CHAPTER 110

Development of an RGB LED panel controller system for smart traffic lights

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ABSTRACT
This work reports the development of an electronic device to be applied in an urban traffic light system, capable of showing relevant information such as the remaining time of the signal and additional information from sensor data to control traffic, sharing information useful to drivers and pedestrians. Studies were carried out on the topic of smart traffic management, new strategies under development and improvement in recent years of research, and the consequences of traffic on urban roads, to propose the principle and parameters of the device's operation, based on the system's efficiency. Through studies, it was noted that the traditional traffic light system has its limitations, such as excessive expenses with light bulbs, and problems with electrical failures, in addition to the fact that congestion increases the emission of polluting gases and harms the health of drivers and pedestrians. In this sense, there is the possibility that an RGB LED panel controller offers useful and clear information, received by a device via UART communication so that it is possible to obtain a lower rate of traffic congestion. Soon, a micro-controlled LED panel management system will be developed to replace traditional traffic lights and focus groups.

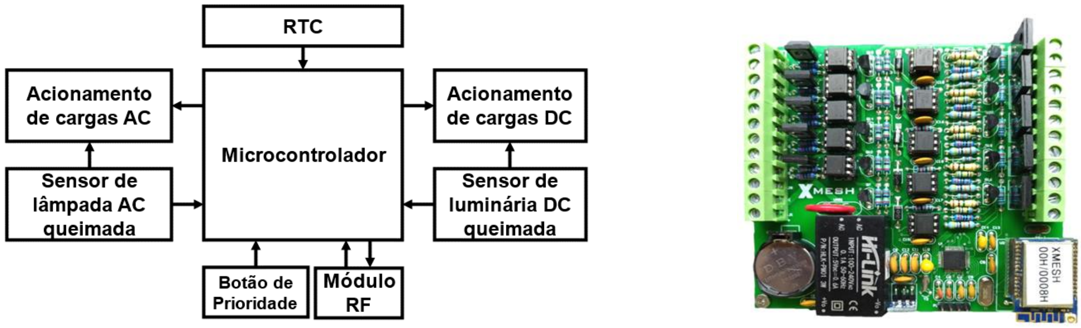
Keywords: Semaphore. RGB LED. Smart traffic management.

1 INTRODUCTION

1.1 THE TECHNIQUE STATE DESCRIPTION

In order to propose an electronic device with a low financial cost, in previous works, the authors Oliveira et al. developed a traffic light controller *hardware* with wireless communication. Controller *hardware* is understood to be an electronic circuit capable of activating and reading the status of all its lamps (with AC/DC power), having an input for the pedestrian priority button, and communicating via a wireless network. wire through a radio frequency (RF) module. Both the high-level architecture and the electronics board can be seen in Figure 1.

Figure 1 – The used traffic light system's high-level architecture (left image) and electronic board (right image).



Source: Oliveira (2019).

RTC
Actuation of AC charges   Micro-controller   Actuation of DC charges
Sensor of burnout AC bulb   Sensor of burnout DC bulbs
Priority Button - RF module

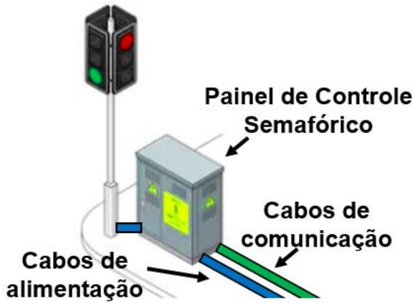
The complete description of all the building blocks of the high-level architecture of the traffic light electronic circuit in Figure 1 can be found in (OLIVEIRA; MANERA; LUZ, 2019). The traffic light controller can trigger a Vehicular Focus Group (GFV) - composed of red, yellow, and green lights for vehicles - and a Pedestrian Focus Group (GFP) - composed of red and green signaling lights for pedestrians.

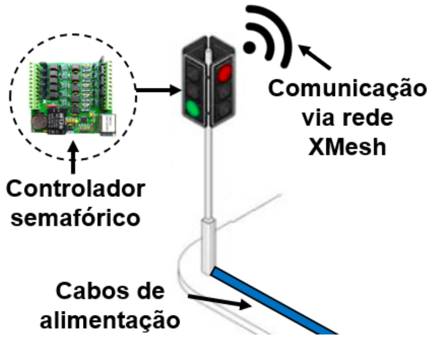
The communication protocols ZigBee, Z-Wave, MiWi, Bluetooth, 6LoWPAN, and 802.15.4 are some of the most used protocols in Wireless Sensor Networks (WSN). However, although there are already several technological applications using such protocols, there are still significant improvements to be explored, such as routing table algorithms, reduction of average energy expenditure, reduction of latency between network nodes, increase in bandwidth, increase in area coverage, an increase of nodes in the network (STOJMENOVIC, 2005).

The present work makes use of the recent XMesh wireless network technology, developed especially for the concept of smart cities (use in devices with little available memory and low processing power, serving numerous network points), capable of providing a *Virtual Private Device Network* (VPDN) for each network application (LUZ; MANERA; DONATI, 2017; OLIVEIRA; LUZ; MANERA, 2020; OLIVEIRA; MANERA; LUZ, 2021). By using the controller system in conjunction with the XMesh network, the need for not only the traditional traffic light control panels but also the communication cables between the various intersections of the city is eliminated. As a result, the vandalism practices of traffic light controllers are reduced (due to their reduced size, the controller system used can be installed inside the GFV) and cable theft (communication is carried out via wireless network), which are the agents causing the inoperability of most traffic light systems. The traffic light controller system also implements the Green Wave routine (synchronization between successive crossings/intercessions) in real-time. Figure 2 displays the improvements of the control system used as a basis for this work.

Figure 2 – Comparison between a traditional traffic light controller system (left image) with the traffic light controller system used as a basis in this work.

1. Semaphorical Control Panel
2. Supply cables
3. Communication cables





Source: Oliveira (2020) .

1. communication via xmesh network
2. Traffic light Controller Power
3. supply cables

In this sense, following the projects previously developed, this work aims to transform a traffic light that has only GFVs and GFPs into a traffic light with a panel of Red, Green, and Blue Light-Emitting Diodes (Light- *Emitting Diode Red, Green, Blue* (LED RGB)) of matrix and addressable type, arranged in a mechanical support structure, having smooth transition curves between the LED panel for pedestrians and the LED panel for vehicles, in addition to a public lamp. And, as it is a solution that aims to improve previously existing technology, the new traffic light will also have its control and monitoring routines via the XMesh wireless communication network.

2 OBJECTIVES OF THE INVENTION

Develop an LED panel controller equipment to be applied in an urban traffic light system, where information will be exchanged between the traffic light controller (described in the previous section) and the panels, in order to show relevant information, such as the remaining time of the signal, additional information on the number of available parking spaces and sensor data from *Internet of Things* (IoT) applications from the region around the traffic light, to carry out traffic control and share such information with drivers and pedestrians, as presented in Figure 3.

Therefore, within the purpose of this work, the use of an RGB LED panel for traffic light control can contribute to intelligent traffic management, by clearly exposing information to drivers and pedestrians, as well as helping to improve the physical and mental health of citizens. . On the other hand, when using gas or temperature sensors, for example, it can contribute to the development of new public policies to reduce the environmental impact and, in this way, can contribute to the deceleration of global warming.

Figure 3 – Initial idea of the traffic light with luminaire and RGB LED panels applied to intelligent traffic management.

Source: Own authorship.

3 ADVANTAGES OF THE INVENTION

With the increase in the national fleet of vehicles and the limitations of the current traffic light systems that are rudimentary, traffic problems grow more and more, are daily topics in the press and frequently addressed by governments. Therefore, there is a growing demand for solutions aimed at greater traffic flow in urban centers (AZEREDO, 2014; RODRIGUES, 2019; JUNIOR, 2021).

According to Giovanelli et al. (2011), the official fleet of vehicles in the city of São Paulo in 2011 was approximately 7 million vehicles, where 3.8 million of these vehicles circulated daily through the 17 thousand kilometers of roads in the capital of São Paulo. Due to the high number of vehicles on the roads, in 2011, the Traffic Engineering Company (CET) recorded an average speed in the city of São Paulo of 32 km/h in the morning rush hour (7 am to 10 am) and 18 km/h in the early evening rush hour (5 pm to 8 pm). The research was carried out in some parts of the city and, in sections with the most intense traffic, the average speed reached 8 km/h. The slowness of traffic leads to a loss of approximately 30 billion reais annually in lost productivity and material expenses, mainly with wasted fuel (MUGNELA, 2012).

Since vehicles are the main source of air pollution, the greater the number of vehicles in circulation, the greater the emissions of harmful gases into the atmosphere. According to the Environmental Company of the State of São Paulo (CETESB), cars dump 1.7 million tons of harmful substances into the atmosphere every year (GIOVANELLI et al., 2011). About 528,000 tons of local pollutants were emitted per year between 2003 and 2014. With traffic management through a traffic light system, it is possible to reduce the emission of polluting gases into the atmosphere by up to 20% (OLIVEIRA, 2020). In addition to traffic lights controlling traffic through colors, with the modernization of current systems, it would be possible to add sensors that indicate the levels of pollution on the roads, where this information is relevant for traffic improvement.

The project aims to contribute to one of the United Nations (UN) 17 Sustainable Development Goals (SDGs) in Brazil. Specifically the objective of making cities and communities sustainable (Goal 11), where by 2030 it aims to reduce the per capita negative environmental impact of cities, including by paying special attention to air quality and municipal waste management (UN, 2018).

With this, the concept of smart city grows continuously, which includes technologies that promote greater energy efficiency and services in cities. There are intelligent systems for monitoring and managing urban infrastructure and anticipating natural accidents, using sensors and artificial intelligence systems that quickly perceive and respond to events in the physical world (WEISS; BERNARDES; CONSONI, 2015).

To solve these problems, the project offers an opening for a series of applications for traffic management where there is no need to use wires, making it possible to integrate useful information for pedestrians and drivers, which can be presented on the RGB LED panels in a clear. Information such as temperature, CO 2 emission level , quantity and orientation of available parking spaces on the roads, the time count in each traffic light color and the possibility of displaying the average speed of vehicles on the road. The system will control the RGB LED panels at traffic lights for vehicles and pedestrians.

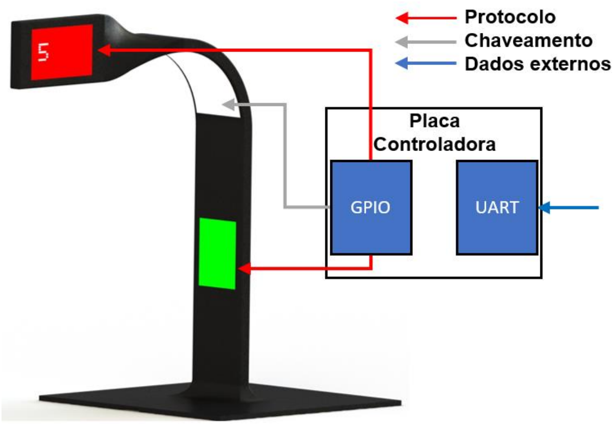
4 DETAILED DESCRIPTION OF THE INVENTION

Starting from the first in designing an RGB LED panel, both for vehicles, with 8 lines and 24 columns totaling 192 SMD RGB LEDs, and for pedestrians, with 11 lines and 9 columns totaling 99 SMD RGB LEDs. Considering that the LEDs are close to each other, which makes their homemade production difficult, the project was carried out on the CAD EasyEDA platform, and the prototyping is being carried out by the JLCPCB. Where the protection's power tracks are thick and well grounded, to reduce heat dissipation.

Since the RGB LEDs are addressable, which requires the use of appropriate protocols and communication buses, specified by the manufacturer's *datasheet* , it was idealized to use an Arduino kit to program the traffic light functions. However, the use of a microcontroller with the lowest possible cost is considered, which meets the requirements of operating in high temperature ranges, due to the working conditions of a real traffic light that is exposed to the sun and rain. It is also required that the microcontroller has a UART peripheral to communicate with the devices that will send the information that will be displayed on the panel, such as the color and time of the traffic light color, sensor data from IoT or other information relevant to the citizens.

Also for the prototype *hardware* and *firmware design*, it is necessary at least 7 GPIOs to control the LEDs, 3 for the vehicular panel, 3 for the pedestrian panel and 1 to activate the LED light of the traffic light itself, which, in the prototype, can be activated via transistor, and in the final version it should be activated via MOSFET (DC luminaires) and via thyristor (AC luminaires). In Figure 4 The initial idea of the RGB LED panel controller system applied to intelligent traffic management is shown.

Figure 4 – Initial idea of the RGB LED panel controller system applied to intelligent traffic management.



1. Protocol
2. Keying
3. External data
4. Controller panel
5. GPIO - UART

Source: Own authorship.

The project, until the moment of submission of this article, is in the *firmware development stage* where it will interpret the data received via UART, such as vehicular red, yellow and green times; red and green times for pedestrians; and special data as mentioned above. The information must be displayed in specific regions of the screen.

It is worth mentioning that the panel designs have already been sent and are awaiting the completion of the prototyping to continue the tests with the performance of the panels in relation to the *firmware* and operation after fixing them in the idealized mechanical structure. The project may undergo minor changes over time due to the accumulated learning and results obtained after the completion of each goal described above.

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