Smart Traffic Management Protocol Based on VANET architecture

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Abstract. *Nowadays one of the hottest theme in wireless environments research is the application of the newest technologies to road safety problems and traffic management exploiting the Vehicular Ad-Hoc Network (VANET) architecture. In this work, a novel protocol that aims to achieve a better traffic management is proposed. The overal system is able to reduce traffic level inside the city exploiting inter-communication among vehicles and support infrastructures also known as Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications. We design a network protocol called Smart Traffic Management Protocol (STMP) that takes advantages of IEEE 802.11p standard. On each road several sensors system are placed and they are responsible of monitoring. Gathered data are spread in the network exploiting ad-hoc protocol messages. The increasing knowledge about environment conditions make possible to take preventive actions. Moreover, having a realtime monitoring of the lanes it is possible to reveal roads and city blocks congestions in a shorter time. An external entity to the VANET is responsible to manage traffic and rearrange traffic along the lanes of the city avoiding huge traffic levels.*

Keywords

802.11p, CO_2 emissions reduction, geocasting, traffic management, VANET.

1. Introduction

Every year a high number of people lose their life in car accidents due to lack of a good traffic management. To overcome these troubles, in these last few years car manufactures and High Level Governance Institutions invested in IEEE 802.11p standard and road infrastructures to increase active and passive safety systems.

The major causes of collisions on our roads are the lack of information, limited sight and drivers distractions. Other accidents, instead, are caused by the irresponsible driving style of some drivers that unfortunately cannot be expected. With IEEE 802.11p, vehicles can exchange messages quite efficiently among themselves using ad-hoc connections with a multi-hop protocol to spread data in an efficient way in order to inform other vehicles about their conditions and about what they have recognized. These technologies can be also used to increase active and passive safety system informing vehicles and infrastructures about dangerous situations that can happen along the roads. Another important aspect of the traffic management can be also addressed in order to enhance the quality of the air around our cities. In fact, many researches surveys demonstrate that the higher is the traffic load, the higher will be the level of CO_2 emissions. Another cause that influences the CO_2 level is the vehicles speed and the average time spent by vehicles inside the city. With a better traffic management, the average time spent by the vehicles in the city will be considerably reduced while the average speed increases. In this way, the overall CO_2 produced by vehicles will be reduced thanks to the smaller number of congested roads. In order to obtain these results, we designed a full integration framework between car sensors and IEEE 802.11p.

The first issue that we faced is the dissemination of protocol messages because in IEEE 802.11p protocol there is a broadcast mechanism to reach all the vehicles with a On Board Unit (OBU). When a vehicle has to communicate some kind of warnings or accidents there is a protocol overhead increment caused by the exchange of warning and position messages. Considering also the general information messages there is a huge amount of packets travelling along the network that may cause a worsening of performances or even compromise network capabilities due to an excessive packet loss. Therefore, we have designed a protocol based on IEEE 802.11p paying attention also on protocol overhead issues. The work is organized as follow:

- A state of the art section in which we describe related works and address the differences and improvements between these works and the one here illustrated.
- The description of the reference architecture and the presentation of the network and system architecture we based on. We also present a brief analytic network model.
- How alerting system is implemented and how on board devices and core computation works.
- A simulation results section is introduced to present the results of several tests in different environments compared to current road system equipped with an IEEE 802.11p wave based protocol and STMP protocol. Our results will show many improvements in terms of average speed, traffic congestion and a notable reduction of CO_2 level inside urban environment.
- Conclusion and future works.

2. Related Works

Recently, the studies related to vehicular networks focus on those solutions that improve the quality of life in the urban environments. Key aspects that are being considered are efficient traffic management and reduction of the CO_2 emissions and pollution. In the literature there are several works that aim to reach these goals. In [1], authors proposed a warning system composed of Intelligent Traffic Lights (ITLs) that provides information to drivers about traffic density and weather conditions. These ITLs reporting those statistics to the vehicles and also they will send warning messages to vehicles in the case of accidents to avoid further collisions. In [2], authors improved congestion control with heuristic techniques to reduce the traffic communication channels while considering reliability requirements of applications in VANETs. Heuristic techniques can be used to define heuristic rules and finding feasible and good enough solution to some problems in a reasonable time. In [3], authors considered the impacts of vehicular communications on efficiency of traffic in urban areas. They developed a Green Light Optimized Speed Advisory (GLOSA) application in a typical reference area and they presented the results of its performance analysis using an integrated cooperative ITS simulation platform. In [8], authors proposed an ITS-based system capable of guiding the driver's decisions, with the aim of reducing vehicle emissions. There is a direct relation between the car's emissions and its speed or acceleration. The goal of this system is to periodically guide the drivers through intersections equipped with ITLs, and recommend optimal speeds to reduce the number of vain accelerations to catch green lights and the number of stop-starts due to red lights. In [5], the authors studied the performance of different warning message dissemination schemes for VANETs under situations classified as adverse due to the very low or very high density of vehicles in the scenario. The efficiency of warning message dissemination processes under these conditions is reduced as a result of frequent network partitioning under low densities, and high channel contention under high vehicle densities. Simulation results showed that these proposed schemes outperform the existing dissemination algorithms in terms of informed vehicles and messages received per vehicle. In [6],the authors designed and tested a primary-secondary resource-management controller on Vehicular Networks. They cast the resource-management problem into a suitable constrained stochastic Network Utility Maximization problem and derive the optimal cognitive resource management controller, which dynamically allocates the access time-windows at the primary users (the serving Roadside Units) and the access rates and traffic flows at the secondary users. They provided the optimal memoryless controllers under hard and soft primary-secondary collision constraints. In [7], authors defined and evaluated two traffic monitoring approaches that can be used leveraging the potentiality of VANETs. The protocols are based on a message exchange through a multi-hop path built on vehicles equipped with DSRC devices. No monitoring infrastructure is needed, except for a single Road Side Unit on a road span of almost 70 km. In [4], authors developed and implemented an instantaneous statistical model of emissions (CO_2, CO, HC, NO_x) and fuel consumption for light-duty vehicles, which is derived from the physical load-based approaches. The model is calibrated for a set of vehicles driven on standard as well as aggressive driving cycles. This model is implemented in Veins Framework that we used in our Simulations. In [9], [10], [11], [12], our previous studies, we focused on the reduction of the co-channel interference in VANETs due to the transmission of data packets between the nodes. Instead, in this paper we aim to find a whole system optimization able to reduce CO_2 emissions, to achieve a better management of urban traffic treating congestion and consequently to reduce the trip travel time of the vehicles.

3. Reference Architecture

In this work, we use a heterogeneous architecture composed of a global city road manager that communicates with Road Side Unit (RSU) picking up information about the real condition of the roads in terms of traffic load. The RSU communicate with the Road Traffic Manager (RTM) in a periodic manner. In order to inform vehicles about roads condition the V2I commu-

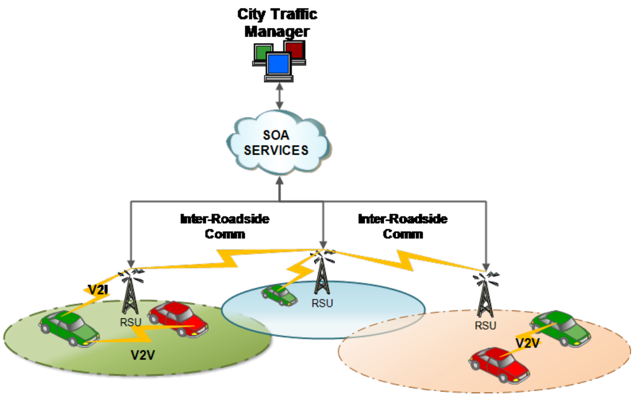

Fig. 1: Reference layered architecture.

nications are exploited. These messages exchanging allow vehicles to keep road information updated making possible a re-computation of the paths. The reference architecture is shown in Fig. 1. The RSU can communicate with the RTM every T_{update} seconds asking for network topology changes. In this message are also carried some important parameters related to covered lanes and roads that are served by the RSU. RTM can exploit these information to evaluate congestion levels updating lanes costs to reduce traffic loads. A dynamic cost is assigned in accordance with the formulas that will be presented in the further sections of this work.

3.1. Urban Environment Definitions

One of the main issues that this work tries to face is a better management of traffic and road congestion in urban and sub-urban areas. Commonly these blocks are recursive and the traffic congestion increase in an exponential way because the drivers cannot find feasible exit gates, and they may be involved into congestion as well as other vehicles that reach the congested areas before them. This represents a big issue for traffic management, in fact, as several surveys have already demonstrate that the higher is the traffic level the higher is the CO_2 level into the air. Using a protocol that allows communication among vehicles can help city traffic management in order to manage congestion in a faster way starting the treatments just at the beginning. This can be made acting a continuous monitoring of the traffic exploiting vehicles communications and fixed devices such as sensor devices along the roads. The whole system can be view as a hybrid network infrastructure composed of several devices with a given intelligence able to collect, store, send and elaborate grabbed information from the environment. Under this point of view, we have to describe some important entities that we are going to address. We refer to a generic Road (R) of the network, where each road is composed of one or more lanes. Each lane is indexed, so if we want to call 2-nd lane of the road R_i we can recall it using the nomenclature $L_{2,i}$. Moreover, it is important to know the length of the j-th lane to perform further computations, these terms will be called $l_{j,i}$. In order to avoid congestion we have to define some critical constraints to model the queues. Thus, we assume that each lane related to a road R admits a certain maximum speed that we will define as $MaxSpeed_{j,i}$. Also, it is important to define an average vehicle length that we assume to be $v_{length} = 2.5$ m.

3.2. On Board Device Cooperation

Taking advantages of IEEE 802.11p based architecture and enhancing on-board device cooperation it is possible to collect a huge amount of data that can be used in order to better understand driver behaviors and predicting, where possible, if something is going wrong observing driver actions on the vehicles and monitoring distances among vehicles and known obstacles such as road borders. For example, it is possible to know information about distances exploiting related sensors, it is possible to have information about vehicle position exploiting the Global Position System (GPS). In this way, we can have the possibility to access all these information in a real-time manner. The OBU is smarter and a little bit more complex than a standard OBU, which is commonly used in an IEEE 802.11p environment. In our scheme, the OBU represents the core of the vehicle system able to communicate with an external world exploiting V2V and V2I communications.

3.3. Neighbor Clustering

A vehicle node can be considered as the neighbour if and only if the distance among nodes is lesser than a certain threshold. Therefore, a node is the neighbour of another one if following relations are satisfied:

$$r_{distance} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}, \qquad (1)$$

$$r_{distance} < \text{NeighThreshold}, \qquad (2)$$

where central node position into the Cartesian plane is $p_1 = (x_1, y_1)$, while the position of the second node is $p_2 = (x_2, y_2)$ and NeighThreshold is the threshold to identify if the second node is enough closer to be a neighbour. The neighbour lists are managed exploiting Position Updated (PosUpdate) protocol message. This message is periodic and it is sent by the vehicle in which the current position (achieved by GPS) are carried, this will be better explained in further sections. Of course, the Latitude and Longitude coordinates are converted into a Cartesian reference system, which has the origin in the upper left corner of the city map area. The propagation of this message PosUpdate is sent towards neighbours only limiting the dissemination on the basis of the vehicles position. This permits to avoid a drastic protocol overhead increasing.

4. Network Architecture

4.1. Entities

In this section, we describe the main entities we used. In particular, we considered three main entities that work in VANET layer and network layer. In the OBU, which is proposed in this work, we provide a core unit that can communicate with vehicles sensors, GPS unit and environmental sensors such as proximity, distance sensors and so on. All thus data are brief elaborated and filtered by the internal core application. Vehicles are equipped with this OBU and they can receive messages from the network layer exploiting multi-hop (V2V) and from the V2I communication that are established between RSU and OBU. The RSU is used to work as connector node between vehicles and Control and Management Center (CMC), in which the RTM takes place. It has also the task to spread messages along the network monitoring neighbour roads as well. When the OBUs reach a covered area they send messages regarding their location and become information suppliers for the RSU and the whole system, helping them to increase the real-time knowledge of the traffic, road and environment conditions. As it is possible to note the RSU is equipped with an internal STMP-Data Base (STMP-DB) that is used to collect protocol messages avoiding multiple sending of the same message and information about its own roads. The RTM that represents the entity that has the main task of managing the whole city traffic. The RTM takes information about roads and traffic level exploiting the VANET layer. In particular, the RSUs have the main task to collect information about vehicles, roads and sensors sending important data to RTM. Once the RTM recognizes a bad event it changes the weights of the related roads and sends messages towards the RSU to communicate weights changes. After that weights computation is made and these messages are sent to the vehicles following dissemination rules in order to avoid congestion and further blocks. Information are used by the vehicles in order to update their local map, a reroute is forced by inner functions.

4.2. Dedicated Protocol Messages

1) Position Update in Smart Traffic Management Protocol (STMP)

Position Updated (PosUpdate) is an inner function that give us the possibility to bring up information about the neighbour vehicles. These information are picked up exploiting protocol messages called PosUpdate. In order to reduce protocol overhead, it is important to limit the total amount of protocol messages that will flood around the network. This is made sending some info-messages, which are related to local issues only to neighbours. In the PosUpdate messages are collected all information related to the position of a vehicle exploiting the on-board navigation systems such as GPS or the position system based on the inner elements of the OBU. Once this information are received they also elaborated and if and only if the distance among vehicles is lesser than a certain threshold the vehicle that has sent the messages becoming a new neighbour. If the distance is greater than the threshold, the vehicle is erased from the neighbour list and no messages are more sent towards it. In this way, messages flood only in a restricted area around the vehicle avoiding worst flooding effects on network performances. This message is generated in a periodic way by each vehicle.

2) Congestion Update

In this work, we try to increase the overall quality of the city traffic management. In order to design this activity we need to monitor the road condition in a real time way. This can be made exploiting several sensors around the city and exploiting also the RSU device that are involved into IEEE 802.11p communication. The working schema is shown in Fig. 2 where the protocol behaviour is shown. The RSU collects the messages coming from the OBU of the vehicles on the own Lanes and sends this information to the CMC. The CMC collects all the information sent by the RSU and sends back the elaboration through the Congestion Updated (CongUpdate) in order to advise if some traffic issues have been found. The RSU sends in broadcast way the messages into the network covering roads areas. In Fig. 2 the Car-A has found a better path going on Lane-A to reach its destination. When the CongUpdate message reaches the Car-A it recalculates the path choosing the Lane-B avoiding blocked road and avoiding wasting of time, saving fuel and reducing CO_2 emissions.

4.3. Traffic Block Detection and Management

Congestion as well as collisions often cannot be predicted or known in advantage due to dynamics of these events that can be directly connected with external factors. When congestion is raising the system can advice these events as traffic congestion to other vehicles that can change their paths avoiding critical traffic level in the involved areas and closer areas as well. But in case

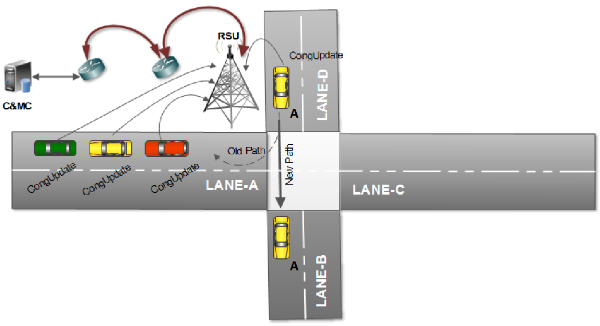

Fig. 2: Road congestion identification.

of high traffic level, this behaviour is not clever. In fact, could be better to find a relation that give us the possibility to identify a fair cost for those roads that momentary reach high traffic levels. Using a high cost, all vehicles can reroute their paths going towards the same area, this may determine another congestion area inside the city. This represents a big issue to address correctly and smarter weighting cost function has to be found in order to estimate the real impact of the collision. In this work, we try to find a relation among several parameters such as travelling time and number of vehicles on the roads, looking for the better trade-off that can allow us to manage in a finer way critical situations. Considering a generic *i-th* road R composed of one ore more lanes we can determine the travelling time as shown in Eq. (3). Where the $|n_{j,i}|$ represent the number of the vehicles on the considered lane. $l_{l,i}$ is the lane length and $S_{k,j,i}$ is the average speed of the *k-th* vehicle on that lane of the *i-th* road:

$$tt_{j,i} = \frac{|n_{j,i}| \cdot l_j}{\sum_{k=1}^{i=|n_{j,i}|} S_{k,j,i}} \; : \; j \in R_i. \tag{3}$$

In Eq. (4), the average space occupied by the *k-th* vehicle is presented, this space is directly connected with the speed of the vehicle. Commonly, it is $\frac{1}{3}$ of the current vehicle speed and it represent the stop space:

$$v_{space} = \frac{1}{n_j} \cdot \left(\sum_{k=1}^{n_{j,i}} length(vehicle_k) + \frac{\sum_{k=1}^{n_{j,i}} speed(vehicle_k)}{k_{speed}} \right). \tag{4}$$

Herein equation used to trigger congestion on a given lane are presented. In this equation, we take into account the current number of vehicles, lane length, the average vehicle length, and the space occupied by the vehicle when their speed is close to 0. When the number of the vehicles is closer to the maximum admissible number of vehicles (see Eq. (5)) then the congestion trigger is raised, this means that the Th_{cong} threshold is reached:

$$maxV_{j,i} = \left[\gamma \cdot \frac{l_{j,i}}{v_{space}} + \left(\frac{\sum_{k=1}^{n_{j,i}} length(vehicle_{k,j,i})}{n_{j.i}} \cdot \delta \right) \right]. \tag{5}$$

The $maxV_{j,i}$ is given by the sum of two components: the first one is related to the number of the vehicles that can travel the lane respecting safety distances, the second one is related to the space taken by several vehicles that are waiting on the lane. It is possible, for example, to change the weight of the waiting queue time, such as a traffic light queue, acting on the δ parameter. Thus, in order to evaluate whether a lane is congested or not, we can use the equations herein shown:

$$h(n_{j,i}) = \{ n_{j,i} - maxV_{j,i} \}, \tag{6}$$

$$K_{cong,j,i} = \begin{cases} \alpha & \text{if } h(n_{j,i}) \geq Th_{cong} \\ \beta & \text{otherwise} \end{cases}, \tag{7}$$

where $l_{j,i}$ is length of the j-th lane of the considered Road (R), $n_{j,i}$ is number of vehicles on the *j-th* lane of the road R, $tt_{j,i}$ is travelling time along the *j-th* lane of the considered Road (R), $S_{k,j,i}$ is the speed of the *i-th* vehicle on the *j-th* lane of the Road(R), $k_{cong,j,i}$ is the congestion factor related to *j-th* lane of the considered Road (R), k_{speed} is coefficient for safety distance computation, δ is coefficient to manage congestion level in terms of queue length, γ is coefficient to manage congestion level in terms of queue safety distance considering the average speed of the vehicles that are travelling the lane, α, β is congestion parameters that are configurable as system parameters. Th_{cong} is the congestion threshold configurable as system parameters, $h(n_{j,i})$ is function of the number of the vehicles that are on the *j-th* lane of the Road (R_i).

At the end the cost of the edge is given by Eq. (8):

$$w_{j,i} = tt_{j,i} + \left\{ K_{cong} \cdot \left(\frac{1}{UpBound_{j,i}} - \frac{1}{InRate_{j,i}} \right) \cdot [n_{j,i} \cdot v_{space}] \right\}. \tag{8}$$

$$Cost_{j,i} = \begin{cases} tt_{j,i} & \text{if } InRate_{j,i} = 0 \\ w_{j,i} & \text{otherwise} \end{cases}, \tag{9}$$

when K_{cong} is equal to α this means that is high probable that a certain level of congestion can be measured on the considered lane. Therefore, it is important to give a different weight on the lane advising other vehicles about this situation. This message is exchanged by protocol starting from RTM.

5. Simulation Results

In this section, we show the results achieved using the Smart Traffic Management Protocol (STMP), that we have already introduced in above sections comparing it with the Wave Short Message Protocol (WSMP) and the Cooperative Awareness Message (CAM). First of all we have to introduce the simulation environment and used constraints in order to better understand achieved results.

5.1. Network Simulator

OMNet++ [13] Simulator with Veins [14] framework has been used to develop our proposal. It is a network simulator based on a modular implementation written in C++. To manage vehicles' mobility, the network simulator is connected with SUMO [15]. Our implementation, STMP has been written on the Veins framework introducing protocol rules and some important components of the system such as RSU and RTM. The aims of this section is to show the goodness of the proposal in terms of traffic management and the reduction of CO_2 emissions. Using the whole framework composed of on-board device collaboration and STMP it is possible to better spread traffic load along the city. It is also possible to view that the protocol help vehicles to reduce their travelling time around the city. The Simulation Parameters and the Congestion Parameters are the following (Tab. 1).

Tab. 1: Simulation table.

Parameter Name	**Values**
Map Size	1.5 [km^2]
Average road length	30 [km]
Average vehicle length	2.5 [m]
Maximum Speed of vehicles	15 [m·s^{-1}]
Vehicle In-Rate	[2, 3, 4, 5]·10^2 $\left[\frac{vehic.}{h}\right]$
K_{speed}	0.35
δ	0.35
Th_{cong}	3
α	1
β	2

In order to evaluate the protocol performances we made a comparison among protocol proposal and the WSMP used for disseminate signalling message along the network, in particular when an accident is found or global information has to be spread along the network. It is important to recall that the WSMP is used to disseminate Wave Short Message (WSM) that are designed to carry signalling data and in further develops to also carry services and applications data ([16], [18]).

1) Signalling Packets

In this simulation scenario, we focus on the protocol overhead reduction. In particular, we are going to show the flooding reduction of protocol messages in case of PosUpdate that will give us the possibility to save a lot of resources reserving them for data transmission. In this scenarios, we planned to use several vehicles that travel along the map roads and to demonstrate the goodness of the proposal we use a version of the protocol without neighbours management and the version equipped with neighbour management. In Fig. 3 is possible to see the total amount of packets in the network when the geocasting based rules are used to disseminate data along the network.

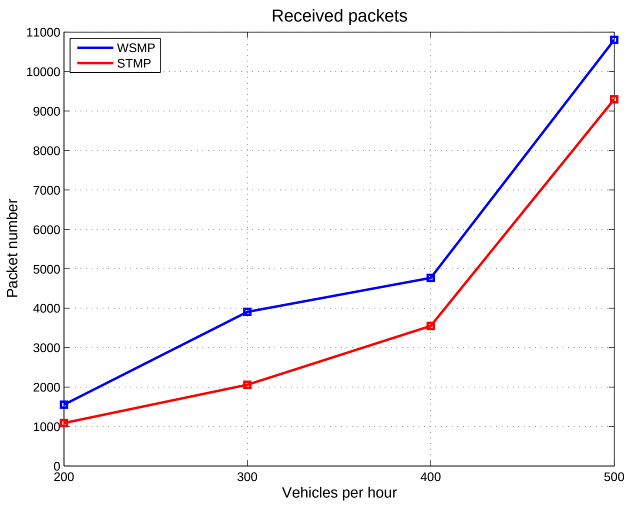

Fig. 3: Average number of received messages per node.

2) Effects on Air Pollution

This simulation campaign aims to demonstrate that using communication and making an efficient cooperation among entities that share the same applicative context it is possible to reach important results for the communities. Thanks to this approach it has been possible to reduce the total amount of CO_2 emissions and the average travelling time and increasing the average speed of the vehicles into the urban area as well. As it is analysed in [3], it is possible to note that avoiding accelerations and decelerations a CO_2 emissions reduction is obtainable.

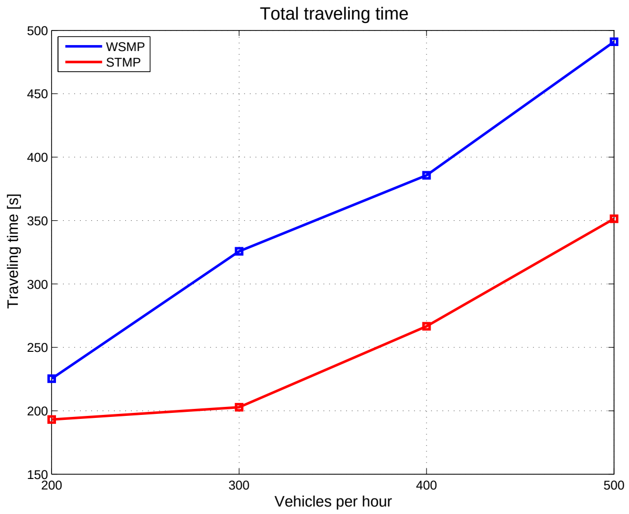

Fig. 4: Average traveling time.

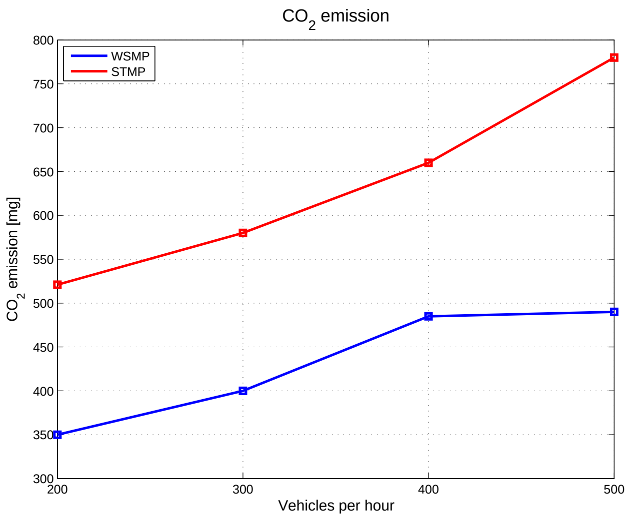

Fig. 5: Average CO_2 emission.

3) Traffic and Congestion Management

In this simulation campaign, we show the benefits of the proposal in terms of traffic management, especially in the case of accidents or when something goes wrong on the lanes. In the first approach, we used the goodness of the idea has been evaluated. In particular, we added some accidents that involve several vehicles along the roads. The accidents we added in are spread along the urban area in order to distribute blocks on several districts of the city observing how the traffic moves around the city rearranging loads on the neighbour roads. We considered the impact of the traffic balancing when STMP protocol is used. Observing Fig. 6 it is possible to carry out some considerations. First of all we can state that the STMP protocol solves congestion issues finding several exit gates allowing vehicles to recalculate paths when the first signals of congestion are also triggered by the monitoring functions included in the overall system. In the beginning the protocols behaviour are comparable but also in this first period the protocol carries out a better behaviour.

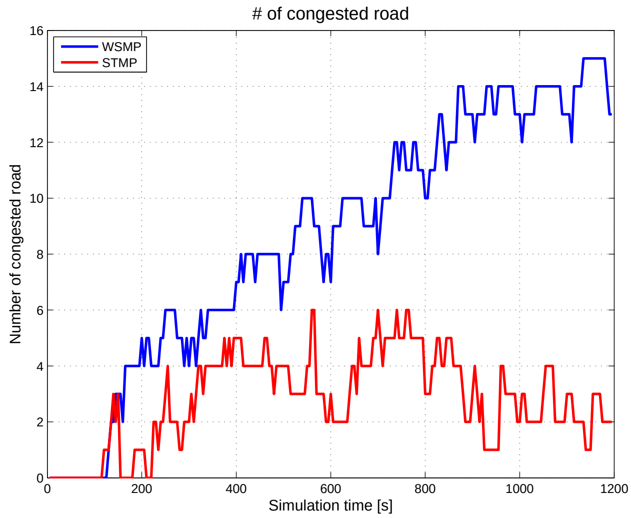

Fig. 6: STMP congestion avoidance behaviours.

In Fig. 6 the number of congested road is given by the sum of the overall city roads that results congested in the observing time. Therefore, as it is possible to note the STMP performs better than WSMP based protocol where only signalling messages such as collisions and warning messages are provided. Moreover, as already stated the congestion can be better managed if it is treated at the beginning of the first events that can cause blocks in the city areas. In Fig. 7 the performance of our proposal versus a CAM based protocol is made [16] and [17]; this protocol tries to manage congestion exploiting the warning and signalling messages to recognize events that may generate congestion in some area or blocks of the city. It is possible to note that our approach performs better reducing the number of congested roads. This is made because it acts previously than other one. In fact, using an efficient monitoring it can notice drivers about changing of the road status. This system helps us to reduce the incoming rate on the congested roads allowing road to keep a good ratio between the vehicles that are coming and those that exit from the road.

4) Total Distance and Total Time Traveled

In this last campaign we have evaluated the performance of the protocols in the term of the total distance travelled by vehicles and total travel time of vehicles. As it is possible to note from Fig. 8 the total distance of the vehicles is higher with the proposal protocol because the STMP reduces congestion and blocks suggesting a route change to the vehicles that are closer to the involved area. Different performances are shown when the traffic loads increase. In Fig. 4 it is possi-

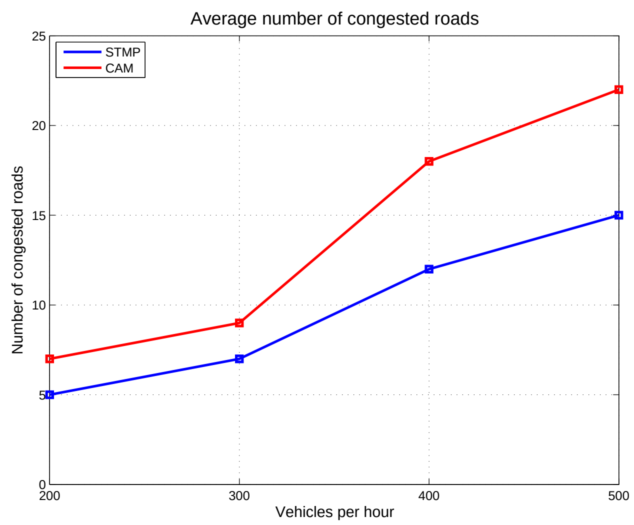

Fig. 7: CAM vs. STMP in term of average number of congested road.

ble to note that the total travel time decreases with the proposed protocol because the STMP avoids road blocks and reduces road congestion by use Traffic and Congestion Management.

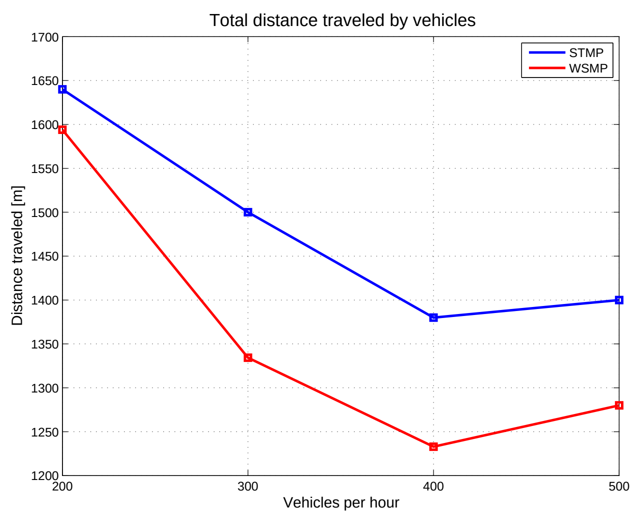

Fig. 8: Average distance per vehicle.

6. Conclusions

The IEEE 802.11p based protocol presented improves the management of the traffic and reduces the total number of the packets sent on the network using a more efficient dissemination technique based on geocasting distribution. In fact how demonstrated into simulation campaigns, some information are important only for those nodes closer to the interested area of the critical event. Integration of on-board devices such as the OBU with the external devices such as monitoring devices, allows us to reach better performances. Spreading information collected by the on-board devices, the behaviour of behind and beyond vehicles is influenced. Finding new routes that allow drivers to reduce travelling time and to increase the average speed it is possible to reduce emissions. As depicted in the simulation results section, these advantages for the drivers bring up an indirect advantage for the air quality of the city reducing the total emissions of CO_2 gas. In this work, another subject of the simulation was the evaluation of the system in terms of protocol overhead, CO_2 level and congestion areas. Results of the simulations show that the proposed protocol enhances many quality indexes managing traffic in a better way addressing congestion before it reaches critical level.

References

[1] BARBA, C. T., M. A. MATEOS, P. R. SOTO, A. M. MEZHER and M. A. IGARTUA. Smart city for VANETs using warning messages, traffic statistics and intelligent traffic lights. In: *IEEE Intelligent Vehicles Symposium (IV)*. Alcala de Henares: IEEE, 2012, pp. 902–907. ISBN 978-1-4673-2119-8. DOI: 10.1109/IVS.2012.6232229.

[2] TAHERKHANI, N. and S. PIERRE. Congestion control in vehicular ad hoc networks using meta-heuristic techniques. In: *Proceedings of the second ACM international symposium on Design and analysis of intelligent vehicular networks and applications*. New York: ACM, 2012, pp. 47–54. ISBN 978-1-4503-1625-5. DOI: 10.1145/2386958.2386966.

[3] KATSAROS, K., R. KERNCHEN, M. DIANATI, D. RIECK and C. ZINOVIOU. Application of vehicular communications for improving the efficiency of traffic in urban areas. *Wireless Communications and Mobile Computing*. 2011, vol. 11, iss. 12, pp. 1657–1667. ISSN 1530-8677. DOI: 10.1002/wcm.1233.

[4] CAPPIELLO, A., I. CHABINI, E. K. NAM, A. LUE and M. A. Zeid. A statistical model of vehicle emissions and fuel consumption. In: *IEEE 5th International Conference on Intelligent Transportation Systems (IEEE ITSC)*. Singapore: IEEE, 2002, pp. 801–809. ISBN 0-7803-7389-8. DOI: 10.1109/ITSC.2002.1041322.

[5] SANGUESA, J., M. FOGUE, P. GARRIDO, F. J. MARTINEZ, J.-C. CANO and C. T. CALAFATE. Using topology and neighbor information to overcome adverse vehicle density conditions. *Transportation Research Part C: Emerging Technologies*. 2014, vol. 42, pp. 1–13. ISSN 0968-090X. DOI: 10.1016/j.trc.2014.02.010.

[6] CORDESCHI, N., D. AMENDOLA and E. BACCARELLI. Primary-secondary resource-management on vehicular networks under soft and hard collision constraints. In: *Proceedings of the fourth ACM international symposium on Development and analysis of intelligent vehicular networks and applications (DIVANet 2014)*. New York: ACM, 2014, pp. 161–168. ISBN 978-1-4503-3028-2. DOI: 10.1145/2656346.2656362.

[7] DE FELICE, M., A. BAIOCCHI, F. CUOMO, G. FUSCO and C. COLOMBARONI. Traffic monitoring and incident detection through VANETs. In: *11th Annual Conference on Wireless On-demand Network Systems and Services*. Obergurgl: IEEE, 2014, pp. 122–129. ISBN 978-1-4799-4937-3. DOI: 10.1109/WONS.2014.6814732.

[8] DOBRE, C. Using Intelligent Traffic Lights to Reduce Vehicle Emissions. *International Journal of Innovative Computing, Information and Control*. 2012, vol. 8, no. 9, pp. 6283–6302. ISSN 1349-4198.

[9] FAZIO, P., F. DE RANGO, C. SOTTILE and A. F. SANTAMARIA. Routing Optimization in Vehicular Networks: A New Approach Based on Multi-objective Metricsand Minimum Spanning Tree. *International Journal of Distributed Sensor Networks*. 2013, vol. 2013, iss. ID598675, pp. 1–13. ISSN 1550-1477. DOI: 10.1155/2013/598675.

[10] FAZIO, P., F. DE RANGO and C. SOTTILE. A new interference aware on demand routing protocol for vehicular networks. In: *International Symposium on Performance Evaluation of Computer and Telecommunication Systems, SPECTS*. Hague: IEEE, 2011, pp. 98–103. ISBN 978-1-4577-0139-9.

[11] FAZIO, P., M. TROPEA, F. VELTRI and S. MARANO. A new routing protocol for interference and path-length minimization in vehicular networks. In: *IEEE 75th Vehicular Technology Conference, VTC Spring*. Yokohama: IEEE, 2012, pp. 1–5. ISBN 978-1-4673-0989-9. DOI: 10.1109/VETECS.2012.6240292.

[12] FAZIO, P., F. DE RANGO and C. SOTTILE. An on-demand interference aware routing protocol for VANETs. *Journal of Networks*. 2012, vol. 7, no. 11, pp. 1728–1738. ISSN 1796-2056. DOI: 10.4304/jnw.7.11.1728-1738.

[13] VARGA, A. and R. HORNIG. An overview of the OMNeT++ simulation environment. In: *Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems workshops*. Brussels: ICST, 2008, pp. 1–10. ISBN 978-963-9799-20-2.

[14] SOMMER, C., R. GERMAN and F. DRESSLER. Bidirectionally coupled network and road traffic simulation for improved ivc analysis. *IEEE Transactions on Mobile Computing*. 2011, vol. 10, no. 1, pp. 3–15. ISSN 1536-1233. DOI: 10.1109/TMC.2010.133.

[15] KRAJZEWICZ, D., J. ERDMANN, M. BEHRISCH and L. BIEKER. Recent development and applications of sumo - simulation of urban mobility. *International Journal On Advances in Systems and Measurements*. 2012, vol. 5, no. 3&4, pp. 128–138. ISSN 1942-261x.

[16] FAZIO, P., F. DE RANGO and A. LUPIA. Vehicular Networks and Road Safety: an Application for Emergency/Danger Situations Management Using the WAVE/802.11 p Standard. *Advances in Electrical and Electronic Engineering*. 2013, vol. 11, iss. 5, pp. 357–364. ISSN 1804-3119. DOI: 10.15598/aeee.v11i5.890.

[17] FAZIO, P., F. DE RANGO and A. LUPIA. A new application for enhancing VANET services in emergency situations using the WAVE/802.11p standard. In: *6th IFIP/IEEE Wireless Days Conference (WD)*. Valencia: IEEE, 2013, pp. 1–3. ISBN 978-1-4799-0542-3. DOI: 10.1109/WD.2013.6686517.

[18] LI, Y. *An Overview of the DSRC/WAVE Technology*. Heidelberg: Springer, 2012, pp. 544–558. ISBN 978-3-642-29221-7.

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