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RESEARCH ARTICLE

SMART TRAFFIC LIGHTS USING IOTTECHNOLOGIES : PROJECT CONCEPT AND PROGRESS

Ousmane Sow[1], Youssou Traore[1], Mame Andallah Diop[1], Ababacar Sadikh Faye[2], Jupiter Ndiaye[2] and Abdoulaye Diop[2]

1. Institut Universitaire de Technologie, Université Iba Der Thiam, Thiès, Sénégal.
2. Université Iba Der Thiam, ED2DS, Thiès, Sénégal.

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Abstract

The rural exodus and population growth has led to the rapid expansion of cities without sometimes developing road infrastructure. This situation is at the origin of congestion in road traffic with a very high number of vehicles. In Africa, cities that have the financial means often use traffic lights with a predefined traffic plan which can be ineffective at sometimes of the day. In this paper, we propose a concept of wireless traffic light terminal, connected and self-sufficient in energy, for installation at intersections without public works on the road. This traffic light terminal is accessible remotely from police stations for its supervision and control. Thus, traffic management at an intersection is carried out remotely and in real time by an agent who selects a traffic plan adapted to the current situation. The objective is to centralize, with few personnel, the management of several intersections equipped with traffic light terminals, for better overall regulation of road traffic at low costs. Our work resulted in a proof of concept, for a four-lane crossroads, made with four Arduino electronic boards, four Lora wireless modules, a Raspberry-pi microcomputer, a camera and a 4G modem. For the software part, a server application developed with the node-red language, on the Raspberry-pi electronic card, provides the graphical interface for monitoring and control. The proposed system integrates a Cloud service that makes the human-machine interface for supervision and control remotely accessible via the Internet.

Introduction:-

Population growth leads to an increase in population density in cities that attract more and more people. This situation has a negative impact on road traffic due to the increase in the number of cars and the lack of roads.

In cities, mobility is a major factor in the development of the various activities that punctuate the daily life of citizens and businesses. Traffic management at intersections is therefore very important and concerns several actors, including the authorities.

As the civic sense of users is not sufficient for self-organization of road traffic, police personnel can be assigned to the task of traffic management.

Corresponding Author:- Ousmane Sow
Address:- Institut Universitaire de Technologie, Université Iba Der Thiam, Thiès, Sénégal.

Traffic lights are a technical solution to replace police officers who can take care of other activities.

The use of traffic lights is old, it was in 1868 that the first traffic light system was installed in London [1].

Depending on the context, fixed-cycle traffic lights can cause congestion that pushes some users to commit red light violations. One of the first experiments in automating traffic light enforcement was conducted in the city of Stockholm (Sweden) between 1972 and 1978 [2].

Today, many works exploit artificial intelligence to improve the efficiency of traffic lights for road traffic management [4] [1].

The web giant Google revealed, on October 6, 2021, that it was working on an AI-based system to reduce the waiting time for drivers at traffic lights [3].

However, the pre-determined traffic light plan remains the basis of the management system of the vast majority of cities in the world with methods such as time scheduling for traffic plan change [5].

Our work is a contribution to the establishment of efficient traffic lights in cities without a lot of financial means, as is often the case in Africa.

Indeed, it is following the call of the municipal authorities of the city of Thiès [6], for university contributions in the resolution of problems of the locality, that we decided to work on the traffic lights quoted by the authorities.

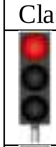
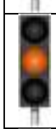
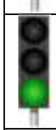
The objective of our project is to develop, with IoT technologies, low cost traffic lights in their manufacturing, installation and operation phases. Thus, the electronic part is made with “open source” embedded systems. The installation will be done without heavy and expensive work on the road thanks to low-consumption wireless technologies and photovoltaic solar energy. The supervision and control of traffic lights remotely from the police station will reduce the staff assigned to intersections for traffic regulation.

This article presents the progress of our work which led to the realization of the proof of concept.

Types of road traffic lights

Colored light signals of different shapes are used for traffic control at intersections. Table 1 presents traffic lights intended for car drivers and pedestrians [7] [8].

Table 1:- Signs for road traffic.

Classic multi-directional lights				*1)* Directional lights (arrows)
	No Trespassing			No Trespassing
	Prohibition unless the driver cannot stop under sufficient safety conditions			Prohibition unless the driver cannot stop under sufficient safety conditions
	Passage authorized			Passage authorized provided you go in the direction of the arrow
2) Conventional lights for pedestrians				
	Crossingprohibited for pedestrians			

	Crossingauthorized for pedestrians

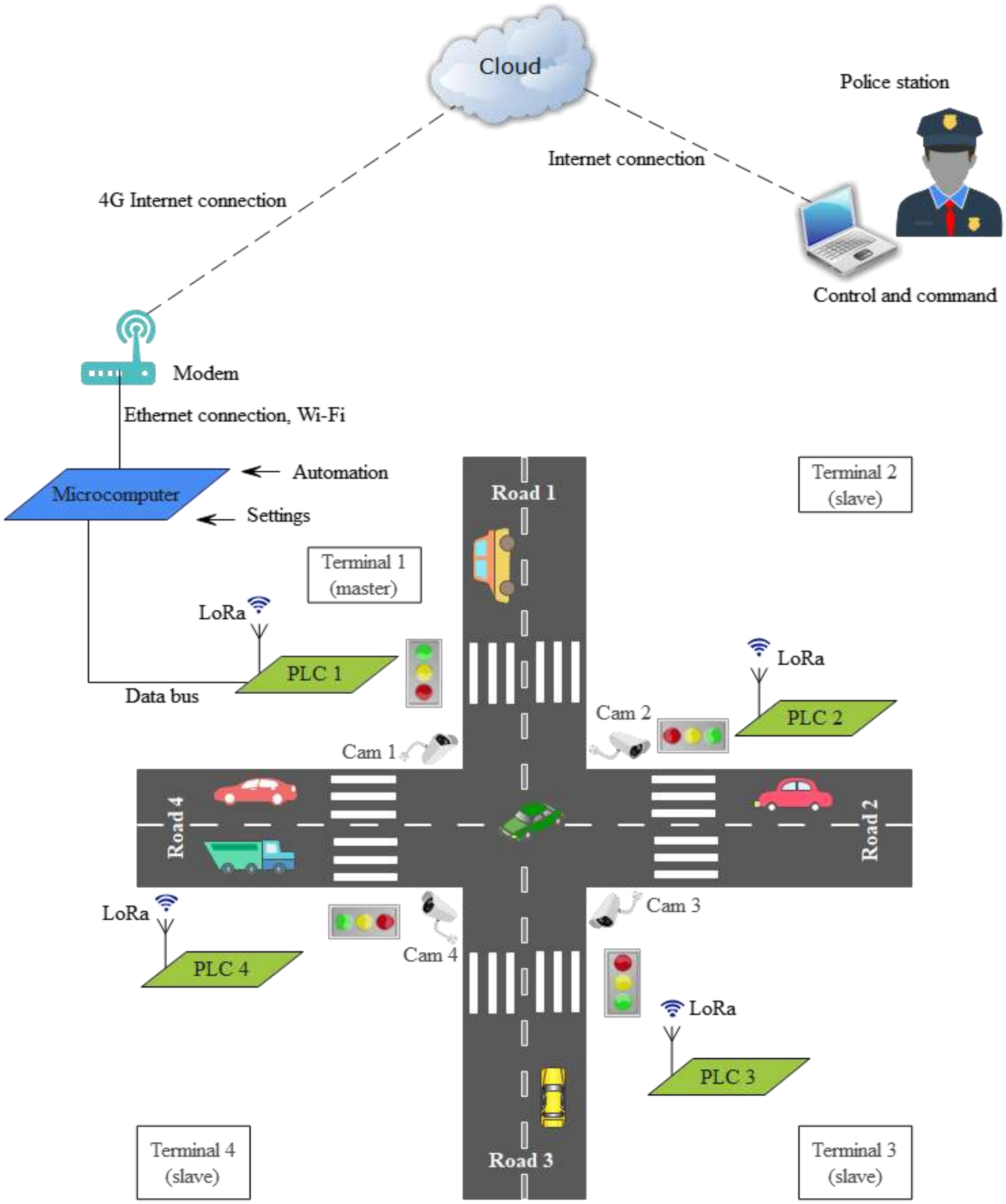


Fig. 1:- Block diagram of traffic light bollards.

Scenarios for the operation of traffic lights at an intersection

In general, during their operation, traffic lights execute a predefined and cyclic traffic plan. Depending on the situation of the day or time, this plan can become a problem for the flow of traffic, so a police officer often takes over to impose other traffic plans from his experience in order to cancel the congestion.

The proposed solution consists of defining several traffic plans with the police, which can be selected in real time from the police station, which has an intersection monitoring service using cameras.

An automatic change of traffic plan is also possible on the basis of parameters set by the police services.

Electronic and computer system design

Figure 1 shows the technical model designed for the realization of our autonomous, wireless, internet-connected and low-cost traffic lights. The acquisition of data by the cameras allows real-time decision-making for the execution of a traffic plan adapted to the situation. Thus a single headquarters can centralize the management of several intersections for overall efficiency on road traffic and for a reduction in the number of police officers assigned to the traffic control function.

A traffic light terminal is installed on each lane of the intersection, it is composed of a camera and a controller wired to different red, green and orange bulbs. There is a master type bollard whichgenerates all the control signals for all the bulbs of the four intersection bollards. The three slave-type terminals receive the states of their respective bulbs by wireless link, which they operate in accordance with the orders of the master. Each traffic light terminal must be supplied with electrical energy by an autonomous solar system.

Materials and Methods:-

The material elements

For the automation of the traffic light terminals, we use the Arduino UNO card as a sequencing automaton of the different phases during cyclic operation. The stability and robustness of this Arduino board presented in figure 2, justifies its choice as field equipment closer to the actuators.

Fig. 2:- Arduino UNO.

Fig. 3:- Module Lora shield 915Mhz v1.4.

For each terminal, the digital ports of Arduino are used to connect the bulbs. For the master-type terminal, the six-bit parallel wired link with the local server is made with the Arduino analog ports operating as a comparator.

The wireless links of the three slave terminals and the master type terminal are made by the Lora module in figure 3 compatible with Arduino UNO.

The four LoRa modules of the four traffic light terminals constitute a wireless local area network with a long range, good penetration of obstacles and low energy consumption. The LoRa module therefore allows the local communication of the four traffic light terminals for a crossroads.

Controlling the intersection by changing the traffic plan is managed by a Raspberry pi card shown in Figure 4. It operates as a server for access by web browser with a computer, tablet or smartphone.

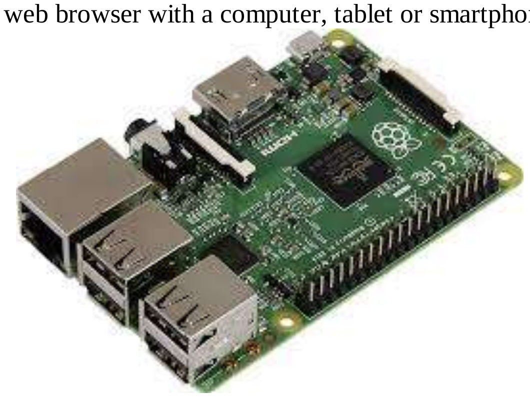


Fig. 4:- Raspberry pi.

Fig. 5:- Modem 4G with wifi.

Only one Raspberry-pi 3 is used per crossroads and it is installed on the master type terminal which is the only access point to the various traffic lights of a crossroads.

The modem with wifi in figure 5 allows the networking of the Raspberry pi with computers by wifi for remote control in the same local subnet near the crossroads. It also provides a very long distance link via the Internet through the Cloud to the police station. Thus, even a smartphone can be used near the intersection to remotely control the traffic lights.

Methodology:-

For this traffic light management project, we have defined types of terminals for the lanes of an intersection, with wireless synchronization with a LoRa module made for the Arduino UNO board. These two cards communicate by serial transmission. On the other hand, we have chosen, for the communication between Arduino and Raspberry, a bit-to-bit link for 6 bits in total. This link allows the transmission of the code representing the traffic plan to be applied at the intersection. This is a number that corresponds to the traffic plan number, each traffic plan is identified by a unique decimal number. Figure 6 shows the wiring of the camera which transmits the images of the intersection, and the connection of the electronic cards of the master type terminal.

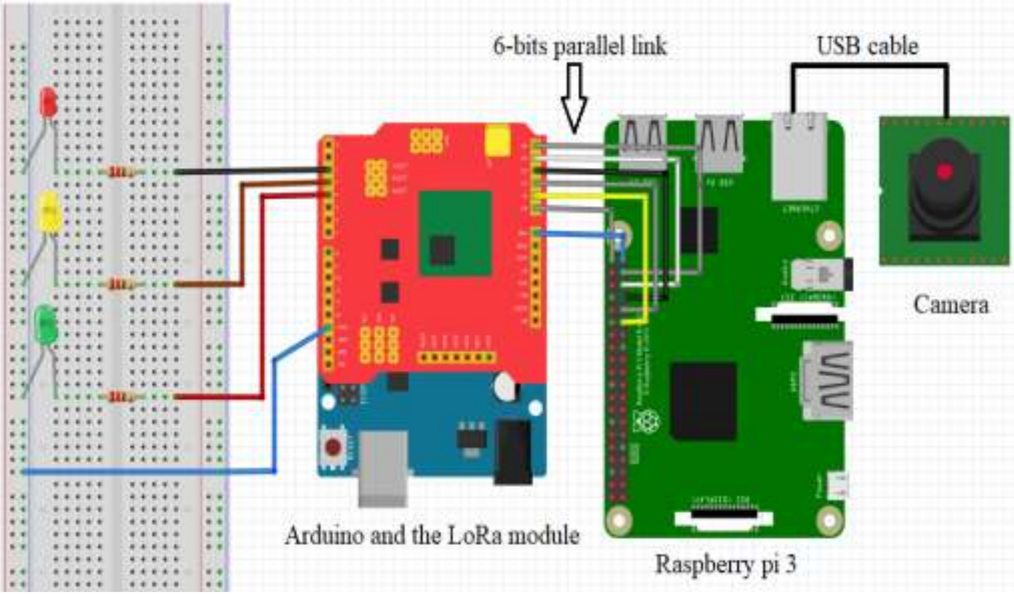


Fig. 6:- Master type traffic light terminal circuit.

The electronic part of the slave-type terminal is shown in Figure 7, it receives from the master-type terminal, via a LoRa signal, a 4-byte frame fixing the states of all the light bulbs in the crossroads. It only processes its own byte to update the states of its own bulbs.

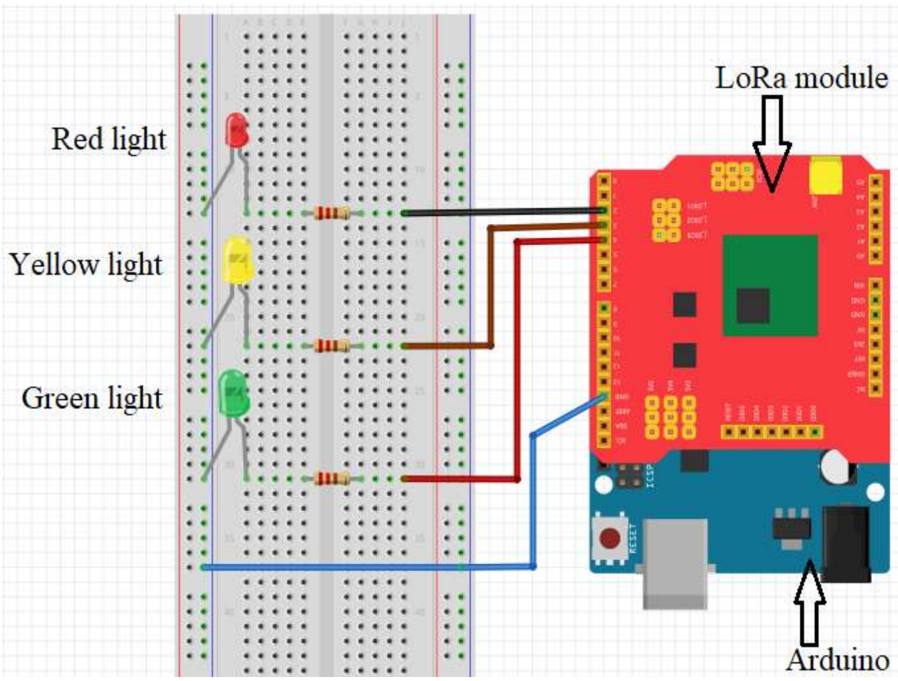


Fig. 7:- Slave type traffic light terminal circuit.

The graphical interface, which is a web page developed with node-red, allows the Cloud service to transmit the traffic plan in real time, by saving the chosen plan number in a file on the Raspberry pi card.

The algorithm designed for this work is illustrated in Figures 8, 9, 10 and 11.

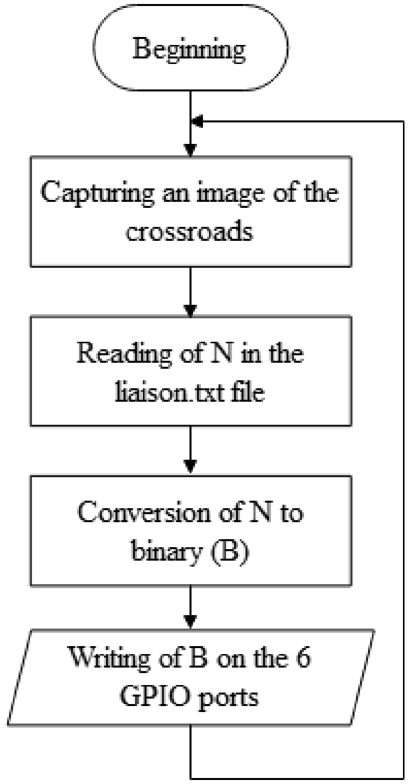


Fig. 8:- The processing of Raspberry pi.

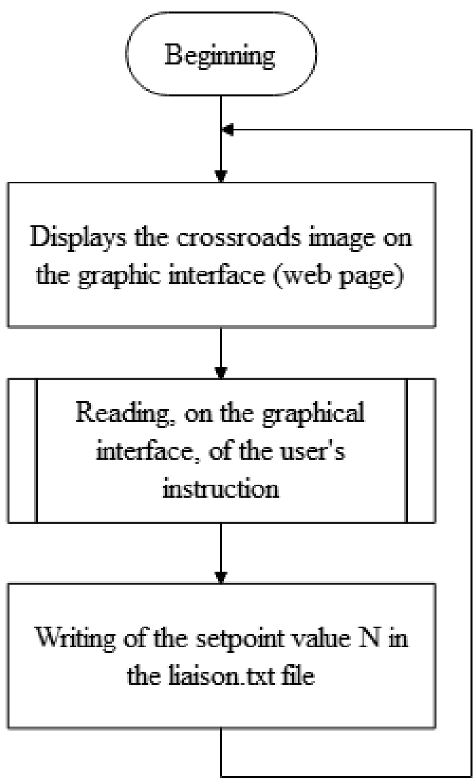


Fig. 9:- Server processing.

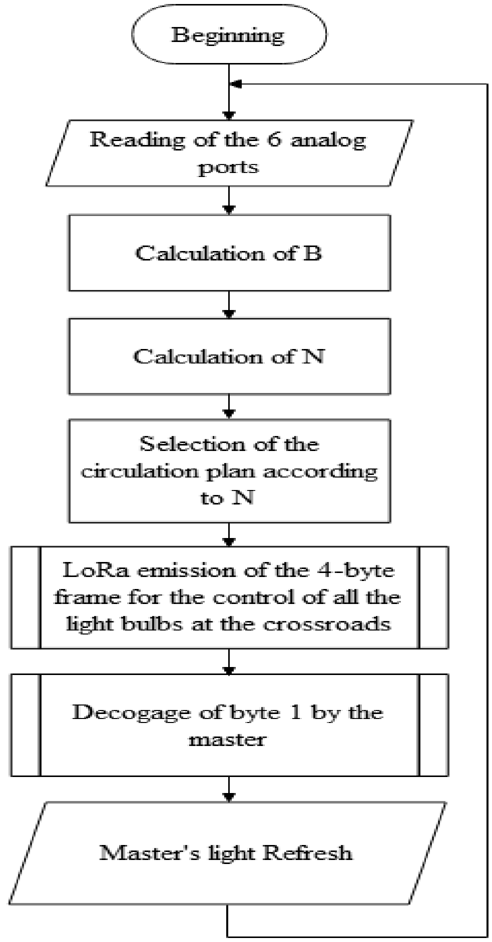


Fig. 10:- The Master Type Arduino Processing.

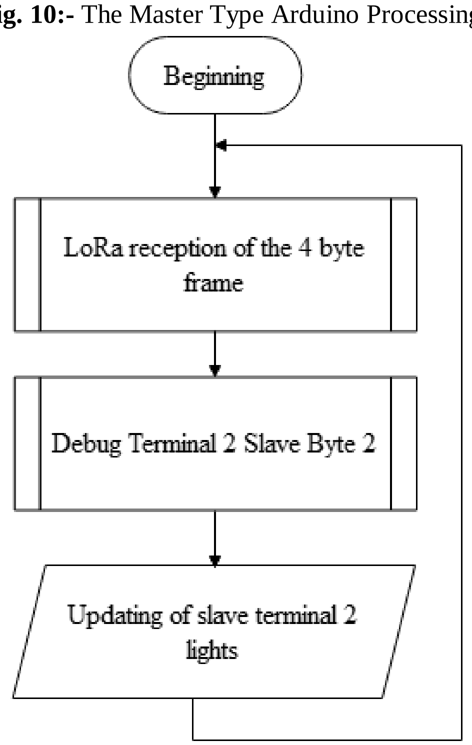


Fig.11:- Slave Type Arduino Processing.

Results and Discussions:-

At the current state of work, we have studied the electronic and software parts of the intelligent traffic light terminal concept. The results obtained are reflected in the production of an electronic model shown in Figure 12, this is our proof of concept.

Table 2 gives the results of street tests for several configurations.

Table 2:- Test results for an intersection.

The LoRa antennas are 1.20 m from the ground					
Distance betweentransmitter and receiver		Quality of the LoRa signal received			
		RSSI	SNR	Observation
Straight positioning (without Obstacles)	32m	-71 dBm	6.25 dB	no mistake
	56m	-81 dBm	6.25 dB	no mistake
	78m	-82 dBm	6.00 dB	no mistake
	107m	-84 dBm	6.00 dB	no mistake
	131m	-88 dBm	6.00 dB	no mistake
	170m	-93 dBm	6.00 dB	no mistake
	274m	-105 dBm	5.25 dB	amistake
Right angle positioning (with obstacles)	92m	-105 dBm	5.00 dB	no mistake
	168m	-105 dBm	4.00 dB	severalerrors

The results show good operation for an area with a diameter of less than 170 meters without major obstacles. In practice, junctions on roads certainly have a smaller area.

We also note a reduction in the range of the wireless link for streets forming a right angle, with buildings as obstacles. Here, too, we can say that on the ground the different traffic lights of a crossroads are certainly in the same open area.

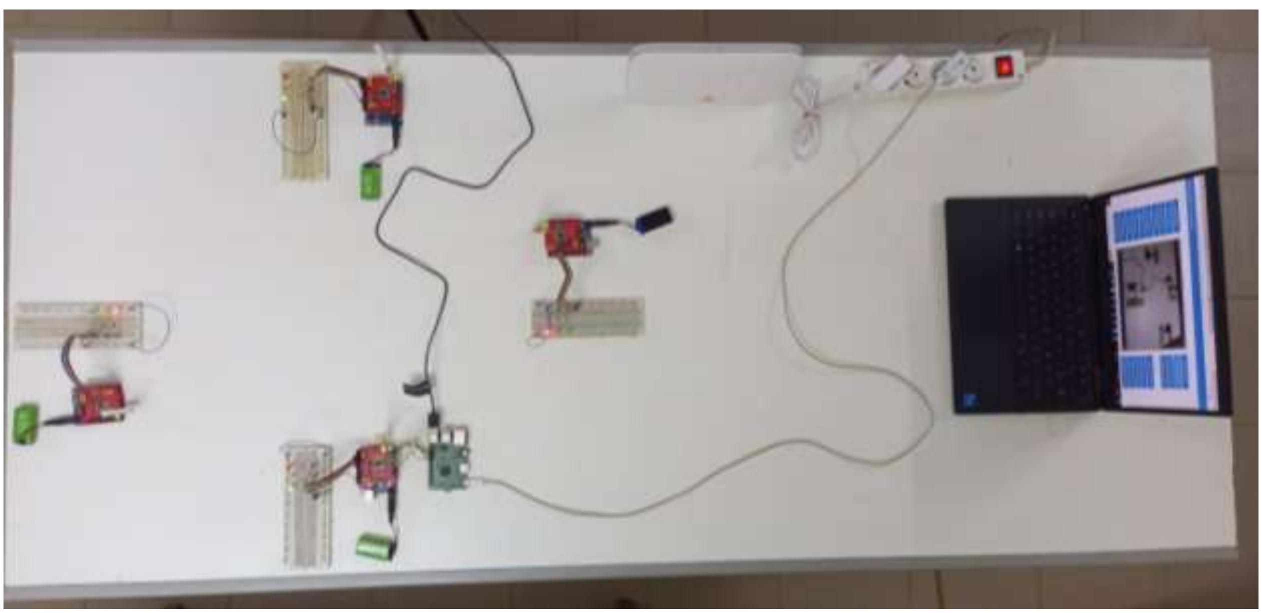


Fig.12:- Experimental model of intelligent traffic light terminals.

Figure 13 shows the result of the design and development of the application for the remote control of traffic lights.

During the tests, our junction was managed remotely next to the city's central police station. The platform worked very well with two 4G internet networks from two different telecommunications operators.

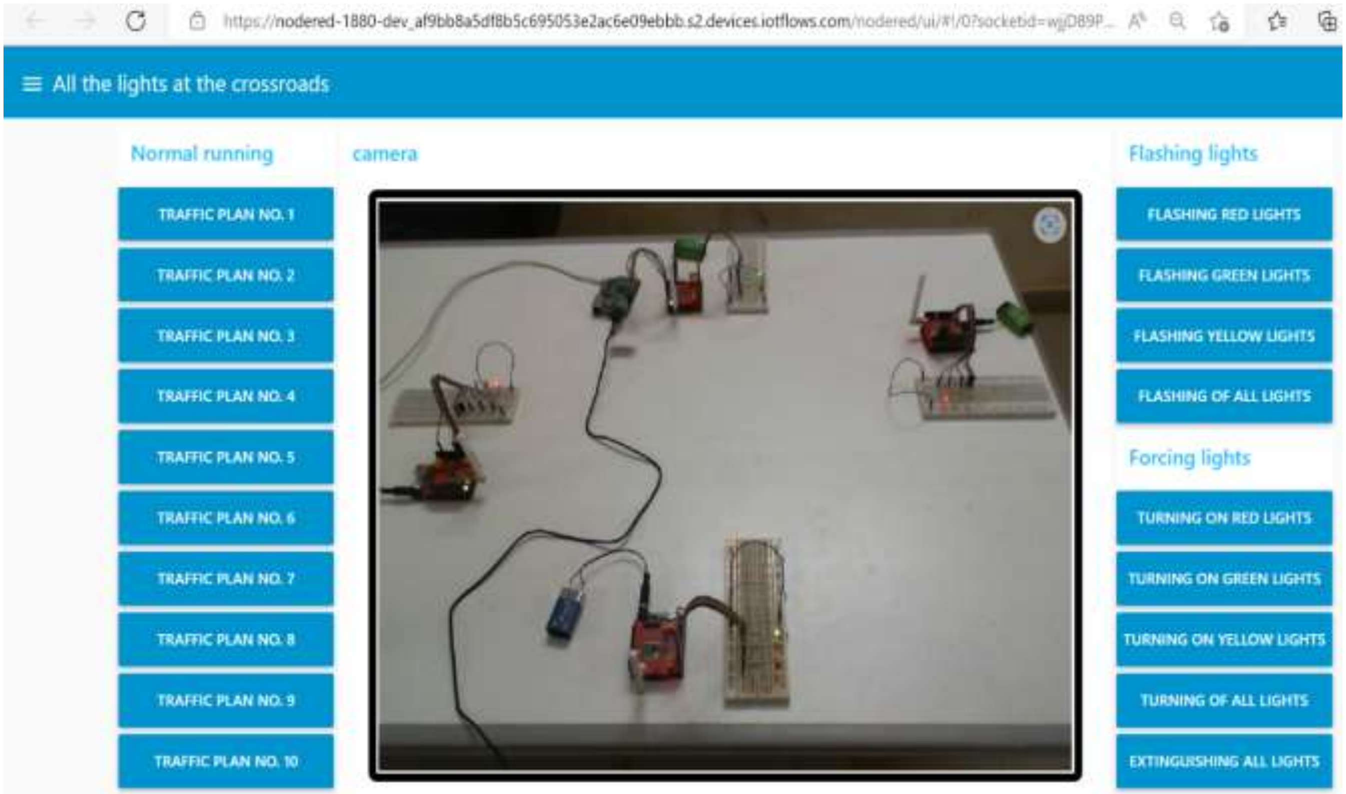


Fig.13:- User interface for supervision and control of traffic light bollards.

The interface offers 64 possible traffic plans or intersection states. Four web pages are available: a main one in figure 13 with all the traffic lights of the intersection, and one for each bollard.

Conclusion:-

For the management of road traffic in medium-sized towns, the proposed solution, based on our concept of intelligent terminal with traffic lights, is indeed a feasible option with open source tools. Indeed, the experimental prototype produced operated in a diameter of 170 m far greater than the extent of the intersections of the city. Thus, the four terminals communicated by LoRa network for the synchronization of the 12 bulbs of the four lanes of the intersection. Remote access via 4G internet also worked from around the central police station 2 km away from the prototype.

For the improvement of the work, we propose the development of a protocol of transmission of the frames of synchronization with confirmations of good receptions by the terminals of the slave type. This will allow the detection and correction of transmission errors, which is very important for safety reasons on the road.

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