VEHICLE NAVIGATION SYSTEM

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ABSTRACT

The paper proposes a vehicle flux estimator, based on Received Signal Strength Indicator measurements in order to prevent the road traffic congestions. Successive RSSI intensity determinations and the corresponding time values were used to estimate the vehicle flux in various conditions. A hierarchical network model, including a simulation module and experimental data, was implemented. In order to estimate the current traffic state, a new strategy in which a special attention was given to information collected from the converging streets near the main crossroads was elaborated. The updated information was used by a road traffic simulator in order to improve the traffic flow.
The proposed solution could contribute to the improvement of the performances obtained using other existing traffic control and monitoring systems.

INTRODUCTION

The main cause of congested traffic is that the vehicle volume is closing to the maximum capacity of the roads network. As the cities evolve one of the problem that rise is traffic congestion.
Congestion involves queuing, slower speeds and increased travel times, which impose costs on the economy and generate multiple impacts on urban regions and their inhabitants. Congestion also has a range of indirect impacts including the marginal environmental causes, impacts on quality of life, stress, safety as well as impacts on non-vehicular road space users such as the users of sidewalks and road frontage properties.
Strategic action to reduce traffic volume to a level where conditions do not vary too much from day to day and practical measures to provide good alternatives for freight and passenger movements, which reduce the intensity of use of scarce road space in congested conditions, are proposed by Goodwin (2004) to solve the traffic congestions.
Several authors present a system that allows vehicles to cooperate in order to reduce the traffic congestion. The proposed vision explores the concept of dynamic time space corridor that can be negotiated between cooperating vehicles to guarantee congestion-free journeys from departure to arrival (Sivaharan et al 2004, Morla 2005).
Mayor (2009) investigates the feasibility of a distributed traffic information system based on Inter-Vehicle Communication (IVC) technology. In IVC-based ATIS (Advanced Transportation Information Systems), vehicles are envisioned to exchange precise position information from satellite navigation data (GPS) via IVC at low cost to optimize traffic flows and provide valuable, real-time traffic information to the drivers.
Another approach developing a new tool for simulation which integrates inter-vehicular communications, Traffic and Network Simulation Environment (TraNS) links and two open-source simulators: a traffic simulator, SUMO, and a network simulator, ns2 is presented by Yang et al 2005.

The proposed paper presents a navigation system that receives real time road traffic information, transmitted in a Wi-Fi based VANET network, in order to detect and estimate possible traffic congestions. A new strategy in which a special attention was given to information collected from the converging streets near the main crossroads was elaborated in order to estimate the current traffic state. The updated information is used by a complex road traffic simulator in order to improve the traffic flow.
The information exchange, regarding congestions and traffic light queues, among the servers placed in the main crossroads and a central control station is performed using a dedicated wired network. In parallel, several vehicles, with Wi-Fi capabilities, form an ad-hoc network in order to transmit warnings. The vehicles send messages, including current speed and other specific zone information to a local server. Based on the received signal strength, the server can determine the position of the vehicle and can approximate if it is in a moving or waiting state. The correlation of these data is

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used to obtain the needed updated information about the current queues length for each crossroad.
The paper is structured in four sections: after the presentation of the early work in the field, the second section describes the vehicle flux estimator based on Received Signal Strength Indicator measurements, the system architecture of the navigation system is presented in the third section; some experiments, tests and simulation results are discussed in the fourth section, the main conclusions and directions of the future being presented in the fifth section.

VEHICLE FLUX ESTIMATION

The paper proposes a vehicle flux estimation stategy based on RSSI measurements as follows.
The time required to cover the distance between two crossroads is used to determine the road traffic volume at different moments. Successive RSSI intensity and corresponding time values measurements are performed in order to estimate the moments in which a vehicle is in the closest position to an Access Point (AP). Three sets of measurements, the first two for AP situated near the origin crossroad (the crossroad corresponding to the origin of a road segment) and the third for an AP pertaining to the destination intersection (the end of the crossroad segment) are needed to calculate the travel time for the corresponding road segment. The three AP correspond to the entering and leave of the origin intersection, and the third to the entering in the next intersection (the end of the segment).
The distributed traffic control units assigned for each crossroad allow the temporary storing and the processing of the data transmitted from vehicles and from neighbor intersections.
Taking into account the temporary data registered, there are two categories of vehicles: cars that enter for the first time in a crossroad and the others, present in the network. In the moment in which the first frame transmitted by a vehicle, which travels on a road segment (street) to an intersection, is received via the corresponding AP, the system verifies if other frames, having the same id, were transmitted from the neighbor crossroads. For each vehicle which travels to and from an access point, successive values, representing the RSSI measured intensity, are compared in order to determine the maximum value, obtained in the closest point from the AP. When the maximum value is found, it is stored and all the others values are deleted. The time moment corresponding to the found maximum value is also registered. For each vehicle crossing the intersections, the moments corresponding to the entrance and leave of that intersection are stored. Based on the correlation between the identity of each access point and its position in intersection, the movement direction of the vehicle (next crossroad) is determined. So, it is possible to transmit the identity data of vehicles to the next crossroads they enter, before their arrival.

SYSTEM ARCHITECTURE

The conceptual network model of the Navigation System is presented in Figure 1.
In the network model, the city map is divided into several, less complex networks. The resulting hierarchical routing network consists of the higher, abstract level, where each area (sector) is represented as a node and the detailed level, consisting of all corresponding areas.
The Simulation Nodes (SN) are represented by computers or virtual machines (running on application servers) used to simulate the traffic behaviour (their main functions are to collect data, to change the control algorithms and to initiate different scenarios).
Taking into account the information exchange initiator, the messages can be local messages (from the road traffic simulator, related to data acquisition, routing system etc.) and inter-zones messages, sent by a different PC, and having a unique or several receivers (broadcast messages). Each node serves several access points which receive/broadcast messages from/to vehicles. The SN is a multi-thread Wi-Fi server which waits for incoming client connections in order to collect traffic information from the vehicles. The Wi-Fi client module is located in the moving vehicle and it initiates an ad-hoc network connection to the server as soon as it enters in the radio range of the server. Then, the client computes the RSSI value of the Wi-Fi server and periodically sends this value to the server.

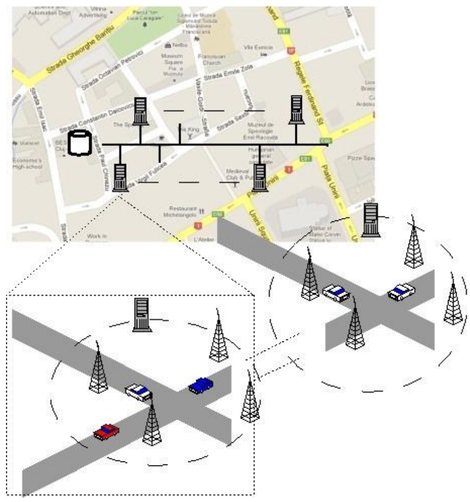


Figure 1: Conceptual network model used for simulation

The software architecture of the system is presented in Figure 2.

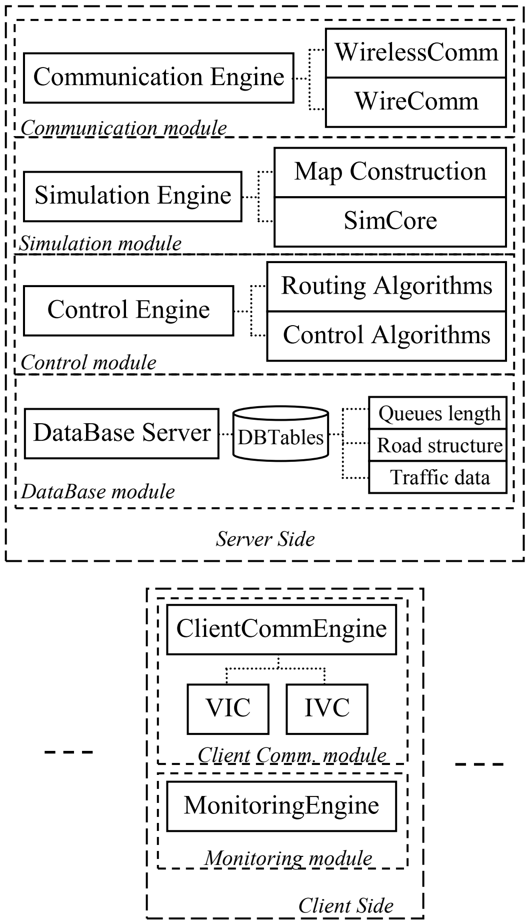


Figure 2: The Software Architecture

Communication Module performes:

- Wireless communication – for the data exchange from traffic (vehicles and infrastructure), to the WiFi AP;
- Wired communication – for the data exchange among different SNs.

Simulation module generates a virtual map for each zone. This module will utilize a virtual representation of the entire system (vehicles, roads structure and communication) and will detect the vehicles movement.

The **Simulation Engine** (SE) reads the information contained in the simulated map from xml files which describe the map and the initial state. The map file contains information about the length of the segment, traffic light, next segment, no. of lanes and type of the segment. The initial state file contains information for each segment regarding the number of vehicles and the time they need to pass through the segment. During the simulation, the program can start several clients all acting in the same manner: first, the client initiate a connection; after this is established, the server sends the initial data (several xml files) to start the simulation; an acknowledgement message is sent in the case in which all the files are successfully transmmited. Then the communication channel is closed.

The **Vehicle Movement Detection** module (VMD) is used to determine the trajectory of the vehicle within a traffic zone based on RSSI. This tool was developed and implemented in Java, using a client-server architecture and Java socket programming in an ad-hoc network. The proposed method is usefull to identify the congested traffic zones.

The Control Module is responsible with the setting up of the control strategies and the routing algorithms (Hierarchical Routing System - HRS).

The HRS calculates the best routes based on the last traffic information. It offers dynamic route guidance, alerting the driver regarding the congested roads and consists of two parts: the Global Routing System (GRS) and the Area Routing Systems (ARS).

The GRS determines the zones with a normal, usual, traffic flow; inside these zones the ARS updates the optimum routes. Finally, the recommended trajectory is composed by the concatenation of the best routes computed for each component area.

In accordance with the distributed approach a hierarchical Dijkstra algorithm is used to determine the best route in both cases (GRS and ARS). Probability values are assigned for possible alternatives inside the routing procedure. The probability tables contain only local information related to the best routes. The final route is composed of a list of nodes constituting the recommended trajectory.

Data Base Server realizes the connection to the data base tables'. The queues length, road structure and traffic data are stored in these tables.

The Client Comm. Module implements the communication functions for clients which are vehicles or traffic signs.

A Vehicle to Vehicle (V2V) communication based scenario was analyzed and tested.

Two different types of communication were taken into account:

- Inter Vehicle Communication (IVC);
- Vehicle to Infrastructure Communication (VIC).

V2V communication can be applied into several scenarios from which can be mentioned danger warnings (inter vehicle) or communication with *traffic signals* (vehicle to infrastructure communication).

Vehicles are able to communicate, to sense their environment, to control their speed and direction, and in general to cooperate with each other. Numerous objects from the urban landscape are also able to communicate and sense their environment (communicating and sensing signposts, sidewalks, and street lamps).

V2V communication system must fulfill some major requirements, like: everywhere availability, utilization of existing technology and low operating costs. As a solution to these problems, this paper proposes a V2V communication based on WiFi technology (available on each computer), the information being sent using ad-hoc networks.

The Monitoring Module displays the received traffic information from traffic signs, other vehicle or from a server, regarding congestions, road closure and the best routes to follow.

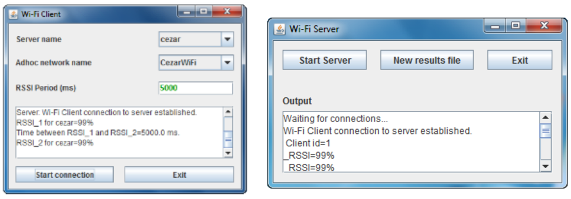
SIMULATION AND TESTING

All the experiments took place in Cluj-Napoca city. The RSSI values were experimentaly determined transmitting data between two WiFi equipments in a client-server configuration in real road traffic conditions. Other results were obtained in different simulation scenarios.

The testing scenario for the VMS simulation was developed based on the following hardware architecture:

Wi-Fi Server: Intel Core 2 Duo Laptop, with 2 GHz CPU, 2 GB RAM and Intel Wi-Fi Link 5300 AGN supporting 802.11 b/g/n;

Wi-Fi Client: Intel Core i7 Laptop, with 1.6 GHz CPU, 4 GB RAM and Intel Wi-Fi Link 5300 AGN supporting 802.11 b/g/n. The Graphical Interface for WiFi Client and WiFi Server are presented in figure 3.



a) b)

Figure 3: a)Wi-Fi Client Java applications; b) Wi-Fi Server Java applications

Figure 4 details the setup of the experiment with two cars (Wi-Fi Client) and one Access Point (Wi-Fi Server) connected in an ad-hoc network.

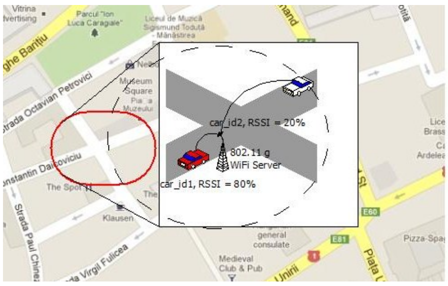


Figure 4: Vehicle movement detection scenario (speed=40 km, time interval=6 s)

For checking out the feasibility of Wi-Fi VMD module, many relevant experiments were initiated, some average values of the obtained results being presented below.

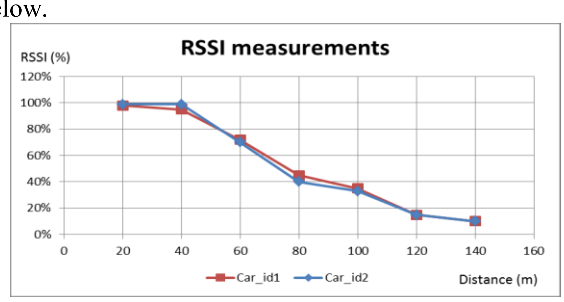


Figure 5: Measurement of RSSI value at different distances from the AP

In the first case, two cars moved and the client RSSI values were measured at different distances from the access point. Figure 5 represents the corresponding variations of RSSI values with the distance.

In figure 6, the presented RSSI values were computed by the Wi-Fi client and transmitted to the server, during a time intervals of 6 s, at speeds up to 45 km/h.

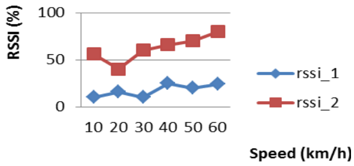


Figure 6: Received RSSI Values from a Moving Vehicle During a Time Interval of 6 s

The VMD module can be successfully used to determine the movement of vehicles within a traffic zone.

The communication between vehicles was simulated and tested using the GloMoSim environment and the mobility of the nodes was implemented using the VanetMobiSim simulator. Inter vehicle communication (IVC), both via hopping among vehicles in the same direction of traffic flow, as well as via cross transmission of information for vehicles moving in the opposite direction, is modelled in figure 7.

For this scenario a part of the Cluj-Napoca city map was considered, the square being zoomed in. All the vehicles with Wi-Fi capabilities are represented with their covered transmission area. The communication on a road segment was established using a single Wi-Fi AP. All the vehicles form a VANET, the whole related traffic information being shared among them.

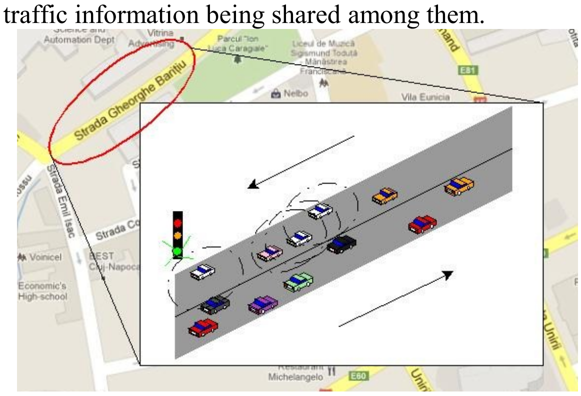


Figure 7: The communication between vehicles

The registration of a queue length during 1000 simulation steps is represented in figure 8. The duration of each simulation step is variable and can be set up at the beginning of the simulation scenario.

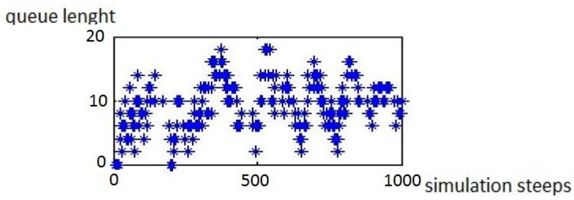


Figure 8: Variation of the queue length

CONCLUSIONS

Successive RSSI intensity measurements and the corresponding time values were used to determine the vehicle flux in various conditions. The permanent updated information was utilised in a simulation system to determine the best routes and to prevent road congestions. The data considered in the simulation network represent the result of experiments conducted in real traffic conditions. The performances can be improved extending the number of AP and modifying their locations in order to complete the needed real time traffic information. The proposed solution could contribute to the improvements of the performances in of other existing traffic control and monitoring systems.

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