# Design of a Real-Time System for Remotely Monitoring Occupancy and Tracking Location of Public Service Vehicles

Muthiani K. M, Karere M. N and Kamau L.

***Abstract*****—**A major cause of accidents in developing countries is overloading of vehicles especially within the public transportation industry. Remotely detecting the overloading incidents would significantly aid in the mitigation of such accidents. Automatic systems are currently employed for detecting entry and exit of people through doors. These systems rely on varying technologies such as Active Infrared (AIR), Thermal Imaging, Treadle Mat Sensors, Cameras with Artificial Intelligence (AI) capabilities, etc. Mobile vehicle tracking using the Global Positioning System (GPS) is also on the rise among vehicle owners in an effort to enhance security and ease supervision. This paper proposes a solution for remotely monitoring the number of passengers in a vehicle using AIR while simultaneously tracking the location of the vehicle. Global System for Mobile Communication (GSM) technology is relied on for mobile communication between a Raspberry Pi 3 microcontroller within the vehicle and an Internet of Things (IoT) database. This system provides relevant regulatory authorities with a remote means to detect overloads hence allowing for enforcement of relevant traffic regulations. Additionally, Public Service Vehicles (PSV) managers can provide potential passengers with information on occupancy and location of PSVs plying various routes on their smartphones through a mobile application connecting with the IoT database.

***Keywords*****—**GPS, GSM, Infra-red, IoT, Mobile Application, PSV, Vehicle Tracking

## I. Introduction

TELECOMMUNICATION has evolved to be a service versatile enough to be utilized in virtually all fields. Paired with Geospatial Information Systems (GIS), it can be used in the public transportation sector to automate the enforcement of regulations. ThePublic Service Vehicles (PSV) sector has grown tremendously over recent years to the point of nurturing an entire industry in itself. Given its magnitude, adequate regulation has proven to be a big challenge. There is also a need to make public transportation more convenient to commuters by providing them with a means of tracking the PSVs using their mobile phones.

Carrying excess passengers, by PSVs operators, is one of the major problems in the sector that require constant monitoring. This is very risky in the event of accidents whereby the excess passengers, who lack a safety belt, are left highly exposed to harm and more often than not suffer severe injuries and fatalities.

Currently, the issue is tackled on an impromptu basis in the form of crackdowns and routine police checks to nab out excess PSV passengers and defiant operators. However, this requires a lot of manpower to physically check the PSVs and identify offenders. There is lack of a real-time remote monitoring system that will ensure continued compliance with the regulation. Additionally, passengers lack a mobile means of tracking the PSV on a real-time basis.

The problem is to be overcome by implementing a system that allows for remotely monitoring the number of occupants in a PSV and consequently alerting relevant authorities in case of excess passengers. The alerts are paired with real-time tracking of the location of vehicles. Furthermore, a mobile application will provide real-time updates on the location and occupancy of the vehicles to passengers.

Once implemented, the remote monitoring system will provide a way to consistently monitor the occupation of PSVs with respect to their capacity. It is projected that there will be a significant increase in compliance with the regulation by the PSV operators. This is expected to translate to fewer fatalities and severity of injuries sustained as a result of vehicle accidents as all passengers should have access to a seat belt. Furthermore, less manpower will be required on the ground while the mobile application will offer passengers great convenience when planning for their travels.

### A. *Statement of the problem*

There is lack of an economical remote occupancy monitoring system for PSVs. Reliance on police checks is not only temporarily effective but also requires a lot of manpower which can be diverted to ensuring security of citizens. Additionally, passengers are unable to remotely track PSVs from the comfort of their homes and have to wait at bus stops for indefinite periods of time. This is highly inconvenient especially during adverse weather conditions.

### B. *Research Objectives*

1) To create a mobile monitoring system which can detect an overload in a PSV and notify the relevant authority in real-time.
2) To create a mobile application that can provide updates on location and occupancy of PSVs potential

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passengers.

## II. LITERATURE REVIEW

### A. Introduction

The world is experiencing accelerated growth in Smartphone ownership. As Smartphones become more familiar to people and finding use in the day to day lives, their influence on society continues to grow. The main driving force for this accelerated growth in Smartphone usage is the availability of a large variety of applications to meet the needs of a wide range of users[1].

The Global Positioning System (GPS) is an earth-orbiting-satellite based navigation system. It is an operational system, providing users worldwide with twenty-four hour a day precise position in three dimensions and precise time traceable to global time standards [2]. General Packet Radio Service (GPRS) and Global System for Mobile Communication (GSM) systems provide inter-working and sharing of resources dynamically between users [3].

A Smartphone application partnered with an in-vehicle tracking device (GPS module) can be employed for mobile vehicle tracking. Location coordinates can be automatically sent through a Subscriber Identification Module (SIM) present in the GSM module to registered mobile users. These coordinates can consequently be plotted on a background map[4].

### B. GPS

GPS was developed by the United States Department of Defence. Its official name is NAVSTAR-GPS. It was originally used solely for military services but later the system was made freely available for civilian use. Since then, GPS has gone on to be widely used across the world for positioning and timing purposes [5].

A GPS receiver receives the signals from at least three satellites to calculate distance and uses a triangulation technique to compute its two dimension (latitude and longitude) position or at least four satellites to compute its three dimension (latitude, longitude and altitude) position[6].

The GPS basically consists of three segments: Space Segment, Control Segment and User Segment[7]. It works in all the weather conditions covering the entire world throughout the year. The global navigation system is based on a constellation of GPS satellites which orbit the Earth two times in a day. Each and every satellite sends a unique signal to the GPS receivers. The GPS receivers then decode the signals and calculate the exact location of the user. The receiver basically uses the time it takes to receive signals as the source of calculating position [4].

### C. GSM

A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. GSM (Global system for mobile) uses a process called circuit switching. This method of communication allows a path to be established between two devices. Once the two devices are connected, a constant stream of digital data is relayed.[6]

For wireless data transmission, GSM and SMS technology are commonly used. The SMS technology through GSM network and GSM modem can be used to provide a user with vehicle location information. Utilization of SMS technology has become popular because it does not involve much cost. It is a convenient and accessible way of transferring and receiving data with high reliability.

The proposed system uses a Smartphone application to track and monitor a vehicle location obtained from the in-vehicle tracking device controlled by a microcontroller. The vehicle's location information and a vehicle’s ID is then transmitted to a web server after a specified time interval using the GSM/GPRS module.A Internet of Things (IoT) database is utilized to store and manage received vehicle's location information. Whenever a user requests the vehicle location, it can be accessed from the database and monitored on Google maps in real-time using a Smartphone application.

### D. Bidirectional IR Sensing

Technologies for counting people comes in many shapes and sizes, offering solutions that can be shaped for differing budgets, entrance configurations and layouts, as well as required accuracy levels and analytical capabilities.

The most basic type of people counting technologies is door-mounted horizontal systems. These include both wired and wireless options, using sensors mounted on the entrance door’s frame that cast a horizontal infrared beam across the doorway. People are counted as they cross the threshold and “break” the beam. Another type is ‘Overhead people counters’. It uses two different types of sensor technology, thermal and video-based.

Each technology has its own pros and cons, and in some cases, businesses may choose systems that utilize a combination of both sensor types.

Installed at access point the IR sensors are set to perform a bi-directional count of all people entering or exiting. This is done by employing a 2-beam technology as shown in Fig. 1. The counter increments a count every time the beam is cut in a particular direction and decrements the count every time the beam is cut in the opposite direction. This makes the system direction sensitive as it records the count direction (IN/OUT). By comparing all entries and exits in real time, the occupancy of a vehicle can be monitored.

With web-based Occupancy Monitoring software, the count data that has been collected can be displayed in real time (live GUI). The software also has the capacity to provide historical data analysis, data aggregation and time plotting.

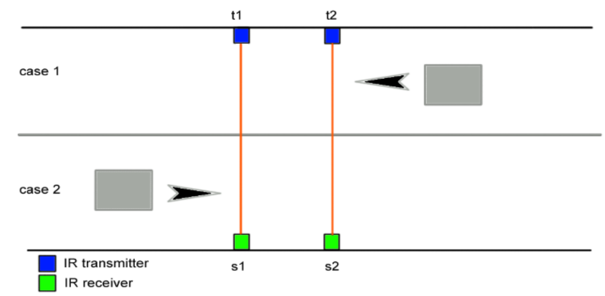


*Fig. 1 Active Infrared*

### E. Related works

*1) Real-Time Vehicle Tracking*

There have been many works published related to the GPS vehicle tracking system. For example, the GPS system has been used to create Geo-Fences about a designated location and give alerts once the driver goes outside that location. However, all these workings are implemented using external hardware interfaces. The accurate tracking of targets is highly challenging without using external modems or tracking chips for getting the exact location of the user.

The work done by Pradip V Mistary and R H Chile represents a vehicle tracking system using a GPS-GSM modem and a micro-controller [5]. The system is implemented for monitoring the movement of any equipped vehicle at any time. In this system, the GPS receiver gets the location data and converts this data into a data string of NMEA 0183 format in a continuously periodic manner. At the operator station, the receiver receives and puts this reading into the GUI application made in MATLAB®. The application contains an algorithm which gets the NMEA reading and converts it into degree format suitable for Google Earth which is called by the application. The system can be improved by connecting GSM modem to the GUI eliminating the need of operator and making the system more reliable.

The work done by Stephen TeangSoo Thong, Chua Tien Han and Tharek Abdul Rahman [8] proposed an intelligent fleet management system which incorporates the power of concurrent Global Positioning System (GPS) and Global System for Mobile Communications (GSM) real-time positioning, front-end intelligent and web-based management to manage vehicle fleet efficiently and effectively. This implemented work includes an intelligent front- end terminal installed in targeted vehicles which communicate with the fleet management control centre through GSM channels. Monitoring is then done by using a web-based dashboard as well as via the Internet or Short Message Service (SMS).

The terminal is powered by Front-End Intelligent Technology (FEI), a comprehensive embedded technology that is equipped with necessary artificial intelligence to mimic human intelligence in decision-making for quicker response, better accuracy and less dependence on a backend server. With less dependency on the backend, a large scale fleet management system could be implemented more effectively. The proposed system was successfully implemented and evaluated on twenty vehicles including buses and cars in UniversitiTeknologi Malaysia (UTM).

*2) Treadle Mat Sensors*

This solution relevant to the APC technologies is produced by several companies operating in the transport industry and somewhat spread in Germany [9]. The counting system uses treadle mats located in the proximity of the vehicle gates, typically on the access steps.

The metal structure can be covered by a layer of rubber and attached to the steps by means of purposely-allocated attachment structures, or simply glued by means of high seal adhesives; the latter solution is less frequently applied because it may deteriorate rather quickly.

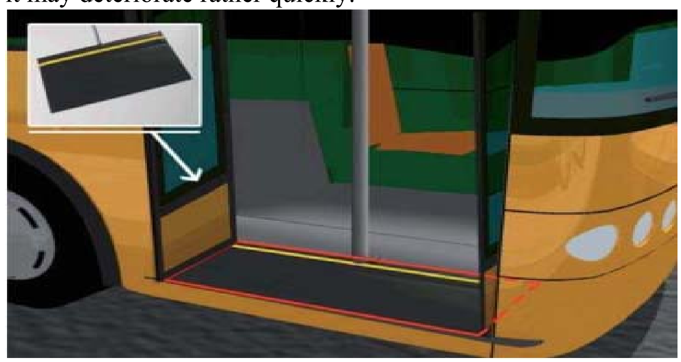

*Fig. 2: Treadle Mat*

After years of field testing, especially in America, a manufacturer (London Mat Industries Matex), estimates that the life cycle of this type of APC may be of up to10 years with remarkable variations (it may reduce even to 3 to 5 years) in case of poor cleaning or use in very cold areas. Very low temperature, humidity, the presence of little stones, sand, water and the like inside the mat may lead to a fast deterioration of the system. Subsequently, studies are in progress to replace the rubber covers of the mates with stainless steel frames, in order to ensure greater protection against the infiltrations of foreign bodies as well as for better and easier cleaning of the sensors.

The following table displays a comparison between Treadle Mats and IR sensors:

TABLE II.1
COMPARISON BETWEEN TREADLE MATS AND INFRA-RED SYSTEMS

| **TREADLE MATS** | **IR** |
|---|---|
| Very accurate (even over 95% in optimum conditions of use) | Generally less accurate than the treadle mats (estimated approx. 90%) |
| No preventive maintenance required | Daily cleaning of the sensors is recommended |
| Fewer issues of erroneous | Higher likelihood of |

| | |
|---|---|
| counter activations due to foreign objects | erroneous activations |
| Generally more difficult replacement | Easier replacement |
| Need for slower passenger flows, possibly in "single row" | Has the capability of managing "faster" and more compact flows of passengers |
| Mechanical parts in the movement are more sensitive to dirt and environment conditions | No moving parts, thus more robust. |

## III. SYSTEM DESIGN

### A. *Block Diagram*

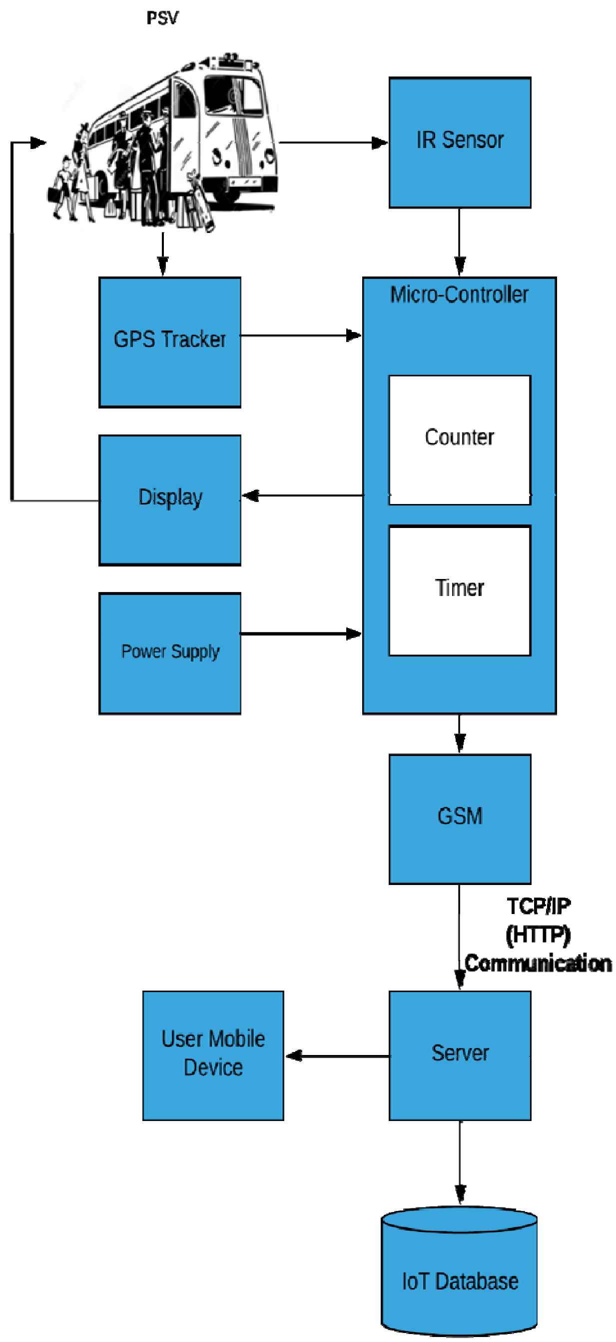


*Fig. 3: Block diagram of PSV monitoring system*

### B. *Flowchart*

Two simultaneous programs on the Raspberry Pi 3 Model B microcontroller are proposed.

*1)* *Vehicle tracking:* This is continuous so as to enable real-time positioning as in*Fig. 4*

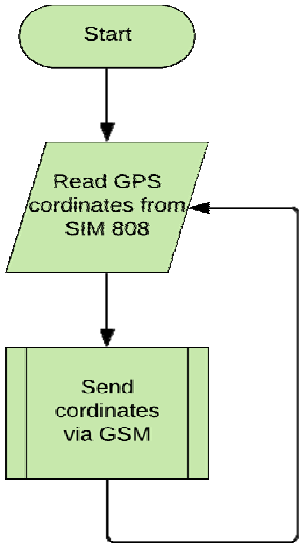


*Fig. 4: Vehicle tracking flowchart*

2) *Occupancy monitoring*: This is to be interrupt-based to allow minimize on power consumption. Overload alerts are to be sent only when the overload exceeds a certain duration limit.

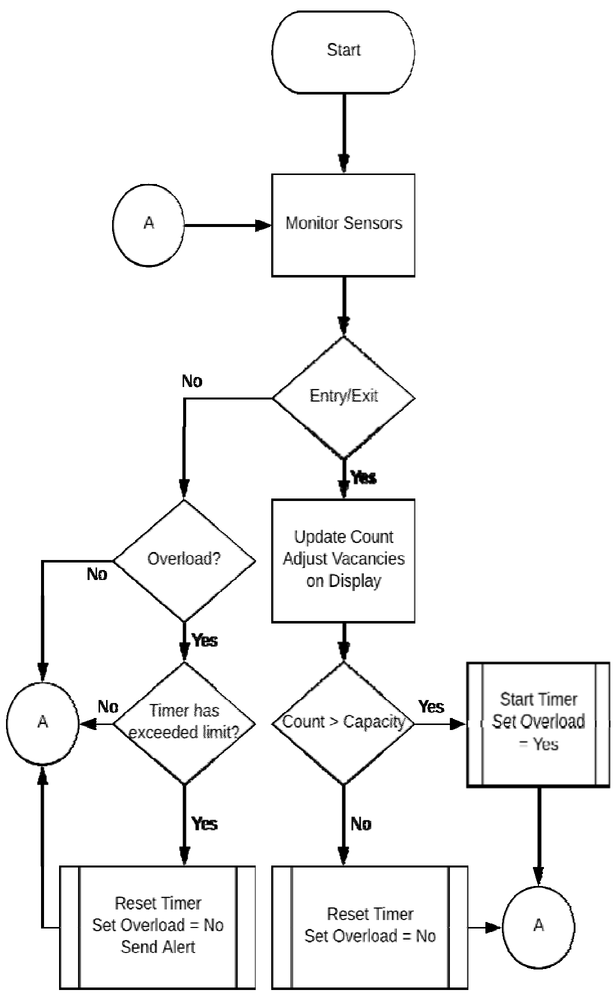


*Fig. 5: Occupancy monitoring flowchart*

## C. Operation

The proposed system will use 2 IR sensor pairs, connected to a counter at the door of the bus to detect passengers boarding and alighting enabling the Raspberry Pi 3 Model B microcontroller to compute the exact number of passengers in the bus at any given time.

The sensors will be positioned in pairs to provide 2 parallel beams that will enable the counter to distinguish between entry and exit and thus increase or decrease the counter respectively. To reduce the probability of a false count, the sensors pairs will be set at two different heights so as to be able to distinguish between luggage and passengers. A timer will be set in sync with the sensors such that the system will only alert the authorities of an excess of passengers if the counter exceeds the limit for more than a specified period of time, say five minutes, to give an allowance of passengers to settle to their seats and excess passengers exit the vehicle.

For the display, we propose a double 7-segment display which will be positioned at the entrance of the bus to display a countdown of the number of passengers remaining to fill the bus as well.

The system will also be fitted with a GPS tracker to keep track of the position of the bus at all times.

The GSM-GPRS module will integrate a cellular internet communication feature to the Raspberry Pi necessary to actualize the network communication sub-system of the project.


*Fig. 6: SIM808 Module with GPS Antenna*

SIM808 modulefrom SIMCOM as shown in Fig. 6 is a GSM and GPS two-in-one function module. It supports GSM/GPRS Quad-Band network and combines GPS technology for satellite navigation.

An IoT platform such as Kaa Project or ThingSpeak offers an alternative to create a database and programming a server to interface it. ThingSpeak is preferred due to enhanced analytics and ability to easily communicate with mobile devices e.g.

microcontrollers and smartphones over HTTP protocol. It additionally offers an easy-to-use interface.


*Fig. 7: ThingSpeakIoT Platform*

Additionally, there will be a mobile application which will fetch data from the database and display it on 2D background map utilizing the Google Maps API. The application will be available to the passengers to inform them of the location as well as occupancy of a vehicle.

## IV. Conclusion

With this design, the system is expected to consistently monitor the occupation of PSVs with respect to their capacity. This will gradually translate to reducing incidences of overloading of passengers by PSV operators. Compliance levels of PSV operators with regulations contained in the Traffic Act will increase while requiring fewer traffic officers on ground. This will improve the passenger's comfort and safety. Furthermore, the mobile application will be of great convenience to the passengers allowing them to better plan their commute as well as allowing for efficient fleet management by PSV owners. In addition to being applicable to the PSV industry, the system can also be used by corporations, institutions, schools, organizations and professional clubs on private buses.

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