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ORIGINAL STUDY

Organization of Traffic on the Main Streets Microcontroller Traffic Lights

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Abstract

Traffic congestion at densely populated intersections and large numbers of vehicles negatively affect people's lives. Due to this, governments try to regulate the flow of traffic in an attempt to reduce traffic congestion. A static control system may prevent emergency vehicles because of traffic jams. Traffic light systems (TLs) have acquired increasing attention in avoiding road jams and traffic detection. They are ubiquitous because of their easy installation, faster information transformation, less maintenance, less compact, and cheaper than other networks' options. The proposed TLs use IR sensors to measure vehicle density and in each instruction, there is a microcontroller that manages the traffic signal. The research aims to minimize the waiting time and maximize the serviced number of vehicles at traffic lights at a jammed multi-road intersection. To prove our solution, the proposed system improved the elements needed for modelling microcontrollers and the sensors in the simulation environment. Finally, experiments were executed using codes for the two models; the normal traffic light and the smart traffic light, and comparing the two systems. The results obtained show that the proposed system can improve other used solutions to reduce vehicle trip duration and the cost of expensive systems.

Keywords: Atmega microcontroller, Traffic light system (TLs), Sensing systems, Traffic signal simulation, Traffic light management

1. Introduction

Since 1912, traffic lights have been in development. It is a signal-using device used to control traffic flows at intersections of roads, railroads, pedestrian crossings, and other areas. Traffic lights have three colors: red, yellow, and green. The red light forbids vehicles from moving forward, the yellow signal alerts traffic to halt, and the green light permits vehicles to move forward in the designated direction [1].

Due to the high volume of vehicles, one of the most common challenges in modern life is traffic congestion at crossroads with dense populations. People's lives are negatively impacted by traffic jams in numerous ways, including higher fuel use, pollution, lost time in traffic, and stress for both drivers and passengers. When the number of vehicles increases and more room is needed for traffic flow, traffic congestion ensues. To lessen traffic congestion, governments attempt to control traffic flow [2].

However, due to the numerous aspects involved, the traffic management problem is challenging. The first is that the traffic flow is dependent on the daytime, with morning and afternoon being the busiest times. It also depends on the weekdays, with weekends having the lightest traffic on Fridays and

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Saturdays [3], the majority of the time, there is significant traffic traveling from cities to their peripheries and vice versa, as well as during vacations and even in the summer. The second point is that the typical traffic light signal system is built with predetermined delays so that the time it takes for the lights to change is fixed on a regular basis and doesn't depend on the actual speed of the flow of traffic. Thirdly, traffic flow at nearby intersections is impacted by the state of the light at the intersection. Last but not least, the traditional traffic signal system disregards the effects of accidents, road construction, and vehicle breakdowns [4,5].

To monitor and manage traffic flow, numerous smart traffic solutions are now available. The perfect time for the green, yellow, and red signals that are adequate for the proper real-time were recommended by researchers, as were mathematical models to compute the waiting times of the cars at intersections, the dispersion of the vehicle waiting for the green light along the path, and. Finding a flexible solution is extremely difficult, if not impossible. Researchers from a variety of fields have worked together to identify potential methods to reduce traffic bottlenecks. As a result, various techniques have been proposed, many of which rely on the development of microcomputers, contemporary hardware, sensors, and traffic light complexity [6,7].

Many traffic light systems employ IR sensors; a vehicle passes between the transmitter and receiver when they are placed on opposite sides of the road. The counter will go up by one and the system will be running. The collected data on-road density will be examined from every angle. The microcontroller, even if it is a PIC, will dynamically lengthen the time of the green light in the instruction with the most PLCs for the vehicle [1,8].

Vehicle traffic is one of the most important issues in contemporary civilization, and it has been extensively researched [9]. Intelligent traffic systems (ITSs) are utilized and its objectives are to minimize waiting times, increase the amount of time that traffic signals are in operation, effectively manage traffic, and decrease the frequency and duration of traffic jams. Track the changing road networks more carefully, use traffic flow prediction to reduce traffic, give emergency vehicles the go-ahead, and seize stolen vehicles [1]. With the help of the data collected by the traffic sensor network, ITS can address a variety of traffic-related issues, including periods of heavy traffic [10].

The goal of the research was to open the green signal for real-time vehicle numbers that are detected by the IR sensors in order to reduce waiting times and increase the number of vehicles that were served at traffic signals at a congested multi-road intersection. Additionally, it strives to prioritize emergency vehicle-equipped development over other construction.

2. Related works

This section presents a comment on the related work that used different optimization techniques in traffic light systems, specifically the works that focused on the location of the sensor and smart traffic light control.

Siddiqi et al. [11] in this paper, ambulances, police, fire brigades, and other vehicles respond to emergencies. In order for the vital trucks to travel to their destination as quickly as feasible, an application and a corresponding solution have been built. In this work, a route between the current location of the emergency vehicle and the intended location in an emergency is found. A mobile app was created exclusively for drivers of vehicles, allowing them to communicate with traffic lights. Also in this method, the person in charge of managing the lights can regulate the traffic lights as vehicles pass. The smartphone application was used to normalize the traffic lights once priority vehicles had passed and arrived at their destination.

Chowdhury et al. [12] The paper suggests a priority-based incident management system that is directed by an unmanned aerial vehicle (UAV) to help electric vehicles (EVs) have minimal clearance time at intersections and, as a result, have a shorter reaction time. In order to ensure that EVs may arrive at the incident location in a timely manner while causing the least amount of interruption to other on-road vehicles, the suggested strategy chooses an optimal path by managing the traffic light phase time. It also takes into account the disruption faced by other nearby non-emergency vehicles adjacent to the EVs' travel path. According to the results of the simulation, the suggested approach reduces the response time for EVs by 8% while increasing the clearance time around the incident site by 12%.

Masanta et al. [13] this paper suggests a three-stage system that can guide and manage traffic and emergency vehicles depending on the rate of congestion. In the first stage, The system analyses the images that have been captured and determines the Index value, which is used to determine the rate of congestion. The width and length of the road that the camera is capturing photographs of determine the Index value for that particular route. In the second stage, the system checks the road for any emergency vehicles, in the final stage; the edge server serves as where all of the processing and decision-making takes place. The suggested system is reliable and takes into account unfavourable weather circumstances like windy and foggy, additionally, it performs well in dim lighting.

Gamal et al. [14] this paper suggests smart detectors monitor and manage real-time traffic data. Detectors can track vehicle IDs and give priority to emergency vehicles in addition to comprehending traffic flow. The study presents an adaptive, flexible, and distributed traffic control system that effectively interprets data gathered from smart detectors to manage traffic signals in a way that cuts down on emergency vehicle response time. The system outperforms the most recent average response time and emergency vehicle routing in a congested location, according to experimental results.

Alkhatib et al. [15] this study suggests a smart Road traffic Control management system termed Urban Traffic Control (UTC) improving the level of road traffic network management by keeping in mind the real-time dynamic traffic flow. UTC offers methodologies including vehicle counting, managing processes, and evaluation of lanes while keeping status in mind to create an orderly traffic arrangement. This entire procedure is accomplished by taking into account the entire traffic network rather than just taking intersections into account. This system's main objective is to reduce traffic bottlenecks by minimizing the distance travelled and the amount of time spent waiting at crossroads and crossings. To determine the traffic flow plan that will cause the least amount of traffic congestion and vehicle waiting time, this study introduces certain indicators and models. These versions include lane weight, traffic jam indicator, and vehicle priority.

Shankaran et al. [16] this study presents a model of a camera-based traffic monitoring and processing system that has particular features for emergency vehicles and reduces cycle time.

Vohra et al. [17] The suggested system emphasizes the delays of time brought on by unnecessary, ineffective traffic congestion to address this issue and solve it with clear-cut logical solutions that would be beneficial to society as a whole. The location of the ambulance is determined by a combined network of computers, and a central controller adjusts the traffic lights adaptively to minimize the victim's delay time to no human interference after calculating and displaying the most efficient route to the accident. The suggested system will be implemented with consideration for emergency vehicles' safety, providing them with a better path.

Mohamed et al. [18] this paper suggest a Smart Traffic Signal (STS) and Intelligent Traffic Management System (ITMS) controller design is suggested in the study. Additionally, the current local traffic control at an intersection should be fair, minimize commute times, provide a decent traffic flow, lessen traffic congestion, and provide precedence to emergency vehicles to meet the demands of future smart cities. According to simulation data, the proposed system performs better than the current management system and may be a candidate for the traffic management system in emerging smart cities. The suggested adaptive method increases the number of vehicles being serviced while simultaneously reducing the average waiting time (delay) by a significant amount.

Deepajothi et al. [19] Convolutional neural network (CNN)-based traffic management for emergency vehicles is proposed in this research. The Raspberry Pi is equipped with the CNN model. The CNN model will accept the traffic-road video and make a speedy decision to let the emergency vehicle through. Compared to conventional image processing techniques, the suggested solution is more accurate and less expensive.

Yousef et al. [20] used information that was recorded as a history of traffic to determine the period of green/red lights for each direction in the intersection. They proposed to use a history-based traffic control algorithm that relied on previous information on all-year traffic to predict the flow of traffic on jammed streets of a crowded city.

Haferkamp et al. [21], suggested using radio signals for detecting the traffic flow and classifying vehicles using measurements of signal attenuation and algorithms of machine learning. The study presented a radio-based approach that combines ray tracing simulations, machine learning, and measurements in the field.

3. Electronic Components Final Stage

As an alternative to the limitations of the normal traffic light, to achieve self-organization the research proposed using a Smart Traffic System consisting of an Atmega microcontroller four IR sensors, and four traffic lights as shown in Fig. 1. The microcontroller is disposed at left while the IR sensors are shown at the right.

4. The Main Components

4.1. ATmega8

Advanced Virtual RISC (AVR) is a family of microcontrollers from Atmel produced in 1996 based on modified Harvard Architecture. Therefore, a microcontroller is a miniature computer housed in

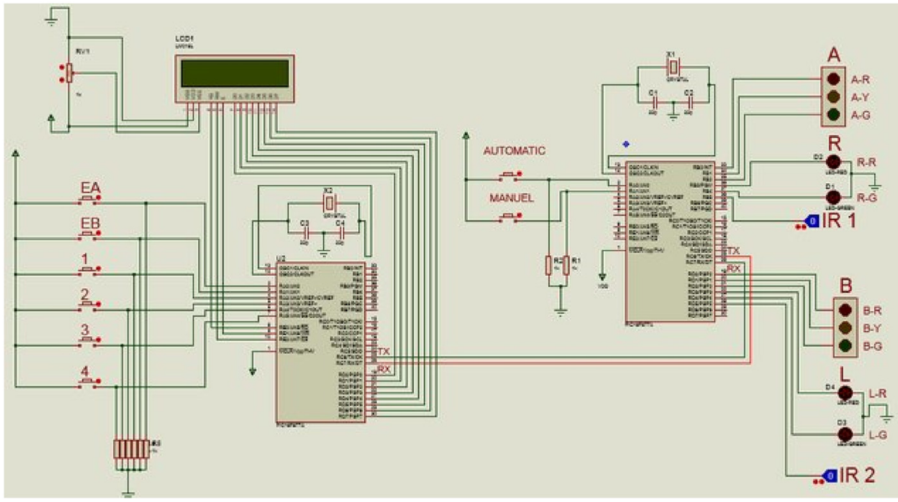

Fig. 1. Circuit Block Diagram Simulated in Proteus [23].

a single IC and may be configured to do a wide range of tasks. AVRs come with a variety of built-in peripherals, including timers, serial connections, and pulse width modulation (PWM), analogy-to-digital converters (ADC), digital input–output (I/O) ports, and many more. AVRs are simple to use and cost-effective.

Atmega8 as shown in Fig. 2 supports 16 MIPS at 16 MHz throughput and runs between 2.7 and 5.5 V. The following capabilities are offered by ATmega8:

- 8 KB Programmable Flash memory (Special type PROM) has 10,000 Write/erase cycles and this memory is used to store programs and it can be changed by the programmer.

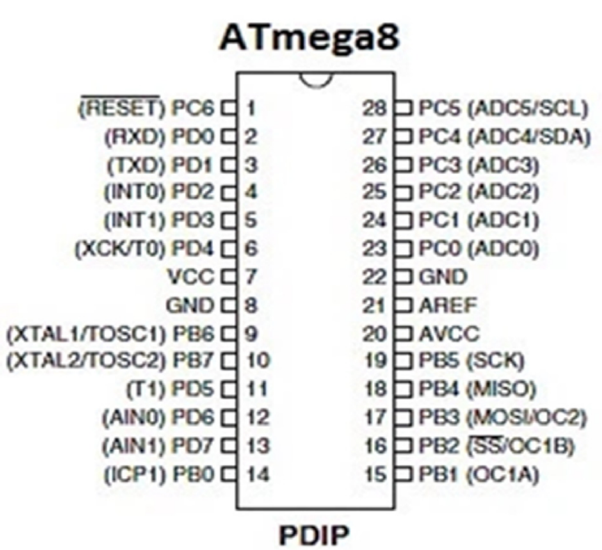

Fig. 2. Pin Configuration of the Atmega Microcontroller [24].

- 1 KB SRAM (Volatile) used as cache or buffer to reduce accessing of flash memory, Thus storing frequently accessed data.
- 512bytes EEPROM has a 1,000,000 write/erase cycle and it can be used to store and access any data for a long time, This can be done by setting special registers inside AVR via the program.
- 23 input/output Lines (PB0-7, PC0-6, and PD0-7).
- Two 8-bit Timers/counter and one 16-bit Timer/counter.
- 3 PWM channels available.
- Communication Protocols 1 USART, 1 SPI & 1 I2C/TWI.

4.2. IR sensors

An IR transmitter resembles an LED in appearance. IR rays are always emitted by this IR emitter. This IR transmitter's working voltage ranges from 2V to 3V. These IR rays can't be seen by the human eye, but they can be viewed through the camera. IR receiver receives the transmitted infrared rays by the IR transmitter. IR receiver resistance is high in the order of mega ohms; the resistance will be very low when it receives IR rays. The voltage of operating for IR receiver is 2v to 3v too.

Fig. 3 shows the circuit of the IR sensor. The value of the used resistor is 330 Ω to descent the voltage otherwise IR transmitter may be damaged. A potentiometer is used to vary the block sensing distance. The output from the transistor collector is taken. Digital output is given by this sensor.

Traffic lights are attached to PORTS B and D, while IR sensors are connected to PORTC on the microcontroller's pins (0, 1, 2, and 3). The output of that particular sensor will be logic 1 if there is traffic

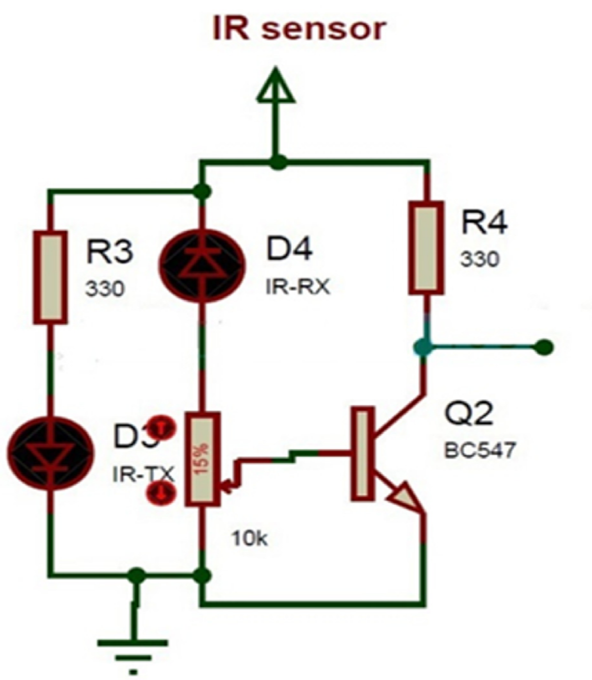

Fig. 3. IR Sensor Circuit [23].

on the road, else it will be logic 0. A program must be built to control the traffic system using these IR sensor outputs. Any path that receives logic 1 from a sensor must receive a green signal, and all other paths must receive a red signal. Here, the IR sensors must continuously be contended to check for the vehicles on the roads of the intersection.

4.3. Traffic light

Light-emitting diodes (LEDs) are yellow, green, and red that are used instead of traffic lights. In classic traffic systems, the LEDs are on a time basis. If the traffic depends on density and it is high in any specific way, the green LED will glow for that specific way and the red LEDs will glow for the remaining paths at the same time.

For simulation purposes, as shown in Fig. 4 these IR sensors must be placed with a trigger button in such a way that the IR receiver should be able to receive the IR rays even if there is an obstruction in the way of this IR pair. The transmitted IR rays strike the object when the power is applied and bounce back to the IR receiver.

5. System Design

To date, none of the many remedies and suggestions that have been made to lessen traffic bottlenecks have been put into action. The high cost of some systems, privacy concerns in systems that use cameras to analyze vehicle density, the inefficiency of this method in challenging weather conditions like fog, snow, heavy rain, or sandstorms in some areas, and the lack of historical data for many intersections in systems that use prediction from historical road data for previous years or even for a short period are all potential reasons for not implementing these solutions. This study suggests employing an intelligent traffic signal system that uses IR sensors and a microcontroller to address the issue of traffic congestion at intersections.

As depicted in Fig. 5, the smart traffic light corresponds to the "+"-shaped intersection of four bidirectional streets. The initial goal of the research is to look at the workings of the existing systems and identify the best tools to use. A test of the planned integrated hardware, software, and architecture design is also included. The next step is to use RFID to find the intersection that has emergency vehicles like police, ambulances, and fire trucks and deal with it.

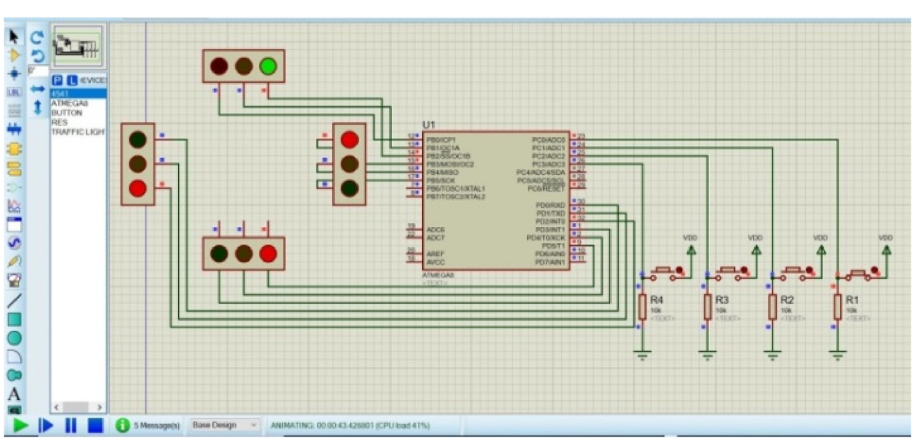

Fig. 4. Replacing IR Sensors with Trigger Button [23].

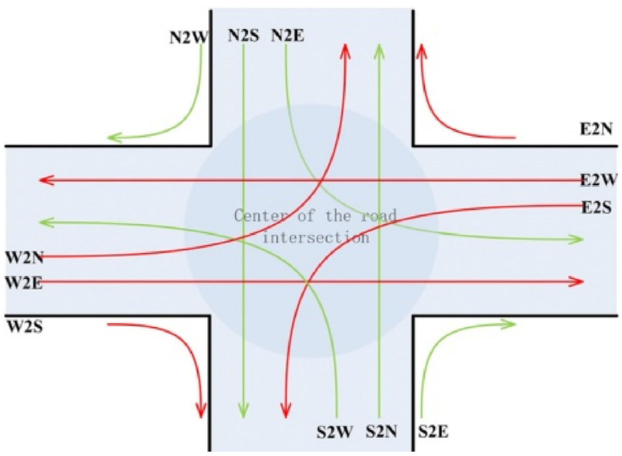

Fig. 5. Intersection of Four Bidirectional Roads [22].

5.1. Traffic light configurations

The proposed smart traffic signal system has four possible configurations, the first of which will permit turning to the right and left and crossing from the west to the east forward. The second configuration will enable turning to the right and left while crossing from the south ahead to the north. With the third configuration, you can move from the east forward to the west while making turns to the right and left. The fourth configuration will enable turning to the right and left while crossing from the North ahead to the South.

5.2. IR sensors and density traffic light

The beginning of the day, when students leave for school or university and when workers report to work, is when traffic congestion in the city most frequently occurs. They frequently come from the same direction. The same combination is also seen in carefully watched departure times close to businesses, organizations, schools, and institutions. There is a need for a system that can sense the density, determine how many vehicles are at intersections, make a decision, and manage the traffic light at that intersection because there are fewer vehicles at night and many streets are empty at midnight.

A 38 kHz square wave signal is routinely and continuously produced by the infrared (IR) transmitter and is picked up by the traffic controller-attached IR receiver. When a vehicle passes in front of the IR transceivers, causing the IR radiation to bounce, the system is activated. The vehicle density counter is increased during this activation procedure, which the traffic controller will analyze.

The Smart Traffic Light System will determine how many vehicles are coming and crossing the intersection. The number of vehicles is measured using infrared sensors that measure density; one sensor is positioned at the intersection, while others are located at varying distances in the beginning and center of the street heading to the intersection. These sensors are linked to a microcontroller, which regulates the traffic signal. The Atmega microcontroller controls the traffic light. The three suggested

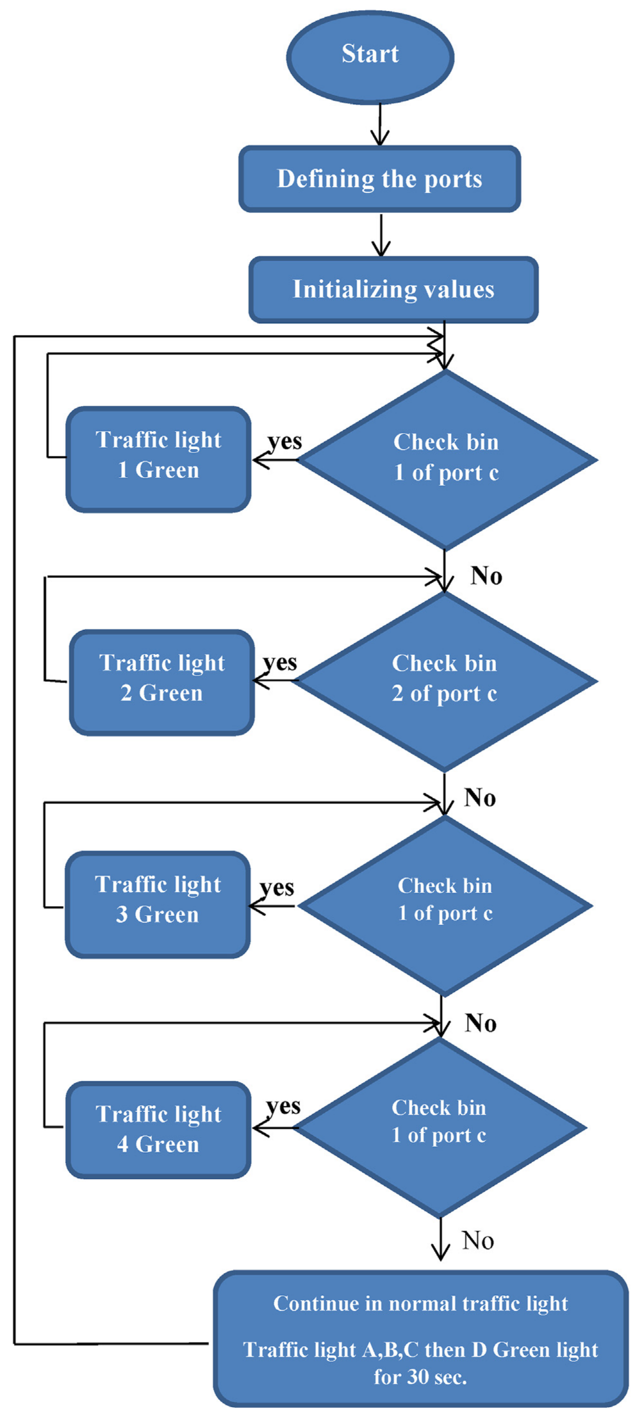

Fig. 6. Flow Chart of the Proposed System.

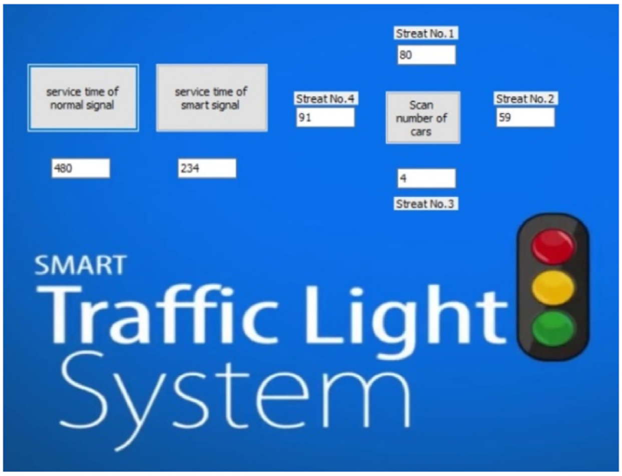

Fig. 7. c# Program Built in VB.net with Calculated Example.

lighting transition slot modes are the typical mode, traffic jam mode, and mild traffic mode. These three settings are altered dynamically and instantly.

When the number of vehicles is equal, small, and close together, the Atmega microcontroller will stay in the normal mode, rounding the intersections and opening the green light for 28 s, 2 s for the yellow signal, and 30 s for the red signal. In the second mode, the microprocessor will turn green the construction with the highest density and keep it green until the intersection is empty and all vehicles have passed through, then the less dense one, and so on. Finally, in the third mode, it will not open the green light at junctions where there is no car to avoid wasting time. The proposed smart traffic light system will continue acting in that way until the end of the conjunction then it will return to the normal mode.

In the second mode, the microprocessor will turn on the green light for the construction with the highest density and keep it on until the command is completed and all cars have passed through the junction, then the less dense one, and so on. Finally, in the third mode, it will not open the green light at junctions where there is no car to avoid wasting time. The proposed smart traffic light system will continue to function in this manner until the conjunction ends, at which point it will return to its normal state. Fig. 6 depicts the suggested model's flow chart.

6. Results and Discussion

To compare and examine the suggested STLs two code models in C# are built, the first model for the normal traffic light system and the second model for the system, also a program is made using VB.net to determine the service time of each system as shown in Fig. 7.

For the number of vehicles in each intersection a number generator is used, the system will take a read of the actual real-time vehicle density every cycle with n, supposed that every vehicle will take 1 s to cross the junction (n) represents the total number of vehicle s in each cycle. The normal signal system will deal with vehicles by taking a round to all four intersections until they are empty. This will take 30 s for every intersection round and it will waste 30 s also for an empty intersection if the proposed system takes the example shown in the figure from the program that computes the service time at each system as shown in Table 1 and Table 2, as follows:

Table 1 show that in proposed system will search for the maximum number and empty it. The system takes four variable length rounds and determines the total serviced time it will be the summation of all the intersections" numbers. Thus, in the proposed system, it will take 234 (seconds) to empty all the intersections.

While, Table 2 shows that in the normal signal, it will round to all the intersections even the empty ones and in each cycle, it will be across 30 vehicles, thus, concluding that the service time for the proposed system can be determined by multiplying the number of rounds by 30, while in the normal system, it will take 480 s to serve all the vehicles.

Fig. 8 shows a sample of chosen data taken from the random generator of the VB.net program. (9) Cases were taken and the serviced time needed for each case in the two systems was as shown in Fig. 9.

From Figs. 8 and 9, the proposed system is better than the normal system in all the sample data, and in any case, it can be chosen because it depends on the real-time that the vehicle needs. From case no.9 this system also can conclude that if there is a conjunction in one of the intersections there will be a high difference in the service time between the two systems. , In case 8 all the intersections' vehicle

Table 1. Proposed traffic signal.

Round No.	1st Intersection	2nd Intersection	3rd Intersection	4th Intersection
	80	**59**	**4**	**91**
1				**0**
2	**0**			
3		**0**		
4			**0**	

Table 2. Normal traffic signal.

Round No.	1st Intersection	2nd Intersection	3rd Intersection	4th Intersection
	80	59	4	91
1	50			
2		29		
3			0	
4				61
5	20			
6		0		
7			0	
8				31
9	0			
10		0		
11			0	
12				1
13	0			
14		0		
15			0	
16				0

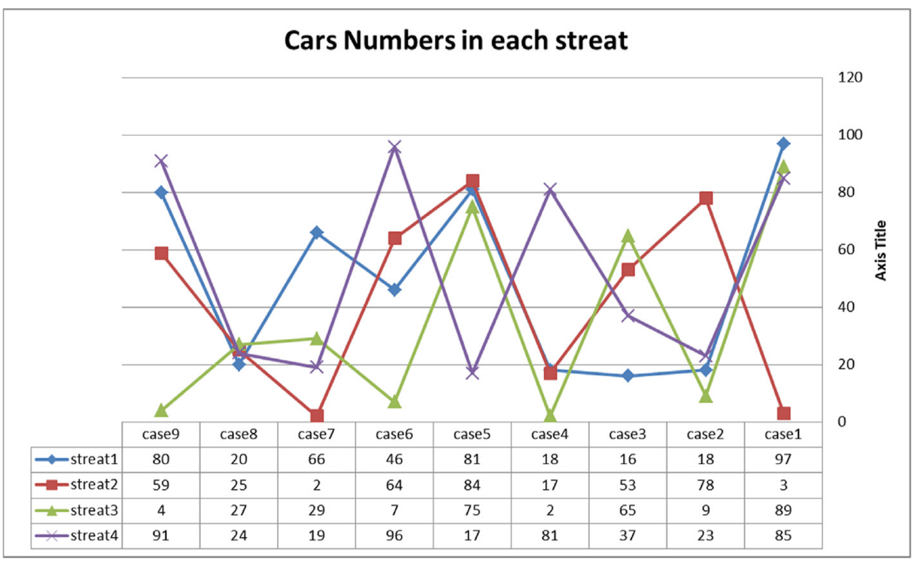

Fig. 8. Studied Cases and Number of Vehicle s at each Intersection.

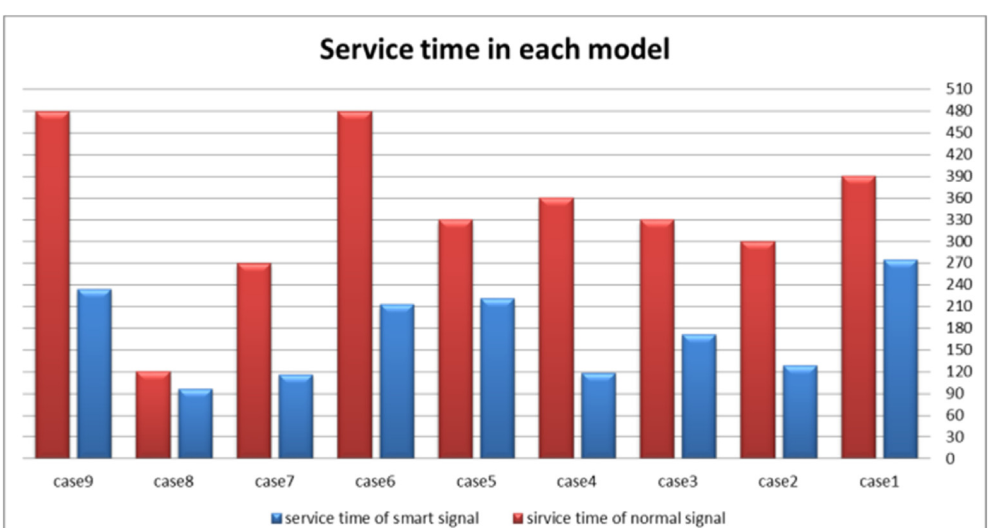

Fig. 9. Cases Service Time.

numbers were less than 30, so the difference in service time between the two systems will be low and the proposed system is still giving less time to serve all the vehicles at any number of vehicles on the intersection. Here, if the proposed system will help to decrease the time at the traffic light and there will be fewer conjunctions, less serviced time, a high number of serviced vehicles, and fewer traffic jams to minimize the Average Waiting Time (AWT) consequently, the Average Queue Length (AQL), save fuel, less stress for the drivers and less accidents are achieved in the proposed system.

7. Conclusion

The system created may prove to be a step in the right direction for creating a dynamic traffic control model that can aid in time and fuel savings. Since IR sensors are placed on both sides of the road, which makes maintenance and replacement simple, they have a considerably wider practical range than the ones the system used. They may also be a better option than other sensors. In the suggested model, numerous RF receiver−transmitter pair modules can operate effectively at the higher range.

The STL system can be extended easily; the system is more suitable for cases when traffic jams change in a dynamic way within a short period. In addition, the proposed system allows transitions smoothly between sequential traffic light settings by considering offsets.

7.1. Limitations of this study

- Traffic light system may work improperly due to IR sensors which may sometimes absorb normal light.
- The system may have incorrect reads for large distances because IR sensors work for fewer distances only.
- IR sensors may not detect the traffic density accurately so it must be arranged.
- Ideas for future research consider variables such as using RFID to sense the emergency vehicles (police, ambulance, and firefighter), pedestrians, and disruption of a certain vehicle at the intersection and crowded downstream street after the intersection to form an integrated traffic signal system that takes into consideration all the variables and actual conditions.

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