An Optimization Approach for Emergency Vehicles Dispatching and Traffic Lights Adjustments in Response to Emergencies in Smart Cities

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***Abstract*—The adoption of sensors-based monitoring approaches has opened up a range of possibilities for data recovery, distributed processing, and quality evaluations in urban scenarios. In this evolving scenario, efficient emergency management systems provides a fundamental service for modern cities, exploiting different sensing and processing technologies for the real-time handling of critical situations. Actually, such systems are expected to implement emergency detection, alerting and mitigation services in order to avoid or relieve the negative impacts of critical events on the inhabitants' perceived quality of life. In this sense, after a critical event is properly detected, emergency vehicles may be dispatched as quickly as possible to respond to such detected situations, potentially reducing the probability of deaths and injuries. Therefore, this paper proposes a selection algorithm to dispatch emergency vehicles in smart cities, assuming that emergency alerts are dynamically released exploiting any support system. Then, dispatched vehicles are prioritized as they move on a city, by optimizing the operation of traffic lights. Such an optimization approach is implemented and evaluated using different simulation tools and programming libraries, providing important contributions to emergency management in smart cities.**

***Index Terms*—Emergency Vehicles, Emergency Management Systems, IoT, Smart City, Traffic lights.**

I. Introduction

Urban centers may have to deal with various critical situations on a daily basis, such as traffic accidents, fire outbreaks, urgent patient transport, violent protests, among others. A considerable number of those events can pose a serious threat to the lives of the inhabitants, potentially incurring social and economic instability, environmental crises, or even affect the political relations among urban entities [1]. Hence, in order to avoid such catastrophic situations, the negative effects of critical events need to be mitigated as soon as possible. For this, it is necessary to perform efficient planning when dealing with the most common emergencies, in addition to acting quickly to reduce possible losses of human lives. In this way, Emergency Management Systems (EMS) must work in a symbiotic manner with other sub-systems for more efficient functioning, although some urban mobility challenges can directly (positively or negatively) interfere with the performance of those systems.

Urban mobility is directly linked to several problems found in modern cities. Among such problems, we can highlight traffic congestion, air and noise pollution, spatial inequalities and an overall decrease in the quality of life of the inhabitants [2], [3]. Besides, the high density of vehicles traveling on the roads can cause accidents with varying degrees of severity. In this sense, several technologies and paradigms have been proposed in the literature to alleviate these problems and other derivatives. The Internet of Things (IoT) paradigm, Vehicular Ad hoc Networks (VANET) and Intelligent Transport Systems (ITS) are some of the various technologies that can assist in solving the aforementioned problems [4], [5]. Generally speaking, the central idea of IoT is to integrate different technologies and communication solutions, while VANETs propose establishing communication between the vehicles on the roads with themselves or with some infrastructure. Finally, ITS have tools and technologies to deal with various mobility-related problems. Therefore, the efficient combination of these three technologies can be essential to reduce or even mitigate some of the mentioned problems.

Urban mobility issues grow at the same rate as the number of city dwellers increases. According to the study by Mota et al. [6], approximately 40% of the inhabitants of São Paulo (Brazil) spend an average of two hours commuting. This spent time sets in motion a series of critical social and economic events for the cities. The same study showed that the caused disorders produced a high estimated economical loss, representing about 7.5% of the city's GDP (Gross Domestic Product). However, financial disruption is not the only critical factor related to urban mobility challenges. Also noteworthy is the high emission of carbon dioxide (CO_2) in the atmosphere and the increase in traffic accidents. As presented by Lopes et al. [7], particular motor vehicles are responsible for the emission of 60% of CO_2 in the transport sector, potentially contributing to the ongoing global warming [8]. In addition to this problem, traffic accidents also deserve special attention. In particular, according to the World Health Organization (WHO), this type of accident was the 8th largest cause of death in the world in 2016. Still, projections show that in 2030 it will be the 10th largest cause of death worldwide, remaining in the top 10 [9]. In this sense, ITS provide services that can improve traffic efficiency and safety, in multiple aspects, with some works in the literature addressing different mobility-related problems.

Therefore, the contributions of this work are twofold. First, an algorithm for automatic assignment of Emergency Vehicles (EV) is proposed, considering three basic vehicles types: ambulances, fire trucks and police cars. For that, we exploit the emergency alarm system defined in [10] (for scalar data) and [11] (adding visual information), which issue emergency alarms that are used as input into the proposed dispatching algorithm. Second, since emergency vehicles could be delayed while attending an emergency alarm, we also propose an optimization approach for the traffic lights that are in the way of the selected routes, in order to prioritize emergency vehicles and reduce their trip time. For both proposed approaches, we intend to reduce the delay between an emergency alarm and the effective team assignment to respond to that alarm, potentially increasing the efficiency of this type of emergency management service in smart cities.

The proposed algorithms are implemented and simulated using the combination of OMNet++ [12], VEINS (Vehicles in Network Simulations) [13] and SUMO (Simulation of Urban Mobility) [14] tools, considering the mid-size Brazilian city of Campinas as reference. Such proposals and evaluations have not been proposed before, to the best of our knowledge.

The remainder of this paper is organized as follows. In Section II, related works concerning emergency vehicles in urban areas are discussed. Section III presents the basic foundations for the functioning of the proposed approach. The proposed algorithms and procedures are presented in section IV. Section V presents the preliminary results of this work, followed by the conclusions and references.

II. Related works

When an incident is identified, usually the first thing to do is to call a responsible agent to respond to the call [23]. If someone informs the call center that a fire is occurring, the fire brigade is immediately activated and a fire truck is sent to extinguish the flames and make the first calls to the survivors. When the triggered emergency refers to a traffic accident with possible victims, an ambulance is sent to the scene to provide first aid and refer the victims to the nearest hospital, if necessary. In both situations, police officers are also sent to the sites to control the population and/or organize traffic, preventing incidents from getting worse and reaching other people. For such complex scenarios, several applications of Emergency Management Systems (EMS) have been proposed in the literature in order to assist teams in different ways, as discussed in this section.

There are different technological approaches to be considered for emergency management. For example, the Radio Frequency Identifier (RFID) is a technology widely used in IoT applications, supporting automatic identification, storage and retrieval of data remotely, through a sticker pasted on the object of interest [16]. Because it has a simple implementation architecture (basically requiring a tag, a reader, and a host computer or middleware), and in conjunction with other technologies (sensors, actuators, etc.), RFID is widely used in computing environments, ITS and IoT [24]. In this context, the work in [15] makes use of RFID tags to support the development of a congestion control system to facilitate the movement of ambulances on the roads. When this type of vehicle approaches an intersection, the system performs the identification and changes the traffic light to "green", causing traffic to flow in that direction. Following the same line of application, the work in [16] proposed a traffic control system that also makes use of RFID tags that identify emergency vehicles (fire trucks and ambulances were cited) when they approach an intersection, changing the flow direction to "free" (green light), reducing the intensity of congestion on that specific path.

Tozan and Donmez [17] proposed the use of genetic algorithms to determine the minimum number of ambulances that should be at emergency stations and also to maximize population coverage considering the limited number of available ambulances. The proposed algorithm deals with the problem of the set of coverage (Set Covering Problem - SCP) or maximum location of coverage (Maximal Covering Location Problem - MCLP). Although the computational cost is high, the use of evolutionary algorithms provides relevant results for coverage problems, which can achieve a maximum (or minimum) global solution, instead of stopping at local (or minimum) maximums, exploring other regions in space search engine [25].

The use of Deep Learning (DL) or Deep Neural Network (DNN) techniques has become a strong tendency to deal with various problems involving emergency vehicles. For example, the use of Convolutional Neural Networks (CNN) are often considered in the area of processing/identifying objects in visual data (images or videos) [26]. In this way, CNN can be used to identify ambulances in chaotic traffic scenarios, like India [18]. In that work, the authors used a CNN architecture called SSD Mobilenet, which allows quick detection of objects in an image, in addition to working in environments with limited computational power. In addition to this detection system, the authors also used an algorithm that identifies sounds, more precisely from ambulance sirens, which act as a filter for false positives, serving as support for the object detection architecture. In other words, the proposed hybrid framework uses the SSD Mobilnet to quickly detect ambulances in the middle of several vehicles, using visual information, together with sound data used to validate that the detected object is in fact an ambulance.

Differently, the work in [19] was based on the Cooperative Intelligent Transport Systems (C-ITS) for emergency vehicles, which developed the efficient domain range for emergency vehicles on C-ITS, optimizing service time in an emergency situation. In addition, they proposed the implementation of the security process applied to C-ITS vehicles and the authorizations to exercise the right of way for emergency vehicles, in order to mitigate the potential risks of cyber attacks and acts

TABLE I: Comparison between the application domain, applied technologies and the main benefits of related works.

Work	Application domain	Application technologies	Application benefit
[15]	Congestion control system	RFID	Traffic flow relieving
[16]	Congestion control system	RFID	Traffic flow relieving
[17]	Optimization	Genetic Algorithms	Minimum required ambulances in a base station
[18]	Object detection	Convolutional Neural Network	Quick detection of objects in an image
[19]	ITS	-	Security in data transfer
[20]	EMS/Optimization	Ant Colony Approach	Dispatching and coverage
[21]	ITS	VANET	Fast route for emergency vehicles
[22]	Traffic management system	VANET	Quick rescue operation
[23]	EMS	Priority-based algorithm	Automatic vehicle assignment
Our approach	EMS	Algorithms, actuators and VANET	Vehicle dispatching and traffic lights adjustments

of sabotage, as well as in cases of Relevant usage has been subjected to an Extended Failure Mode and Effects Analysis (FMEA) to assess the inherent openings that can be exploited by cyber attacks.

The article proposed by Ibri et al. [20] applied a basic sequential algorithm, which is a coupled ant colony system (Ant Colony System - ACS) based on the taboo search heuristic, as a parallel solution to solve an integrated dispatch and coverage problem of an emergency vehicle fleet management system. To streamline the process, an algorithm tuner was used, and an adapted version of the master-slave ACS was developed based on the parallel neighborhood assessment approach for the taboo search procedure. To validate the experiment, the authors used the "pure" version (synchronously) and compared it with the tuned (asynchronous) version, concluding that the first strategy improves the quality of the solution and the execution time.

The work of Petrov et al. [21] resorted to the implementation of Ad Hoc Vehicle Networks (VANETs) based on V2X, in order to strengthen road safety and create conditions for a fast and reliable route for emergency vehicles. For this purpose, the emergency vehicle approach alert system was used, guaranteeing privacy (PEEV-WS) based on requirement analysis. Despite assisting in the formation of an emergency route without obstacles, the system was unable to maintain the available emergency route.

Still considering this trend, the work in [22] proposed the use of a Vehicle Network (Vehicle Network - VN) at Fog, based on the software-defined network (SDN) that can support the use of fog-enabled VN services on a large scale. Given the diversity of use of VN in Fog, the design principles for Vehicle Software Defined Networking (VSDN) enabled for Fog were adopted, focusing on the perspectives of systems, networks, and services. These techniques were used in a traffic management system for emergencies, to provide a quick rescue of emergency vehicles, based on real traffic accident data.

The adopted approaches can also have broader applicability. In [23], the authors proposed an algorithm for the automatic allocation of emergency vehicles in crises in smart cities. When a sensor identifies an event (fire, temperature rise, leakage of toxic gases, etc.), it transmits the captured data to a central, which in turn processes the information and sends the number of vehicles required to the incident site to mitigate the occurrence. However, that work considers only the Euclidean distance between the event site and the emergency vehicle, not considering the actual path that the vehicles take.

As can be seen, the RFID technology [15], [16] is widely used for the rapid identification of a vehicle of interest and to release the flow of traffic on that specific path, although other approaches could be applied (such as visual detection of emergency vehicles [27]). The use of neural network techniques [18] also provides interesting tools for detecting objects in chaotic scenarios, but it is not limited to just that. The presence of heuristic optimization methods [17] is also an important factor when the application environment and its known deficiencies are previously considered.

III. Sensors-based emergency detection and alerting

When approaching emergency management in smart cities, sensor-based systems and IoT devices are of great importance to automate such tasks. Such hardware can be used in several approaches and solutions to detect, alert and mitigate emergencies, helping monitoring risk zones and broadcasting critical information to authorities in order to take action on any critical event.

With the advent of the IoT paradigm, sensors and sensor networks have been used to monitor urban environments, retrieving since elementary scalar data such as noise, humidity, temperature and pollution, to more complex data like urban traffic and resources management. When any of the deployed sensors detect an abnormal situation, some application system may be triggered to take some action and fix the problem. This sensor-actuator model is the basis for most emergency management systems in smart cities.

An alarm system must be able to detect an event of interest and forward detailed information about what is happening, for more accurate decision-making by supportive applications. In this sense, what is necessary is a sensors-based approach capable of collecting scalar and visual data from multiple areas, processing them in order to identify abnormal situations. In this paper, such a system is provided by the work described in [10], which will be responsible to release emergency alarms that will be exploited by the proposed algorithms in this paper. The fundamental parts of the reference system presented in [10] are described as follows:

- Event of interest (EI): It is any critical situation that may cause some financial loss or cause risk to people's lives;
- Event report (ER): It is a descriptive report containing all the information and metadata identified by the sensors, comprising their GPS location and the time (timestamp) of the detection;
- Risk zone (RZ): It is a monitoring region that is associated with some type of previously known risk, indicating the severity of an emergency in a given area;
- Emergency alarm (EA): It is the final output of that system, which will be processed in this paper. An alarm contains spatial (GPS coordinates) and temporal (timestamp) information of the emergency, as well a numeric severity index computed using different data. An issued alarm (JSON message) can be exploited in any possible way, by any requesting system.

The exploited emergency management system can be configured according to the characteristics of any considered city, with a high degree of autonomy in its services. If there is a need to deploy more detectors (Events Detection Units - EDU) on areas that historically have a higher risk of emergencies, this can be easily implemented since the services are decoupled. Risk zones also provide a high level of flexibility. For example, industrial regions usually demand a lot of attention from the authorities, especially when dealing with toxic or flammable materials. As a result, these regions can be configured as high-level risk zones. The performed configurations can even go further, for example considering rainy seasons or the presence of hospitals in an area.

Fig. 1 presents the operation scenario of the proposed approach. In that figure, a city can be mapped by specific risk zones, which have different severity levels. In the presented example, a region with factories (red circles) has a high risk of fire, impacting its risk level and the relevance of the eventually issued alarm. Since two or more events may be detected at once, in different zones, an EMS may process such information accordingly.

In the scenario showed in Fig. 1, two events of interest happen simultaneously and are detected in different zones. After this detection, different reports are processed to the computation of two different emergency alarms. Actually, the difference in the expected impacts of the alarms is a piece of critical information that guides the dispatching of emergency vehicles (or any other mitigation service). Then, in the case of a car accident or a fire, for example, different numbers and types of vehicles (ambulance, fire trucks or police cars) can be assigned, depending on the severity level and types of the events reported in the processed emergency alarms.

Therefore, exploiting the highly flexible system described in [10], which already deals with the complex tasks of detecting emergencies and formatting alarms, we could focus on the dispatching of emergency vehicles after an emergency alarm is issued and received by our algorithms, including both the emergency vehicles selection procedure and the traffic lights optimization after those vehicles are dispatched.

Fig. 1: Generic urban scenario for the assigning of emergency vehicles during critical situations.

IV. Proposed approach

Due to the accelerated urbanization process worldwide, emergencies are becoming more and more common. In this complex scenario, this work proposes algorithms to support the maturation of emergency management systems, more specifically addressing mitigation of emergencies by rescue operations. Actually, combining specialized algorithms and some ITS resources, we propose a general mechanism to quickly and efficiently respond to received emergency alarms, with the expected outcome as the selection of emergency vehicles and the implementation of optimization mechanisms on traffic lights.

Fig. 2 presents the logical organization of the proposed approaches, which are further described in the next subsections.

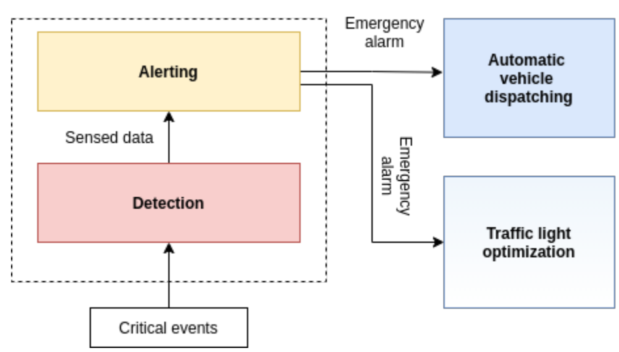


Fig. 2: Proposed approach when mitigating emergencies in smart cities.

A. Dispatching emergency vehicles

When an emergency alarm is received and properly processed, the first proposed service takes place. Then, vehicles are automatically assigned and dispatched to the location of the reported emergency, taking into account the nature of the critical events indicated within the emergency alarm, for example reporting a fire, a police-related incident, a medical emergency or any catastrophic event. Such information is vital when selecting the ideal emergency vehicles to be assigned.

Since we expect that the quick response of those emergency vehicles can directly reduce the probability of economic and human losses, the selection of the most suitable emergency vehicle (and associated response team) is of paramount importance. Therefore, our proposal addresses the dynamic allocation of vehicles to move toward an incident site after it is detected by any emergency alert system that monitors the city, although we believe that sensors-based approaches will be the fastest option in most cases.

Due to scope limitations and the great number of challenges to be handled in this research area, which could be addressed from multiple perspectives, this work was concerned with only three major groups of critical events in an urban context. These groups of incidents, which are very common in modern cities, are described as follows:

- Fire incidents: it is any type of critical event that is generated or may produce fire. This is very common in cities, demanding an immediate response of a fire brigade;
- Health emergencies: some critical situations may put people in danger, demanding the dispatching of ambulances to the affected area. Additionally, health incidents may be reported by individuals in areas with no other emergency, for example when people are suffering a heart attack and need immediate assistance;
- Police-related incidents: urban violence, car accidents, public disturbances and even terrorist attacks will demand quick actions by the police, which will be usually implemented by the dispatching of police cars.

These generic specifications are useful when associating emergency vehicles to emergency alarms, with the important remark that since a single emergency alarm may be comprised of multiple critical events, more than one emergency vehicle may be dispatched at once. Hence, for a received emergency alarm, one or more emergency vehicles may be assigned.

Finally, all vehicles depart from their respective operating stations, which can be a fire brigade, a police station or a health care service (medical clinics, hospitals, etc.). More specifically, we define that vehicles will depart from their operational stations (point A) toward the location of the detected emergency (point B). If necessary, that is, depending on the reported events within the emergency alarm, that vehicle is still sent to treatment centers (point C). This work does not consider the return of vehicles to the operating stations after the completion of the operation, but it could be considered in future versions of the proposed algorithm.

B. Optimizing traffic lights

When some type of emergency vehicle (ambulance, police car or fire truck) goes onto the road, it forwards broadcast messages (using the 802.11p protocol [28]) to all road nodes, which will be others vehicles or one or more RSU (Roadside Unit) implemented in a VANET context. Such messages present its geolocation, the type of vehicle, whether it is in operation or not, the vehicle's route and some metadata that are important to the receivers.

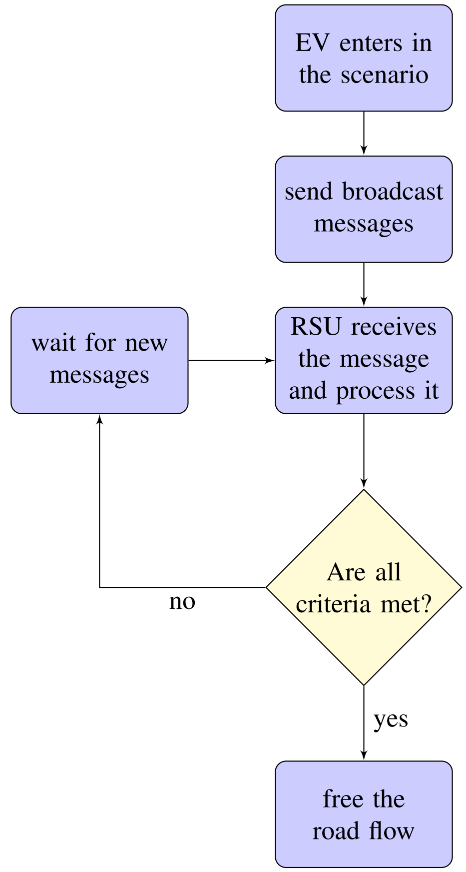


Fig. 3: Flowchart for the optimized traffic light operation in the presence of emergency vehicles.

The defined urban scenario comprises a number of RSU, each one dedicated to performing control functions on an optimized traffic light on the roads. When a vehicle approaches a traffic light, it performs the necessary checks to clear the flow of that road, potentially reducing the travel time of these vehicles. The checks are a) the allowed vehicle type and b) the minimum distance between the emergency vehicle and the next traffic light (see Table II). The algorithm procedure can be seen in Fig. 3.

V. Simulation results

A. Creating the simulations environment

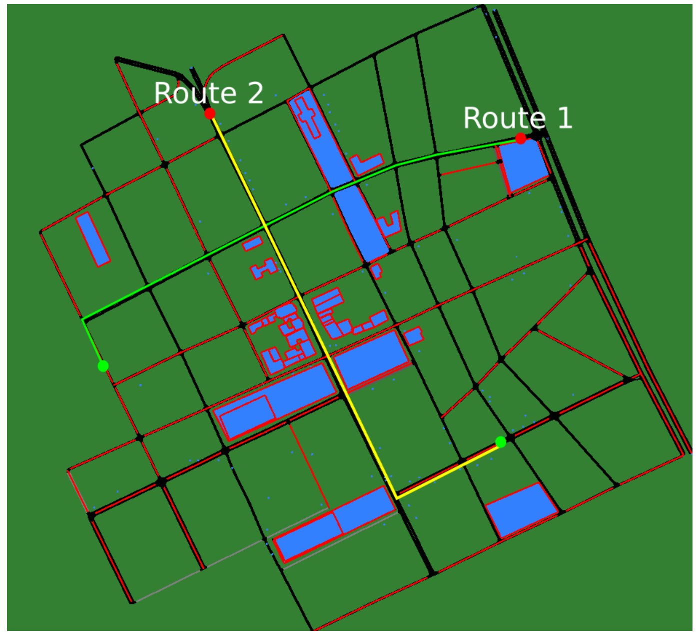
Due to the complexity of carrying out real experiments, especially when it comes to urban mobile networks, this paper made use of software simulation for the practical application of the proposed approach. In this context, the following simulators were employed in a coordinated and integrated manner to carry out the experiments in the defined urban scenario:

- SUMO - (*Simulation of Urban Mobility*) [14] is a road traffic simulation package, highly portable, and designed to handle road networks;
- OMNet++ - (*Objective Modular Network Testbed*) [12] is an open-source network simulation environment based on discrete events that allow the modeling and experimentation of communication networks. It is a simulator widely used and integrated with several application domains;
- Veins - (*Vehicles in Network Simulation*) [13] is an open-source simulation environment that allows data exchange between V2V vehicles (*Vehicle to Vehicle*) and vehicles with V2I infrastructure (*Vehicle to Infrastructure*). The idea is to use Veins as a tool that allows the integration between SUMO (traffic simulator) and OMNET++ (network simulator). The integration of the simulation environments will be carried out through TraCI/Veins. TraCI is a component written in Python that performs the integration between SUMO and OMNET++ through the creation of a TCP socket. It is intended to integrate the maps generated by Open Street Maps [29], generating vehicular routes and network files from real road parameters.

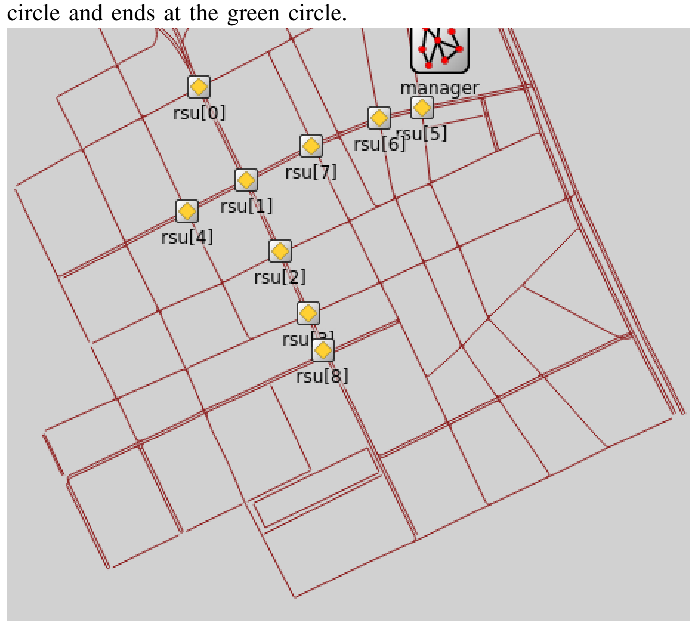
Fig. 4 presents the base traffic network for the simulation. All traffic network elements (streets, buildings, traffic lights, etc) come from Open Street Maps and are processed using tools from the SUMO library.

A simple simulator was implemented in JavaScript to generate random events on the map, supporting the execution of the planned simulations. This simulator takes as a parameter the number of random events, the types of events (healthcare, fire, and police occurrence), a central point (which includes the coordinates of the operations center), and a radius. Through these parameters, the system generates random events and indicates the geolocalization and the type of the event on the map. Afterward, the alarm system receives this information and forwards the emergency alarm to the operations center, in order to initiate the process of mitigating the emergency (assigning emergency vehicles). It is also known in advance which are the treatment centers (usually hospitals) in the considered city, which can be assumed as fixed positions that will not change over time. Routes are calculated using the Multi-Level Dijkstra (MLD) algorithm [30].

In Table II, it is presented the parameters and settings employed in the simulations. Two categories of vehicles were included in the scenario: passenger vehicles and emergency vehicles (as detailed previously). The “broadcast interval” determines the interval at which messages are sent by emergency vehicles, while the “warning EV distance” determines the minimum distance between the EV and the RSU (associated with a traffic light).



(a) Network scenario presented in SUMO, with the respective routes used in the simulation. The predefined route starts at the small red circle and ends at the green circle.



(b) Network scenario presented in OMNET++ with RSU locations.

Fig. 4: Traffic network for the center of Campinas, Brazil. Coordinates: -22.90119N, -47.05707E, -22.90591S, -47.06325W.

B. Performed simulations

The performed simulations were intended to evaluate the feasibility of the proposed approach in an urban scenario, concerning both the assignment of emergency vehicles and their movement on a city as they compete with regular vehicles. Actually, the first expected result, which is the selection of emergency vehicles based on the received emergency alarm, is straightforward, once the alarms are properly generated and transmitted by some emergency management system like the one described in Costa et al. [10]. In fact, the results presented in Costa et al. [23] were initial indications of the reasonable

TABLE II: Simulation parameters and settings.

Parameter name	**Parameter value**
Predefined routes	2
Passenger vehicles	100
Emergency vehicles	6
Communication standard	IEEE 802.11p
Broadcast interval	2s
Warning EV distance	200mt

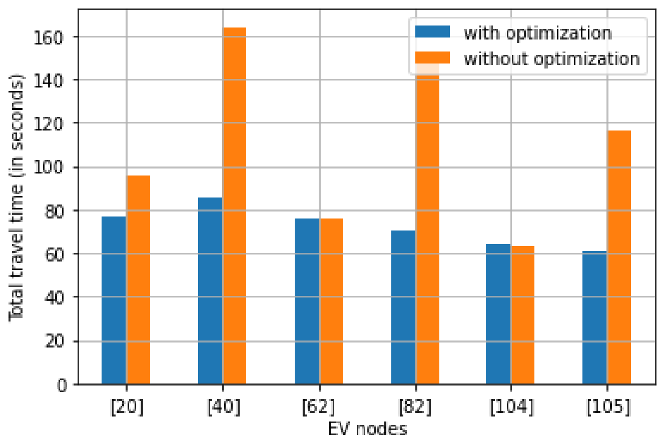


Fig. 5: Evaluation of total travel time with and without traffic light optimization, for the emergency vehicles.

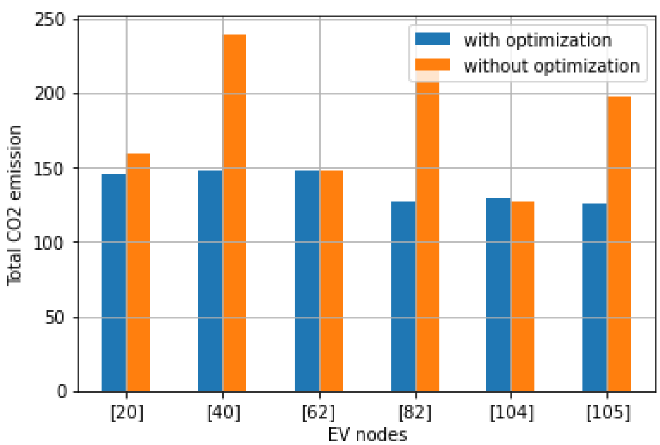


Fig. 6: Evaluation of total CO_2 emissions with and without traffic light optimization, for the emergency vehicles.

association between critical events and emergency vehicles, and the same result could be achieved in our simulation. However, the second proposed approach, which is the optimization of traffic lights as an automatic response to an active emergency alarm, had to be analyzed in detail, as discussed in this subsection.

During an urban crisis, the proposed solution could provide valuable support for efficient response in several types of occurrences, being able to reduce the loss of lives and negative economic impacts. In the performed simulations, the achieved results were obtained from a controlled simulation environment so that it is possible to evaluate how the application responds when an emergency alarm arrives at the operations center.

Two different environmental conditions were tested: a) with traffic light optimization and b) without optimization. Fig 5 shows the total time spent by the EV, while Fig. 6 presents the amount of CO_2 emitted by each emergency vehicle. In those Figures, the presented information corresponds to emergency vehicles identified by their nodes ID. This way, we have nodes [20], [62] and [104] corresponding to vehicles included in the first route, while nodes [40], [82] and [105] correspond to vehicles included in the second route.

The correlation between Fig. 5 and Fig. 6 happens because the less time a vehicle is on the road, fewer CO_2 is emitted. As an important remark, although the proposed algorithm supports the assignment of more than one EV for a single emergency alarm, depending on the critical events that are encompassed by it [10], the simulations were performed for a direct association of one "type" of an alarm to a single corresponding vehicle (healthcare $\rightarrow$ ambulance, fire $\rightarrow$ fire truck, and police occurrence $\rightarrow$ police car). Nevertheless, this is a simplification for the sake of simulations implementation, with no impact on the performed evaluation.

Finally, concerning the results, for the general average taking all emergency vehicles, the algorithm showed a reduction of approximately 39s between the scenario with traffic light optimization (72.16s) and without optimization (111.16s).

CONCLUSIONS

The challenges of urban mobility have been diverse in recent years for the scientific community. Traffic congestion problems have been extensively explored and several interesting solutions can be found in the literature, including, for example, detecting congestion and suggesting diversion of routes to avoid them. As such, these tools are of paramount importance for emergency management systems, as they provide critical resources for an efficient allocation of emergency teams, considerably decreasing travel time, which could potentially reduce injuries and deaths in critical situations. Because of this, a single emergency vehicle to respond quickly to critical situations is highly necessary for large urban centers.

The delay in responding to emergencies can be a critical factor to harden the impacts caused by them, whether vital or economic. The sooner a fire is put out, for example, the less damage it will cause. Similarly, the sooner a life is rescued from an accident, the more likely it is to recover. Therefore, the development of tools that can help cities and public/private bodies to deal with daily crises in the best way is essential for the efficient mitigation of these crises. In this sense, the proposed system proved to be capable of identifying an emergency alarm (generated by a detection/alert system) and quickly distributing emergency vehicles to the location of the detected emergencies, and from there to the nearest treatment center (if necessary). In the presented results, the proposed approach reduced the travel time of the dispatched emergency vehicles, indicating that it may become an important service when dealing with traffic delays when addressing urban emergencies.

As future works, we will further explore other applications in the ITS domain, processing other settings and real-time data. Route suggestion algorithms will be also considered. In addition, we intend to explore more efficient algorithms for automatic vehicle allocation, instead of using a previously established knowledge base. In addition to these future expected contributions, we will propose the reduction to the number of RSU that control the traffic lights, with only one RSU having to control a specific number of traffic lights, as long they are within range.

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