Wireless Sensor networks with Zigbee and WiFi for Environment Monitoring, Traffic Management and Vehicle Monitoring in Smart Cities

D. Rahul Naik[1], Lyla B. Das[2], *Member IEEE*, Bindiya T. S.[3], *Member IEEE*
Department of Electronics and Communication Engineering
National Institute of Technology Calicut, Kerala - 673601, India
Email: [1]nrahul009@gmail.com, [2]lbd@nitc.ac.in, [3]bindiyajayakumar@nitc.ac.in

***Abstract*—In this paper, the use of sensor networks in environmental monitoring, vehicle monitoring and traffic management, which are important in a smart city are discussed. Sensors in Zigbee and Wi Fi networks form the back bone of this work. Low power networks like Zigbee and connectivity provided by WiFi are needed to realize the concept of Internet of Things (IoT).**

The main cause of environmental pollution in most cities are industries and automobiles emitting poisonous gases. This paper discusses the implementation of a unit which senses the presence of such gases and uploads the information to a website, and also sends messages to the concerned people. The second part of this work is a vehicle monitoring unit, that can be fixed in vehicles. This system tracks the location of the vehicle, detects accidents to the vehicle and monitors its engine temperature and the presence of poisonous gases from its exhaust. In the case of the vehicle is stolen, it also has the feature to locate the vehicle and prevent it from moving until a message is sent by the owner.

The third part of the work, in which, vehicles which do signal jumping are detected and penalised. This feature is very relevant to the countries like India where traffic rules are regularly violated. The density of the traffic around traffic junctions is measured and information updated in the website. An Android app is developed so that all the required information is easily available. The paper describes the hardware and software implementation of the prototype system.

Keywords: Smart cities, Internet of Things, Wireless Sensor networks, Traffic management, Smart vehicle

I. INTRODUCTION

Wireless sensor network (WSN) is and integral part to implement the concept of Internet of Things (IoT), which has affected all the aspects of our life. The concept of IoT has led to the design and development of connected devices, which can perform the functions of sensing, monitoring and actuation. One important application area of IoT is smart cities. Many cities of the world are rapidly introducing sensor based connected networks towards this goal. Environmental monitoring, vehicle monitoring and traffic management come under the scope of the design of smart cities using WSNs.

II. LITERATURE SURVEY

The paper by Zanella et al gives a review about IoT methods for smart cities [1]. The paper discusses the importance of measuring the noise levels and traffic congestion as a part of a smart city project. Thiyagarajan Bojan et. al. have discussed the use of GSM based alerts and notifications [2]. Yongjun et al. have shown the use of RFID and GPS based intelligent transportation systems in IoT based smart cities [3]. In the paper by Vong et.al., vehicle emission is tracked by using RFID technology, in which the higher emitting vehicles are identified and messages are sent to the vehicle owners from a control station [4]. The paper [5] by Xiaojun et.al mentions the methods to perform environmental monitoring. The paper by Rohini Temkar et. al. gives suggestions for real time monitoring of vehicles and detecting traffic congestion [6]. Paper [7] discusses the health and enviornmental issues due to the globalization. Paper [8] deals with the methods to control the vehicle emission.

In the existing literature, the monitoring and notification systems for only a limited set of functions are discussed. This work involves the design and implementation of a functional IoT application covering many aspects of a smart city. A very high end, fast processor is used for better efficiency. The processor has many GPIO pins to which more sensors may be added. In a smart city environment, many more parameters may need to be monitored. In this paper, it is proposed that, in cities, central sensor units may be placed at traffic junctions, which is a very convenient location for monitoring many important parameters of a city life.

The paper is organized as follows: Section III describes the working of the system. In Section IV, the hardware and software used is discussed briefly. In Section V, the implementation results are given. Section VI concludes the paper.

III. WORKING OF THE SYSTEM

The functionalities of the project are listed below

1) Environmental monitoring
    - Air pollution monitoring
    - Vehicular emission tracking
    - Noise pollution monitoring
    - Temperature measurement
2) Vehicle monitoring
    - Accident detection
    - Tracking of stolen vehicle
    - Engine temperature and exhaust monitoring

3) Traffic management
   - Measuring traffic density
   - Signal jump detection
   - Road block notification

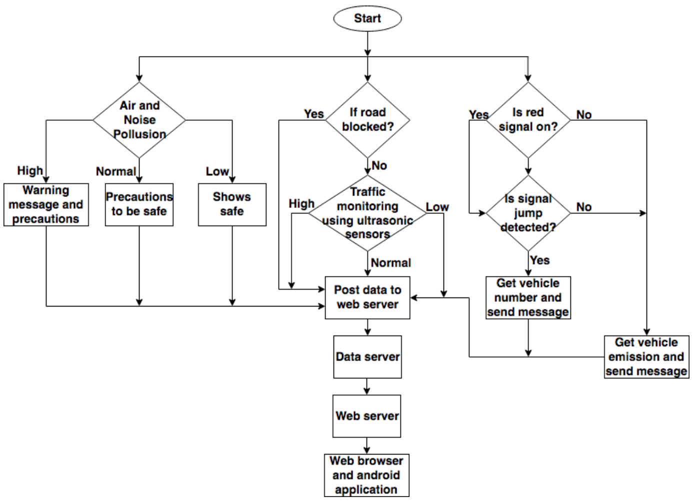

Fig. 1: Flow chart showing the working of the control unit

The system consists of two units, namely Control Unit and Vehicle unit. The control unit is a hardware unit which may is placed at traffic junctions, while the vehicle unit is meant to be attached to vehicles.

A. The Control Unit

Fig. 1 shows the flow chart of the working of the control unit. It monitors noise and air pollution. All information taken from the sensors is uploaded to the web and decisions are taken accordingly. If the values exceed a threshold, alerts and notifications are sent. Traffic management is also done by the control unit in tandem with the ultrasonic sensors placed at the dividers of the road. It senses the density of the traffic and through the website gives the information about the level of traffic congestion. There is also a facility to detectthe vehicles who jumps the red signal. Such vehicle numbers are identified and information is sent to the authorities and to the owner of the vehicle.

B. The Vehicle Unit

Fig. 2 shows the flow chart of the working of the vehicle unit, which is to be present in all the vehicles. This unit communicates with the control unit continuously through the Xbee module. Its most important components are the gas and temperature sensors to measure the temperature, and the level of CO and other poisonous gases in the exhaust of the vehicle. The system is programmed in such a way that when a vehicle is at a junction, emission levels that are sensed are sent to the web through the control unit and if the value is above the permitted level, a message is sent to the authorities and to the vehicle owner. The control unit uploads this information to the website for reference and record. The unit has an accelerometer also, which is used to sense the tilt of the vehicle. If the tilt is above a pre-specified level, it is assumed that an accident has occurred. The location of the vehicle at that instant is sensed and sent to the owner of the vehicle and to the ambulance system. As part of vehicle safety, a mechanism for locating and retrieving a vehicle if it is stolen is incorporated. Initially, the owner must register his vehicle into the system using his mobile number. If the owner realizes that his vehicle is stolen, he can send a message to the vehicle, which will make the vehicle to stop and also send its location. The vehicle will move forward again only after it gets a message from the owner to start it.

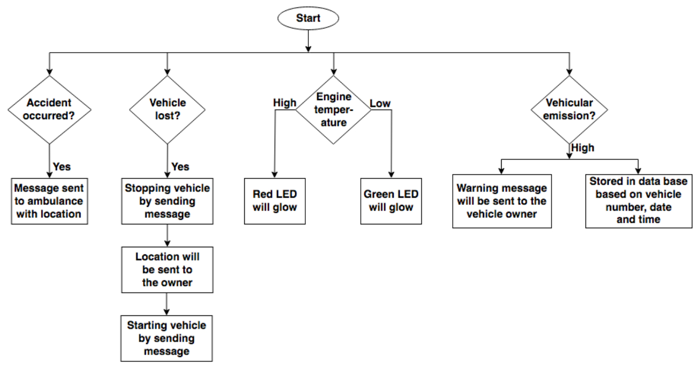

Fig. 2: Flow chart for the operation of the vehicle unit

IV. IMPLEMENTATION

A. The Control Unit

Fig. 3 shows the block diagram of the Control unit. It has a high end embedded processor and many sensors. This unit may be placed at all traffic junctions, which is a convenient point to place it. The control unit is the central unit from where information goes to the governing authorities through the website.

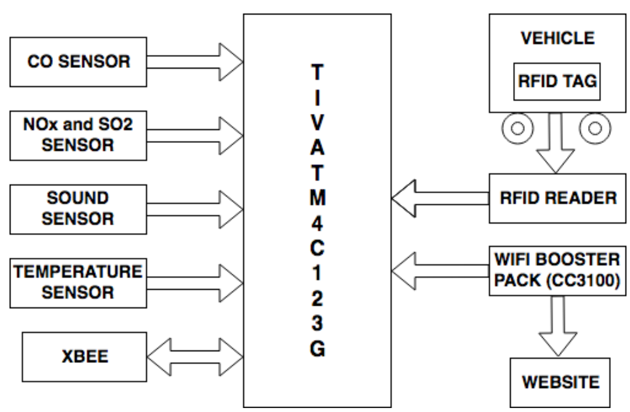

Fig. 3: The block diagram of the control unit

The processing unit used is a TIVA board which has a high end Cortex-M4 processor with a clock frequency of 80 MHz [9]. It has sufficient number of GPIO pins for connecting many more sensors. However, the board does not have Wi-Fi connectivity and so a compatible Wi-Fi booster pack, CC3100 of Texas Instruments [10] is used.

The CO (carbon monoxide) sensor, NO_2 Nitrogen Dioxide) and SO_2 (Sulphur dioxide) sensors are gas sensors for monitoring the quality of air around and close to the traffic junction. The air quality can be judged from these sensors and appropriate messages can be put up in the web page associated with this application. The outputs from the sound sensor and the temperature sensor are also uploaded to this web page. The Xbee module is used to communicate with the vehicle unit. There is an RFID reader in this unit, which reads the RFID tag of the vehicles which stop at the junction.

B. The Vehicle Unit

Fig. 4 shows the block diagram of the vehicle unit. This unit uses an Arduino Uno board and has sensors and actuators to implement the functions shown in the flow chart in Fig. 2. Communication between the control unit and the vehicle unit is done using the Xbee module, which uses the ZigBee Protocol. It has a temperature sensor for measuring engine temperature and a gas sensor for sensing the presence of poisonous gases in the engine exhaust. The accelerometer senses the tilt of the vehicle and detects the occurrence of accidents to the vehicle. The GSM module sends alerts and notifications to the mobile numbers of the owner and the driver and GPS module tracks the location of the vehicle.

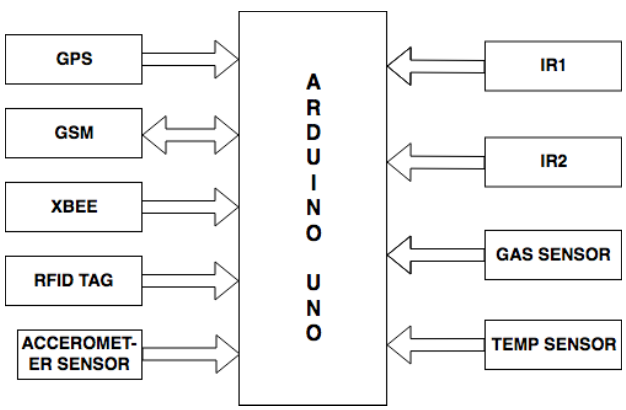

Fig. 4: The block diagram of the vehicle unit

IR1 and IR2 are Infrared Obstacle Sensor modules, which have built-in IR transmitter and IR receiver, that sends out IR energy and looks for the reflected IR energy to the detect the presence of any obstacle in front of the sensor module. The module has an on board potentiometer, that lets the user adjust the detection range.

C. Traffic Management

To measure the traffic density, this system uses a series of ultrasonic sensors which are placed on the dividers by maintaining equal distance between two sensors. These sensors give binary values to the microcontroller. If all sensors give 'one', it is understood that the traffic density is high. If only a few sensors give a high, it is taken as low traffic density. Messages are put up in the website accordingly. Fig. 5 shows the placement of the sensors along the dividers of the road.

Fig. 5: Ultrasonic sensors place at road dividers for measuring traffic density

D. Signal Jump Detection

If any vehicle does the signal jump at a red signal, it is detected automatically by using this system. The components used are two IR sensors, Xbee, and GSM. Two IR sensors are connected to the front and back of the vehicle. When there is a red signal at the junction, vehicles have to be stopped before the white line. If a vehicle crosses the line, the output from the second IR sensor goes high and a command is sent to the control unit using Xbee. When controller gets this Xbee command, it sends a penalty message to the vehicle owner and it is also displayed on the website along with his vehicle number, date and time.

E. Software Design

For the TIVA module in the control unit, the Energia Development Environment is used. This is an open source development environment suitable for the processors of Texas Instruments. The Web server is designed with PHP as back end and HTML, CSS (Cascaded Style Sheet) and JavaScript for the front end. The controller in the control unit is connected to the internet and posts data to the web server continuously. The Web server has different web services for each task. When data is posted to a web service (using the http protocol), data validation is done and data is saved in the data server, which has an SQL database. The communication between the database and the web server is established using a PHP SQL connector. Data is well structured and maintained in the database for easy data extraction based on area/vehicle number. When a user opens the browser and accesses the website, it shows all the data taken from the data server based on user input. HTML is used to display the webpage and CSS is used to add styles to the web pages. An android app has been developed, using Android Studio for better user experience, which extracts important data from the web server and alerts the user about traffic and pollution details.

V. RESULTS OF THE IMPLEMENTATION

The system is designed to perform a number of actions for sensing, monitoring and taking appropriate decisions. The hardware and software has been designed for these actions. All these functionalities are tested and good results are obtained.

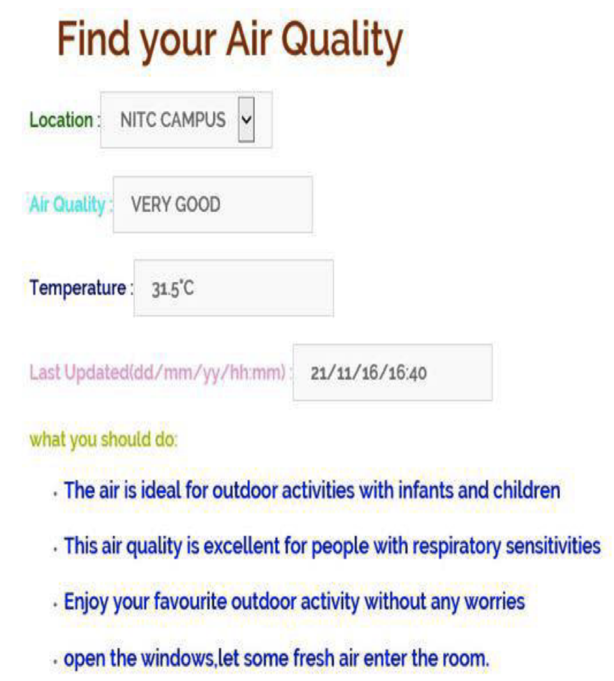

Fig. 6: The message posted on the website when the air quality is good

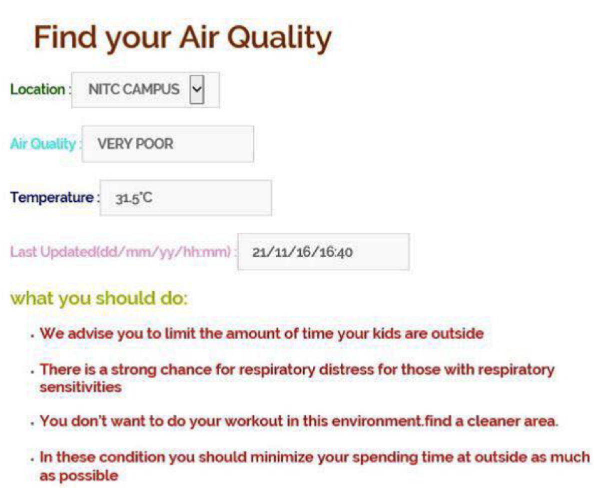

Fig. 7: The message posted on the website when the air quality is poor

For air quality check, users may select a location in the webpage. Once they do the selection, the air quality and temperature will be displayed on the website along with the date and suggestions depending on the air quality. Fig. 6 and 7 show these messages for the case when the air quality is good and bad respectively.

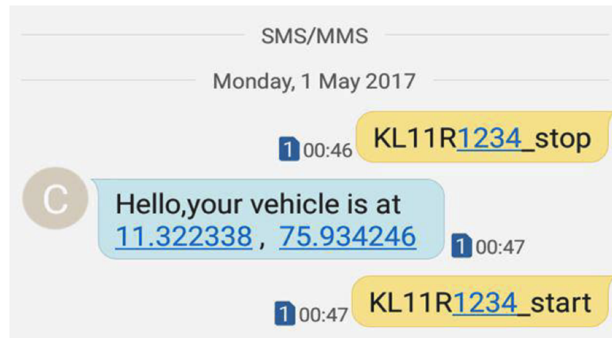

Fig. 8: Tracking of stolen vehicle


Traffic Updates

Junction	Traffic Status	Last Updated
Kattangal	Blocked	2017-04-17 22:40:44
Nit	Free	2017-04-23 17:02:58
Kunnamangalam	Normal	2017-04-05 15:30:00
Chatamangalam	Blocked	2017-04-17 23:45:25

Fig. 9: Traffic updates on the web

Fig. 8 shows a sample SMS received in the owners mobile number when he tries to track his stolen vehicle. The message shows the co-ordinates of the location where his vehicle is currently in. He can use Google maps with this co-ordinate information to trace the exact location. Once such a message is sent from the vehicle unit, the vehicle will be unable to move until the owner sends a start signal.

Fig. 9 shows the traffic updates on the web signaling traffic density at various locations in the city. Fig. 10 shows the penalty message received by the mobile phone of the owner of a vehicle which has been detected to have jumped the red signal. Fig. 11 is the image of the Android App developed which brings all the necessary information to any inhabitant of the city.

Fig. 10: Penalty for vehicle which has done signal jump

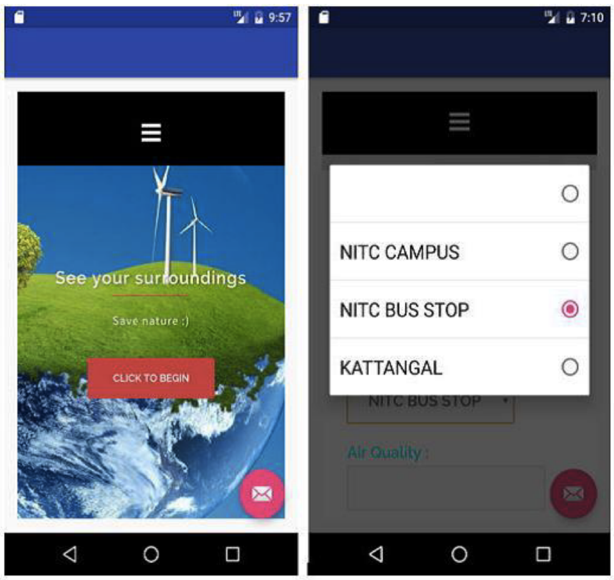

Fig. 11: Android app developed

VI. CONCLUSION

A city is a place where people with different interests, requirements and expectations live. Also, different cities have different levels of basic infrastructure. Many cities of India have been identified as candidates for being developed into being ‘smart’. This paper focuses on some important aspects that need attention when a comprehensive scheme for IoT based city management is envisaged. The system proposed in this paper has been tested for a prototype that is developed.

The most important point in IoT for cities is that the smartness is to be achieved with the least amount of human intervention. Machine-to-machine communication and Machine to-infrastructure communication are the two essential requirements in a smart city project. This requires highly reliable networks and low power sensors and equipments. Before trying to make a city ‘smart’, it is imperative to ensure a minimum infrastructure for it. Once this is done, systems for monitoring and controlling, as in this paper, may be easily integrated into the infrastructure of the city and citizens will learn to use these systems for a more comfortable life.

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