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University of Tripoli's Real-Time Density-Based Traffic Light Controller on FPGA

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الملخص

الهدف من هذا البحث هو تصميم منظومه تحكم ذكيه تتحكم في تقاطعات الطرق و توجيه حركة المركبات لتقليل نسبة الازدحام داخل حرم جامعة طرابلس, تم استخدام الشريحة القابله للبرمجهFPGA للتحكم في هذا التصميم. كما تم استخدام لغة Verilog HDL لبرمجة و تصميم هذا المشروع. قمنا بتصميم هذا المشروع ليكون نموذج عملي ليتم تنفيذه داخل حرم جامعة طرابلس. يقدم هذا النظام المروري خاصية تمكن من تقديم وقت مناسب للإشارة الخضراء اعتمادا على درجة إزدحام الطريق و بهذا نضمن تقليل الإزدحام بطريقه أسرع في الطرق المزدحمه. يقدم هذا النظام أيضا خاصية تمكن سيارات الطوارئ من الحصول على أولوية المرور في أي وقت دون أن تنتظر الإشارة الخضراء. و يوفر هذا النظام للسائق خاصية الإطلاع على مستوى إزدحام الطريق عن طريق شاشات عرض مثبته في بداية الطريق لتمكن السائق من إتخاذ القرار لإختيار الطريق الأقل إزدحاماً. يمكن استخدام هذا النظام في عدة مناطق ولا يقتصر على جامعة طرابلس وذلك بعد تحويره و إجراء إضافات عليه.

ABSTRACT

The university of Tripoli encounters today's mobility challenges such as increased traffic and congestion. This paper presents a real-time density-based traffic light controller system. The system ensures saving time for faculties, students, and employees by reducing congestion within the university campus. Real-time traffic density is detected using an array of display screens and infrared (IR) sensors placed on each four-way intersection. The display screens provide information on road congestion to show the right way to enter or exit the campus. The system continues monitoring the data coming from display screens and IR sensors and provides real-time traffic. in case of emergencies, the system gives the priority to emergency vehicles using radio frequency identification (RFID). In this research work, the basic modules of the proposed real-time density-based traffic light controller system are designed and simulated with Verilog Hardware Description Language (HDL) and implemented on Cyclone IV GX field-programmable gate arrays (FPGA). This design will contribute to the stabilization and optimization of the traffic at the University of Tripoli campus.

KEYWORDS—Traffic Light Controller, Verilog Hardwar Description Language, FPGA, RFID, IR infrared.

INTRODUCTION

Nowadays, due to the increasing number of vehicles, it is easy to cause a traffic jam. Traffic jams occur when the vehicle is completely stopped for a long time [1]. The traditional traffic light is no longer able to deal with traffic jams and congestion, especially since it has a fixed period of time for all roads in the intersection, whether the road is congested with traffic or not, and does not take into account emergency situations, that led us to think of designing a smart and efficient system to overcome those issue. FPGA-based intelligent traffic light controller (TLC) has been studied to model an efficient traffic flow system to replace traditional traffic light controllers based on a 24-hour delay, where different traffic light delays are applied to each time zone [2]. A priority sequence approach has also been developed by manually modifying the wait time for each route [3]. A 24-hour TLC manages the movement of traffic on four routes established by [4]. In [5]. The main feature of our system is that it relies on detecting infrared sensors (IR) and corresponding radio frequency identification (RFID) readers to organize and control traffic. Density-based traffic and emergency are automatically managed and controlled by FPGA as a system on a programmable chip (SOPC). Another dynamic TLC has also been proposed where traffic density is measured as a function of the number of active sensors[6]. Another useful feature is offered in our proposed system, to avoid congestion at the intersection and road closure, the traffic light changes, according to the information that received from sensors that installed in the main roads, the traffic light activates the condition all-red , which is make all traffic lights at the intersection light up in red and stop cars until there is enough space for cars to pass. To facilitate the movement of the driver and avoid congestion, display screens were installed in the entries of university, showing the congestion of each gate to make it clear for drivers to choose the appropriate entrance and the least crowded way to use, and other display screens are installed inside the university campus, showing the extent of traffic congestion on the roads which show the least crowded path to reach the university exits.

METHODOLOGY

A. SYSTEM STRUCTURE OVERVIEW

This system manages a four-way intersection. Five IR sensors are installed on each road to monitor the density of the vehicles. They are separated from each other which gives us the best indication of the traffic density. RFID readers is installed on the four roads to detect and identify emergency vehicles. The RFID reader emits radio waves and receives signals back from the RFID tag that installed in the emergency vehicles. Tags, which use radio waves to communicate their identity and other information to nearby readers. Interference between readers and tags can prevent the system from working effectively, correct installation and auditing the frequency spectrums used by devices within the same environment can avoid potential interference issues. A traffic display screen is installed at the beginning of each road to help drivers to avoid crowded roads and choose the fewer traffic ways to enter or exit the university campus.

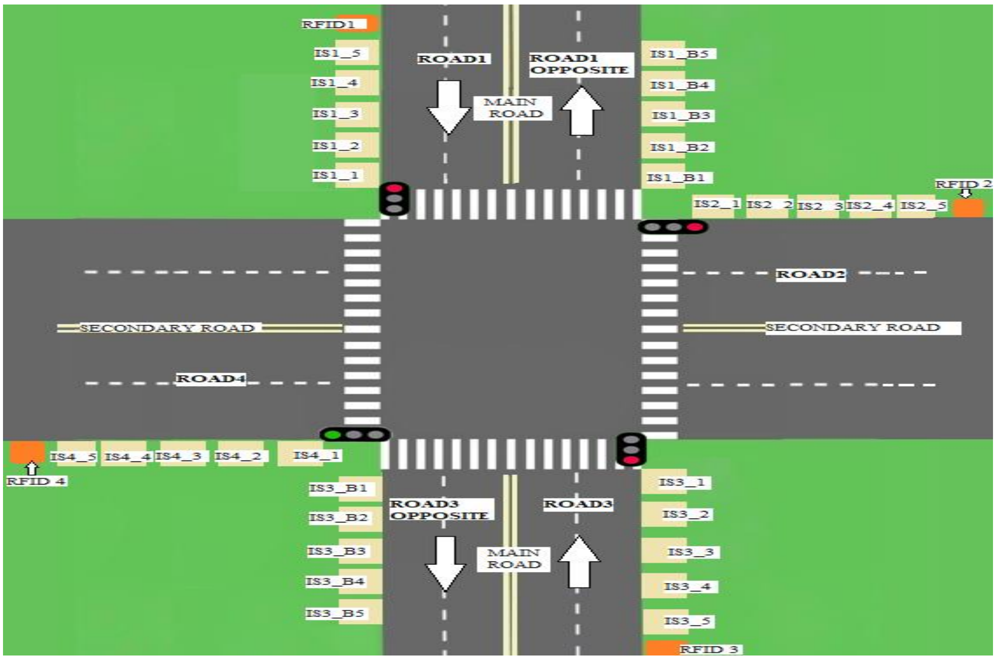

Figure 1. The structure of the system

B. SYSTEM ALGORITHM

The system consists of nine states each road has two states green and yellow and one common state where all roads are red. Also, the system has three different flow of state diagrams depending on the emergency signals and the traffic density of the road.

TABLE 1. The system states.

States	**Meaning**
R1G	**Road one is green and the other roads are red.**
R1Y	**Road one is yellow and the other roads are red.**
R2G	**Road two is green and the other roads are red.**
R2Y	**Road two is yellow and the other roads are red.**
R3G	**Road three is green and the other roads are red.**
R3Y	**Road three is yellow and the other roads are red.**
R4G	**Road four is green and the other roads are red.**
R4Y	**Road four is yellow and the other roads are red.**
ALLRED	**All roads are red when one / both of the main back-roads is/are full.**

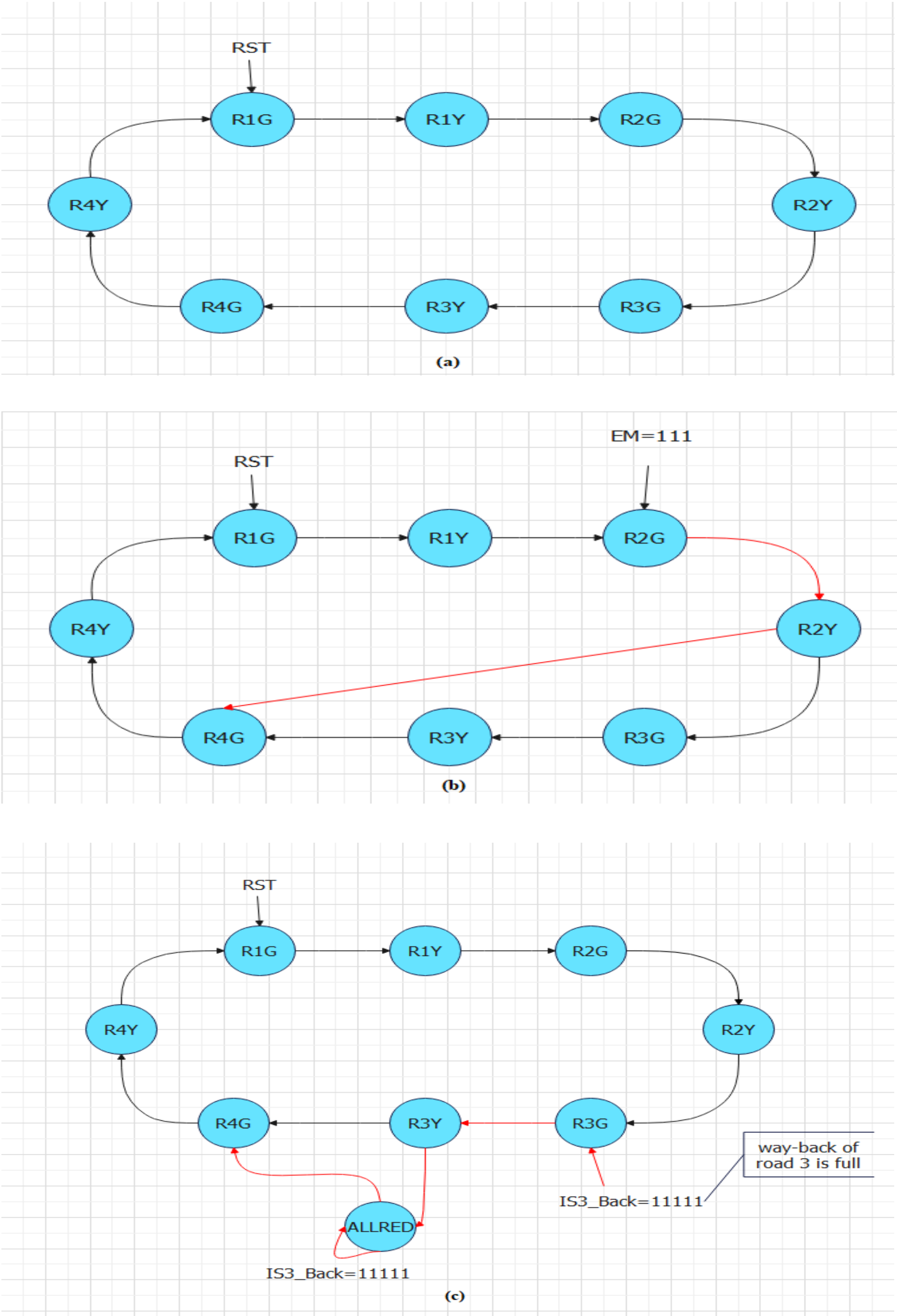

Figure 2: (a) The normal state transition of the system; (b) The state transition in presence of an emergency vehicle on road four; (c) The state transition when road three opposite direction is full of vehicles

The traffic system manages a four-way intersection. The system always starts at road one, then checks for any emergency or all-red signals. If not found the system receives output signals from the five sensors on road one, which indicate the traffic volume level. Upon the receipt of the five sensors signals, the green light time period is set and the system flow continues as shown in figure 2-(a). Otherwise, if an emergency or all-red signal present the system flow changes as shown in figure 2-(b) and figure 2-(c) respectively. Figure 3 shows the flow chart when road one has the green light and the flow chart of the other roads is similar to this. Figure 4-(a) shows the flow chart when road one has the yellow light. Figure 4-(b) shows the flow chart when all roads are red.

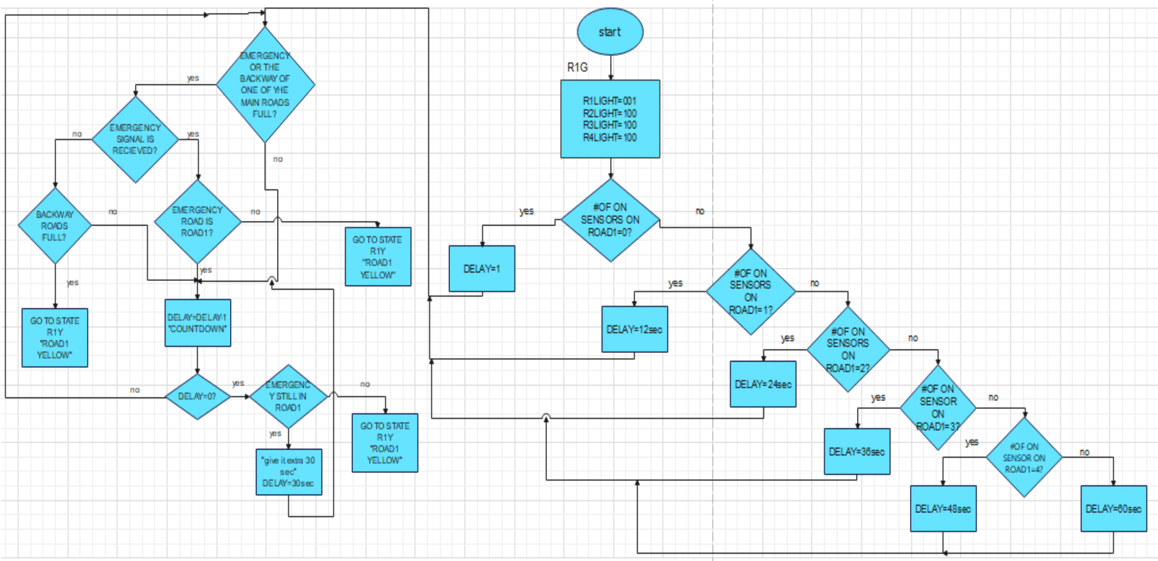

Figure 3. Flow chart of road one green state

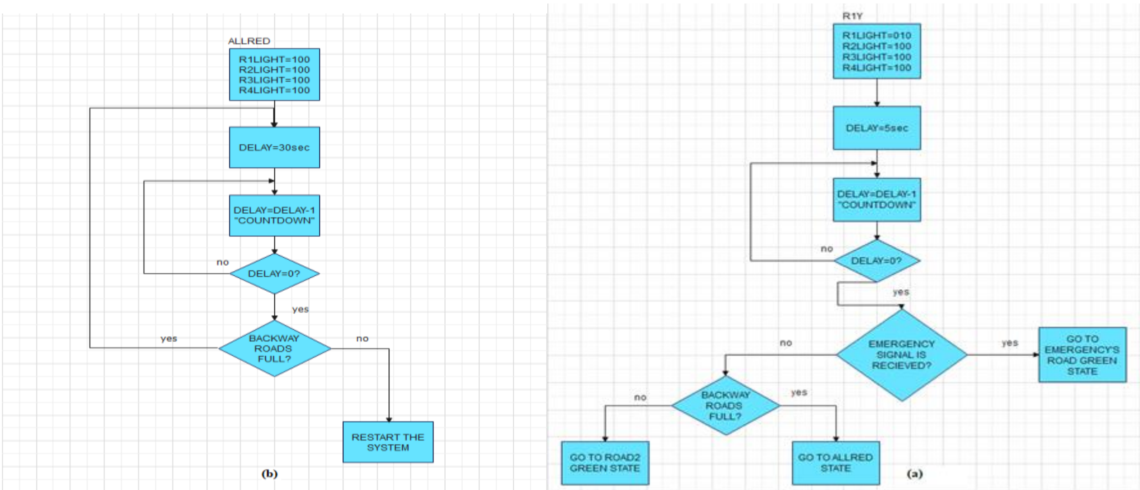

Figure 4: (a) Flow chart of road one yellow state; (b) Flow chart of all red state

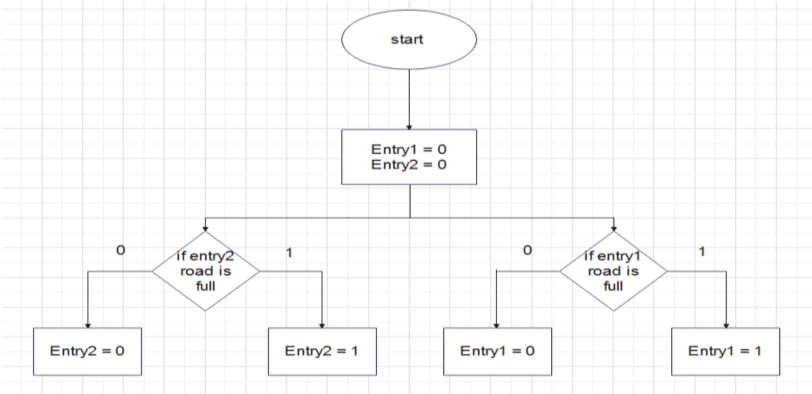

Figure 5. Flow chart of the entrance display

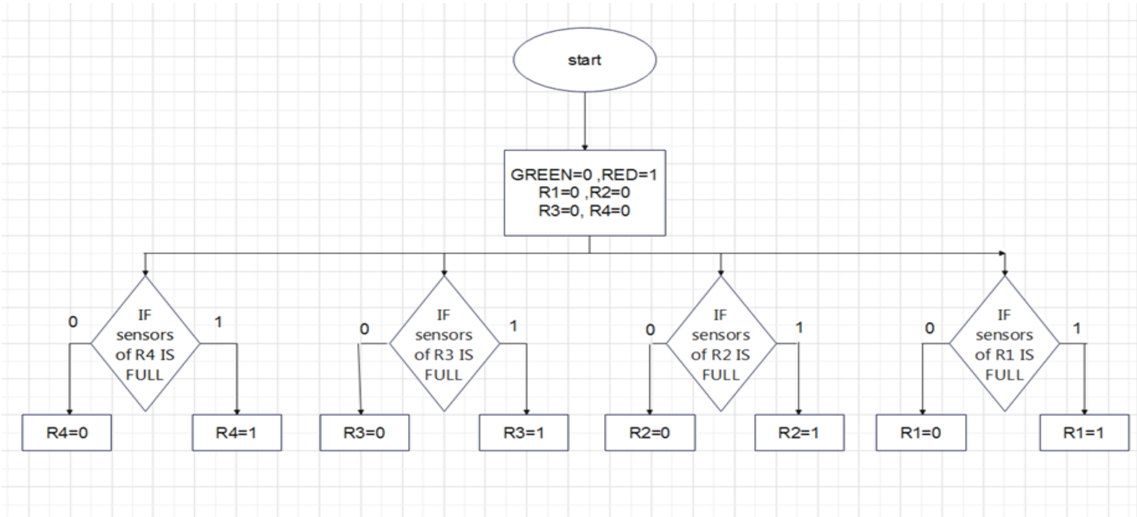

Figure 6. Flow chart to monitor traffic density level

C. Features offered in the traffic system:

1. ***Real-time density-based variable traffic signal time:*** This intelligent traffic system is integrated with a real-time density-based system. Suppose at any moment, road one is to get the green signal but the traffic density on road one is too low, it is not wise to give a fixed amount of time for different traffic density levels. This TLC will be able to realize this and give a green signal to road one for time based on the traffic density on that particular road, ensuring proper management of traffic based on the density of the roads. Figure 3 shows the flow chart of road one green state with different green light time delays based on traffic density.

2. ***Giving priority to emergency vehicles to pass at any time:*** The system allows emergency vehicles to pass. When it is detected on a particular road. Figure 2-b shows a state transition of a case when an emergency vehicle is on road four while it is a green signal on-road two. The TLC turns road two's signal to yellow then to red and then grants the green light to road four where the emergency vehicle is passing.
3. ***Preventing four-intersection getting paralyzed:*** The TLC prevents the intersection from getting paralyzed when one or both of the main roads opposite directions are full of vehicles. If any road is granted the green light the four-intersection will be paralyzed even if the other roads are empty. Figure 2-c shows state transition when road three opposite direction is full. The system enters an all-red state where all roads are given the red light to make some time for the full roads to get less crowded. Figure 7 shows the problem when road1 opposite direction is full and the green light is granted to road4.
4. ***Setting priorities for special cases:***
I. If more than one emergency vehicle is present on different roads. The nearest next road in turn is granted the green light. Suppose road one has the green light and road two and road three have emergency vehicles on them the green light is granted to road two and then to road three.
II. If an emergency vehicle is passing on a particular road and the opposite direction of the main roads are full of vehicles the system will not allow the emergency vehicle to pass unless the opposite roads get less crowded.
5. ***Traffic display:*** To facilitate the movement of vehicles and avoid traffic jams, display screens have been installed throughout the university, showing the congestion of each gate to make it clear for drivers to choose the appropriate entrance and the least crowded way to use. Also, other display screens were installed inside the university campus, showing the extent of traffic congestion on the roads which show the least crowded path to reach the university exits.

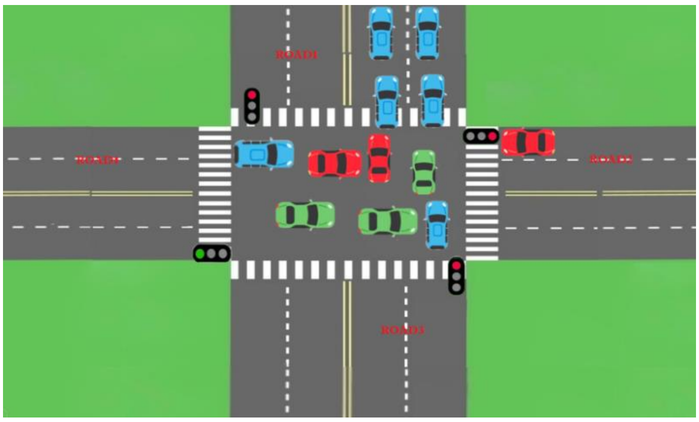

Figure 7. The case when the road1 opposite direction is crowded with vehicles causing the intersection to get paralyzed

RESULTS AND DISCUSSIONS

To verify the working of the system, we have used ModelSim-Intel-ALTER to obtain the timing diagram. In the timing diagram R1light, R2light, R3light, and R4light represent the traffic light for the four roads where 100, 010, and 001 represent green, yellow, and red, respectively. The inputs IS1, IS2, IS3, IS4, IS1_BACK, and IS3_BACK are the input IR sensors for road1, road2, road3, road4, road1 opposite direction, and road3 opposite direction, respectively their values vary from 00000 to 11111 which represent the traffic density on each road. and for simulation purposes EM input which represents the passing emergency vehicle and its values 0xx,100,101,110, and 111 which represent no emergency vehicles, emergency vehicle on road one, emergency vehicle on road two, emergency vehicle on road three, emergency vehicle on road four, respectively. The output state represents the current state of the traffic system; the output delay represents the time assigned to the traffic light and its values of 60, 48, 36, 24, 12, and 1 sec. Its value depends on the input IR sensors. Figure 8(a) presents different traffic densities and different traffic light times based on the IR sensors on each road. Figure 8(b) presents a case when the main road three opposite direction is full of vehicles if we grant green light to any road that will cause the problem referred to in Figure 7. This problem is resolved by giving all roads red lights for a certain amount of time to take some time for the crowded road to get less crowded. Figure 8(c) present represents passing an emergency vehicle on road four.

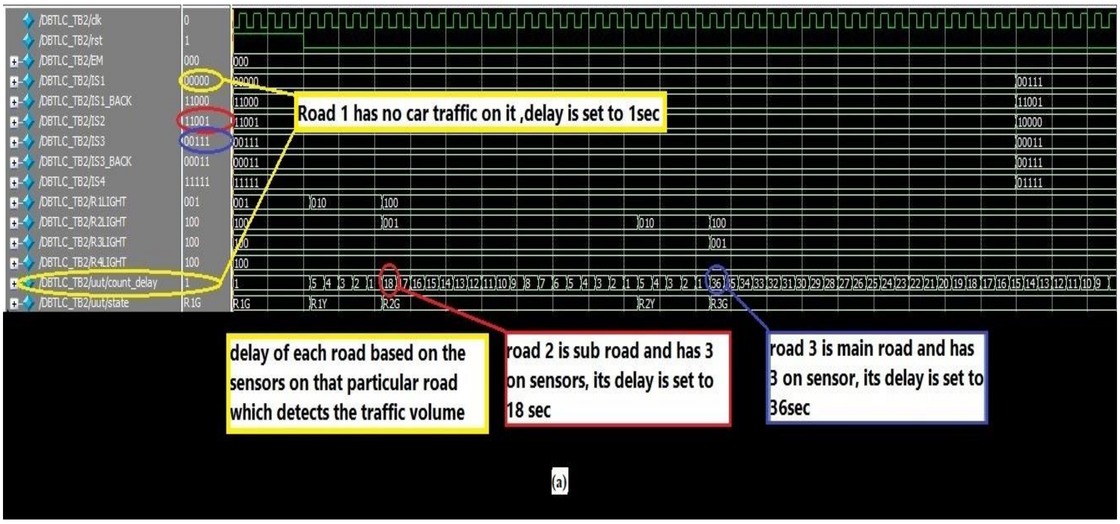

Figure 8- (a) The timing diagram for different traffic densities and different traffic light times

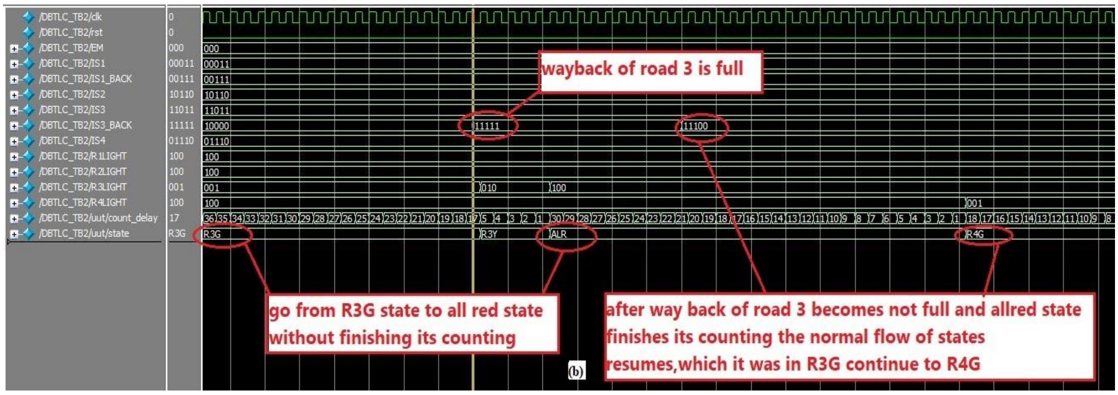

Figure 8-(b) The timing diagram for case when road three opposite direction is full

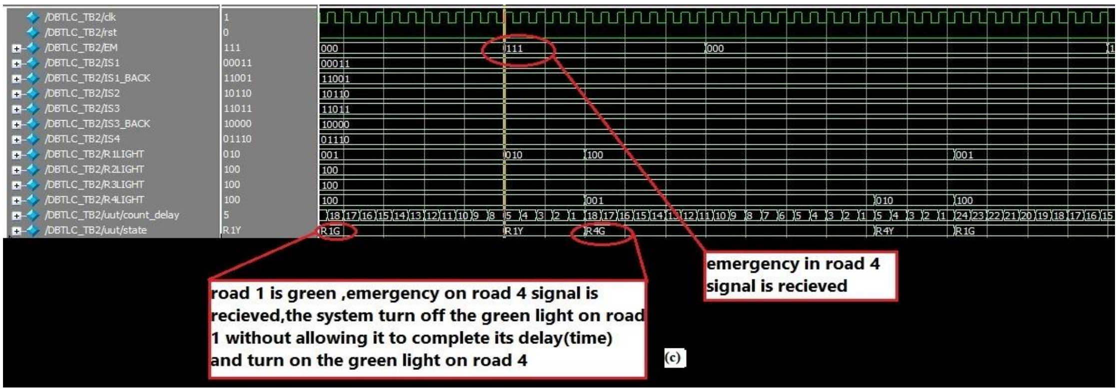

Figure 8-(c) The timing diagram of an emergency vehicle on road four

CONCLUSION

The key contribution of this paper is to design, simulate, and implement an efficient real-time density-based traffic light system. The system is designed specifically to reduce the traffic and congestion on the university of Tripoli campus. The system is able to make real-time decisions and choose the proper traffic signal based on the traffic density. The main features of the system are that can make smart decisions to prevent the intersection from getting paralyzed and gives the priority to emergency vehicles. After verifying the traffic light controller system module, the design was simulated and verified using Intel-Altera software tools, then the system was implemented and tested using the Cyclone EP1C6Q240C8 FPGA evaluation platform to test the functionality of the system in hardware. Future work can be extended to replace the infrared sensors with vehicle detection in a video sequence using image processing techniques. the system records the car movement and calculates the density of vehicles to decide the time delay of the traffic light for each road.

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