IEEE 802.11 TRANSCEIVER MODELING AND ANALYSIS FOR VEHICULAR NETWORKS

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An important issue in Intelligent Transportation Systems is traffic management. This gets more difficult with population growing, movement of population to urban areas and technological advances. These factors result in decreased efficiency of the infrastructure, longer vehicle trips, increased pollution, increased queues of vehicles and decrease in quality of life of the population. Vehicular networks category of Intelligent Transportation Systems consists of on-board transceivers and infrastructure devices to collect, process and analyze the vehicular data. This paper focuses on the 802.11 transceiver modeling and analysis as part of a network discrete event simulation tool.

Keywords: On-Board Unit, Intelligent Transportation Systems, Access Point

1. Introduction

Intelligent Transportation Systems introduce a wide array of Information and Communications Technology services to transportation industry (infrastructure and vehicles). These services are set to improve highly the quality of the transportation infrastructure, with focus on safety, productivity and reliability [1].

An important issue in ITS (Intelligent Transportation Systems) is the traffic management. This gets more difficult with population growing, movement of population to urban areas and technological advances. These factors result in decreased efficiency of the infrastructure, longer vehicle trips, increased pollution, increased queues of vehicles and decrease in the quality of life of the population.

Initial stages of ITS development, design and implementation were conducted to solve and prevent traffic congestion problems on different configurations of roadside arteries. The higher interest in ITS comes from the desire to reduce traffic congestion, by better exploiting of current infrastructure and consequently saving a lot of money.

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An integration of the already existing Information Technology was reasonable, in order to simulate traffic, to allow control in real-time and design an efficient communication network. Furthermore, the initial strong connection between Information and Communications Technology and transportation experts has developed to systems of great assistance to human development and transportation industry.

Extension of the initial ITS services and purposes reached very high levels and also allowed the use in homeland services (tracking), environmental purposes, social equity and data processing [2].

ITS applications include, but are not limited to, Adaptive Cruise Control (ACC), Vehicle to Vehicle (V2V) communications, navigation, safety systems, fleet management, intermodal communications, passenger information, traffic signs, trip planning, travel assistance, toll collection and parking systems. Some of these applications of ITS are also shown in Figure 1.

Fig. 1 - ITS generic uses and technologies involved [3]

Vehicle to Vehicle Communications (V2V) focus on technologies (mounted on board of the cars) designed to provide excellent wireless data connection between two cars.

From the applications mentioned, for example Passenger Information Systems offer useful information based on collected traffic data, like arrival and departure times, delays and causes of delays. Toll collection corresponds to road pricing technologies, with the aim to avoid congestion by electronically collecting road fees. Optimized parking systems combine sensors with vehicular networks in order to provide information about available parking spaces. It is obvious that developing or even improving already existing systems which can provide any of the above mentioned applications can be of great importance.

2. Simulation

In order to test and select the parameters for the applications that would benefit from the simulations, OMNeT++ was chosen as a wireless network simulator for modeling the vehicular environment, which would use proprietary mobility modules of OMNeT INET Framework.

OMNeT++ (Object Modular Network Testing in C++) is a discrete event simulation tool, with the focus on modeling of communication networks. This tool is used in this project in order to provide a simulation model for wireless communication networks between vehicles and infrastructure.

This tool provides the infrastructure in order to develop simulations of specific systems. It does not provide description and directions on simulating a network, and therefore a more applicable defining term for OMNeT++ is simulation framework. OMNeT++ is open-source software that can be used freely for non-commercial purposes.

There are several simulation modules that do not appear in the original setup of OMNeT++ and are built as extensions to the basic simulation framework. Such works incorporate MiXiM and INET frameworks used for mobile and wireless simulations, Castalia for wireless sensor networks, OverSim as flexible overlay network simulation framework. These simulation modules highlight on specific factors and provide a better approach on modeling mobile and wireless networks.

OMNET++ main components include simulation libraries, NED (Network Description) files management, a graphical user interface for the simulation (Tkenv), a graphical editor for NED files, documentations, command line interface, INI file management and many other utilities.

OMNET++ uses NED language (can be edited with any text tool), mainly to support the user on creating and editing easily parts of the simulation. NED is used to describe the topology of the network. This incorporates everything related to a specific network.

The building blocks are modules, whether they are compound or simple modules. The simple modules are the building units in the NED file, while the compound modules incorporate a number of simple modules. Both types of modules are coded in C++.

When two modules need to be connected, gates have to be defined and also connections need to be set correctly. In this way a passing point can be defined and also a direct connection with the destination can be set up from the wireless point of view. Gates need to be specified for both compound modules and sub-modules. The sub-modules are internal modules of the compound modules, but do not necessarily represent a simple module. The communication

channel can be influenced additionally by introducing new parameters control from different configuration modules.

Message sending is possible after the gates and connections are correctly set up. This can be decided in several ways, from definition of a message file to predetermined messages. A model of OMNeT++ incorporates NED topology files, messages that describe the data transmitted and simple modules or compound modules.

The Tkenv simulation GUI (Graphical User Interface) is primarily used for tracing and debugging of the on-going simulation. It mainly provides a detailed display of the whole process and notifies the user on every single event, providing him with the exact simulation results and steps in real time.

The INI file is used to store and influence parameters of the model implemented in OMNeT++. Also various configuration options related to the simulation can be controlled from the INI file.

The simulation libraries are used to cover and influence specific tasks of the simulation, from random number generators to queuing tools. Animation and tracing of the events is performed with different options and tools available for the user.

Simulations can be recorded in OMNeT++ IDE and analyzed afterwards, as event recorded log files. Some of the facilities of this tool are described here.

The users will organize their simulation-based research into various "experiments". An experiment will consist of several "measurements", which are typically (but not necessarily) simulations done with the same model but with different parameter settings; that is, the user will explore the parameter space with several simulation runs [5].

3. Communication

Wi-Fi is the commercial name for the technologies built on the standard of communication 802.11, utilized for local wireless networks with similar speeds to those of Ethernet. Wi-Fi support and compatibility are provided at this moment by many, if not all, new hardware mobile devices, routers and operating systems.

All new laptops and wireless devices have also a built-in Wi-Fi card that allows automatic usage of the service, with the possibility to connect to hotspots. These hotspots allow users Internet access via Wi-Fi and are available in places like universities, airports, restaurants, hotels and other public places. Cards with different Wi-Fi technology can communicate with each other, with the use of frequency hopping techniques. Wi-Fi can also support internal roaming, as movement from one access point to another access point, when the signal is too weak.

The reliability of Wi-Fi is also endorsed by the Wi-Fi Alliance, which has as members more than 200 companies, with the aim of testing and certifying the interoperability of the products, following 802.11 specifications [6]. 802.11 networks can be organized to work in infrastructure mode, with one station providing connection to all other devices, or ad-hoc mode when the devices can form networks by connecting directly to each other without the aid of another linking device. An access point connects the covered devices to another network.

Coverage of an access point can range from 30m to as much as kilometers for advanced equipment. When connected Wi-Fi mobile device moves away from an access point the signal strength decreases logarithmically and ultimately affects the quality of service of the system. Wi-Fi has a carrier frequency of 2.4GHz. The channels used are separated by 5 MHz and have a bandwidth of 22MHz. As a result, channels overlap and five possibilities of available non-overlapping channels exist.

In this section some of the advantages and disadvantages of communication technologies are highlighted. Then, the choice of this technology for the purposes of this paper is justified.

Bluetooth uses the same radio frequencies of Wi-Fi and is regarded to be used more on personal devices; hence the category of Bluetooth applications is used in Wireless Personal Area Networks (WPAN), while for Wi-Fi is WLAN (Wireless Local Area Networks). Bluetooth has as advantage the low power used, but as disadvantage the range of communication and data rate, that does not exceed 1Mb/s [7].

GPRS has as advantage the use of the existing telephony network, but has as disadvantage the scalability of the network, with limited possibility of further extensions of the already deployed access points, unless it is a requirement to the operators in order to deliver services for ITS. There are unknowns about GPRS exact setup and value of parameters to be used for specific scenario, that Wi-Fi provides a reliable option for further steps of the project. While Wi-Fi access point can be set up on any areas, the cellular networks infrastructure cannot be extended or managed in areas where unsatisfactory traffic results occur.

Wi-Fi in comparison with cellular networks can provide better data rates and can be used for real-time applications. Although scalability is an issue for cellular networks, it relies on an already deployed working infrastructure, while Wi-Fi complete network can be regarded as being pricey and daunting task.

Besides the aforementioned advantages of Wi-Fi, the main reason for choosing it as the employed communication technology in this report is that its performance can be accurately modeled in the chosen tool for the simulation. This tool is OMNeT++ INET Framework. Therefore, the chosen technology for

communication between access points and OBUs (On-Board Units) is Wi-Fi. Following the use of Wi-Fi, with carrier frequency 2.4 GHz, MobiSteer is a system that proposes the use of directional antennas for 802.11 links, mounted on top of the vehicle, to enhance the connectivity of the on-board devices with access points or road-side units [9].

Cars can serve as mobile sensors, providing a range of sensed information involving information related to the car, driving condition, road condition, traffic and environment that can be uploaded into some form of "infrastructure" database to be queried by other cars or by some monitoring application [10], [11]. Another configuration makes use of embedded mobile sensors to collect data from cars in traffic. The information is sent to other similar devices or to specific access points, which forward the information to a processing unit in the infrastructure. This configuration is used by CarTel project [12]. The project is a distributed, mobile sensing and computing system that uses phones and custom-built on-board telematics devices. [13].

4. Modeling and analysis

Two main elements of typical ITS systems which were mentioned in the previous sections are OBUs and access points. In the previous chapter the available options for the communication technology between these two elements were discussed. In this section these two devices are first further investigated. For each device it is explained how it is modeled in OMNeT++ and what are the relevant parameters for each element. Then, the OBU (On-Board Unit) data packets which are being transmitted between these two devices are described. Finally, the chapter discusses the scenario of the proposed work. The modules are displayed as building blocks in Figure 2.
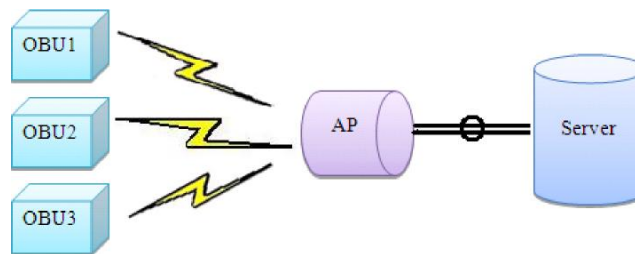

Fig. 2 – Modules involved

The access point represents the device that links the On-Board Unit with the other blocks from the infrastructure, connecting the wired network from the infrastructure with the On Board Units of the cars.

An access point is a mobile device capable of receiving and transmitting information from other mobile devices. The access point offers a connection with

another network (wired or wireless), only after authentication of the mobile devices is performed and association with the access point is done.

Each access point can serve limited information and store additional information in the buffer, therefore buffer usage and estimation is important. When the capacity of the access point is exceeded a management of the overlaps needs to be employed in order to support additional information.

The access point receives the information from the OBU, but is regarded as a passing point, a node, in the system's architecture. Information will be stored in the access point when the capacity is exceeded; the data received from the OBU would be passed on to next devices in the infrastructure.

A wireless access point in OMNeT++ is used in connection with a wireless host, respectively the OBU. An access point compound module has three sub-modules as it is shown in Figure 3:

- a notification board
- a mobility module and
- a module representing the network interface card of the access point.

The parameters which can be modified for the access points in our OMNeT++ .ini file are as follows:

- The beacon interval is the rate at which the access point sends the beacon frame.
- Number of steps for authentication
- Maximum numbers of retries per message
- MAC addresses auto generation
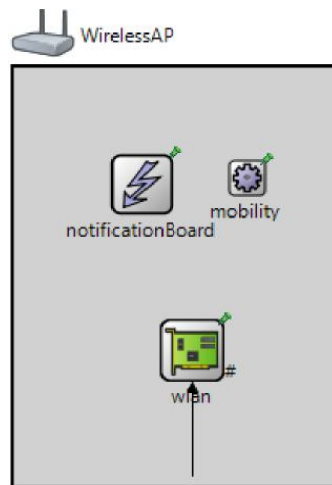- Position of the access point on the playground in OMNeT++ (x and y values).

Fig. 3 – Access point modules

On-Board Units are responsible for vehicle to infrastructure (V2I) communications. The OBU module generically contains a GPS receiver, storage capacity, processor, power management units and operating system.

A display of the sub-modules of the OBU in OMNeT++ is shown in Figure 4. The initial configuration is that of a standard host.
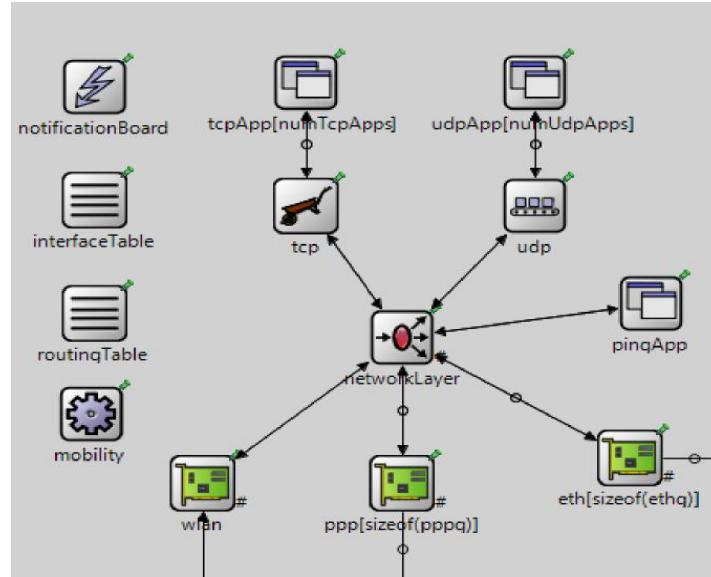

Fig. 4 - Initial host / OBU configuration

The issue with the configuration in figure 4 is that not all the modules used are useful for the purpose of this project (communication between the OBU and access point).

The initial configuration was reduced to configuration shown in Figure 5. One of the reasons for these choices is the fact that UDP (User Datagram Protocol) is suitable for the overall configuration of the system and tasks of the simulation; therefore the TCP (Transmission Control Protocol) module was removed.
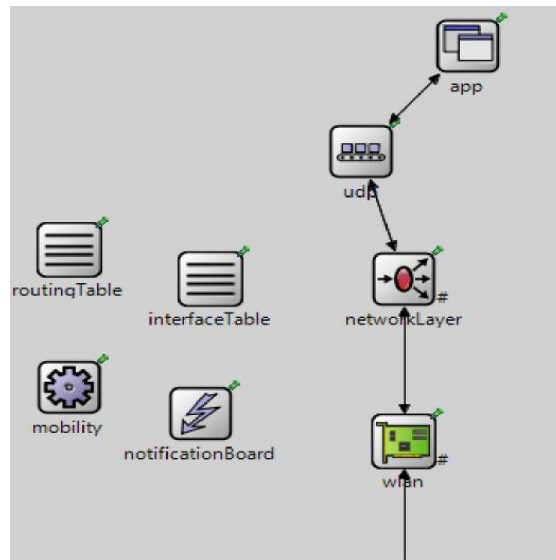
Fig. 5 - OBU configuration

In order to compensate the disadvantage of no confirmation of receiving the packets, UDP is preferred over TCP/IP because:
- the server can handle multiple clients at the same time; broadcast and multicast available
- speed advantage over TCP
- no connection based model restriction, application flexibility.
But UDP has as disadvantage over TCP/IP:
- no acknowledgement, no guarantees of success (a packet can be sent twice, not be delivered at all or delayed).

UDP protocol uses an additional checksum for the addressing information and the payload. The packets that have incorrect checksums will be discarded on the next level of the architecture.

The Mobility sub-module handles movement parameters of the device, sets rules based on parameters overwritten with respect to some borders (actions when criteria are met or not met for being in a confined space). Even if the device is fixed, the mobility sub-module is still being defined and set to 0, because of INET specifications. These previously highlighted four modules of the OBU in OMNeT++ have no gates.

Linear Mobility simulates a line path of a device with speed, angle and acceleration as inputs at specific time interval. Mass Mobility has the device, after following a straight line, turn at a specific time with an angle and then go straight again for a while, then next step is again a turn and so on. Null Mobility signifies that the module has a fixed position.

The speed can be set up as a parameter. The deviation of the trajectory also can be specified as a parameter (in degrees). In Mass Mobility this parameter plays a key role, as it handles the turning of the module, after a straight line. Acceleration can also be an input and it is specified in m/s^2.

For analysis of low complexity Null Mobility is suitable, as it would take out all the movement parameters. On a higher complexity level and appropriate for vehicle movement on roads would be Linear Mobility or Mass Mobility, because roads from simulation perspective can be considered straight. Mass Mobility also adds the possibility for turns.

The Parameters of the wireless host, represented as the OBU, are as follows:

- The number of channels
- Mobility model of the OBU
- Mobility parameters (x, y, speed, also acceleration, deviation or specific mobility patterns can be defined)
- The update interval for the OBU data
- Delay of the probe request
- Maximum channel time for the OBU
- MAC address auto generation
- Maximum queue size in frames

The two devices involved are the OBU which is regarded as a mobile device and an access point, which is regarded as a fixed device. The ultimate goal of the OBU is to send messages with relevant data (OBU packets) to the access point.

First step in the OMNeT++ scenario is that the OBU acknowledges the access point (the access point sends periodically beacons to signal the possibility to connect to 802.11 WLAN) and thus the possibility to have a connection through the access point with the infrastructure. After this event, the OBU would start the connection establishment procedure as per 802.11 specifications [8]. After the OBU is associated to the access point, it will start sending the OBU data message at the update interval.

To do the simulation, a hierarchy mode of implementations has been used. In the first step only a single access point and a single host are considered and their behaviors are studied. Then, in the second step, multiple access points and multiple hosts are added to the playground (working sheet of OMNeT++) and again the important features of the network are studied. The playground of this step of the simulation is shown in Figure 6. The main sub-modules of access point are WLAN, notification board and mobility. The WLAN sub-module itself contains three sub-modules: management, mac, and radio.
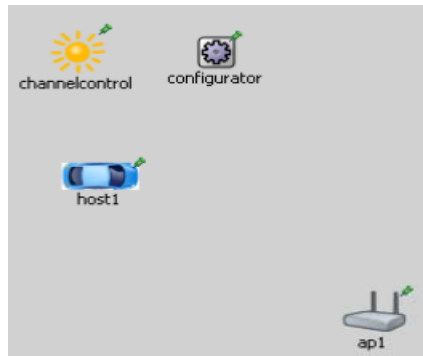
Fig. 6 - Playground of the simulation with access point and on-board unit

5. Conclusions

Considering the currently available technologies for the ITS systems, one of the most important issues is the cost of the implementation of these systems. It is obvious that any employed implementation should be cost effective. To study ITS systems from this point of view, in this chapter the factors which are important on the final cost of the system are studied. The most important questions here are: how much data is needed for OBU packets and how often should the data be transmitted. The answers to these questions might depend on the expectations from the system. High frequency of OBU packet transmissions has a direct impact on the size of the buffers in the access points. Besides, it increases the possibility of collision and loss of packets.

In the proposed system of this paper, the connection establishment between the OBUs and the access points and studying the characteristics of this connection are the main concerns. Therefore, there is no need for such high number of data transmissions.

An alternate way to the OBU-access point connection described in the analysis section would be having access points designed in INET as wireless routers, using a similar configuration to that of a wireless host. The wireless router performs the functions of a wireless access point, router and switch.

Further adjustments and improvements to the current configuration in OMNeT++ can be done by combining / "coupling" the simulation tool with a road traffic simulator, specifically microscopic simulation models.

Acknowledgements

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