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An Intelligent Transportation System with Computer System Architecture approaching Safe Passage in Adaptive Traffic Light

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***Abstract*— This paper report discuss a system which can help saving fuel and time with active adaptation to speed on urban roads. An especially designed algorithm featuring prediction of speed, incorporating Raspberry Pi model B interfaced with GPS and GSM (for GPRS). This system follows secure server-client architecture developing a widely accessible infrastructure. It holds potential to provide an intelligent traffic management alternative with enhanced navigation capabilities along with synchronization of traffic lights. This system furnishes an efficient, reliable, intelligent and secure alternative for existing ITS (Intelligent Traffic Systems).**

Keywords-Intelligent Traffic System; Serve-Client Architecture; Navigation;Raspberry pi; GPRS.

I. INTRODUCTION

The rapid increase in traffic congestion is a matter of serious concern for many countries. A research conducted by Plunkett Research Ltd. In 2009 depicts that more than 50 million new cars are manufactured each year [9]. The 2011 Urban Mobility Report estimates total annual cost of congestion for the 439 U.S. urban areas is of 101 billion dollars, with 4.8 billion hours of delay and 1.9 billion gallons of excess fuel consumed [3].

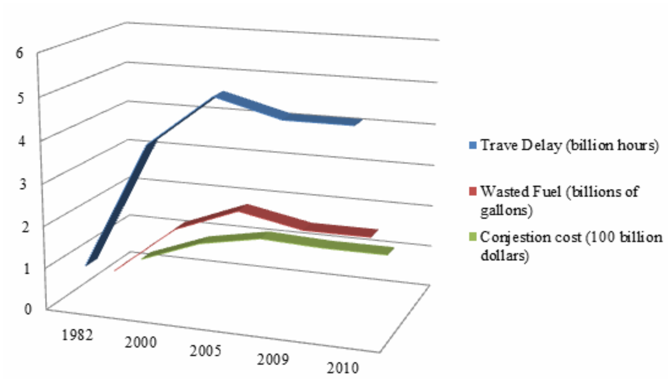

Fig. 1. Graph showing urban mobility report 2011

The overall ceasing and leaving pattern followed at traffic intersections increases fuel consumption by 17%, CO_2 emissions by 15% [1]. Currently most of the vehicles are equipped with GPS (global positioning system). The idea is to equip this existing system with a further augmentation which can feature it potent enough to avoid the traffic lights. This could be done by linking every traffic light with a Server, and every vehicle with a navigation enabled device with an active link to the server will make it possible to be used in most of the existing devices. Countdown timers for pedestrian traffic signals are much more common in the USA and the rest of the world, and drivers can sometimes use these to predict when the light will turn green. However, very often these are not visible from far away but only after one has reached the intersection. At that time it is too late for drivers to adapt speed and so they need anyway to completely stop the vehicle. Furthermore, at some intersections it is not easy or even possible for the driver to predict the time when the signal will change its status. In this paper report a system has been proposed as a solution to wastage of fuel and time due to traffic congestion and idling of vehicles at traffic lights. This system can shrink the cost of stationary sensors and video cameras which require high cost and maintenance. For this a common relation between speed, distance and time is used.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

This system provides an estimation of speed to the vehicles approaching a traffic light and at what speed the vehicle will avoid it. This could be done by obtaining the time durations for which the traffic light remains green, the cycle period of the light and the distance between the traffic light and vehicle. Further the estimated speed for safe passage from traffic light would be calculated by a model B Raspberry pi computer and will be displayed on the screen attached to it. So at every intersection vehicles will pass within their specified time frame rather than waiting for one.

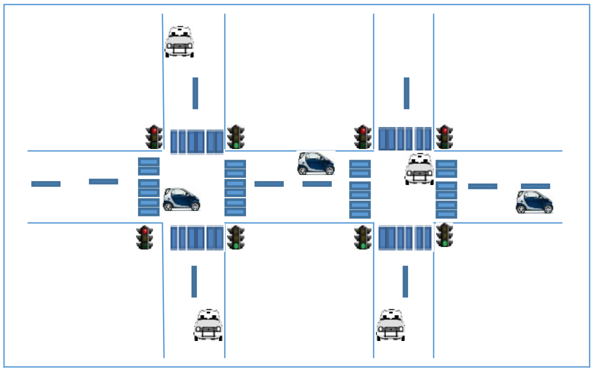

Fig. 2. Intersection of roads.

Safety is of paramount importance in the automotive field. The most common failure conditions in a traffic light detection system are either visual obstructions or false positives such as those induced by the brake lights of other vehicles. The proposed system overcomes with these failure conditions as it employs server architecture and real time monitoring of data from the traffic lights to a vehicle involving less probability for errors.

II. RESEARCH FOUNDATION

ITS (Intelligent Traffic System) is a topic of huge concern to our developing world and a lot of prior research has been done but due to diversities of technologies and fields in ITS the absence of a unified system exist. Many systems have been implemented so far but none of them was efficient and capable enough to be used universally. A-GPS probe approach with the help of mobile phones has been proposed by Sha Tao et.al for estimating congestion on roads along rolling time periods, providing real time traffic maps on mobile phones [13] but the approach was not considered efficient enough as the processing of data collected was not real time and it involved a glitch in detecting and providing irregular congestion details. Camilla Morellato el.al proposed a bus priority system which is being used by many countries in the world [2] but the common difficulty being faced by this system is the unpopularity of public transport especially busses among people in major cities. Another system proposed by Ms Promila Sinhmar et.al featuring IR-sensors with Microcontroller estimates the congestion of vehicles by counting them [10] but later on it was examined that if the light delay is not updated manually accurate enough, it could result in traffic congestion. Nathaniel Fairfield et.al discussed a traffic light mapping and detection system which portraits a method of automatically mapping the 3D positions of traffic lights by detecting its state with onboard cars with cameras [7] but the sensors used such as sonar, radar and lidar involve a huge capital to be invested and decreases the cost effectiveness. A multiple traffic light control using a genetic algorithm is discussed by T. Kalganova et.al attempting to use an algorithm to improve the fixed cycle traffic lights into a coordinated behavioral system controlled by a genetic algorithm for decreasing the overall network delay [14] but further research showed that the algorithm was very complex to be implemented on a large scale but also not accurate enough. Xu li et.al proposed a vehicle-based mobile sensor network for traffic monitoring involving collection of data from sensors in taxies and processing them for traffic monitoring [15] but making the system limited to only taxies narrows its role on a large scale. Another system of involving wireless sensor network based approach is proposed by Khalil M. Yousef involving the flow control system of ITS [6]. The system involved establishment of separate infrastructure which results in inefficiency. A Bluetooth stem based signaling approach was revealed by Paolo Valleri involving the use of Bluetooth with raspberry pi for detecting and estimating traffic with adoption open source hardware and software [8] but the detailed study of the proposed method depicts that the detection and estimation is very less precise and is inefficient to handle critical traffic conditions. A paper proposed by Sahar Lazim Kadoory et.al about an embedded web based server for road traffic monitoring employing wireless sensor network with WLAN [12]. Although the detection and analysis of vehicle is done still no real time application is preformed also there is a requirement of separate infrastructure.

III. HARDWARE DESCRIPTIONS

This system uses a Raspberry Pi model B for computing process along with it a GSM module has been used for its GPRS facility interfaced with GPIO pins of raspberry pi. For navigation purpose a GPS module is used, and a standard HDMI display for displaying the user interface involving navigation maps and speed related information.

A. Raspberry Pi model B

This system incorporates Raspberry Pi model B as its central nervous system on receiver side. Raspberry Pi is credit card sized Linux computer having 512 MB RAM, 2 USB ports and an Ethernet port for internet connection it uses an ARM1176JZFS processor operating at 700MHz and video core 4 GPU it boots using a SD card installed in FAT32 partition. The Raspberry Pi has 8 dedicated GPIO pins, a UART, i2c bus, SPI bus with two chip selects, i2s audio, 3v3, 5v, and ground [4].

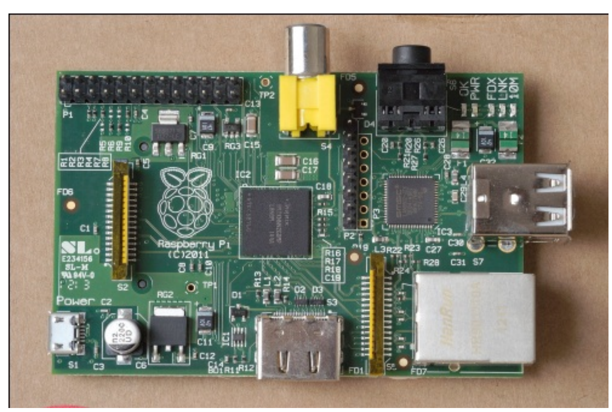

Fig. 3. Raspberry Pi model B

B. GSM Module

In order to establish a link between server and the vehicle a GSM module is utilized also wireless dongles can also be used as Raspberry pi supports almost all types of internet dongles [11].

Fig. 4. GSM module.

C. Display Unit

In order to display the calculated information on maps and for navigation purposes a standard HDMI display is used.

Fig. 5. A standard HDMI display.

D. Navigation

For navigational purpose GPS is recommended as it features worldwide coverage, it is a constellation of 24 or more satellites flying 20,350 km above the surface of the earth. Each one circles the planet twice a day in one of six orbits. A GPS signal consists of 3 important parts:

- A satellite ID (called the Pseudo Random Code)
- Almanac data (orbital information for all the satellites)
- Ephemeris data (the orbital information for the single satellite in question, including the very precise clock information necessary to calculate the distance)

To calculate its distance from a satellite, a GPS device applies this formula to the satellite's signal: distance = rate x time, where rate is (c) and time is how long the signal traveled through space [5].

Fig. 6. GPS module.

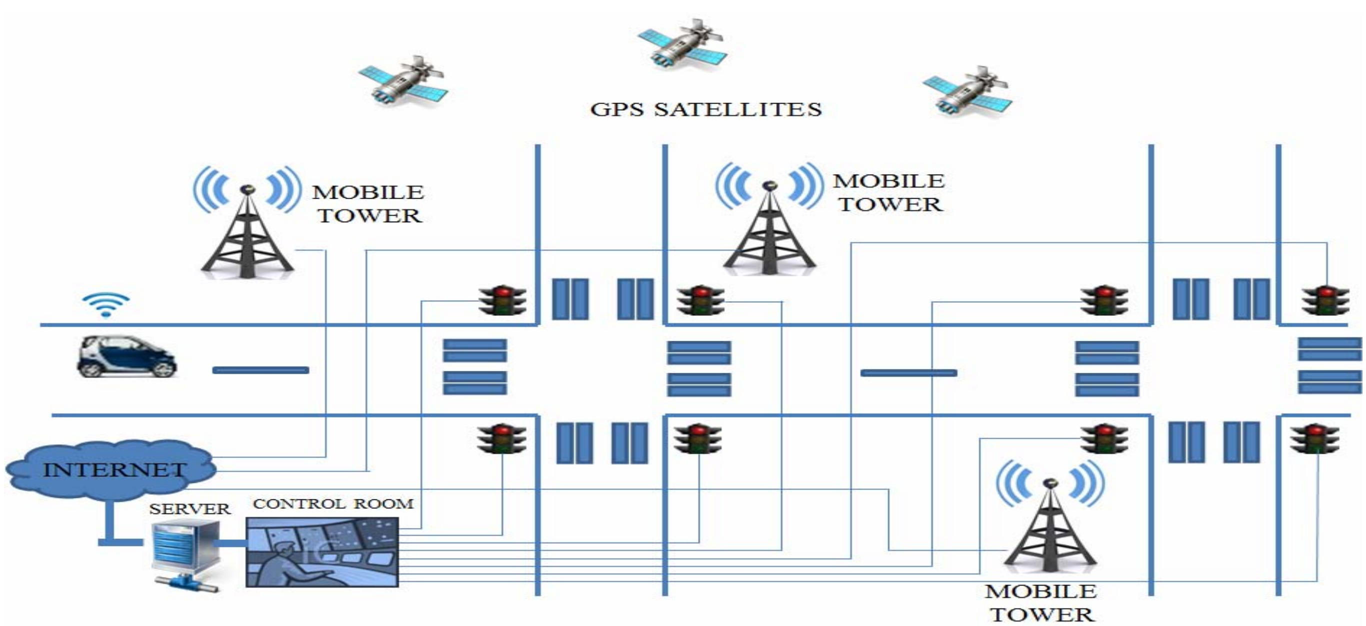

Fig. 7. Architecture of Intelligent Transportation System

IV. SERVER SIDE SYSTEM DESIGN

The server acts as a middle level in the interconnection of client level to the traffic lights. It also functions as a data accumulator and provides the client with the appropriate information required for computing speed. The functions that the server is performing are as follows:

1. Receiving information from traffic lights involving data about timing, status, emergency situations and congestion.
2. Receiving data from vehicles including id of vehicles, direction of movement, location of client and destination to be reached.
3. Providing clients with information about the unique identification numbers of the traffic lights and intersections in the proposed path of the vehicle.

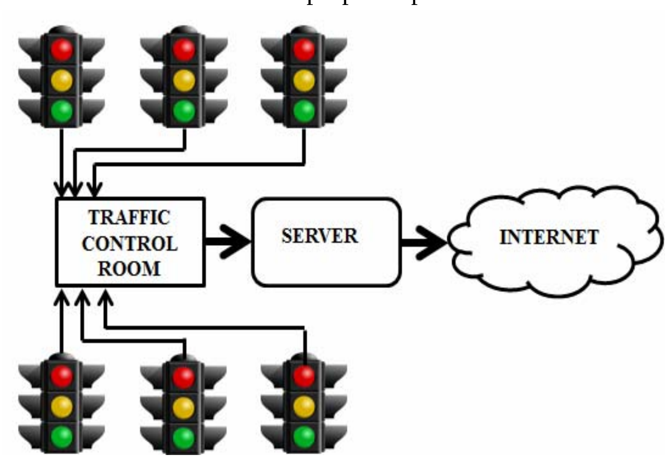

Fig. 8. Server side system block diagram.

Server receives dynamic information from the traffic lights and sends it to the client and in the process of routing this information it provides authentication, real time monitoring of vehicles on roads with their exact locations and an artificial and intelligent system which can control and regulate the flow of traffic in an entire city.

V. CLIENT (VEHICLE)- SIDE SYSTEM DESIGN

A path determination interface is setup to facilitate the mapping of road segments. It works as per the steps given below:-

1. Determination of path according to the current location feed and destination set.
2. Sending the route related information to the server in a form of a static html file.
3. Calculating the required speed from the data provided by the server.

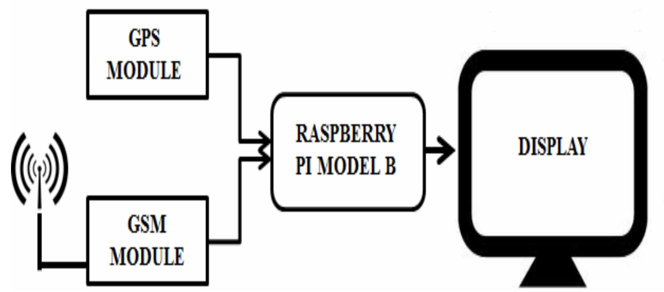

Fig. 9. Client side system block diagram.

The static file should contain following parts:-

1. Unique Address of the vehicle – A unique ID of the vehicle (required for filtering on server end).
2. Destination name and coordinates– The name of the destination along with its coordinates.
3. Current location name and coordinates- The name of the current location along with its coordinates
4. Direction – The direction of movement within the road segments.
5. Distance to be covered- The total distance that is to be covered by the vehicle in its journey.

VI. ALGORITHM

Step 1: Acquire data from the GPS module
String GPS="A*79|0.9|&C0000011111
&D0026:164&E10000000&Y00180000";

Step 2: Calculate distance between the current location and the destination,
int dist=(distance); // in meters

Step 3: Set the limit of speed to maximum,
int speed=max; // maximum speed

Step 4: Calculate time to reach the traffic light
int time=(dist/speed);

Step 5: Calculate safe passage
if(time=clear-pass)
    clear(); //call clear function
else
    unclear(); //call unclear function

Step 6: clear();
Display the maximum speed.
disp(max);

Step 7: unclear();
Add next passage frame,

Step 8: return to step 5.

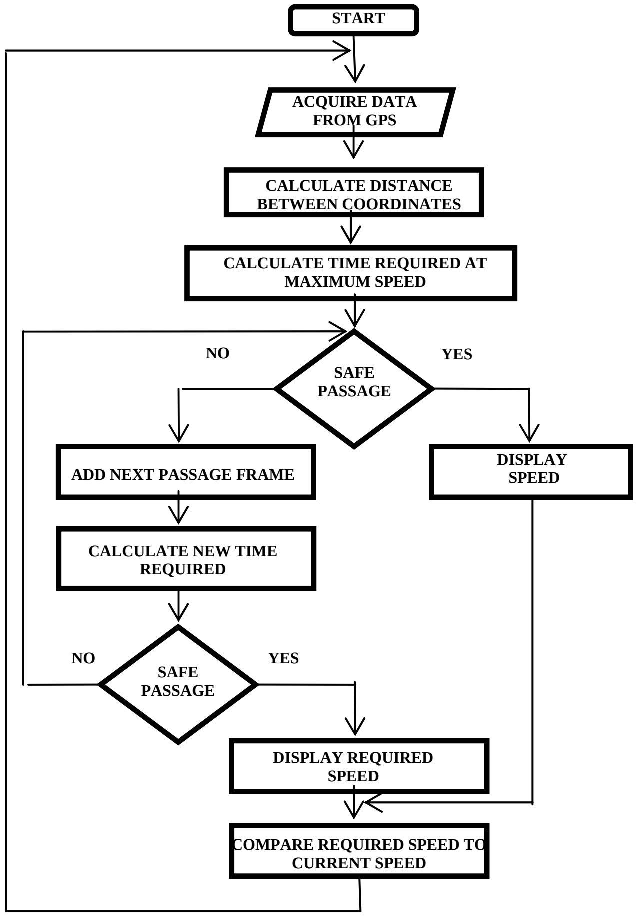

Fig. 10. Control flow diagram

VII. TRAFFIC LIGHT DATA

The data to be sent to the server, in order to get data efficiently a traffic table is used. Following are the requirements of the traffic table:

1. Unique identification number of red light.
2. Data being displayed on the display at traffic light.
3. Signal status of the traffic light green, red or yellow.
4. Flip time the time when the red light flips its status.
5. Congestion information at the traffic light to provide client with prior information of accumulation of vehicles at the intersection of roads so that client can take appropriate measures.
6. Emergency information about any accident or any other emergency at the intersection.

The data is to be sent by interfacing the traffic control room and server for the exchange of data between traffic light and client side of the system. All the data are to be sent in the form of a dynamic file as there should be no delay in the calculation of time at the client end so that there should be negligible error in the calculation of speed.

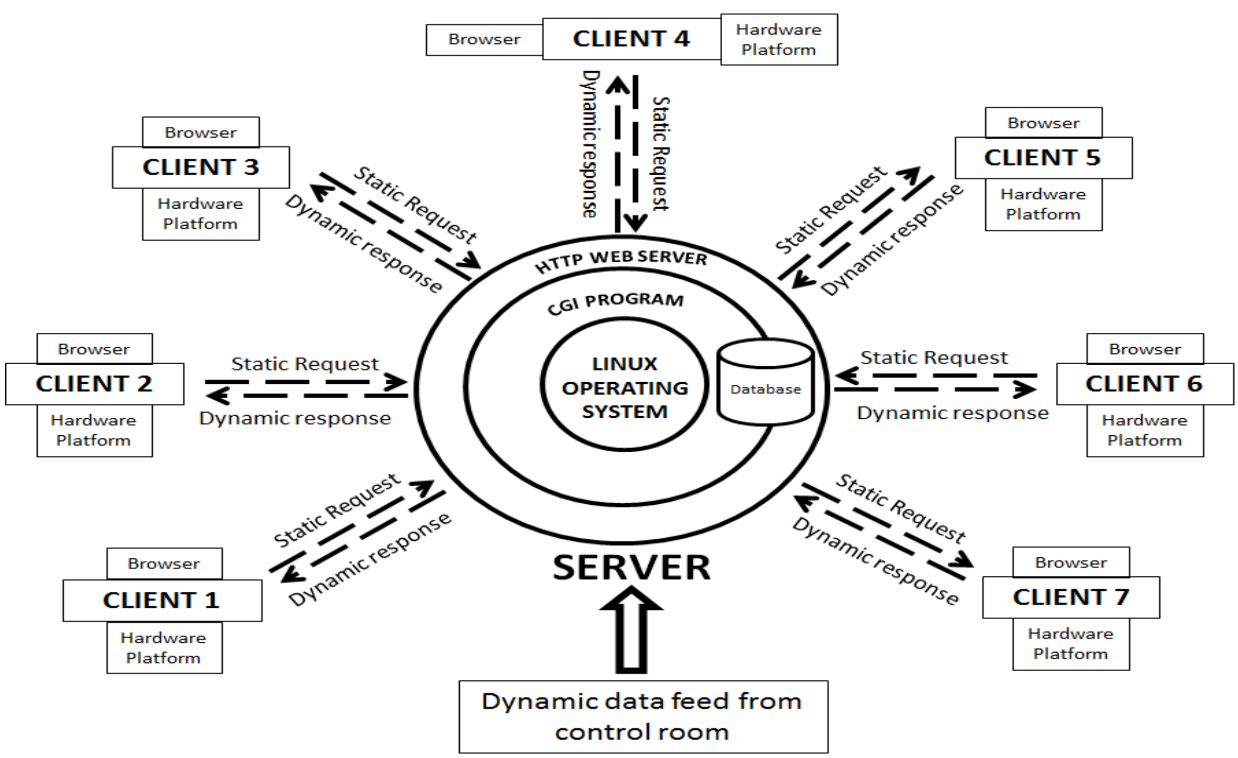

Fig. 11. Server Architecture

VIII. SIMULATION RESULTS AND EVALUATION

This system is meant to be controlled by an automated intelligence which further can be monitored using a central control room. The management and the maintenance of the system will be the sole responsibility of the control room. The major task of the control room will be monitoring flow of traffic, road usage patterns, and prediction of traffic congestions so that vehicles can also be routed from other routes hence developing a stable traffic environment with distributive movement of vehicles thus saving time and fuel. The control room can also find the vehicles with their unique identification number which would turn out very useful for controlling illegal movement of vehicles and tracking stolen vehicles. Many simulations were carried out on this system following are the tables and graphs depicting the movement of vehicles with and without interaction with traffic lights.

Some assumptions that were taken while calculating results are:

1. Speed limit of the road to be 50 km/hr.
2. Flip time of the traffic light changing its state is 30 seconds.
3. Static time being displayed on the traffic light display is 24 seconds and is descending in nature.

Assuming the vehicle without any interaction with traffic light and constantly moving at a speed of 40 km/hr.

TABLE I. VEHICLES WITHOUT ADAPTATION OF SPEED ALGORITHM

Distance	Speed in km/hr.	Time taken in hrs.	Time static when reached the red light	Safe passage
20 m	40	$5X10^{-4}$	22 s on green	Yes
50 m	40	$1.25X10^{-3}$	19 s on green	Yes
500 m	40	$1.2X10^{-2}$	9 s on red	No
1000 m	40	$2.5X10^{-2}$	23 s on red	No
2000 m	40	$5X10^{-2}$	23 s on green	Yes

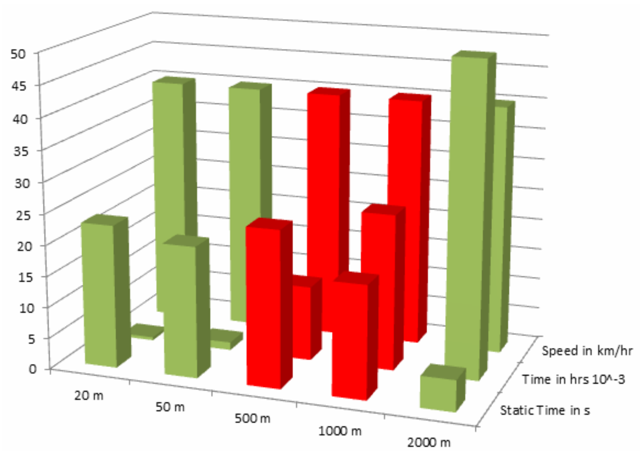

Fig. 12. Movementof vehicle wihout adaptation of speed algorithm

Assuming the vehicle with synchronised interaction with traffic lights and adjusting its speed accoring to the algorithm provided above.

TABLE II. VEHICLES WITH ADPTATION TO SPEED ALGORITHM

Distance	Speed in km/hr	Time taken in hrs	Time static when reached the intersection	Safe passage
20 m	50	$4X10^{-4}$	23 s on green	Yes
50 m	50	$1X10^{-3}$	21 s on green	Yes
500 m	30.5	$1.6X10^{-2}$	25 s on green	Yes
1000 m	50	$2X10^{-2}$	18 s on green	Yes
2000 m	50	$4X10^{-2}$	5 s on green	Yes

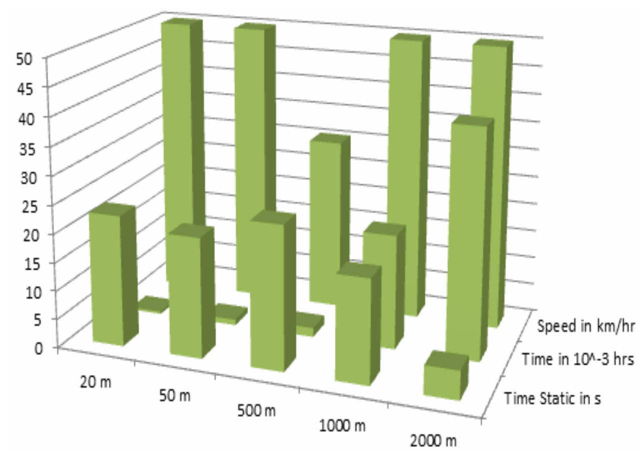

Fig. 13. Movement of vehcile with adaptation of speed algorithm

There were certain vehicle trajectories which were tested along with the integration to google maps.

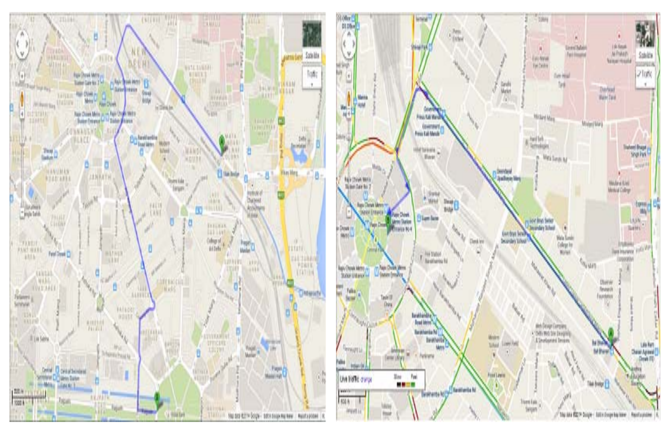

Fig. 14. Vehicle trajectories along with the integration to google maps

VIII. CONCLUSION

In this paper report a method of intelligent traffic controlling system is presented with automatic interaction of traffic light with the vehicles. The proposed method takes advantage of growing use of GPS and server client architectures in current state of the practice systems. Based on simulation results devices can be developed enabling vehicles to automatically adjust the routes as per the traffic conditions in real time basis. The advanced server and filtering techniques enables the system to monitor vehicles effectively. The use of this system will marginally decrease the wastage of fuel, time and congestion on roads. The detailed study of the system shows that in the near future such systems will make an artificial intelligent system saving fuel, time and making traffic congestion less prominent.

IX. FUTURE SCOPE

Future research may lie in investigating several enhancements to the current implementation, including the following areas:

- Emergency notification system providing a portal where emergency notification would be generated as soon as any emergency situation occurs.
- Cloud connectivity on real time basis will ensure accurate and precise traffic updates on any handheld device.
- A Simple mobile phone based application which will turn advantageous in using the existing infrastructure.
- Use of this system as a wireless sensor network will provide microscopic approach to understand traffic conditions more easily.
- Generation of notifications for traffic department about any reckless or over speeding driver.

Further research can focus upon developing a system with artificial intelligence so that it controls the flow of traffic. One can look forward to increase the reliability of the system with advance algorithms and installation of a high speed network which diminishes the probability of errors.

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