Prioritisation of Emergency Vehicles Using Intelligent Road Traffic Management and Control System

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Abstract: Technology growth brings innovation and production of various kinds of new vehicles, leading to road traffic congestion especially in urban cities. As such intersections are congested with traffic delay and access denial especially for emergency vehicles which are for unique and essential services. This paper presented an intelligent road traffic control and management system that gives priority to emergency vehicles at intersections as demanded. This system manages and controls traffics at intersection using Road Side Unit (RSU) to calculate traffic queue, differentiate other vehicles from emergency vehicles at the intersections tracks/pathways and forwards the necessary information to Traffic Management Centre (TMC) of each unit that will thereafter communicates with a Central TMC to calculate and allocate time for permitting or denying access to road. This yields efficient and effective result in managing intersection tracks/pathways. This approach increases road capacity, traffic flow, prevents traffic congestions, accident and thus increases society economic growth and good for intelligent road traffic management and control system.
Keywords: RSU (Road Side Unit), TMC (Traffic Management Centre), Emergency, Track/Pathway, Intersection, Illumination

Introduction

Growth and development in urban cities brings about increment in automobiles and growing of traffic which leads to traffic conflict. This became tedious job for the traffic warden to control the traffic in a city like Lagos, Nigeria where traffic control systems are not meeting the present day traffic density. According to Yousef, *et. al.* (2010) the existing methods for traffic management surveillance and control are not adequately efficient in terms of performance, cost, and the effort needed for maintenance and support. For example, the 2007 Urban Mobility Report estimates total annual cost of congestion for the 75 U.S. urban areas at 89.6 billion dollars, the value of 4.5 billion hours of delay and 6.9 billion gallons of excess fuel consumed (Zhiyong, 2007). Many metropolitan cities faced traffic challenges today as a result of continuous increase in traffic congestion. Initially urban traffic is being managed and control by the traffic warden who stand at the intersection to control the traffic affair. Gradual traffic increase that resulted into traffic jams as a result of incapability of traffic warden to physically control the traffic. Likewise, when the emergency vehicle is far away from traffic warden's standing position at the intersection. Traffic warden may not be able to identify its presence in order to manually give way as such getting stuck in traffic jams. All this together brings about light traffic management system challenges. This is the process of using manually set static traffic control light to manage and control the affairs of road traffic at the traffic intersection. However, limitation of light traffic control management system has been identified as there were lapses as a result of fixed traffic allocation time. This will not give emergency vehicle any preference, even when closer at the traffic control intersection. Sometime the intelligent traffic management system may allocate longer time to the less congested traffic lanes, while the most congested track lanes may put on hold. It does not provide timing based on priority, necessity nor recognize emergency vehicle (Khalil & Jamal, 2010 in Thoka, *et. al.,* 2019). Predetermined timing schemes of traffic control system has become order of todays' traffic control system, where control system remain fixed until further resetting is required, irrespective of variance in road track congestion and emergency need (in time of ambulances, fire brigade, various form of accidents and so on).

Fig. 1: Heavily Traffic Loaded Intersection (Source: Amnesh *et. al*., 2012)

Figure 1 is a pictorial representative of activities of heavily Traffic Loaded intersection. During the peak hours, most of the intersection are constantly blocked with long queue of vehicles without movement, just because they have Red illumination "ON"; whereas some other lanes with less or no traffic volume are traffic free just because they have Green illumination "ON"; due to lack of intelligence of the existing traffic system. Whereas, the fundamental principle of urban traffic control system is to be able to respond to dynamic changes of the traffic demand. Emergency vehicles may have to be delayed unnecessarily waiting just because vehicles ahead of it may have to wait as a result of Red illumination "ON" perhaps emergency vehicles may end up claiming life and cause collision while trying to enforce itself "ON" while Green illumination is "OFF" as a result of emergency. Analysis of current traffic control system in the South Eastern Nigeria city shows that some of the intersection are controlled by traffic wardens while some are not manned at all, some of these intersection also have traffic signals strategically located but are not intelligently manage or active. There is no effective intelligent traffic system that works twenty-four hours a day (Osigwe *et. al.,* 2011). According to Gültekin *et. al.* (2010) urban population of more than 10 million people require planners to collect and manage traffic data on 24 hours 7 days per week basis. Improper control of traffic congestion could result into loss of time, opportunities miss, frustration, loss of organizational productivity cost by the workers, trade opportunities loss, delivery delay, which goes on increasing and contribute negatively to National economy growth (Singh & Pradeep, 2013). Several measurement has been introduced by the Government to reduce delays experienced by drivers at intersections such as construction of flyovers, ring shaped roads, restriction of large vehicles in the city, introduction of one way roads, traffic controlling by the traffic warden and automatic signal controlling systems (Wannige & Sonnadara, 2009). The present traffic system has fixed time interval for green and red signal illumination. Controllers are based on old microcontroller such as AT89C51 which has very less internal memory and no in-built ADC (Dinesh & Swapnili, 2012) which does not provide the required flexibility to the system. Traffic Light Control is the process by which the electronic signals are being used to control the traffic flow at the road intersections to maintain easy flow of traffic. Local time based traffic controllers must be monitored and field adjusted periodically to ensure efficient traffic operations (Ashley, *et. al.*, 2013).

Different approaches /tools among which can be used for the implementation of intelligent road traffic signal management system and emergency vehicle priority preference is fuzzy logic. This is a powerful tool for processing non-deterministic and non-linear problems. It can represent fuzzy and qualitative knowledge, and so it can imitate human reason logic. It deals with uncertainty in Engineering by attaching degrees of certainty to answer to logical questions (Zhiyong, 2007). It has the capability of mimicking human intelligence (Wannige & Sonnadara, 2009). Fuzzy controller uses vehicle loop detectors, to measure approaches flows and estimate queues where it data can be used for decision, at regular time intervals, whether to extend or terminate the current signal phase. Expert system uses a set of given rules to decide the next action for traffic signal control system. It can be used to change some of the control parameters. The expert systems can communicate in synchronization, it performance on the network depends on the rules that are used. For each traffic light controller, the set of rules can be optimized by analyzing how often each rule fires, and the success it has. The system could even learn new rules. Wen (2008) describes dynamic and automatic traffic light control using forward chaining type of reasoning approach. Traffic congestion causes great financial losses, health hazards and environmental pollution (Wannige & Sonnadara, 2009), which has negative impact on national economic growth. Lack of efficient traffic control leads to loss of lives as emergency need of ambulance may continually delayed (continually getting stuck in traffic jams). Mismanagement and traffic congestion results in long waiting times, loss of fuel and money. It is therefore utmost necessary to have a fast, economical and efficient traffic control (Sarika & Gajanan, 2013). The identified challenges bring about intelligent traffic control system, where the emergency vehicles will be identified and consider first, based on the calculated arrival time at intersection. Traffic light without intelligent yielded no positive result to traffic control and management. The remaining of this paper is organized as follows. Section II discusses the literatures reviewed for this paper. Section III discusses research methodology, Section IV is the result of the research and finally, Section V discuss the results and concluded the research.

Literature Review

There are different types of technologies, used by different road traffic intelligence management and control system, such as: Artificial neural network (ANN), IR Sensors, RFID's, Zigbee, Traffic warning systems, Big Data, Bluetooth and so on (Chandana, *et. al*., n. d). Consideration and implementation of intelligent traffic control system has the potential to reduce and control delay caused by traffic signals since significant amount of delay to transit vehicles in urban areas is caused by traffic signals (Peter and John, 2002).

Artificial neural network (ANN)

Artificial neural network has the capabilities such as non-linear mapping (or generalization), self-adapting, self-organizing and self-learning. Due to this, it has been widely used in many fields such as signal and information processing, pattern recognition and automatic control (Zhiyong, 2007).

Zigbee

ZigBee for intelligence traffic control system was implemented in Thoka et al. (2019) paper. ZigBee has advantages of low-power rate for digital radio transmission, it can transmit about 10 -100 meters' distance, it requires low data rate applications and as such long battery life and most less expensive wireless personal area networks (WPANs). ZigBee transmitter (contains PIC16F877A microcontroller and ZigBee module) is placed in an emergency vehicle. Transmitted data from microprocessor is received from an ultra-sonic sensor placed at the traffic pole through its microcontroller and ZigBee module. When the sensor recognizes emergency vehicle and data transmitted to the traffic control section automatically, system clears the emergency lane by turning the signal to green, to give access to the emergency vehicle at the track.

Intelligent Traffic Signal Control (ITSC)

This is a system consist of AVR-32 microcontroller with inbuilt 8-channel ADC to receive IR-input from IR-transmitter embedded in the emergence vehicle. IR sensors is used for emergence vehicle detection. Having detect an emergency vehicle, it passes emergence vehicle by open up the gate and closed it immediately the emergency vehicle has passed. This is done using genetic algorithm to find the traffic flow information at signalized intersection using previous data (Dinesh and Swapnili, 2012).

Methodology

This work proposes an efficient communication and control system that coordinate the operation of road traffic system components, in a manner that work on both single and multiple road intersections. Each sensor node placed by the roadsides of the proposed scheme called RSU (Road Side Unit), will collect it data and send it to central processor called TMC (Traffic Management Centre) in a real time. Emergency vehicles are identified based on TMC contact with emergency vehicle hardware Figure. 2, fixed within the emergency vehicles alert indicator light placed on the emergency vehicles to indicate an alert, shown in Figure. 3. The system generates permitted traffic length, through RSU, by calculating the number of sensor(s) contacted vehicles. This assigned designated value of six (6) to each contacted vehicle, and multiply it with the number of contacted sensors (readers) (x) (to be generated by RSU contact). That is $(6*x)$ = Green light illumination tine/duration (where x is the number of vehicle(s) on the track/pathway contacted with RSU) measured in Seconds. The result generated here will be green light permitted time interval per seconds. However, this is reset per calculation cycle. In term of emergency vehicle, system monitors the emergency vehicle's location and provides estimated arrivals time, using the emergency vehicle contacted with RSU (out of (10) ten RSU) distance from the intersection. Then reset the cycle, given priority to the present emergency track, based on the calculated arrival time (while other tracks illumination is off "RED", emergency track Illumination is on "GREEN"). Then system will reset to normal after the departure of the emergency vehicle.

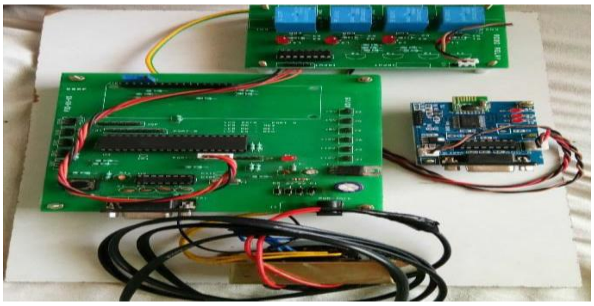

Fig. 2: Emergency Vehicle Hardware (Source: Thoka, 2019)

Fig. 3: Emergency Light alert

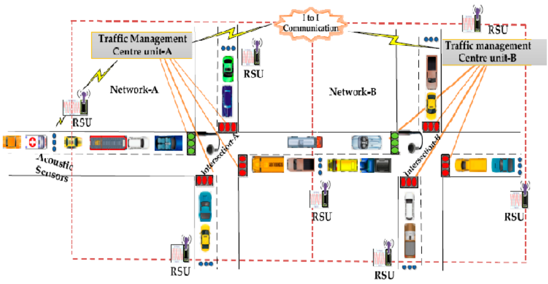

Fig.4: Urban Traffic Management System (Source: Kapileswar and Gerhard, 2016).

Figure 4 is a pictorial representation of an urban traffic management system. Data value is being generated and read in, based on the number of vehicle contacted with RSU (Road Side Unit). RSU, the wireless sensor placed by the roadside to read the traffic queue length, identify and give report on emergency vehicle per track. Data recited by RSU is interpreted and managed by TMC (Traffic Management Centre of each unit). Unit TMC communicate with Central TMC where the value(s) are assigned to recited /generated data, add up and calculated for every track/pathway. Result calculated is used for appropriate timing of intersection signal illumination control "ON/OFF".

TMC (Units and Centre) are connected and communicate via on-line to other devices such as RSU, Cameras, Traffic signals and so on, in such a way that operators supervised/monitor the state of the road. The Centre TMC determined time, traffic illumination should stay on/off in a certain state, before switching to the next state. The order of states is predetermined based on the path/track content; that is, the vehicle volume or emergency present in a track will be placed/calculated against other tracks. The study was carried out on an intersection, and the following states were determined having compared volume and content of the vehicles on each of the tracks on the intersection.

Table 1: State Determinant Table per Circle.

States Determined based on the Volume for a Particular Circle

Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**	**Column 8**	**Column 9**
Circle	Roads	Numbers of Vehicles assigned per RSU	Numbers of given RSU per Road	Numbers of RSU contacted with Vehicle	Value assigned per RSU	Numbers of vehicles on the Road	Value generated by RSU	Green light Illumination per circle in Seconds
First Circle	Road A1	5	10	10	6	50	60	60
	Road A2	5	10	4	6	20	24	24
	Road B1	5	10	2	6	10	12	12
	Road B2	5	10	8	6	40	48	48

Column 1: This is Circle; stated that the whole four roads action (Road 1 to 4) is a set of circle.

Column 2: This is Roads; which stated the action(s) of each road on the intersection, the actions can belong to any of the four roads, the action(s) do(es) not fixed to any particular road.

Column 3: This is Number of vehicles assigned per RFIR; state the number of vehicles a particular RFIR can read/access at a time.

Column 4: This is number of given RFIR (sensor) per Road, which is equal to 10 in here.

Column 5: This is numbers of RFIR (sensor) contacted with Vehicle, which is varies here; road A1=10, road A2=4, road B1= 2, and road B2=8.

Column 6: This is Value assigned per RFIR (sensor) which is 6 here.

Column 7: This is number of vehicles on the road (that is column3 * column5) which varies;
Road A1=50, road A2=20, road B1=10, road B2=40.

Column 8: This is value generated by RFIR (sensor) (that is column5 * column6) which varies; road A1=60, road A2=24, road B1=12, road B2=48.

Column 9: This is Green Light Illumination per circle in Seconds, which varies; road A1=60, Road A2=24, road B1=12, road B2=48. Which is the value generated by the RFIR(sensor).

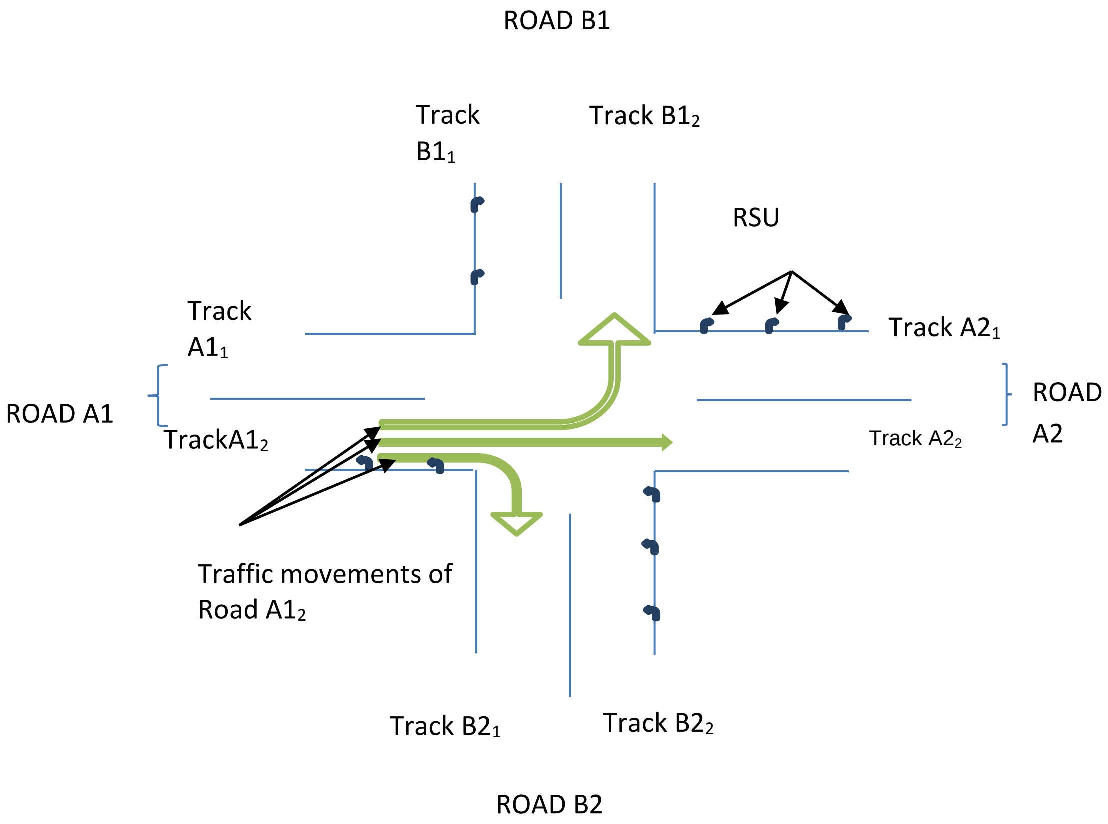

Fig. 5: Intersection Possible Roads Traffic Movement at Particular Point in Time (Source: Conceptual Model)

Figure. 5 is a pictorial representative of possible traffic movement on Roads A1, A2, B1 and B2. Road A1 is divided into track $A1_1$ and track $A1_2$, track $A1_2$ is "TO" movement track/pathway, while track $A1_1$ is the "FRO" movement track/pathway. The possible tracks movements of each track depend on the state of the road traffic in action, Tack $A1_2$ contains tracks movement from West to track $B1_2$ of Road B1, track $A2_1$ of Road A2 and track $B2_1$ of Road B2. Road A2 is divided into track $A2_1$ and track $A2_2$, track $A2_1$ is the "TO" movement track/pathway, while track $A2_2$ is the "FRO". The possible track/pathway movements of each track depend on state of the road traffic in action, Tack $A2_1$ contains tracks/pathway movement from East to track $B1_2$ of Road B1, track $A1_1$ of Road A2 and track $B2_1$ of Road B2. Road B1 is divided into track $B1_1$ and track $B1_2$, track $B1_1$ is the "TO" movement track/pathway, while track $B1_2$ is the "FRO" movement track/pathway. The possible tracks movement of each track depend on the state of the road traffic in action, Tack $B1_1$ contains tracks/pathway movement from North to track $A1_1$ of Road A1, track $B2_1$ of Road B2 and track $A2_1$ of Road A2. Road B2 is divided into track $B2_1$ and track $B2_2$, track $B2_2$ is the "TO" movement track/pathway, while track $B2_1$ is the 'FRO'. The possible tracks/pathways movement of each track depends on the state of the road traffic in action, Track $B2_2$ contains tracks movement from South to track $A1_1$ of Road A1, track $B1_2$ of Road B1 and track $A2_2$ of Road A2.

Emergency Vehicle Priority Preference

When traffic controller receives the request for service by the emergency vehicle, through the sensor; the controller will attempt to provide a green "ON" signal, by monitors the emergency vehicle's location and provides estimated time of arrivals to the various signalized intersections along the route minutes before the vehicle's arrival. The earlier the traffic controller receives the estimated time of arrival, the more time it has to adjust its cycle, for priority vehicle with the least amount of traffic disruption; by either going short in the cycle to allow for an early green, going long to extend the green, or doing nothing if the requesting vehicle will be arriving on green with no adjustment.

Result

Table2: ROOT A1 Traffic Movement Table

	Track Movement from	Track Movement to	Green light Illumination State per Circle in Seconds	Red light Illumination State	Yellow light Illumination State
1	Track $A1_2$	Track $B1_2$	60	OFF	OFF
2	Track $A1_2$	Track $B2_2$	60	OFF	OFF
3	Track $A1_2$	Track $B2_1$	60	OFF	OFF
1	Track $A2_1$	Track $B1_2$	24	OFF	OFF
2	Track $A2_1$	Track $B2_1$	24	ON	OFF
3	Track $A2_1$	Track $A1_1$	24	ON	OFF
1	Track $B1_1$	Track $B2_1$	12	ON	OFF
2	Track $B1_1$	Track $A2_2$	12	ON	OFF
3	Track $B1_1$	Track $A1_1$	12	OFF	OFF
1	Track $B2_2$	Track $B1_2$	48	OFF	OFF
2	Track $B2_2$	Track $A2_2$	48	OFF	OFF
3	Track $B2_2$	Track $A1_1$	48	ON	OFF

Table 2 shows the possible track/pathway movement of the following tracks/pathways on an intersection at a point in time: from Road A1, Track $A1_2$ there will be movement to Road A2 Track $A2_2$ for duration of 60 Seconds, Road B1 track $B1_2$ for duration of 60 Seconds and Road B2 track $B2_1$ for duration of 60 Seconds. From Road A2, Track $A2_1$ there will be movement to Road A1 Track A 1_2 for duration of 60 Seconds, Road B1 track $B1_2$ for duration of 60 Seconds and Road B2 track $B2_1$ for duration of 60 Seconds. From Road B1, Track $B1_1$ there will be movement to Road A2 Track $A2_2$ for duration of 60 Seconds, Road A1 track $A1_1$ for duration of 60 Seconds and Road B2 track $B2_1$ for duration of 60 Seconds. And finally from Road B2, Track $B2_2$ there will be movement to Road A2 Track $A2_2$ for duration of 60 Seconds, Road A1 track $A1_1$ for duration of 60 Seconds and Road B1 track $B1_2$ for duration of 60 Seconds.

Discussion

Traffic signal illumination is determined based on the volume of vehicles present on intersection tracks/pathways. Sensors (RSU) placed by the road sides scan through its contact with the vehicles/emergency vehicles present at intersections' track/pathway and make use of queue volume at track/pathway at a point in time to supply information to the Table 1 located in the database. The green light illumination is determined by multiplying column headings: (Numbers of RSU contacted with Vehicle), the result which titled (Green light Illumination per circle in Seconds) then will determine the green light illumination time. However, the traffic controller receives request for service by emergency vehicle, through the sensor (RSU), this will attempt to provide a green signal by either going reducing on going cycle duration/timetoallow early green illumination "ON", or extend green illumination "ON", nor doing nothing if the requesting vehicle will be arriving on green illumination "ON" with no adjustment.

Table 1 is a database information showing the states determinant information of a particular intersection at a point in time, (That is, at instance) on an intersection where the Intelligent road traffic signal is highly in active. Figure 1 show the track/pathway movement/activities at a particular intersection at a point in time and Table 2 show the varied in green light illumination which was determined by the volume of tracks/pathways congestion. Movements from Track $A1_2$, has the highest seconds of green light illumination of 60 seconds been having highest volume of 60 vehicles on its track/pathway, follow by Track $B2_2$, has the second in highest seconds of green light illumination of 48 seconds been having next highest volume of 40 vehicles on its track/pathway, follow by Track $A2_1$, has the third in highest seconds of green light illumination of 24 seconds been having third highest volume of 20 vehicles on its track/pathway and finally Track $B1_1$, has the least seconds of green light illumination of 12 seconds been having least volume of 10 vehicles on its track/pathway. However, when the detector(s) receive an acceptable incoming transmission on emergency vehicles on any of the tracks/pathways, priority will be given to the track/pathway and a relay will send to the traffic controller to pre-empt the signal for the oncoming emergency vehicle. Pre-emption works by forcing the controller out of its current operation and into a preconfigured pre-emptive state. Once the traffic controller receives a pre-empt signal, it begins the sequence to bring the controller into the pre-emptive state. This includes terminating vehicle phases, overlaps, and pedestrian phases not called for in the pre-emption.

Conclusion

The applied RSU is an intelligent Road Traffic Signal to control vehicle traffic and provide priority preference for emergency vehicle(s). It helped to decongest the urban intersection highways by dynamically rotating the state/time allocation for each state/per cycle based on road track/pathway volume and content at any point in time. The system monitors the emergency vehicle's location and provides estimated time of arrivals to the various signalized intersections along the route minute before the emergency vehicle's arrival. The earlier the traffic controller receives the estimated time of arrival, the more time it has to adjust its cycle for the priority vehicle with the least amount of traffic disruption. This help to prevent unwanted incidence such as accident, unnecessary delay/collision of emergency vehicles and so on.

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