

Preventing urban traffic congestion using VANET technology in urban area

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Abstract. Urban mobility is one of the most important factors in the development of any nation and can act as a strong stimulant for economic expansion. Moreover, the rapid urban population growth in recent years has resulted in a substantial rise in the number of urban vehicles. But, the infrastructure on urban routes frequently isn't adequate for a big number of urban vehicles. This inadequacy leads to several problems, including road insecurity, time loss and pollution. Congestion is one of the biggest issues and a significant hindrance to the road transportation system. In order to maximize the efficiency of the existing road network infrastructure, one idea is to leverage modern communication technologies to transmit traffic data, including the locations of accidents and risky road conditions. As a result, the congestion prevention system (CPS) presented in this study can assist drivers in improving their travel. CPS would be the best option for cutting down on travel time and fuel usage, avoiding traffic jams and lines, and ensuring that the current road infrastructure is used more effectively. The CPS is based on a methodology that examines accurate and valuable real-time traffic data. Experimental results for reducing urban traffic congestion have been highly encouraging according to the simulation of the system under various scenarios. We intend to include artificial intelligence in our system in future studies to improve it.

1 Introduction

Worldwide rapid urbanisation is leading to an ever-increasing number of vehicles on the road, particularly in developing countries [1]. This increasing number of vehicles in circulation is not always matched by an abyssal growth in terms of urban road infrastructures, resulting in enormous traffic jams in cities such as Lagos, Cairo, New Delhi, etc. However, traffic jams have many detrimental effects on population density, urban economics, city perception, quality of life for residents, and even social and ecological development. In fact, the majority of the time wasted in traffic is not employed for work or recreation. Traffic congestion has a very high economic cost since, in addition to the time wasted, it wastes a significant amount of energy, increases pollution, impairs attention at work, lowers productivity, and raises stress levels. Congestion has various causes among which the primary ones include the rising volume of traffic brought on by that of urban transportation demand. In the context of emerging smart cities, infrastructural possibilities to reduce this urban phenomenon include road construction and expansion, installing intelligent traffic light systems or building

an intelligent roundabout [2]. These solutions cost a lot more to maintain continuously and require more room for construction. In order to improve driving, especially in the most difficult scenarios, another option would be to deploy driver aid systems and supply more information. However, in practice, these choices may not always result in the reduction of either travel time or fuel usage that is desired. The system must therefore have the ability to analyze, interpret, and use real-time gathered data, as well as adhere to the most pertinent recommendations, in order to resolve this issue. However, the development of intelligent transportation systems (ITS) depends on their ability to communicate effectively and reliably. [3]. In this regard, vehicle ad hoc networks and intelligent transport systems are of special interest (VANETs).

One of the most crucial ITS technologies, VANETs uses wireless communications to increase the usability, efficiency, and safety of road transportation [4]. They are basically based on MANETs, which are mobile ad hoc networks that can benefit from quick two-way communication between only vehicles (V2V) or between vehicles and infrastructure (V2I) [5, 6]. This enables it possible for them to play a significant part in offering cutting-edge services and solutions in the road transportation industry

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[7, 8]. In order to optimize the more effective and secure use of road infrastructure, VANETs are able to provide reliable traffic data in real-time. Due to their low latency, DSRC (dedicated short-range communications) are used by VANETs to broadcast high-speed messages in numerous directions, although their coverage is relatively constrained [2]. Researchers have proposed V2V communication for automobiles to connect with roadside units (RSUs) in order to solve this issue, and VANETs do not need a significant expenditure to be put into place [8, 9]. Vehicles utilizing VANETs can benefit from a variety of location technologies with great accuracy, whether it be relative or even global position, in addition to high-speed communication at a low-cost [5]. The VANET-based Congestion Prevention System (CPS), which is suggested in this work, intends to prevent traffic jams for a most effective and efficient use of the current road network by examining real time gathered data [2].

Following this paper remainders' structure: In the 2nd section, we make a critical analysis of related works. Then in sections 3 and 4, we present in detail our system and experimental results, respectively. Finally, section 5 will conclude our paper.

2 Related work

The problem of road congestion in urban areas is one of the oldest and most worrying for urban mobility and sustainability. Faced with the exponential growth of road vehicles quantity in recent decades, the infrastructure has often not been developed to effectively meet this growing demand [2, 10]. Such a configuration poses numerous problems in several respects, including road safety, loss of time and pollution, and many others directly linked to the aggravation of road congestion. The scientific community in all fields is working hard to produce results that will help in the design and planning of infrastructure to limit this phenomenon.

One of the solutions proposed to limit congestion phenomenon is to optimise the deployed traffic lights at road junctions by analysing the real-time collected traffic data [8]. This approach has the advantage of minimising the loosing time at an junction and maximising the cars number crossing that junction. On the other hand, the whole traffic lights from various road junctions must be synchronised traffic flow improvement in every directions [2]. But, the local synchronisation of the traffic lights of one intersection with the others will affect them all in the network of roads. Thus, the desired optimisation may not be attempted at neighbouring intersections causing more congestion. One attempt to remedy this problem, as proposed by researchers, is to favour high-demand roads. The latter strategy becomes ineffective when traffic is heavy or when there are special events including temporary changes or road closures favoured by construction, accidents, etc. This problem alternative would consist of using new information and communication technologies (ICT) to collect and transmit traffic data in real-time like conditions and accident locations data, for dynamic and therefore efficient use of the given infrastructure. Thus, a system of

adaptive traffic light control based on V2V communication has been proposed by [11]. This system has the advantage of reducing the waiting time of vehicles at junctions and the queue lengths in traffic jams.

In relation to smart cities, C.T. Barda et al. [8] proposed a VANET framework that includes intelligent traffic lights (ITLs) with the function of collecting the passing vehicles' traffic information, and maintaining city traffic statistics data, then sending them to automobiles. In addition, ITLs send alerts to vehicles wishing to use a lane in the event of an accident to avoid further collisions and congestion. M. Fogue et al. [12] presented the design of the e-NOTIFY system that allows automatic detection, warning and assistance in case of road accidents based on the capabilities offered by new vehicle-to-vehicle communication technologies. The system is designed to improve post-crash care through the rapid and best management of upcoming emergency resources, thereby increasing the success of treatment of associated health emergencies and the survival of people injured in road accidents.

For detecting road traffic jams, R. Bauza et al. [9] have a system called COperative Traffic congestion detECTION (CoTEC) consisting of a cooperative V2V communications-based technique and fuzzy logic without any sensor infrastructures deployment. M. Milojevic and V. Rakocevic [13] presented an algorithm for detecting and quantifying traffic congestion levels in a fully distributed way. The algorithm they proposed ensures that a minimum amount of data is sent to help reduce the load on the network. This is particularly important for VANETs where many different applications operate on an exhaustive channels.

By revising the routes of cars whose existing routes contain the stopped road segment only after an en-route event occurs, the authors of [14] suggested MNTR would lessen the computational complexity. Given that these cars will only be rerouted twice, it is important to note that MNTR uses a two-step rerouting process (i.e. the allocation of the next turn and then the complete recalculation of the route). As a result, MNTR can significantly cut the average travel time with only a small adjustment to route allocation.

A. Akabane et al. [15]. on the other hand propose a people-centred approach to managing vehicle traffic in urban centres, which they call APOLO. Its main approach is to periodically analyse the Spatio-temporal parameters of drivers' mobility patterns to manage vehicle traffic flow in urban areas. Better yet, APOLO could reduce the idle time (about 50%) and travel time (about 17%) by slightly increasing the total travel distance [2].

Based on the literature research, our primary goal is to create an able CPS to aid drivers in having a best trip, avoiding lengthy lines and congested places, and reducing travel time/fuel consumption while maximizing the flow of traffic. But, the system requires more information than just the vehicle's location and final destination. For this, we employ VANETs to communicate information between vehicles and sensing equipment as well as among the vehicles themselves in order to gather and analyze all the essential data on driving conditions in real-time.

3 The proposed system

The best route based on distance can be found using the most recent navigational technology. However, the path is no longer regarded as optimal; perhaps it becomes the longest path when there is an incident obstructing traffic or when the its flow exceeds the capacity of the road infrastructure. In this instance, optimality is actually focused on minimizing losses as opposed to maximizing gains [2]. The aim of the proposed system consists to find the best path depending on the situation, avoid congestion and long queues, reduce travel time, reduce stopping times at each roundabout or intersection, and finally maintain traffic flow throughout the road network, without any investment in road infrastructure. By operating this system, it could also help in reducing: fuel consumption, waiting time, greenhouse gas emissions, traffic jams, and driving stress while improving road safety.

3.1 Methodology

Searching for an optimal route requires firstly the collection of information about the infrastructure and the traffic to analyse it. So, the first step of our method begins by recognising the road map given by figures 3.1 and 3.1.

On the other hand, gathering and analyzing data can be a highly challenging procedure, particularly if the route covers a significant region. We shall segment the map into discrete regions for this purpose based on their capacity and geometric characteristics. This split of the map, as seen in figure 2, enables calculations in each area simultaneously, which will improve the functionality of our system, particularly while looking for the best course of action. As a result, rather than the whole map being depicted by a unique graph, each zone will instead be depicted by a specific graph along with a global graph, where the vertices represent the zones and the edges represent the best routes connecting each zone to its neighbours.



Figure 2. Example of the division of map for a given urban study area

The second step is to collect the trip information for all vehicles and record it in the database as shown in figure 3.1. Only two route IDs, the change of date & time are recorded in the HistoryTrips database for each car when there is a route change. This information is used as a foundation to estimate the movement of the vehicles in the following phase. The database design employed in our simulations is the same as that in the publication. [2].

The third step consists of predicting the travel time for a specific road at a given time. For example, in figure 3.1 The car (C) on road R0 at time t0 has four options: either to go to roads R1, R2, or R3 or to return to road R0. If none of these options is taken, the chosen road will be that having the shortest travel time when the car reaches it. To achieve this, we need to know how long it will take at t1 for routes R0, R1, R2, and R3. If route R3 is picked, we also need to know how long it will take at t2 for routes R4 and R5, and so on.

Therefore, it is important to first estimate how many vehicles are expected to be on a road when a vehicle arrives at that road in order to compute the travel time of that route. To do this, we employ the recursive function "getNbrVehicle," which computes the time difference between the projected arrival time of the vehicle and the road's travel time. If the outcome is adverse, the function returns the number of cars currently on the road. If this is not the case, we use historical data indicating the date and time to calculate the probability of passing the road. We then use the same function to calculate the expected number of vehicles for each adjacent road using the already calculated difference as input length. Finally, we add the probability times to this calculation to determine the number of vehicles for all adjacent roads.

Finally, we discover the best route between the vehicle's current location and its destination using Dijkstra's algorithm [16, 17]. The straightforwardness of Dijkstra's algorithm's implementation and its effectiveness in static graphs are two justifications for employing it. In order to establish the areas through which a car should pass, the first step in determining the ideal path is to find the global graph's shortest path between the location of the vehicle and the destination. The next stage is to identify graph with the shortest path that connects the vehicle's current location to the previously identified adjacent area.

3.2 Proposed architecture

The planned strategy can only be put into practice if our architecture is able to deliver value-added services. Consequently, VANETs form a substantial part of our architecture. As a result, each zone in figure 3.1 must have a roadside unit (RSU) connected to server that manages and stores data in databases. This is because the road map will be split into many zones (see figure 2).

4 Experiments and results analysis

According to the literature review, several tools have recently been used for road traffic simulation. Each of these

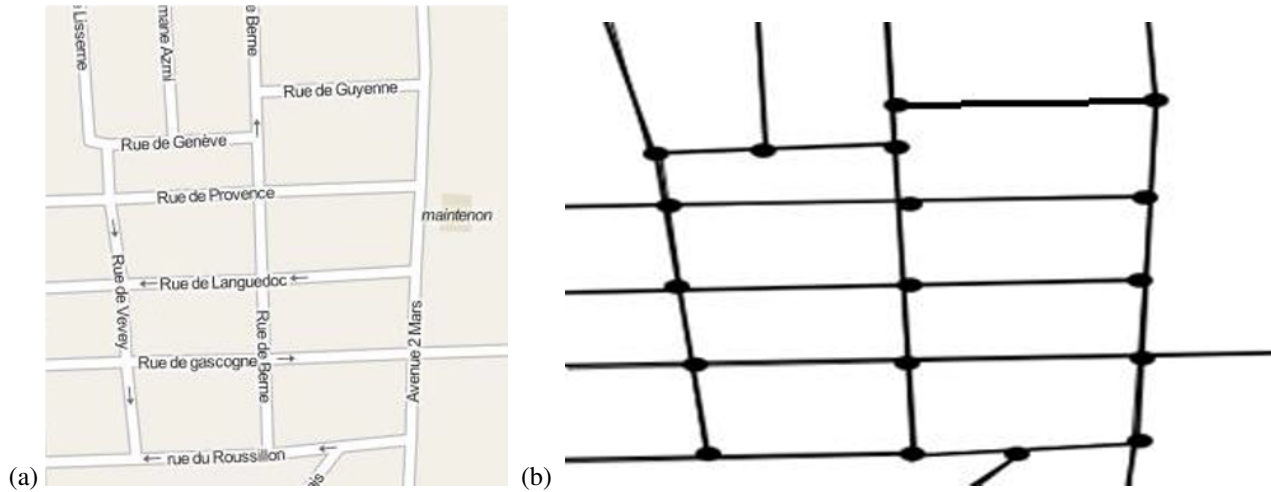


Figure 1. Visualizing the (a) chosen map part (b) its graph: the edges correspond to the roads and the vertices to the intersections of roads.

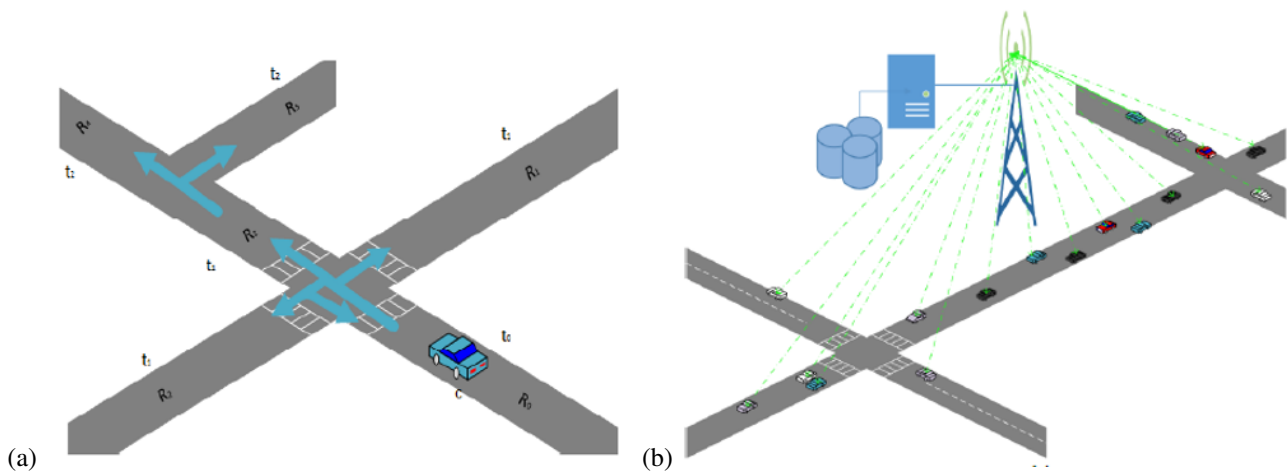


Figure 3. Illustration of (a) the different possibilities at the junction for a vehicle arriving and (b) the system architecture.

tools has peculiarities that differentiate it from another. As the aim of our research is a global control of the environment simulation, the most suitable tool is the Urban Mobility Simulation (SUMO) platform [2, 18]. SUMO is an open-source software simulator for use with microscopic traffic flows, designed to handle large real-world road maps. SUMO is used in conjunction with OpenStreetMap to simulate traffic in many locations across the world, with a focus on the urban setting, which is most frequently plagued by congestion issues that reduce the effectiveness of urban movement and degrade the environment. The SUMO tool also can function as a server to provide a dynamic Traffic Control Interface (TraCI) simulation [19]. This dynamic simulation through the TraCI interface uses the TCP protocol which therefore allows for scenario change during run-time.

4.1 Simulation protocol

For testing the efficiency of our system, we consider a real map like the one shown in "Figure 2" and an esti-

mated number of 10,000 cars to obtain a dense traffic. We also take into account a number of simulation scenarios to demonstrate the effect that the integration of our system will have on the traffic. We chose a precise number of vehicles at random for each of these situations, placing them in various simulation phases and map locations. The chosen cars employ our technology to identify the best course of action, while the other vehicles choose the quickest route. We record information on each vehicle's position, speed, and amount of greenhouse gas emissions as we run all scenarios. The following section analyzes this data.

4.2 Results analysis

We analyse and interpret the results obtained in this section by measuring the system performance indicators including average speed, average fuel consumption and average CO₂ emission rate of the different scenarios which are illustrated in figures 4.2, 4.2, and 4.2, respectively.

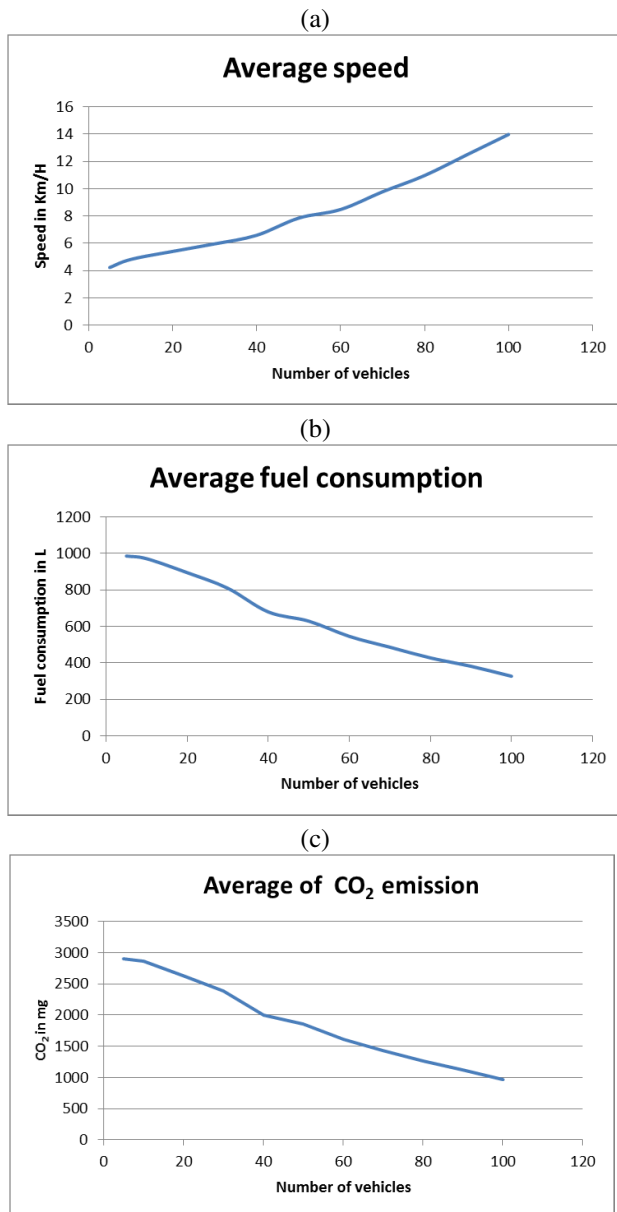


Figure 4. The average speed (a), fuel consumption (b) and CO₂ emission (c) of all vehicles in each scenario

The illustration in figure 4.2 shows the overall average speed the cars in each situation in relation to the number of cars. From this illustration, we can see that as the number of selected cars rises, average speed also increases. This suggests that the selected vehicles' waiting times are getting shorter, which suggests a shorter journey time.

Figure 4.2 shows the journey's average fuel consumption for all cars in each scenario. It highlights the decrease in the average fuel consumption when the number of selected vehicles increases, and the average fuel consumption decreases. This result shows that for the selected vehicles, there is a decrease in travel time.

However, figure 4.2 shows a decrease in the average CO₂ emission as the number of vehicles selected increases. Thus, the saving in fuel consumption shown in figure 4.2 and the reduction in the amount of greenhouse

gas emissions (figure 4.2) would also be due to the minimum travel time of the selected vehicles.

Figure 4.2 shows the CO₂ emissions from traffic when no vehicles are using our system. As can be clearly seen, the critical CO₂ emissions are concentrated on the main roads. Additionally, we show in figure 4.2 the CO₂ emissions of the traffic when 100 vehicles use our system. We notice in this second simulation that the CO₂ emissions are scattered on almost all the roads on the map with very few critical values. The constant increase in road traffic means that existing solutions to improve traffic flow are obsolete or inadequate, but the implementation of our system avoids traffic jams and therefore consumes less energy while reducing CO₂ emissions. Thus, our system has many advantages in terms of economic, environmental sustainability, social and road safety as it reduces long traffic jams on the road which stresses the drivers and leads to accidents.

5 Conclusion

This paper addressed the problem of path optimization in road networks by proposing a CPS-based on a new approach [2, 4]. The proposed CPS is based on an approach to analysing useful and reliable real-time traffic information collection. The used real-time information is provided by the VANET, and the vehicle travel history to obtain the optimal path from source to destination. By segmenting the road network into numerous autonomous zones, the proposed CPS may accommodate very expansive road networks. The obtained simulation results show the enormous potential of the CPS to improve the flow of road traffic. On the other hand, the indicators evaluated by our simulation scores confirm the efficiency of our system. Indeed, it shortens travel times in congested areas, enhancing traffic flow and enhancing road safety. For our future work, we intend to develop and validate the suggested technology by contrasting the outcomes with data from various disciplines.

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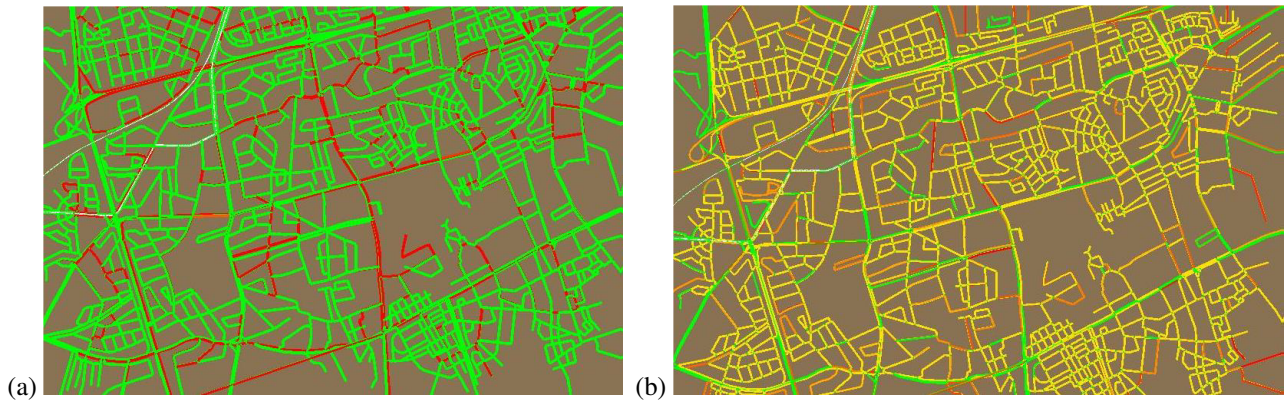


Figure 5. Visualizing CO2 emissions according to the traffic in the first (a) and second (b) scenarios.

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