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MODELLING AND CONTROLLING SYSTEM FOR ROAD TRAFFIC

BY

CAMELIA AVRAM*

Technical University of Cluj-Napoca

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Abstract. A distributed architecture utilized to simulate road traffic using virtual machines and modern communication techniques and tasks scheduling is proposed. Based on collected information, which is used by complex road traffic simulator, the proposed system can estimate the current state in order to improve the traffic flow.

Key words: modelling and simulation; communication systems; road traffic control.

1. Introduction

Cities and traffic have developed hand-in-hand since the earliest large human settlements. The same forces that draw inhabitants to congregate in large urban areas also lead to sometimes intolerable levels of traffic congestion on urban streets and thoroughfares. Effective urban governance requires a careful balancing between the benefits of agglomeration and losses of excessive congestion.

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 (Goodwin, 2004).

Congestion involves queuing, slower speeds and increased travel times, which impose costs to the economy and generate multiple impacts on urban

* *e-mail*: camellia.avram@aut.utcluj.ro

regions and their inhabitants. Congestion also has a range of indirect impacts including the marginal environmental and resource impacts of congestion, impacts on quality of life, stress and safety as well as impacts on non-vehicular road space users such as the users of sidewalks and road frontage properties (Mayor, 2005; ECMT, 2007).

This paper proposes a distributed architecture used to simulate large scale systems (road traffic), using virtual machines and modern communication techniques and tasks scheduling.

It is important to use intelligent systems for traffic simulation, routing strategies and scheduling techniques in order to achieve an optimal usage of resources. Scheduling of message queues has strong similarities with algorithms used for giving different service rates (Barr *et al.*, 2008; Yang & Recker, 2005).

The key motivation behind of this research is to create a simulation system that can execute discrete event efficiently simulations (different traffic situations, control algorithms, designing new roads), yet achieve the transparency within a standard language and its runtime (Piorkowski *et al.*, 2008; Sundell & Tsigas, 2003).

For managing an urban traffic system, a hierarchical system that consists of several locally operating systems (virtual machines), each representing an intersection (to test several control algorithms and acquire data from traffic) of a traffic system or an area (depends on the configuration and the complexity of the area) is proposed.

Efficient control of urban traffic requires the implementation of a sufficiently accurate model allowing prediction of the effects of various control actions (such as adaptation of red–green phases at different intersections) (Padron, 2009; Pathak & Shrawankar, 2009). Given the size of the plant it is important that one can use a distributed implementation of this simulation model. The computational efficiency is also improved by using a heterogeneous model, where some parts of the network are represented by a macroscopic model (Papageorgiou *et al.*, 2002), other parts by a microscopic model (Tufail *et al.*, 2008). Each component represents some randomness in the evolution of the plant.

2. System Architecture

Mainly based on wireless connections, the system provides the following navigation functions:

a) Collects and recovers the traffic information trough local VANETs and access points installed in each traffic zone.

b) Displays the position of the current vehicle and its destination on the digital map.

c) Plans the shortest/fastest route from the current position to destination using an hierarchical Dijkstra algorithm and displays the route on the digital map.

d) Tracks the vehicle route on the digital map.

e) Shows the real-time traffic information (emergency or congestion) on the display.

f) Re-plans local routes based on emergency or congestion information.

g) Reports traffic accidents.

A friendly graphical user interface was developed to provide real time visualization of interest information.

The conceptual network model of the Navigation System is presented in Fig. 1.

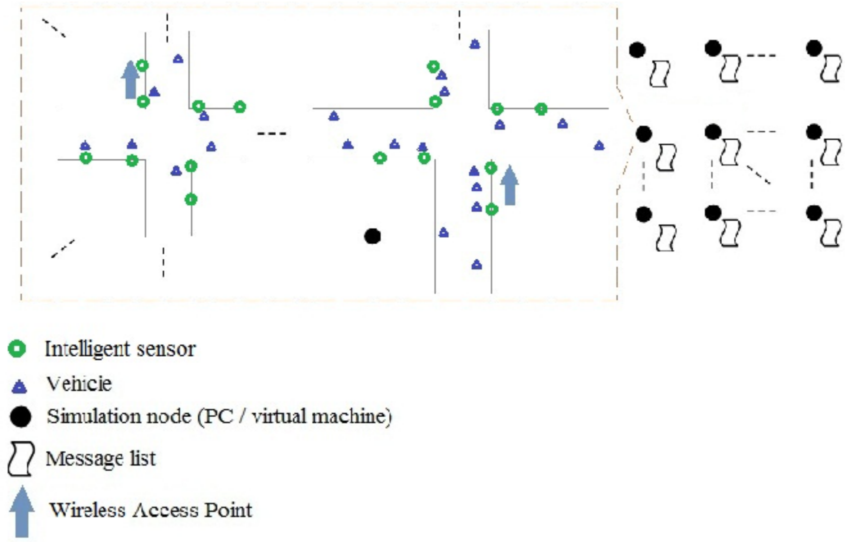

Fig. 1 – Conceptual network model used for simulation.

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 nodes (Simulation Node – 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 (Personal Computer), 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 server which wait 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 (Received Signal Strength Indicator) value of the server and periodically sends this value to the server. The server stores the received RSSI values in a database and using these values it determines if a vehicle is in a movement or waiting state. The SN also receives and computes data from intelligent sensors.

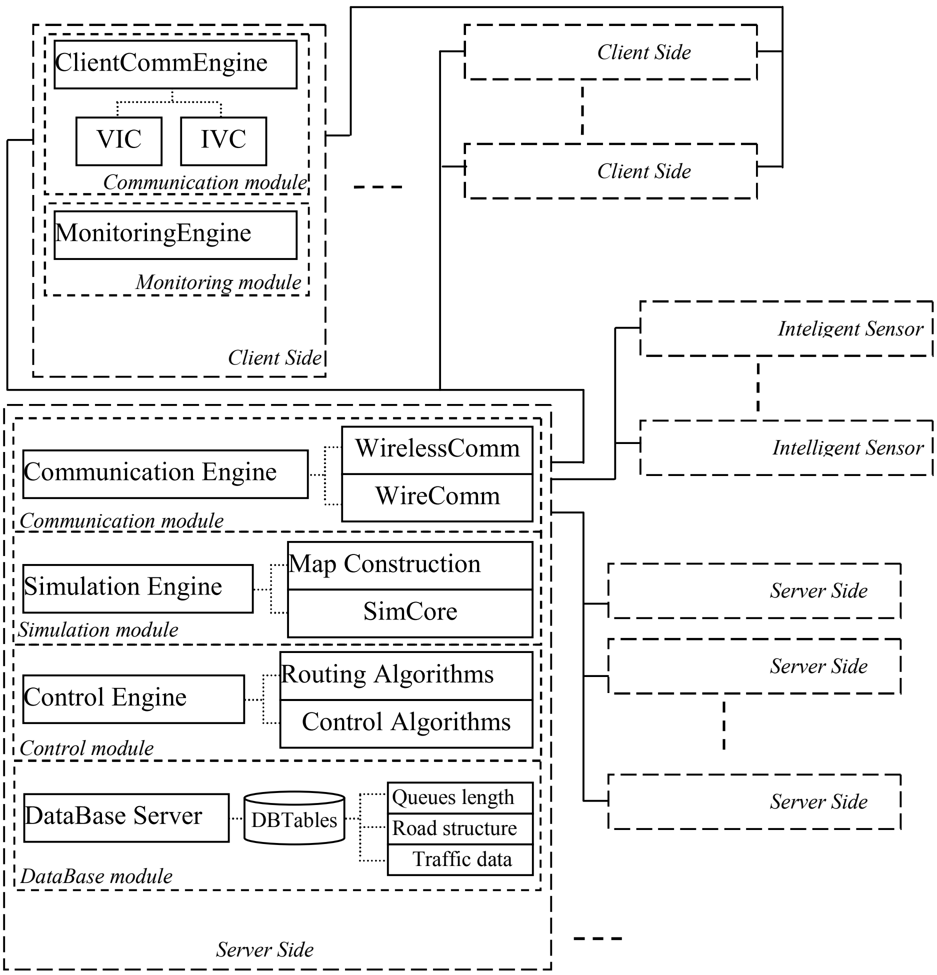

Fig. 2 – The software architecture.

The intelligent sensors send data concerning the number of vehicle which pass into his are.

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

Communication Module realizes two types of communication

a) Wireless communication – for the data exchange from traffic (vehicles and infrastructure), to the Wi-Fi, Bluetooth and ZigBee AP.

b) Wire communication – for the data exchange among different SNs.

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

The *Simulation Engine* (SE) reads the information contained in the simulated map from xml files which describes the map and the initial state. The map file contains information about the length of the segment, traffic light, next segment, number 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 and all act in the same manner.

First, the client requests a connection; after the communication channel is established, the server sends the initial data to start the simulation (several text files); the client sends an acknowledgement message in the case in which it received all the files and then the communication channel is close.

The application is distributed and RMI – IIOP Java technique is used for implementation. For each simulation client, a client and a server module is implemented with RMI – IIOP.

The *Vehicle Movement Detection* module (VMD) is used to determine the vehicle movement within a traffic zone. This tool was developed and implemented in Java, using a client–server architecture and Java socket programming in an *ad-hoc* network. This new method was proposed in order 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, acceptable, traffic flow; inside these zones the ARS determines the actual optimum routes. Finally, the recommended trajectory is composed by the concatenation of the best routes computed for each component area.

Both GRS and ARS use a hierarchical Dijkstra algorithm in order to determine the best route. It was chosen because is especially suited for the proposed distributed approach. A probability value is assigned for all possible alternatives inside the routing procedure. The probability tables contain only local information related to the best routes. For each node, the next segment of the route is determined. The final route is composed of a list of nodes constituting the recommended trajectory. When the route is complete, or the maximum number of nodes in a route is reached, the response is sent back to the driver.

In the *Data Base module* the connection to the data base tables' trough the Data Base Server is realized. 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 analysed and tested.

Two different types of communication were taken into account:

a) Inter Vehicle Communication (IVC).

b) Vehicle Infrastructure Communication (VIC).

V2V communication can be applied into several scenarios from which can be mentioned inter vehicle (danger warnings) or vehicle to infrastructure (communication with traffic signals) 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 on the urban landscape are also able to communicate and sense their environment (communicating and sensing signposts, sidewalks, and street lamps).

V2V communication system must fill some major requirements, like available every ware, use an existing technology and no operating costs. As a solution to these problems, this paper proposes a V2V communication based on Wi-Fi 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 best routes to follow.

3. Simulation Module

The mathematical model that forms the basis for our distributed simulation consists of many interconnecting components, the outflow of an upstream component being the inflow in the next down-stream component. For road networks where the distance between intersections is big, one often can assume that the traffic state is roughly the same over segments of a length of several hundred m. This allows the use of macroscopic models, describing the evolution of the following aggregated variables (no individual vehicles are represented):

a) the flow, $q(x,t)$, of vehicles, vehicles/min., at time t and at location x;

b) the density, $\rho(x,t)$, of vehicles at time t and at location x, [vehicles/km], and

c) the average speed, $v(x,t)$, of these vehicles, [km/h].

Classical macroscopic models develop partial differential equations for the evolution of these aggregated variables, and simulate the behaviour of the network by time and space discretization See *e.g*. the METANET simulator, in the paper written by Papageorgiou *et al*. (2002).

In the simulator for urban traffic, used in this paper, are taken into consideration different models, for long segments (macroscopic model) and for short segments (microscopic model) (Tufail *et al*., 2008). Vehicles enter a short segment, *n*, through its upstream boundary at the event time *j*-th vehicle enters segment *n*. Vehicles are then propagated *via* a sequence of consecutive cells, moving to the next cell as soon as they can have driven a distance equal to the length of the cell (this time is calculated using the current speed of the vehicle), and when the next cell is free (not blocked by another vehicle, nor forbidden by safety constraints imposed by downstream vehicles).

4. Simulation Results

At the end of the simulation, the program generates a file with measurement data for each segment and a file with all the events that occurred during the simulation. This data file contains the time, speed and the number of cars per each segment (an average between all the lanes in case of the short segment).

The output data file is used in a Matlab program to draw the time evolution on the segment during the simulated period of time. This graphical representation is not done in Java because Matlab has a specialized toolbox for graphics drawing and interpretation. For example, the simulation result has been used to analyse the delay of the cars during the simulation, because we know the time needed to pass the short segment and for the long segment we know the average speed and the length of the segment.

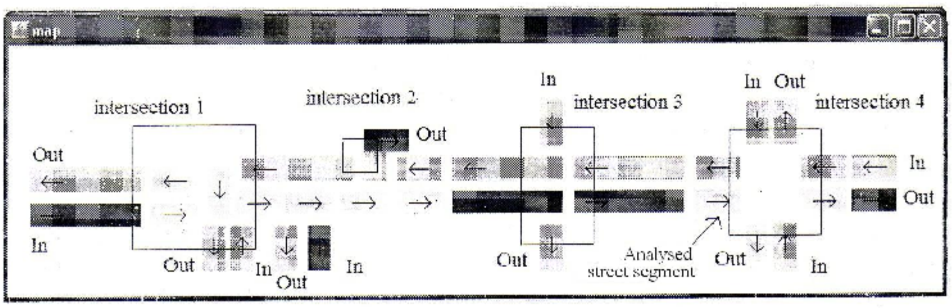

Fig. 3 – The analysed simulation result.

A colour code was chosen to represent the congestion: red for congested traffic, yellow for fluid but low speed traffic and green for unrestricted traffic (Fig. 3). The simulated area is formed by four intersections and the connection streets among them. Vehicles can enter in this zone by one of the marginal segments, marked in the figure with “In”, and can exit using one of the segments marked with “Out”. Several situations were simulated (*e.g*. blocking a lane or an entire, simulating an incident). The length of the simulation steep is variable and can be set up at the beginning of the simulation. A segment can turn into a crowded area when the traffic is congested, the road is closed (for different reasons like infrastructure updates or car accidents) or in rush hour.

5. Conclusions

Congestion appears in many contexts and is caused by various situations; this paper proposes a method to avoid traffic closure by rerouting vehicles based on real time information. In this paper a model of a network system and the associated communication system used to update the road traffic state are presented.

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