

# Traffic Flow Optimization and Vehicle Safety in Smart Cities

S.Krishnan<sup>1</sup>, T.Balasubramanian<sup>2</sup>U.G. Student, Department of Computer Science, Sri Venkateswara College of Engineering, Sriperumbudur,  
Tamil Nadu, India<sup>1</sup>U.G. Student, Department of Computer Science, Sri Venkateswara College of Engineering, Sriperumbudur,  
Tamil Nadu, India<sup>2</sup>

**ABSTRACT:** This paper provides the conceptual model of a system implementing traffic flow optimization and vehicle safety by using Internet of Things and LiFi technology in smart cities. The Internet of Things concepts are used to gather the information about the day to day happenings, this data is stored in the cloud and the information acquired is used to predict the best route for the user to a particular destination using machine learning algorithms. LiFi technology is used in the data transfer through light which can be used for communication between vehicles. This communication is used to prevent road accidents and to provide vehicle safety.

**KEYWORDS:** Traffic flow optimization, Vehicle safety, Internet of Things, LiFi, Smart city, Machine Learning.

## I. INTRODUCTION

There are two major problems which people all over the world face. One is traffic congestion. Traffic congestion is a condition on road networks that occurs as the use of road increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. The most common example is physical use of roads by vehicles. When traffic demand is great enough, the interaction between vehicles slows the speed of the traffic stream and results in some congestion. The roads are congested with traffic due to a large number of vehicles going on the same road at the same time. As demand approaches the capacity of a road, extreme traffic congestion sets in. When vehicles are fully stopped for periods, this is colloquially known as a traffic jam or traffic snarl-up. Traffic congestion can lead to drivers becoming frustrated and engaging in road rage. Traffic congestion has a number of negative effects like wasting the time of drivers and passengers which causes delays, which may result in late arrival for employment, meetings, and education, resulting in lost business, disciplinary action or other personal losses and, fuel wastage which in turn causes air pollution and carbon dioxide emissions owing to increased idling, acceleration and braking. There is also a higher chance of collisions due to tight spacing and constant stopping-and-going.

The second one is road accidents. A traffic collision, also known as a motor vehicle collision (MVC) among others, occurs when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or utility pole. Traffic collisions may result in injury, death and property damage. A number of factors contribute to the risk of collision, including vehicle design, speed of operation, road design, road environment, and driver skill, impairment due to alcohol or drugs, and behaviour, notably speeding and street racing. Worldwide, motor vehicle collisions lead to death and disability as well as financial costs to both society and the individuals involved. The number of road accidents over the years has increased drastically [1] and they are a cause of a major concern in most of the cities. It is also a major cause of death in the cities all over the world. Road injuries occurred to about 54 million people in 2013. This resulted in 1.4 million deaths in 2013, up from 1.1 million deaths in 1990[2].

LiFi [3] is a new technology in communication invented by Harald Haas in which data is transmitted using light waves. It uses visible light or infra-red or near ultraviolet spectrum for wireless communication.

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The Internet of Things (IoT) is the network of physical objects—devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data.

A smart city is an urban development vision to integrate multiple information and communication technology (ICT) solutions in a secure fashion to manage a city's assets – the city's assets include, but not limited to, local departments information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services. The goal of building a smart city is to improve quality of life by using technology to improve the efficiency of services and meet residents' needs. ICT allows city officials to interact directly with the community and the city infrastructure and to monitor what is happening in the city, how the city is evolving, and how to enable a better quality of life. Through the use of sensors integrated with real-time monitoring systems, data are collected from citizens and devices - then processed and analysed. The information and knowledge gathered are keys to tackling inefficiency.

## II. RELATED WORK

There have been many solutions for the problems of traffic flow optimization, traffic congestion avoidance and vehicle safety. Isa et al.[4] suggests that there have been many approaches to solve the traffic congestion avoidance problem like Traffic signal control, Traffic routing, Turning Restriction, Congestion Pricing.

The implementation of traffic signal control has been widely discussed and accepted in literatures since couple of decades ago [5]. There are two types of traffic signal control that actively been discussed in the literature. First is traffic signal control at freeway or ramp metering and second is traffic signal control at intersections. Ramp metering is used to improve the merging process between off ramp and motorway by regulating inflow and maximizing throughput by maintaining road capacity. The inflow entering the motorway is depending on signal strategy used.

Recent development in ramp metering is by employing active traffic control where real time data is gathered through installed detector and communication equipment. The collected data will be used by control algorithm in deciding traffic signal. The data collected are traffic density, queue length, vehicle location and etcetera. Ramezani et al. [6] integrates estimation and prediction data including total demand and boundary of queue length in control strategy algorithm. In addition, [7] manipulated historical data especially error in queue length together with real data as a guideline to control the signal in their proposed project named Queue Length Information Fusion Based Iterative Learning Control Approach (QLIF-ILC). Furthermore [8] enhanced ramp metering implementation by eliminating conflict between shoulder and ramp lane. They introduced traffic control signal at shoulder lane right before on-ramp traffic. It will stop the traffic from coming at shoulder lane in order to give a way for traffic from on-ramp to merge at the main road. Loop detector is used to collect traffic information in real time, and then the signal at ramp and shoulder lane will be alternated based on the info collected.

Another approach is optimizing traffic signal control at intersection. It helps in employing road capacity efficiently and improves throughput of the network. It can reduce average waiting time by generating green wave at congested intersection, hence reduce traffic density and improve traffic flow. To create optimize green wave, real time data is needed. Recent method used to gather data instead of loop detector are wireless sensor network (WSN), Radio Frequency Identification (RFID) and vehicular ad-hoc network (VANET).

Traffic routing is a process of allocating network path to the transportation systems towards less congested area.

Several studies have been carried out on implementing traffic routing. One of the proposed adaptive route planning system is using A\* Algorithm [9]. The concept proposed by the author is similar to available navigation system, however the system will consider historical data and predicted data in planning the route. Historical data is the planned route from the previous request so that the planned route provided will consider future traffic density.

The third groups of approaches is Turning Restriction or Turning Restriction Design Problem (TRDP) approaches focus on designing or finding a set of restrictions at intersections to promote traffic flow.

A demand control strategy is one of the solutions in combating traffic congestion [10]. Congestion pricing is a surcharge applied based on demand of the road. Basically the idea is to reduce the road demand and distribute the demand in several other roadways by encouraging drivers to travel during off-peak periods, or divert to less congested

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routes, or opt to other transportation alternatives such as public transport. It is believed able to help in distributing demand and minimize the impact of traffic congestion. This similar concept has been applied in communication services where a charge during peak hour and off peak hour is different. Similarly, there are also works done by Chen et al. [11], Subramanian et al. [12] and others related to vehicle safety.

### III. METHODOLOGY

The system proposed consists of two major components:

#### A. LiFi component: -

The LiFi component consists of two parts: One part is the LiFi transmitter which is placed in the traffic signals as proposed by Baeza et al. [13] and in the vehicle's rear side. The other part is the receiver which is placed in the vehicle's front side. The transmitter transmits the data from the traffic signal light which is received by the photosensitive receivers placed on the vehicle.



Fig.1: This shows the different data sent through different colour lights.

As shown in figure 1, unique data is sent through different light signals. This light is received by the photosensitive receiver placed on the vehicle and the data is processed for further displaying information to the users.

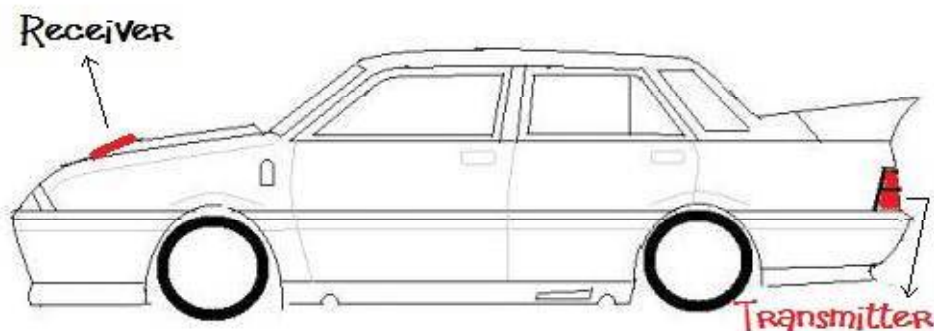


Fig.2: This shows the placement of receiver and transmitter placed in a car.

When the brake is applied the brake light glows, thereby transmitting the data to the receiver placed in another vehicle. Thus it alerts the other vehicles behind that the vehicle has applied the brake.

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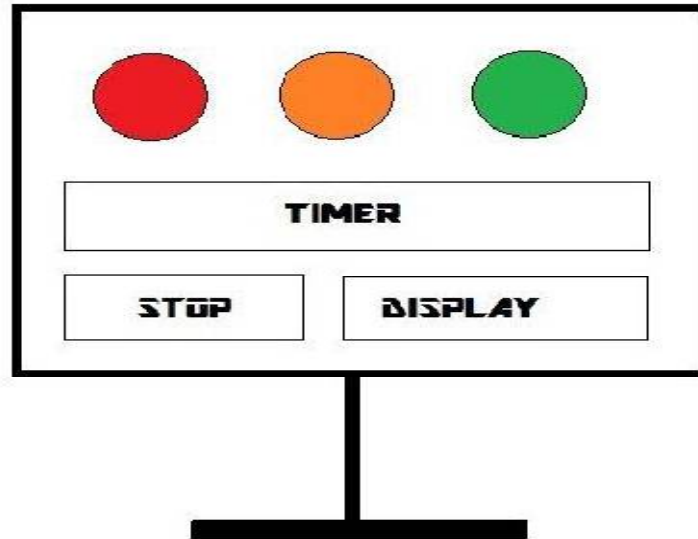


Fig.3: The prototype of display system placed inside the vehicle.

The figure 3 is the prototype of the display system present inside the car which actually tells the users the current traffic signal, the timer for the green signal, the stop which alerts the user when the brake has been applied in the vehicle in front. The display block consists of the map.



Fig.4: Concept of the actual display system in the mirror placed inside the car.

## B. Internet of Things component :-

The data about the number of vehicles present and traffic congestion in that area is acquired from the following three sources:

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1. Sensors placed at the roads and road junctions.
  2. Traffic cameras placed in the roads.
  3. Bluetooth data acquired from the mobile phones of the drivers.
- The day to day data collected from the sensors is stored in a local server.

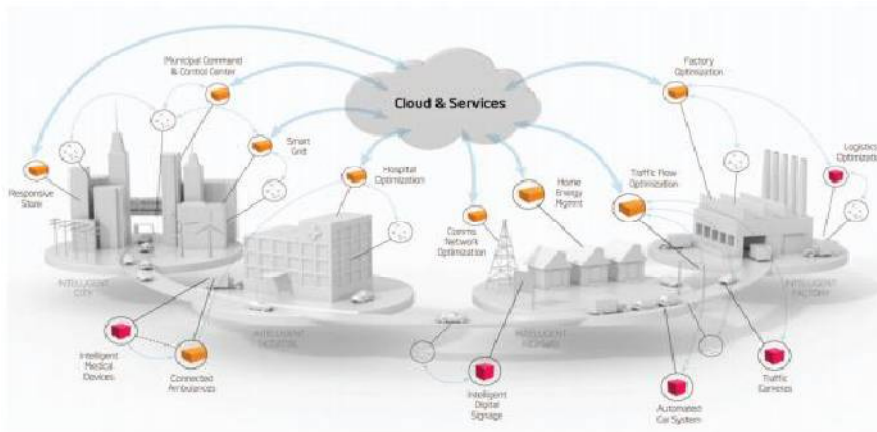


Fig.5: A picture of a smart city data collected and stored in the cloud.

By forming blocks of data, data is grouped and analysed in sectors. This useful data stored in the local server or the cloud, which can be utilised for finding the traffic prone areas and predicting traffic congestions. The data stored is in the form of Big Data which is analysed and mining for various purposes. This data can be analysed using machine learning algorithms like Regression tress, Kalman filters and the best route for reaching a destination i.e., the route with least traffic congestion and least accident prone route can be determined.

**Algorithm:**

1. The date, month and time at which route must be predicted is passed as an argument to the module.
2. Using this information, the tables from which data must be extracted are determined.
3. The data is extracted from these tables at required time frames and are used to train the system.
4. Once the models have been generated, k-fold cross validation is performed and the model which performs the best is selected.
5. This selected model is now used to predict data at the required time in the future.

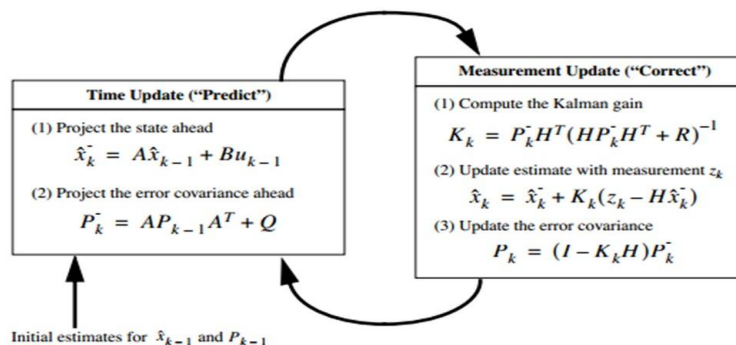


Fig.6: Algorithm for traffic prediction

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## IV. SIMULATION AND RESULTS

The algorithm was simulated with a sample data set. It predicts the traffic at a particular point of time specified by the user and recommends the best route for the user at that time.

ROAD	OBSERVED	PREDICTED
AB	49.0	41.0
BA	45.0	49.0
CD	23.0	31.0
AE	34.0	33.0
CE	39.0	38.0
CF	45.0	47.0
AD	43.0	47.0
EC	40.0	43.0
DC	34.0	38.0
BE	20.0	29.0
EB	25.0	26.0
BF	33.0	38.0

Fig.7: Route Predictions

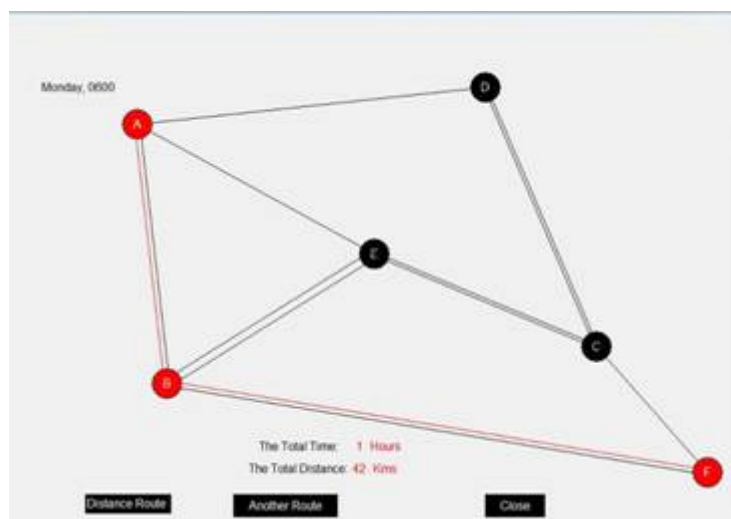


Fig.8: Route Recommendation

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The above figures Fig.7 and Fig.8 show the route prediction for the sample data set using the Regression tree and Kalman filter algorithm. Fig.7 shows the predicted values and the actually observed values of traffic for the various roads. The route highlighted in red colour in Fig.8 is the route recommended by the system for the particular destination specified by the user at that point of time. Thus the traffic flow can be optimized by making every user travel in the route recommended by the system and congestion can be avoided.

## V. CONCLUSION

Traffic congestion and road accidents are a worldwide problem in the modern world. They create a number of issues in everyday life. Numerous approaches have been proposed in solving them and they have been reported in various publications. We have thus proposed the model of a system that optimizes the traffic flow using the Internet of Things and provides vehicle safety using Li-Fi technology in a smart city. This model will help in reducing congestion in roads and preventing road accidents.

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