Smart Road-Lights and Auto Traffic-Signal Controller with Emergency Override

Mohammad Faisal Naseer(✉), Khan Bahadar Khan, Muhammad Sannan Khaliq, and Muhammad Raheel

The Islamia University, Bahawalpur 63100, Punjab, Pakistan
iamfaisalnaseer@utlook.com

Abstract. We proposed a scheme for smart road-lights and auto traffic-signal controller with emergency override, based on an Arduino microcontroller. It estimates the extent of the existing vehicular concentration using ultrasonic sensors, providing different time slots to each road based on traffic density. The proposed system attempts to reduce the probability of traffic jams caused by the unmanaged traffic lights. Another aim is to provide a hassle-free, pre-eminent clearance for the emergency vehicles. In order to do so, we designed a portable remote that uses Bluetooth modules to communicate with the signal controller. The controller responds to the arrival of any such vehicle and acts accordingly. The objective is to reduce the delay of emergency vehicles for reaching the scenes of disaster with minimum possible interruption to regular traffic flow. Moreover, this article aims to incorporate the design of the intelligent street lighting system to endorse the idea of "energy on demand". Conventional street lights in areas with a low frequency of passers-by remain active most of the night without purpose, which is wasting power, consequently. To curb this problem, we advocate the use of Ultrasonic sensors to detect the motion of the automobiles or pedestrians, hence, activating lights when required with optimal energy consumption.

Keywords: Traffic signal system · Smart street lights · Arduino microcontroller · Bluetooth communication · Ultrasonic sensors · Density based signals · Emergency vehicles

1 Introduction

With the increasing human population and therefore, the number of vehicles, traffic signals plays a substantial role in managing traffic flow in cities. The earliest of methods for organizing traffic was to have a traffic warden deployed at each of the junctions to manually control the traffic flow through hand gestures. However, this was sometimes quite challenging for the drivers to comprehend the hand signals, hence came the need for a different way of controlling the traffic-by using traffic lights. Implemented back in 1912, traffic signals have managed traffic ever since, providing safety and ease to both drivers and pedestrians. Generally, traffic signals are placed on the road junctions where the traffic intersects or roads traverse each other.

I. S. Bajwa et al. (Eds.): INTAP 2018, CCIS 932, pp. 526–537, 2019.
https://doi.org/10.1007/978-981-13-6052-7_45

Traffic lights require control over coordination between different signals to guarantee the smooth flow of the traffic. However, orthodox traffic control signal flops in managing time, as it allocates the same time to each road without any concern regarding whether the traffic is more or less. With the increasing number of vehicles on the road, the limited resources provided by existing infrastructure lead to slower speeds, longer trip times, and increased queuing of automobiles. Traffic on the roads is at its peak during the rush hours. Increasing number of vehicles approaching an intersection relative to that of leaving, due to conventional traffic lights, may cause the condition called “bottlenecking”. Other reasons for congestion may include inadequate infrastructure and the asymmetrical distribution of economic growth. This causes the drivers to face unnecessary waiting, which is not endurable in every case, as being on time is important to everyone. The wait, sometimes, may become the reason for the road-rage and anger normally seen on the signals. Being stranded in heavy traffic is a nuisance for everyone, even the police warden controlling the traffic.

Sometimes, there is also a possibility for the emergency vehicles to be among those stuck in the traffic jam, causing life threatening situations. Emergency vehicles, such as ambulances, firefighters, and police cars, normally require to speed through the traffic and even have the authority to cut-through the signals to arrive at the emergency sites in the shortest possible time. Even the matter of seconds can be crucial in saving lives. Emergency vehicles normally proceed through the junctions by using blaring sirens, horns, flashing lights or any other type of audible or visible alarm to alert other vehicles and pedestrians in the area. Often however, serious accidents occur at intersections due to the fact that in recent years, drivers travel in air conditioned cars with their windows rolled up and often with the radio turned on that prevents them to hear the warning siren of an approaching emergency vehicle. Same is the case with pedestrians on the crossings who either do not notice the visible alarms or sometimes, cannot hear the audible alarms due to impairment or headphones on their ears.

This called for the dynamic control of the traffic during rush hours along with priority based clearance for emergency vehicles. The Authorities needed to find new methods of overcoming this problem like construction of new roads, flyovers etc., but limited resources and budgets don’t allow such projects to be initiated easily. Therefore, a cost effective solution had to be devised using the present state of infrastructure available to apply automation and intelligent control methods.

Another aim of this proposed paper is to design an intelligent street lighting system. Conventional street lights consume energy by being active all the time, even when there isn’t any vehicle or pedestrian present in the locality. Street lighting is an expensive, but important need in any city. Typically illumination accounts to 10–38% of cumulative energy bill worldwide (NYCGP 2009). By mere incorporation of the conventional lighting system with the Ultrasonic sensors may help reduce this staggering cost. Our proposed endeavor is to amalgamate the concept of smart road lights with the smart traffic signals in order to save some of the most important entities in this technologically driven era- time, cost, energy and most importantly, saving lives. This article is organized into five sections: Introduction (Sect. 1), Related Literature (Sect. 2), Proposed scheme (Sect. 3), Results and Discussion (Sect. 4) and the Conclusions and Future work (Sect. 5).

2 Literature Review

In the literature, several traffic signal systems employ the use of the PIC microcontroller for controlling the traffic light system [1, 2, 4, 5, 11] and a PLC microcontroller in others [8, 9]. ARM7 microprocessor is also used in some cases [6]. Many of the researchers have used IR sensors [2–7, 9] for the density or motion detection feature. The idea is that the IR transceivers are placed on both sides of a road. Moving automobiles interrupt the communication between the IR sensors, activating the system and incrementing the counter. The information regarding the density received from other roads is also processed in order to allocate different time slots for each of the lanes conjoining the intersection. M. Srivastava et al. have proposed using the pressure sensors instead of the IR sensors [8] while in some cases the motion sensors are used [2].

RF emitters are employed in paper [6] to send warning signals to the transceivers mounted at each intersection in order to notify the traffic system about the arrival of any emergency vehicle. The normal signal lights arrangement is altered consequently to provide a clear and hassle-free route to the emergency vehicles. But the concern with RF remote is that there is a possibility of an unauthorized person forging the remote and trying to access the control system at the same frequency. Similarly, the downside of using the IR sensors is that they communicate over short, limited ranges and are not viable to be used for wide lane roads. Simple control switches are used in [1] for the emergency override feature. Isa et al. [2] and Ghazal et al. [11] proposed employing the ZigBee transceivers for wireless communication between emergency vehicles and the traffic signals. Some of the researchers have used Radio Frequency Identification (RFID) technology for emergency vehicles to cut through the traffic signals in order to reach the emergency sites on time [4].

Dakhole et al. [6] proposed the use of GPS to link with the signal controllers and to provide the location of any accident to the ambulance. The proposed ambulance was equipped with RF transceivers to communicate with signal controller as well as the GPS module. Some of the works use Raspberry Pi as a microcontroller and an image processing practice to predict the traffic concentration [10]. But the drawback of such techniques is that they require the procurement of high quality images which is not generally the case, as images are vulnerable to different weather conditions especially the rain and fog. Therefore, we propose the use of remotes working over Bluetooth in a Personal Area Network (PAN) for secure communication. The control system will allow access only to the authorized emergency personnel. Similarly, using the Ultrasonic sensors instead of IR sensors allows enhanced detection ranges.

For the smart street lighting system, Krishna [12] and Swathi et al. [18] used IR and PIR sensors for motion detection, which in turn activate the lights. In some of the papers [17, 18] ZigBee transceiver modules, while in [12] internet connections are used for communication between the street lights. The purpose of this communication is to share the intended route of the vehicles with road lights and for monitoring, controlling and metering of the smart street lighting system. The individual lights would be activated or deactivated using sensors and can be set to any level, depending on traffic volume.

3 Proposed Model

The aim of this project is to create a prototype of a conventional traffic junction using Ultrasonic sensors and remotes working wirelessly on Bluetooth technology. This system detects the motion and send the data continuously to the central unit so that these parameters can be displayed and processed at the central unit. The block diagram of our proposed model is shown in the Fig. 1.

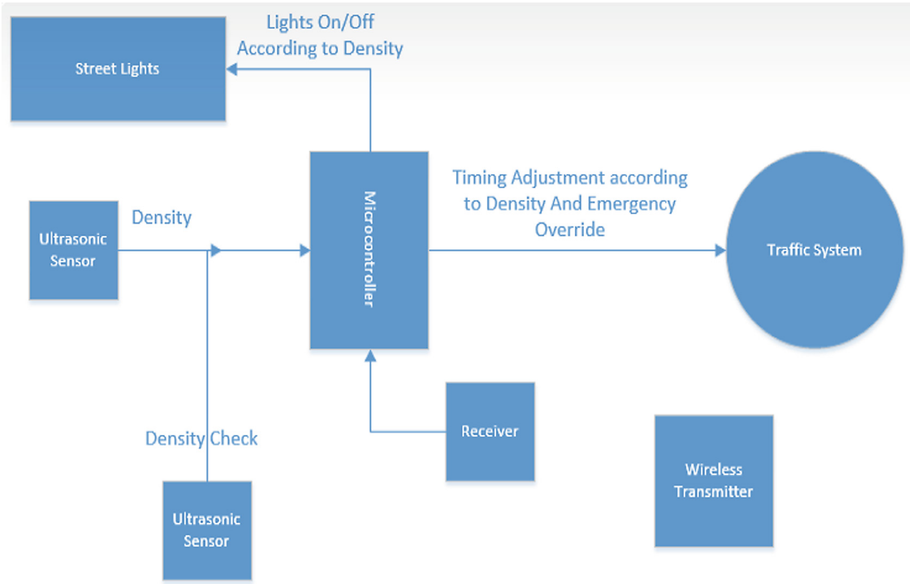

Fig. 1. Block diagram

In this era of technological advancement, there is an ever increasing need to find ways to make inventions cost effective and energy efficient. In this regard, this proposed model tries to achieve that purpose to some extent. The proposed smart traffic lights control system corresponds to an intersection of 4 uni-directional roads to form a "+" shape as shown in Fig. 2. It shows the intersection mounted with two traffic signals, labelled A and B, controlling the incoming car flow from roads 1 and 2. The other two lights labelled R and L are show the right and left deviation, respectively. Two Ultrasonic sensors are mounted on both sides of roads 1 and 2.

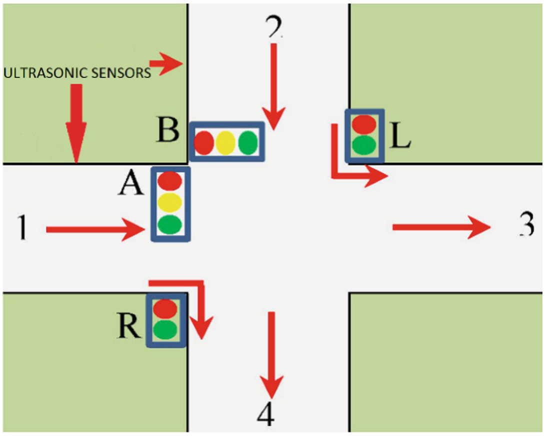

Fig. 2. Junction of 4 unidirectional roads

3.1 Hardware Components

The equipment used in our proposed model are:

Arduino UNO. Arduino UNO is a microcontroller panel, which consists of an ATmega328P controller chip. It is used in the smart street lighting system and in the portable remote for emergency vehicles as a main controller. There are 14 computerized input/output pins in the Arduino UNO. 6 output pins can be utilized as PWM. It works on a 16 MHz quartz crystal oscillator. It consists of a power pin, a USB port, a header and a reset button. The microcontroller board is interfaced with a computer or a laptop by using a USB cable. The Arduino UNO board uses the Arduino Software Integrated Development Environment (IDE) for programming and user interface. The Arduino UNO and variant 1.0 of the Arduino software IDE were one of the pioneers and earlier versions of the Arduino. The ATmega328 microcontroller board comes with a built-in bootloader that enables the user to upload different codes. A simple USB cable is used to upload the written code onto the microcontroller. The Arduino UNO uses its STK500 protocol to communicate with the computers.

Arduino Mega. This is a microcontroller board based on the ATmega1280 chip. In this project, it is used in the traffic light system and has a Bluetooth slave device connected to receive data from the remote transmitter used for the emergency override purposes. It is used due to the fact that it has more number of pins than the Arduino UNO, 54 input/output pins to be precise. 14 of its pins are used as Pulse Width Modulation (PWM) output. It also consists of 16 analogue input pins, 4 hardware serial ports, a header and a reset button. It works on a 16 MHz crystal oscillator and can be powered by using a power jack or a USB connection port. The microcontroller board is interfaced with a computer or a laptop by using a USB cable.

HC-SR04 Ultrasonic Sensor. The ultrasonic sensor is used in this prototype for detecting the presence of vehicles or pedestrians in the smart street lighting system. This sensor is also used in the traffic signal system for density detection. It is interfaced with the Arduino microcontroller. It is a module with 4 built-in input/output pins, namely Vcc, Trigger, Echo and Ground. The Ultrasonic HC-SR04 module has two eyes like figures on the front which act like a transmitter and a receiver. The transmitter transmits an ultrasonic wave of 40 kHz frequency. This wave travels in the air, at different angles in the vicinity of the sensor and when it hits any object, it reflects back in all the different directions. The recipient side of the sensor detects the echo or the reflected wave and measures the object's distance by this simple equation:

$$\boldsymbol{S} = \boldsymbol{vt}/2$$

Where,

S = Distance of the object
v = Velocity or motion speed of the object
t = Time

HC-05 Bluetooth Module. HC-05 module is a Bluetooth Serial Port Protocol (SPP) module, designed for wireless serial connection. The serial port Bluetooth module is a 2.4 GHz radio transceiver. It uses CSR Blue core 04-External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). In this proposed prototype, this module is used in the portable remote for wireless communication between the emergency vehicles and the traffic signal controller.

3.2 Density Based Traffic Lights

The designed smart traffic control system corresponds with 4 bidirectional roads meeting at a junction. In the traffic signal, we use three lights of color Red [R], Yellow [Y] and Green [G]. For the purpose of vehicular density checking, we use ultrasonic sensors. Distance of the obstacle can be measured using the travel time and the speed of sound. A programming loop starts when the system is turned ON, checking if there are any obstacles present in front of the ultrasonic sensor and if any, its distance is calculated. When the distance of the obstacle is less than the specified range, the microcontroller will cause the traffic-signal to provide a timing delay to that particular lane allowing more cars to cross the junction hence, reducing the congestion. Furthermore, this model provides three different modes of lighting transition contemplating to the volume of the traffic: the normal mode, low density mode, and high density or traffic jam mode. Each lane has 2 or 3 sensors mounted one after the other to determine the intensity of the traffic jam. If there is an obstacle or an automobile present in front of the first sensor, the low density mode will be instigated. Similarly, the 2nd sensor will determine the highest density mode prompting the signals to be activated for a longer period of time. The three time slots associated with these modes are illustrated in the Table 1.

Table 1. Traffic density modes

Traffic modes	Delay time
Normal mode	10 s
Low density mode	20 s
High density mode	30 s

In normal flow the each red and green light turns on for 10 s and yellow is for 3 s. When traffic density is increased at Lane 1 and its corresponding sensor detect high density, then the time of that road green signal increased to 20 s and it is same for roads 2, 3 and 4. If traffic is increasing at the same time at two roads 1 and 2 then the green signal time for both roads 1 and 2 is increased to 20 s. If traffic is increasing at three roads or four roads at a time, then the green signal time increased respectively three or four roads.

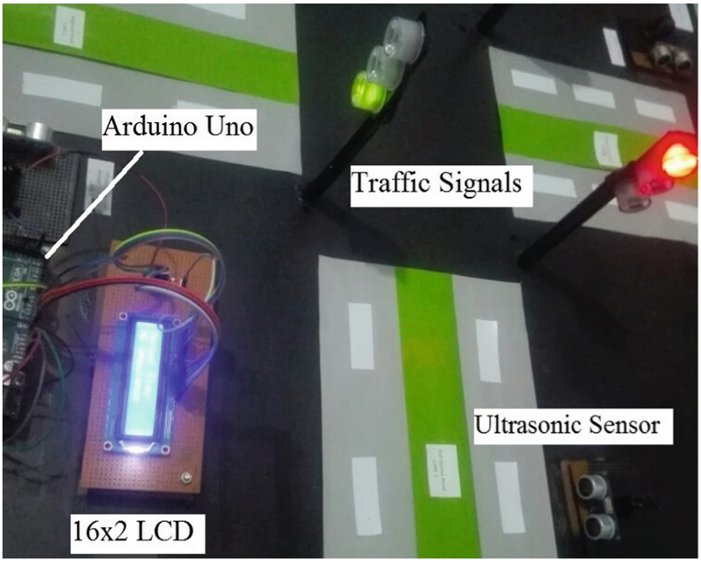

Fig. 3. Proposed traffic signals controller model (Color figure online)

The traffic junction controller consists of an Arduino Mega microcontroller, a Bluetooth slave module for receiving, and an LCD to display the information. HC-SR04 ultrasonic sensors are also interfaced with the microcontroller for density detection, which send data to the controller, hence adjusting the time slots of signals for each lane of road. It is shown in Fig. 3.

3.3 Emergency Vehicle Clearance

Every now and then we hear in the news about the fatalities caused by the stuck emergency vehicles in the congestions. In this model, when an emergency case is faced, emergency vehicles can be instantly cleared using a wireless remote. The remote is connected with traffic system using Bluetooth modules. Table 2 shows the emergency traffic configuration using a portable remote.

Table 2. Emergency traffic configuration

Button	Traffic Configuration
A	1-G ON 2-G OFF 3-G OFF 4-G OFF
B	1-G OFF 2-G ON 3-G OFF 4-G OFF
C	1-G OFF 2-G OFF 3-G ON 4-G OFF
D	1-G OFF 2-G OFF 3-G OFF 4-G ON

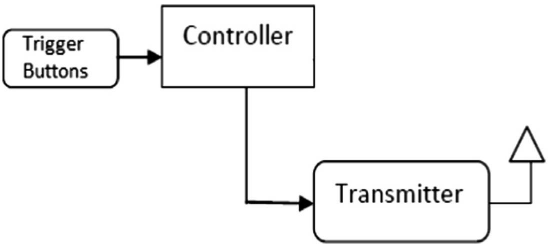

Fig. 4. Ambulance unit

When an emergency vehicle is stuck on road 1, the driver presses button A to instantly turn on the green light on road 1 and all red signals of other roads will be activated. The LCD provides display of the lane from which the ambulance or a fire brigade car is approaching, warning the authorities and the road users. In the same fashion, buttons B, C and D on the remote will clear their corresponding paths. By using the Bluetooth technology, the control system will allow access only to the authorized emergency personnel, hence, making the system secure.

An ambulance unit, shown in the Fig. 4, consists of an Arduino microcontroller interfaced with the Bluetooth transmitter. When the emergency responder presses a button on a remote, a connection is established with the junction controller. The controller in the Fig. 5 illustrates the traffic signal junction controller. It receives the

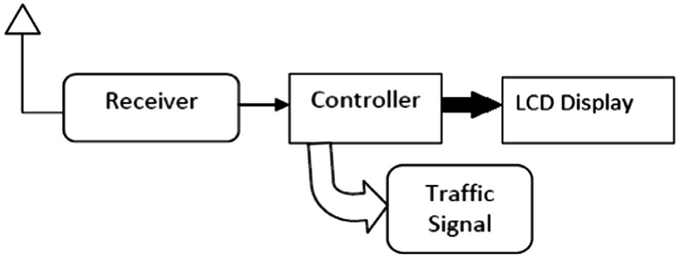

Fig. 5. Traffic junction unit

signal, analyses the lane from which the ambulance is approaching, displays the appropriate information on the LCD screen and allocates a clear path for the emergency vehicle.

3.4 Smart Street Lighting System

Another promising aim of this project is to incorporate the design of smart road lights. The conventional street lighting infrastructure is associated with just a number of Ultrasonic sensors integrated with the Arduino microcontroller to provide a simple, cost effective, energy optimal solution. The Ultrasonic sensors are placed strategically over the roads for movement detection. When the 1st ultrasonic sensor detects any vehicle movement, then the selected number of lights are prompted correspondingly and remain active until 2nd sensor detects vehicle. The controller checks if the 1st sensor's area is cleared of the automobile or not. If this is the case, then it turns off the lights and the 2nd sensor lights will activate and so on. The benefit of this model is that if the car breaks down in front of any of the sensors, it will continuously check the presence of the obstacle in order to keep the road lit unless it is cleared (Fig. 6).

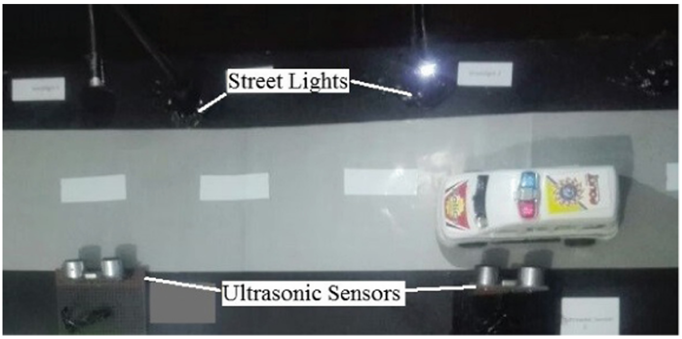

Fig. 6. Smart street lighting system prototype

Design parameters of the street light system, as shown in Fig. 7, are:

- ***Spacing***: Distance between the adjacent lights, measured along the road. The ratio between the space and height has conserved more than 3 to ensure uniformity.
- ***Outreach***: Horizontal distance between the light pole from the actual light mounting frame is termed as its outreach.
- ***Overhang***: Distance between the centre of the light to the neighboring edge of the road horizontally. The overhang is kept at one-fourth the height of pole for better distinguishability of footpath or pavements.
- ***Width***: It shows the road's width.
- ***Mounting Height***: Height of the mounting pole from the ground.

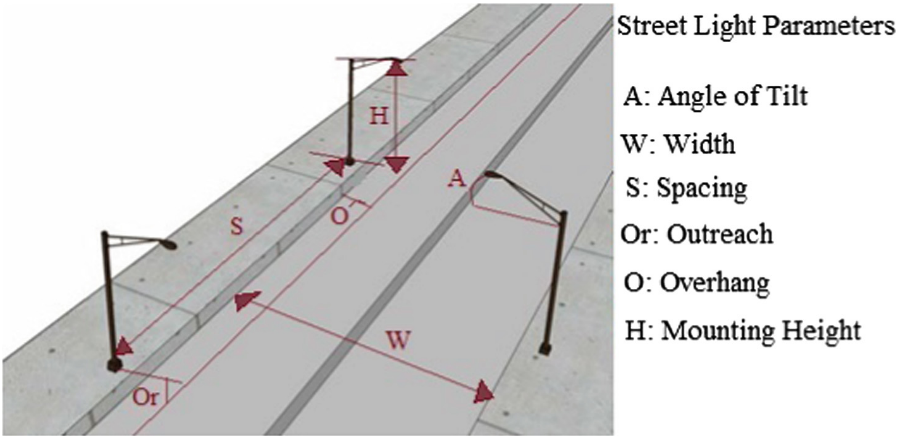

Fig. 7. Design parameters

4 Results and Discussions

This project has been designed to reduce the ever increasing traffic congestion on the roads, while providing the cost effective and lifesaving solution. This system detects the motion and sends the data continuously to the central unit so that these parameters can be processed. In addition, passengers will avoid unnecessary wait at traffic signals and emergency vehicles will be given priority by allowing them to control signals remotely. Furthermore, street lights work on the same principle also; activating only with the motion detection. Compared to the existing models, we have used the Bluetooth modules rather than RF or IR remotes for safe and secure wireless communication. The reason is that the RF remotes are easy to forge and the wireless communication can be intercepted easily. The problem with IR sensors is their Line of Sight (LOS) working and short ranges. In contrast to some other previously proposed models, we have used Ultrasonic sensors for detection of vehicles or pedestrians rather than IR sensors in the street lighting and traffic signal systems due to their relatively longer ranges and better reliability. Further comparisons are shown in Table 3.

Table 3. Comparison of sensors [19]

Parameters	IR sensor	Ultrasonic sensor
Frequency	353 THz	40 kHz
Range	10 cm–80 cm	2 cm–10 m
Beam pattern	Narrow (line)	Conical

As shown in the table above the IR sensor works in a narrow beam and has short ranges. Ultrasonic sensor, on the other hand, has better range and is more reliable as compared to the IR sensors. Therefore, we have used this sensor in our proposed model of traffic signal and street lighting system. For our portable remote option for emergency override feature, we have employed Bluetooth HC-05 modules for safe and secure wireless communication which would not have been the case with RF remotes (Table 4).

Table 4. Comparison of wireless communication devices

Parameters	ZigBee	Wi-Fi	NRF24L01	Bluetooth
Frequency band	868 MHz–2.4 GHz	2.4 GHz–5.9 GHz	2.4 GHz	2.4 GHz
Range	10 m–20 m	50 m	10 m–150 m	10 m
Data rate	20–250 kbps	54 Mbps+	250–2 Mbps	3 Mbps

5 Conclusions and Future Work

In this era of technological innovation, there is an ever increasing need to find ways to make inventions energy efficient. In this regard, this proposed model tries to achieve that purpose to some extent. The first part, called the density based signals reduces the needless waiting at signals, hence saves time. By the provision of prioritized clearance for emergency vehicles, precious lives can be saved. The smart lighting system helps in saving huge amounts of electricity cost and energy. The model is merged to create a cost effective, easy to use, and an endeavor feasible for implementation.

In future, research on developing and using innovative wireless technologies can help to make this system even more effective. Employing Wi-Fi modules would allow thousands of internet users to share their intended routes with the smart roads and signals through the cloud structure or Internet of Things (IoT). This would, therefore, allow other users to know the traffic conditions, car accidents on the roads, etc. hence drastically reducing the traffic congestion in cities. In order to accomplish a complete synchronization, the integration of different traffic controllers can be monitored in the future.

References

1. Kham, N., Nwe, C.: Implementation of modem traffic light control system. Int. J. Sci. Res. Publ. **4**(6) (2014)
2. Isa, I., Shaari, N., Fayeez, A., Azlin, N.: Portable wireless traffic light system (PWTLS). Int. J. Res. Eng. Technol. **3**(2), 242–247 (2014)
3. Sinhmar, P.: Intelligent traffic light and density control using IR sensors and microcontroller. Int. J. Adv. Technol. Eng. Res. (lJATER) **2**(2), 30–35 (2012)
4. Geetha, E., Viswanadha, V., Kavitha, G.: Design of intelligent auto traffic signal controller with emergency override. Int. J. Eng. Sci. Innov. Technol. (IJESIT) **3**(4), 670–675 (2014)
5. Kavya, G., Saranya, B.: Density based intelligent traffic signal system using PIC microcontroller. Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET) **3**(I), 205–209 (2015)
6. Dakhole, A., Moon, M.: Design of intelligent traffic control system based on ARM. Int. J. Adv. Res. Comput. Sci. Manag. Stud. **1**(6), 76–80 (2013)
7. Jadhav, A., Madhuri, B., Ketan, T.: Intelligent traffic light control system (ITLCS). In: Proceedings of the 4th IRF International Conference, Pune, 16 March 2014
8. Srivastava, M.D., Prerna, S.S., Sharma, S., Tyagi, U.: Smart traffic control system using PLC and SCADA. Int. J. Innov. Res. Sci. Eng. Technol. **I**(2), 169–172 (2012)
9. Khattak, M.: PLC based intelligent traffic control system. Int. J. Electr. Comput. Sci. (IJECS) **II**(6), 69–73 (2011)
10. Vidhya, K., Banu, A.B.: Density based traffic signal system. Int. J. Innov. Res. Sci., Eng. Technol. **3**(3), 2218–2222 (2014)
11. Ghazal, B.: Smart traffic light control system. In: Third International Conference on Electrical, Electronics, Computer Engineering and their Applications (EECEA). IEEE (2016)
12. Krishna, G.V.: Intelligent Street Lighting. Int. J. Innov. Eng. Technol. (IJIET) **8**(2) (2017)
13. Pearson, J.W.: Automated traffic control system having an interactive emergency vehicle warning therein. U.S. Patent No. 6,987,464, 17 January 2006
14. Obeck, C.J.: Traffic signal control for emergency vehicles. U.S. Patent No. 5,014,052, 7 May 1991
15. Smith, M.R., Davidson, J., Pfister, H.: Emergency vehicle warning and traffic control system. U.S. Patent No. 4,704,610, 3 November 1987
16. Tank, M.A.: Review on Smart Traffic Control for Emergency Vehicles. Int. J. Comput. Appl. **112**(7) (2015)
17. Leccese, F.: Remote-control system of high efficiency and intelligent street lighting using a ZigBee network of devices and sensors. IEEE Trans. Power Delivery **28**(1), 21–28 (2013)
18. Swathi, A., Silva, L.R.: Remote control system of high efficiency and intelligent street lighting using a ZigBee network of devices and sensors. Int. J. Innov. Technol. **03**, 673–678 (2015). ISSN 2321-8665
19. Adarsh, S.: Performance comparison of Infrared and Ultrasonic sensors for obstacles of different materials in vehicle/robot navigation applications. In: 2016 IOP Conference Series: Materials Science and Engineering, vol. 149, p. 012141 (2016)