International Journal of Technology and Engineering Studies
volume 4 issue 2 pp. 57-63 doi: https://dx.doi.org/10.20469/ijtes.4.10003-2

Lean Traffic Control (LTC) for Emergency Vehicles Applied in Developing Countries: Tehran Transport Planning

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Abstract: This paper is proposing, innovating, and developing a model, namely server-centric, which is a great asset in reducing the cost and producing better performance. Internet of Things (IoT) is applied, a central controller web server and a microcontroller system is utilized by applying the Global Positioning System (GPS) and Fuzzy Controller System (FCS) approach. This Lean Traffic Control (LTC) can dynamically and automatically control traffic signals in order to open the path to get to the destination as soon as possible. It can be performed by considering three main steps: 1- Central controller webserver, 2- Communications software application, and 3- Communications hardware application. The primary prototype of this project is ready, and future work will need the LTC system to be tested in real-world performance. By implementing the traffic signal pre-emption, road safety can be increased and emergency response reduced. Thus, the regular traffic will confront minor or no inconvenience.

Keywords: *LTC, GPS, FCS*

Received: 20 November 2017; ***Accepted:*** 23 February 2018; ***Published:*** 13 April 2018

I. INTRODUCTION

Producing a safe and flowing traffic for transportation is the most essential infrastructure for the industry development and for augmenting the social convenience level, besides its having effect on increasing urban smart system in the country. The problems of transport, such as environmental pollution, energy resource depletion, increased losses of material and spiritual events caused by accidents, problems of supervision and management in the transportation in suburban areas, increase in the time wasted, and the rapid growth in demand for transportation, especially during peak hours in all cities of the world, have become a serious problem.

The concept of smart urban system is to provide a sophisticated and integrated system of ICT, and IOT, which supplies the smart city with a manageable and secure communication system. One of the main concepts in smart city is the transportation problem. ITS with the new term "IOT" are used within the network of physical systems [1] (connected and smart devices), including in vehicles, buildings, and other embedded cases which, by being connected to the networking and communications software with soft objects using electronic sensors and relays to the collection and exchange of information, is feasible (Figure 1). The integration of connected and smart devices using tools, resources, and expertise, such as engineering concepts and coordinated Lean traffic, productivity, software technology, hardware and telecommunications, is applied to create a genuine integrated intelligent system, to prevent all and every time wastage and accelerate transportation, increase productivity, and improve efficiency and safety in the urban transport system.

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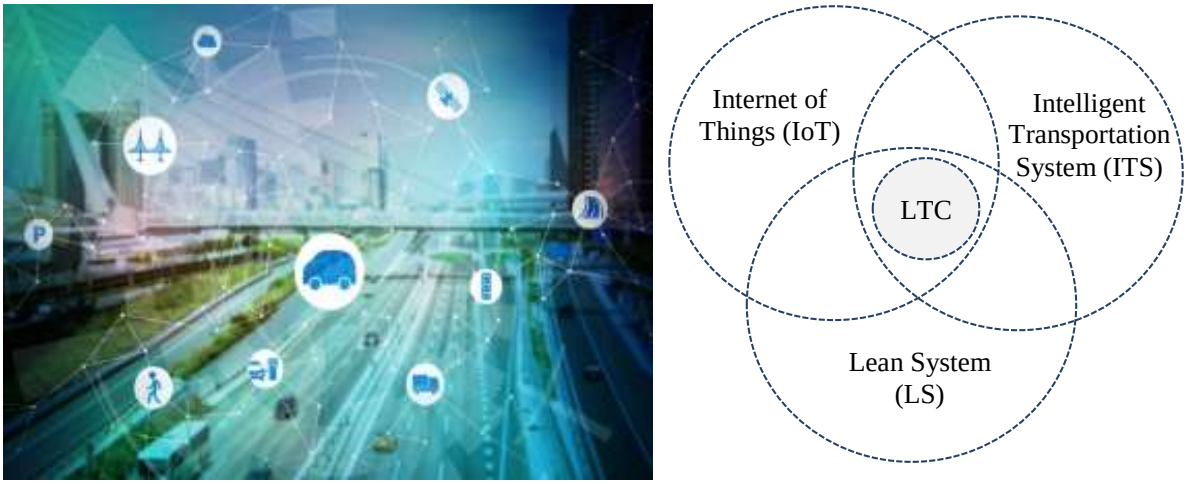

Fig. 1. The proposed LTC model for smart city

The proposed LTC model for the smart city is utterly important for the vehicles in the lines of firefighting engines, ambulances, police cars, etc. which provide utmost priority in urban transport system. In order for the Emergency vehicles to get to their destinations promptly, obstacles, such as unnecessary waste of time at the intersections or traffic lights, specifically in the rush hours on congested routes, can cause dangerous accidents, leading to losses in life and property or resulting in fire due to gas leakage. Pure traffic control system, Lean Traffic Control (LTC), a new integrated and innovative model (affordable model Server base), a domestic product, is designed and manufactured to facilitate transportation, especially emergency vehicles. In the pure traffic control system, the software and hardware systems in Server base work in coordination with each other [2, 3].

II. FOUNDATION STUDIES

Many researchers have worked extensively on the efficient usage of traffic information to determine green light sequences, by developing pre-emption systems that utilize the distance between the emergency vehicle and the intersection, based on GPS for the signaling time. A number of traffic management schemes have been implemented to prioritize emergency vehicles[4]. To support this work, extensive research is performed in association with intelligent traffic control system design for providing clearance for emergency vehicles [5, 6, 7, 8, 9, 10].

Based on the above-mentioned supported work, this integrated system, with the ability of controlling and processing the location of the emergency situations intelligently, is able to promptly decide the best transportation paths, with the consideration of the shortest traffic routs to avoid the traffic congestions, using FCS in the Control Center Web server. Lean traffic control system (Microcontroller device installed in traffic control system) conveys the software decision and order to the hardware to control the traffic lights dynamically and automatically, and keeps them green for the purpose of opening a path for the emergency vehicles to get to their destination as soon as possible [11]. Considering the situation of the emergency vehicles, in the case of lack of cooperation from other vehicles in that vicinity, the license plate number of the vehicle at fault will be recorded after the second warning, and will immediately be sent to the main control office and the person at fault automatically. The significance of this research work is to design the accrue traffic control system by considering the IoT and Lean concept for more advantageous use. Also, several advantages, like cost, and feasible system implementation, are offered by the proposed system.

III. LITERATURE REVIEW

Dynamic traffic signal helps in having a cost effective system, along with minimizing the delays, which provides road safety and proliferates response time [12, 13]. To achieve this goal, several existing technologies use stand-alone hardware. The previously unsuccessful common usage of dynamic traffic light system was applied by the sound-based technology systems from the siren of the vehicles for which the waves initiated from the acoustic audio sensors were used:

A. Sound Based Systems

In order to identify the pattern of waves from the siren of the emergency vehicle, the system of acoustic audio sensors is used. This system can operate independently, or with another system. The activation of the movement

pre-emotion in this system caused confusion in the wrong cross-roads because of the reflection of sound waves in different directions. It was the weak point of this system which could be alleviated by installing sound simulation of a siren, and required hardware for sensors at every crossroad. It is a great burden [14].

B. *Optical Systems*

The Linear Traffic Signal preemption system emits infrared detecting beam to change traffic lights at the crossroads, by applying the hardware sensors installed in front of the vehicle which provides a feasible right of the way for the emergency vehicles to pass without confronting obstacles. The application of this system leads to three disadvantages which are:

1 - High cost of installing the sensor hardware in both the intersection and the ambulance.

2 - Weather conditions, like pollutants or other atmospheric conditions, cause poor preemption.

3 - As the Optical system is insecure, the pre-emption of the hardware could be illegally and easily forged [14].

C. *Radio-Controlled Systems*

It takes care of the traffic problems, including the hardware installed in the vehicle, which confront the disadvantages of the linear traffic signal. While the severe weather conditions have no effect on Radio signals, additional hardware are required, which adds to the cost [14], and [15]. Based on the previous study, the search gap is the lack of identification of the proper communication system between software, hardware, emergency vehicle and devices in traffic light, and the server. In this paper, by paying attention to the accuracy of GPS and Server-centered network system, and the advantage of using IoT concept, an innovative and economical solution is introduced, in which the GPS provides the required data for a pre-emptive system to facilitate the vehicle with the pre-emption that it needs, when approaching the traffic signal. This system takes care of all the limitations present in the old system.

IV. METHODOLOGY

Methodology for this system is classified into three main steps as follows:

A. *Step 1: Central Controller Web Server*

Central Controller Web Server coordinates all of the emergency vehicles in the city by receiving their signals and identifies the traffic light position to send pre-emption signals to traffic signal controllers accordingly by using the FCS approach. Per the request of the clients, the web server function is to deliver files and web pages, using the Hypertext Transfer Protocol (HTTP) for both sites of data processing and decision-making. These functions can be performed by the Web Server:

1. Accepts emergency vehicle Login and Status authentication provided by Android device.

2. A Server Database accepts the geo-coordinates of the emergency vehicles and monitors them.

3. Computes the closest approaching traffic signal for each emergency vehicle.

4. Upon the passage of the emergency vehicle from the intersection, the server sends the preemption command to the related traffic controller to change the light into normal mode.

5. The statistics of the pre-emptive signals are maintained for each vehicle through communication software application.

B. *Step 2: Communications Software Application*

The developed application model system will be installed in every emergency vehicle by using high-security code for sending the pre-emption signal to receive GPS coordinates and transmit GPS signals. The Central Server, through Internet, can communicate with traffic signal controller [16, 17], upon getting the transmitted signals. The staff of each ambulance carries a designed Smart Software through which he can locate the manager and find the shortest distance to the destination, with the help of a secure login and Google maps which will use the location manager and provider to perform the following functions:

1. By using a secure Login, the staff of the Emergency vehicle can find the shortest distance to the destination, via Google maps which display the path and final destination.

2. Through GPS location manager, the regular updates are sent to the Central Web Server when the vehicle is considered as an emergency case by the staff. The Geo-coordinates of the vehicle are in the Central Web Server.

The National Marine Electronics Association (NMEA 0183) protocol will send a string which will be read by applying Visual Basic (VB) program, installed at the vehicle unit, which acts as a communication link to the GPS receiver [18].

C. *Step 3: Communications Hardware Application*

The central controller web server makes the decision to change the traffic light color, using FCS approach based on the current vehicle position, by sending the signal into microcontroller which is installed at traffic lights before arriving at and after passing the intersection. The pre-

emption signal, which is sent by the emergency vehicle, will be received by Microcontroller system (Raspberry Pi) based on the following rules:

1) Normal mode: Using pre-stored timing in a cyclic manner, normally operate the traffic signal lights and Buzzer.

2) Switch to emergency mode: The pre-emption commands are accepted by signal lights from Web Server which switches to the emergency mode smoothly.

3) Switch back to normal mode: Switching back to normal mode is done by accepting the command from the Web Server which indicates the return to normal mode.

This LTC can dynamically and automatically control traffic signals in order to open the path to get the destination as soon as possible.

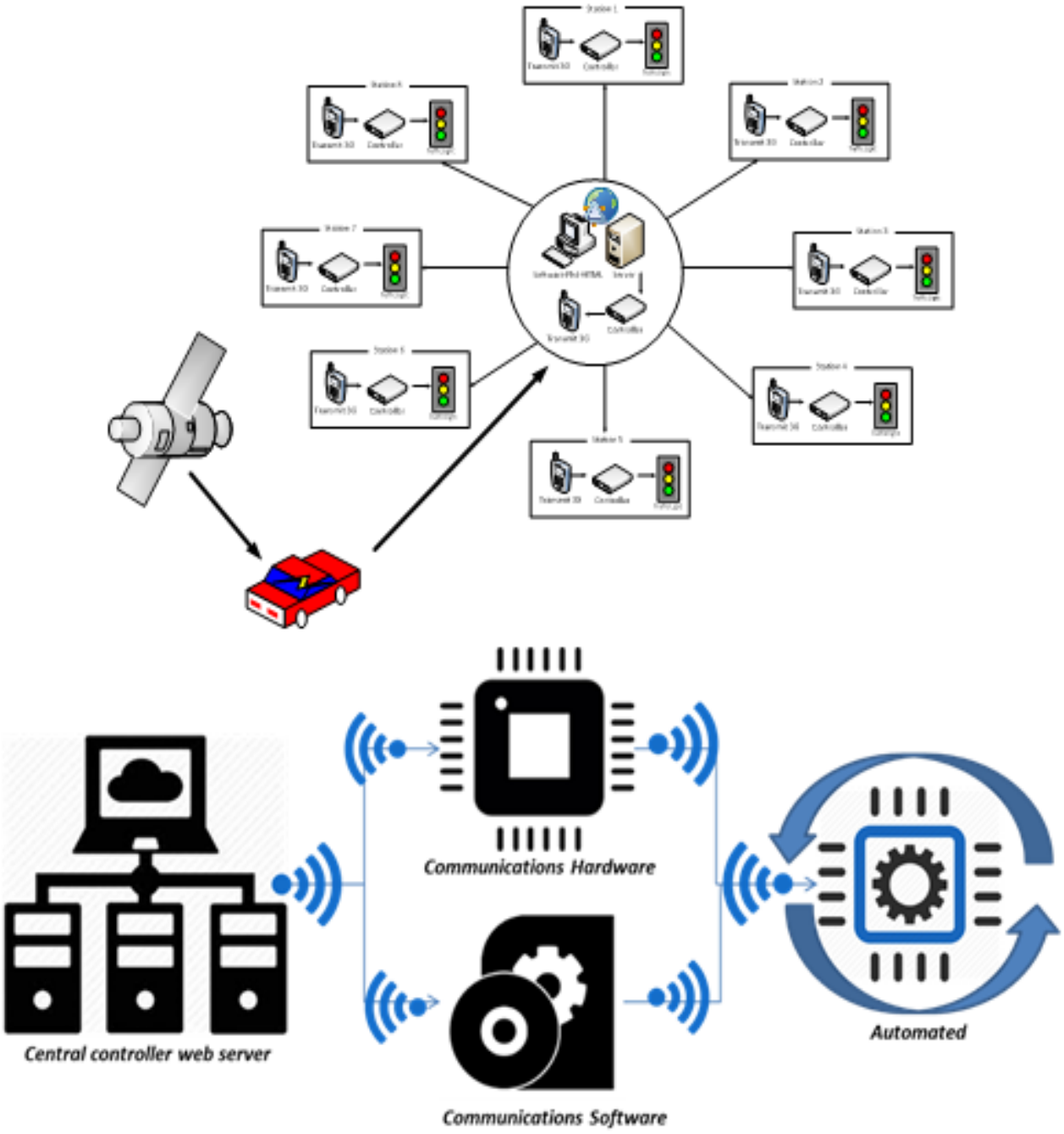

Fig. 2. LTC

V. DISCUSSION

This discussion entails several advantages of using LTC, like cost and feasible system implementation, which are offered by the proposed system.

1. An emergency pre-emption system is able to manipulate traffic signals in the path of an emergency vehicle that approaches a congested intersection with conflicting traffic, and allows the right of the way (or a green light) for it to pass through uninhibited. And also helps to reduce response times and enhance traffic safety.

2. The expense of hardware implementation for emergency vehicles can be reduced significantly by using Android-based phones.

3. Every traffic intersection requires Microcontroller and Ethernet Shield, which are open sources at a low market price.

4. In recent years, GPS technology has advanced in improvement so as to locate the places accurately. This accurate location finder, which is so precise to the millimeter, is via GPS satellites using their atomic clocks. Therefore, severe weather conditions cannot have any effect on false triggering of pre-emption because of the GPS accuracy.

5. The benefits of this system is to secure the entire system as of the central secure web server. Illegal hardware, not recognizable by the central server, cannot preempt signals.

The detailed clarification of Table 1 shows that our proposed model does not need any extra device as do the Line of sight and radio system to run this system. Radio system requires interface of electronic noise, but our proposed system does not need any. In previous research, Low computational microcontroller-based siren sound detection system, done by the authors [15], a siren sound detection system with low processing power was designed. This proposed method outperforms the existing siren detection methods in terms of processing power and cost. Also, in the research done by the authors [19], detection of siren sounds using Fast Fourier Transform (FFT) detects the siren sound in 0 dB (S/N ratio), and also the siren sound using the Doppler Effect. This work only detects the ambulance siren sound and neither alerts the traffic nor changes the traffic signals. Another research performed by the authors [20] reveals the Detection of siren sounds based on a pitch detection algorithm, which is capable of detecting the emergency vehicle in the presence of pitched and non-pitched noise. The proposed algorithm outperforms the complex pattern recognition algorithms. The siren signal missing rate of the algorithm is very low. Our proposed model, on the contrary, does not need any.

TABLE 1
THE ADVANTAGES OF THE DEVELOPED MODEL RATHER THAN OTHER APPLIED SYSTEM FOR AUTOMATIC TRAFFIC LIGHT SIGNAL CONTROLLER

Consideration	Acoustic System	Line of Sight System	Radio System	Proposed Model (LTC)
Needed extra devices?	No	Yes	Yes	No
Affected by the interface of electronic noise?	No	No	Yes	No
Needs obvious line of sight?	Yes	No	No	No
Destructions by weather conditions?	No	Yes	No	No
Possible preemption of other approaches?	Yes	No	Yes	No
Triggering pre-emption illegally?	High	High	High	Low
Monitoring and Log statistics through centralized traffic signal?	No	No	No	Yes

The proposed model does not need any obvious line of sight, while the others do. In the previous research done by the authors [21], the Emergency vehicles siren and flashing light detection are based on acoustic and optical sensors, with high cost for effective solution, using which, Distinct emergency vehicles are detected. The proposed system alerts the drivers of normal vehicles and pedestrians about the approaching emergency vehicle. Another research performed by the authors [22] specifies the Cross microphone array-based emergency vehicle detection which determines the incoming direction of siren sound. The proposed system for source detection outperforms the existing sound intensity techniques. It delivers precise warning data to the driver. The authors [23] have proposed Digital image sensor-based emergency vehicle detection and display system for a vehicle, which analyses and detects the emergency vehicle in an image using image processing techniques. It is revealed in comparison

that our proposed system does not need any obvious Line of Sight. Weather conditions have no effect on our proposed model, Radio System, and Acoustic System, but they affect the Line of Sight System. There is a possibility for Pre-emption of other approaches for Acoustic and Radio systems, but not for others. Triggering pre-emption illegally in other systems is very high but in the proposed system, it is very secure. Monitoring and Log statistics through centralized traffic signal is possible in our proposed system, but not in the others, such as studies done by [14]. The LTC communications hardware and software devices as shown in Figure 3.

Fig. 3. The communications hardware and software devices for LTC

VI. CONCLUSION AND RECOMMENDATIONS

This developed model, installed at intersections for signals pre-emption, facilitates the passing of the emergency vehicles easily and quickly to handle the hazardous and dangerous conditions which can affect the human life and assets. The novelty of this study, considering the emergency vehicles difficulties in reaching the troubled destination on time, relates to the conceptual framework which uses and integrates three main concepts which are: ITS, IoT, and using a concept by lean in this research area. By implementing the traffic signal pre-emption, road safety can be increased, and emergency response reduced. Thus, the regular traffic will confront minor or no inconvenience. The methodology for implementing this model applies the received data from the GPS. The GPS receiver and Processor Module, installed in the vehicle, process the received signal. Consequently, the position, heading, and velocity, which are Navigational Vehicle Data, are generated by the Receiver and Processor Module of a GPS. A main central web server controller used to receive a GPS coordination of all emergency vehicles identifies the traffic light position, and then sends dynamic signals to traffic light. Finally, after receiving the signals from the server makes decision and the microcontroller, which is installed at traffic lights, changes the traffic light colour based on the current car position before arriving at and after passing by the selected traffic light. Finally, in the case of lack of cooperation from other vehicles in that vicinity, the license plate number of the vehicle at fault will be recorded after the second warning, and will immediately be sent to the main control office and the person at fault automatically. This project will be tested on two main crossroads in Tehran Iran.

Declaration of Conflicting Interests

No conflicts of interests are present in this work.

Acknowledgment

The authors would like to acknowledge the Iran National Elites Foundation, and School of Industrial and System Engineering, College of Engineering, University of Tehran for their financial support for this project under the grant No. 140/396237 to be presented in 4th international conference on “Multidisciplinary Innovation for Sustainability and Growth”.

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