared with AODV and DSR.

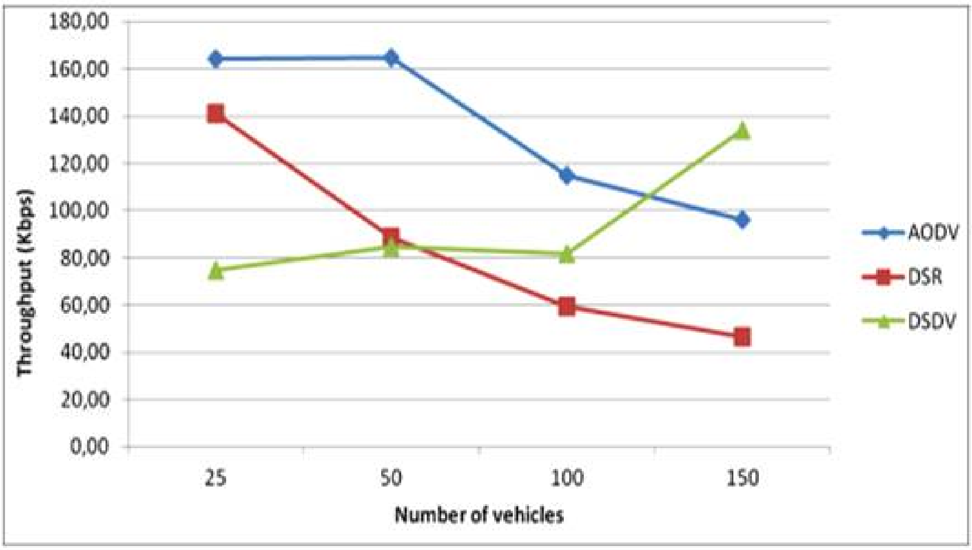

Fig. 5-2. Number of vehicles versus throughput.

5.1.3 Normalized Routing Load (NRL)

Fig. 5.3 shows the normalized routing loads of AODV, DSDV and DSR protocols with constant pause time 0 seconds and mobile nodes from 25 to 150.

X-axis represents the number of mobile nodes & Y-axis represents normalized routing loads.

Experimental results show that the NRL of DSDV is notably lower than the NRL of AODV and DSR when the number of mobile nodes increases.

Because of the requirement of more routing packets to maintain transmission of messages by AODV and DSR, these protocols are more inconsistent and have worse normalized routing loads than DSDV.

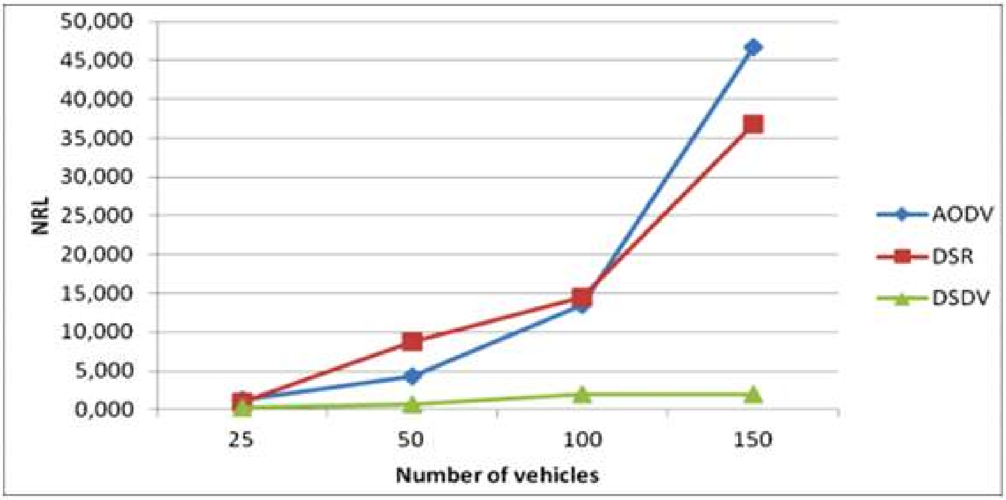

Fig. 5-3. Number of vehicles versus normalized routing load.

Conclusions

In this thesis, I have performed a comparative performance analysis of two reactive protocols and one proactive protocol in terms of following variables, packet delivery ratio, throughput, and normalized routing load. The reactive protocols include AODV (ad-hoc on demand distance vector) and DSR (dynamic source routing) protocols, and the proactive DSDV (destination-sequenced distance vector) protocol.

The results showed that AODV outperforms DSR and DSDV for the lower number of vehicles analyzed, while DSDV outperforms AODV and DSR when the number of vehicles increase.

According to this performance, it is concluded that the less the number of vehicles is, the more appropriate and suitable the reactive protocols such as AODV and DSR are; when the vehicles are more, the proactive DSDV protocol shows better results.

It is expected that the simulation methodology using OMNET++ and NS-2 can be applied to investigate the characteristics of various vehicular communication protocols and networks.

References

References of Chapter 1

[1-1] A. B. Nkoro and Y. A. Vershinin, "Current and future trends in applications of Intelligent Transport Systems on cars and infrastructure," 17th International IEEE Conference on Intelligent Transportation Systems (ITSC), 2014, pp. 514-519, doi: 10.1109/ITSC.2014.6957741.

[1-2] G. H. Tandon, Intelligent Transportation System. (https://www.slideshare.net/gauravhtandon1/intelligent-transportation-system-56391402)

[1-3] Amos Japhet Nsanganzelu, “Intelligent Transport Systems (ITS) in Developing Countries,” Resilient Tanzania Summit, 18-19 FEBRUARY 2019, (https://slideplayer.com/slide/16988296/).

[1-4] Mohammed Amine Togou, “Enhancing infotainment applications quality of service in vehicular ad hoc networks,” Networking and Internet Architecture [cs.NI]. Université de Technologie de Troyes; Université de Montréal, 2017. English. (https://tel.archives-ouvertes.fr/tel-02421004/document)

[1-5] Technical Committee (TC) Intelligent Transport Systems (ITS) in ETSI (https://www.etsi.org/committee/1402-its)

[1-6] R. J. F. Rossetti, S. Bampi, R. Liu, D. Van Vliet and H. B. B. Cybis, "An agent-based framework for the assessment of drivers' decision-making," ITSC2000. 2000 IEEE Intelligent Transportation Systems. Proceedings (Cat. No.00TH8493), 2000, pp. 387-392, doi: 10.1109/ITSC.2000.881094.

[1-7] ITS Korea (https://itskorea.kr/english/main.do)

[1-8] ITS Joint Program Office (https://www.its.dot.gov/)

[1-9] ITS from an offical website of the European Union (https://ec.europa.eu/transport/themes/its_en)

References of Chapter 2

[2-1] OMNeT++ (http://www.omnetpp.org)

[2-2] NS-2 (https://www.isi.edu/nsnam/ns/)

[2-3] A. Papalambrou, K. Stefanidis, J. Gialelis, and D. Serpanos. "Detection, traceback and filtering of denial of service attacks in networked embedded systems," In Proceedings of the 9th Workshop on Embedded Systems Security, 2014. (https://doi.org/10.1145/2668322.2668327)

[2-4] L. Bolong, "A discrete-event simulation tool for resource constrained networks," Master's Thesis (2015, Rensselaer Digital Collections)

[2-5] A. Naji. "A scenario based performance analysis of VANET protocols." (2017). An unpublished thesis submitted in partial fulfilment of the requirements for the degree of Master of Computing, Unitec Institute of Technology, New Zealand.(https://www.researchbank.ac.nz/bitstream/handle/10652/4144/MComp_2017_Naji%20Alobaidi_1373749_Final%20Research%20%28003%29.pdf?sequence=1&isAllowed=y).

[2-6] K. Kaur, N. Kumari, "Evaluation and Analysis of Active RFID Protocol

in Wireless Sensor Networks," International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Vol. 4, no. 2, July 2014

[2-7] A. Haliti, "Update and Evaluate Vehicular Simulation Framework for LTE and 802.11p in OMNeT++", Master's Thesis, Lund Univerisity, 2018 (https://www.eit.lth.se/sprapport.php?uid=1117)

[2-8] R. C. Shah and J. M. Rabaey, "Energy aware routing for low energy ad hoc sensor networks," 2002 IEEE Wireless Communications and Networking Conference Record. WCNC 2002 (Cat. No.02TH8609), 2002, pp. 350-355 vol.1, doi: 10.1109/WCNC.2002.993520.

[2-9] C. C. Chiang, "Routing in clustered multihop, mobile wireless networks with fading channel," IEEE SICON, pp. 197–211, April 1997.

[2-10] Hongmei Deng, Wei Li and D. P. Agrawal, "Routing security in wireless ad hoc networks," in IEEE Communications Magazine, vol. 40, no. 10, pp. 70-75, Oct. 2002, doi: 10.1109/MCOM.2002.1039859.

Reference of Chapter 3

[3-1] G. Janakiraman, T. Nirmal Raj, R. M. Suresh, "AODV, DSDV, DSR Performance Analysis with TCP Reno, TCP New Reno, TCP Vegas on Mobile Ad-hoc Networks using NS2," International Journal of Computer Applications, vol. 72, no. 19, 2013.

[3-2] I. IEEE 2015 5th World Congress on Information and Communication Technologies (WICT) - Marrakech, Morocco - Improvement of location aided routing prot.

[3-3] A. Ambhaikar, L K. Sharma, “Exploring the Behaviour of Mobile Ad hoc Network Routing Protocols with Reference to Speed and Terrain Range”, IMECS 2010, Volume II, March 17 – 19, 2010, ISBN: 978-988-18210-4-1

References of Chapter 4

[4-1] J. Kumar, M. Kulkami, D. Gupta, "The Effects of Black hole attack on AODV and TORA protocols", 2013. (https://www.researchgate.net/publication/272854980_Effect_of_Black_Hole_Attack_on_MANET_Routing_Protocols). DOI : 10.5815/ijcnis.2013.05.08.

[4-2] Jean-Aimé Maxa, Mohamed-Slim Ben Mahmoud, Nicolas Larrieu. Survey on UAANET Routing Protocols and Network Security Challenges. Ad Hoc & Sensor Wireless Networks, PKP Publishing ServicesNetwork 2017. ffhal-01465993 (https://hal-enac.archives-ouvertes.fr/hal-01465993)

[4-3] R. J. Anita and A. N. Rao, "CPLM: Cloud facilitated privacy shielding leakage resilient mobile health monitoring," 2014 IEEE International Conference on Computational Intelligence and Computing Research, 2014, pp. 1-5, doi: 10.1109/ICCIC.2014.7238312.

[4-4] M. Ikeda, E. Kulla, M. Hiyama, L. Barolli and M. Takizawa, "Experimental Results of a MANET Testbed in Indoor Stairs Environment," 2011 IEEE International Conference on Advanced Information Networking and Applications, 2011, pp. 779-786, doi: 10.1109/AINA.2011.64.

References of Chapter 5

[5-1] C. E. Perkins and P. Bhagwat "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers," Computer Communications Review, October 1994, pp. 234-244.

[5-2] M. Picone, S. Busanelli, M. Amoretti, F. Zanichelli, G. -L. J. Ferrari, "Advanced Technologies for Intelligent Transportation Systems," Springer (2015). (https://www.springer.com/gp/book/9783319106670)