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Advanced Traffic Management System for Smart Cities Through Bio-Sensing

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Abstract: One of the major goals of developing countries is to build smart cities. One aspect of a smart city is to build efficient and intelligent traffic management system especially the road traffic that avoids congestions, accidents and many kinds of inordinate delays. Many factors are to be considered for effecting smooth traffic management system that includes the consideration of toxic gases surrounding traffic routes, visualization, Imaging, remote sensing, messaging and a cognitive decision making system. The Traffic management also requires a versatile communication system that facilitate communication among heterogeneous devices and systems. Toxic gases in and around the traffic are quite dangerous and effect the traffic in many ways. There should be a composite system that caters to sensing the toxic gases in around the signal post systems and regulate the traffic based on the extent of presence of the Toxic gases. In this study, a composite bio sensing system is presented that senses various kinds of toxic gases and regulate the flow of traffic based on the extent of presence of those gases.

Key words: Smart city, bio-sensing, traffic congestion, traffic management system, various

INTRODUCTION

The traffic signal system is probably the most important kind of transportation facility in operation today, considering the perspectives of both safety and efficiency. Two-thirds of all miles driven each year on roadways are controlled by traffic signals. In some urban areas, signals at busy intersections control the movement of more than 10,000 users per day. Many techniques are to be used to regulate the traffic flow starting from imaging to visualization. While some techniques uses fixed times to serve the users, the others provide varying amount of time to serve the users which is based on density of vehicles and the number of commuters.

Some signals operate independently and respond to the traffic demands at that intersection alone, while others operate together in a system so that traffic can be moved with as few stops or as little delay as possible. The signal system also has a great impact on energy and the environment. The more times a vehicle stops, the larger the level of pollutants that it emits. Twenty percent of the oil used by automobiles traveling along urban arterials is consumed while waiting at a red light at a signalized intersection. A traffic signal system at its core has two major tasks which include moving as many users through intersection as possible and avoiding the conflict between these users as much as possible. The first task relates to efficiency and capacity while the second relates to safety.

Both tasks are performed by first clearly defining which group of users has the right to use the route at a given time and second by determining how long the users have to wait for the route.

The number of vehicles on the world's roads is expected to double to around 2.5 billion by 2050. Increase in the level of pollutants like carbon monoxide, Sulphur dioxide, etc., causes severe health disorders and even they may severely affect some of the components of vehicles which lead to traffic congestion and sudden fire accidents. Many technologies coming up and the one will reach from one point to other is being revolutionized. Armed with data from sensors in roads and vehicles, cities are already using predictive analytics to anticipate and reduce traffic congestion. Drivers use social media to detect and avoid gridlock. City planners analyze data to pinpoint where new bus routes are most needed. Even the way we park is being reinvented. Cities worldwide face rapid growth and mounting transportation challenges. But that growth also provides opportunities to build intelligent transportation systems that will fundamentally improve how cities manage and citizens use their transportation networks.

Road traffic control involves directing vehicular and pedestrian traffic around a construction zone, accident or other road disruption, thus ensuring the safety of emergency response teams, construction workers and the general public. The traffic is affected due to adverse

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environmental conditions, accidents, movements of emergency vehicles, movement of VIPs, adverse road conditions, overflow of drainage systems, lack of monitoring and control systems, existence of bio gases, pollution, sudden fire accidents at places where there is heavy movement of vehicles, sudden movement or vibrations of earth surface etc. Each factor affects the traffic in one way or the other and therefore needs to be investigated to find the elements that contribute to the factor and determine the mechanisms to control them so that the traffic is regulated in an optimum way. One of the most important factors that influence the traffic is the existence of bio gases and therefore there is a need to find mechanisms to sense, measure and control the same and also find the traffic related factors that get affected due to the existences of the gases. Bio gases that effect traffic is carbon monoxide sulphur dioxide, etc. Many devices are in use for measuring the gases that exits over defined area. The extent of these gases is however dependent on the density of the traffic. Table 1 shows the commonly used devices for measuring different kinds of bio gases.

Bio-sensing sub-system plays very important role in sensing the traffic condition miles ahead of their current position. Sensing any toxic gases and its effect on traffic can be determined. Humidity, viscosity, air flow, earth vibrations and climatic condition detection are the inputs required for sensing the amount of congestion in the traffic line. The more the toxic congestion, the less should be traffic in a particular route. Based on these parameters the traffic congestion must be calculated. The traffic rate must be restricted based on the congestion level and at times, messages have to be transmitted to remote traffic posts for regulating the traffic. After the industrial age, transportation has become a key part of our lives. Recent studies show that breathing street-level fumes for just 30 min can intensify electrical activity in brain regions responsible for behavior, personality and decision-making, stress, etc. Breathing normal city air with high levels of traffic exhaust for 90 days can change the way that genes turn on or off among the elderly; it can also leave a molecular mark on the genome of a newborn for life. Children in areas affected by high levels of emissions, on average, scored more poorly on intelligence tests and were more prone to depression, anxiety and attention problems than children growing up in cleaner air. Older men and women long exposed to higher levels of traffic-related particles and ozone had memory and reasoning problems that effectively added 5 years to their mental age. The emissions may also heighten the risk of Alzheimer's disease and speed the effects of Parkinson's disease. Vehicles moving on roads, burn lots of fossil fuels to work. Emissions from automobile engines

Table 1: Devices for measuring toxic gases

Type of toxic gas	Device used for sensing
Carbon monoxide	Portable analyzer (4000 series) with digital display-carbon
Carbon dioxide	ATI's F12 toxic gas detector
Sulphur oxides	Sulphur dioxide SO_2 city technology gas sensors
Nitric oxides	Nitric oxide NO_2 city technology gas sensors
Nitrous kxides	Solid-state gas sensors using oxygen ion-conducting yttria
Methane	Methane CNG gas sensor-MQ-4
Ethane	Flame proof gas detectors FGD10 series

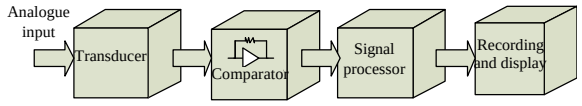

Fig. 1: Block diagram of bio-sensor

contain both primary and secondary pollutants. This is a major cause of pollution and one that is very difficult to manage. This is because humans rely heavily on vehicles and engines for transporting people, good and services. Fumes from car exhaust contain dangerous gases such as carbon monoxide, oxides of nitrogen, hydrocarbons and particulates. On their own, they cause great harm to people who breathe them. Additionally, they react with environmental gases to create further toxic gases. Environment is the first casualty for increase in pollution weather in air or water. If levels become too high CO_2 begins to act as asphyxiate. The increase in the amount of CO_2 in the atmosphere leads to smog which can restrict sunlight from reaching the earth, preventing plants in the process of photosynthesis. Gases like Sulfur dioxide and nitrogen oxide can cause acid rain. CO is a poisonous gas produced by the incomplete burning of carbon based fuels. When inhaled it deprives the blood stream of oxygen, suffocating its victim. Water pollution in terms of oil spill may lead to death of several wildlife species. The decrease in quality of air leads to several respiratory problems including asthma or lung cancer. Chest pain, congestion, throat inflammation, cardiovascular disease and respiratory disease are some of diseases that can be caused by air pollution. Water pollution occurs due to contamination of water and may pose skin related problems including skin irritations and rashes. Similarly, noise pollution leads to hearing loss, stress and sleep disturbance. The process that is generally used to deal with sensing and processing the bio-gases is shown in Fig. 1.

Sensing and monitoring is playing an increasingly important role in traffic management. Sensors are key components in smart monitoring of traffic but sensing the environmental issues is complex. These complexities include sensing the level or quantity of bio gases and communicating it to the base station. There are sensors

Fig. 2: Working of bio sensor

existing for sensing the individual bio sensing components but the major issue is integrating the sensed values. Digitizing analog data obtained through sensors and integrating it using a methodology plays a major role. Integrating includes assigning a fixed weight for each component and compressing the different levels of toxic gases to a single data. Inert nature of CO_2 makes it difficult to measure with sensors that depend on chemical reactions. Optical sensors are affected by dust, water vapor or most chemicals. Choosing sensors which can produce signals with accuracy is needed. The basic working principle of bio sensor can be explained using Fig. 2. Traffic at junctions will get greatly get affected due to presence of various kinds of bio gases which may affect the human beings and may change the environmental condition. It is necessary that the traffic at junction's points and elsewhere be regulated based on the level of presence of the bio gases. Measuring bio gases is complex. Choosing appropriate sensors to measure the bio gases is also complex. Thus, the main problem is to find most appropriate methods for measuring the bio gases and regulate the traffic based on the quantum of gases that exists at different locations on the traffic routes.

Literature review: Road traffic impedance is an important part of traffic assignment and has a direct impact on the urban transportation planning, especially on the optimization of urban road network. The density of intersections, the density of bus stops, non-motor vehicles and saturation can reflect the difference between road and link. The results shown by Nan He, Shengchuan Zhao are evident that the density of intersections, the density of bus stops and saturation have positive effects on unit travel time in Dalian roads (He and Zhao, 2013). These results not only point out the influencing factors but also validate the correctness of the proposed impedance function. Weather conditions may significantly impact a series of everyday human decisions and activities. As a result, engineers seek to integrate weather-related data into traffic operations in order to improve the current state of practice.

Travel times and speeds are two of the elements of a transportation system that may be greatly affected by the weather resulting in deterioration of roadway network performance. The main finding by Ioannis Tsapakis, Tao Cheng and Adel Bolbol (Tsapakis *et al*., 2013) is that the impact of rain and snow is a function of their intensity. Specifically, the ranges of the total travel time increase due to light, rain, snow, temperature, etc. (Xu *et al*., 2013). Macroscopic analysis can be used to describe and estimate the level of service of road network and evaluate the network-wide traffic state. Quantitative mastering the impact of rainfall on urban network is important for understanding stability, planning transportation and traffic management and rainy conditions. The results of the empirical analysis indicate that rainfall has an obviously diminishing effect on traffic variables of the network.

Mobile devices, in particular smartphones and tablets can be used to monitor quality of life parameters. Today mobile devices use embedded sensors such as accelerometers, compasses, GPSs, microphones and cameras without considering, for example, the air quality or the pollutants of the environment. There is a possibility to use the smartphones capabilities to gather data from other phones or sensors. Nowadays, monitoring climate condition's parameters such as temperature and humidity is a prominent factor to control the changes of the environmental condition of living or working places for the human being. This can be obtained by using distributed devices in different environments that contain high-resolution sensors and a wireless transmission apparatus for transferring data to smartphones. The bluetooth was chosen as a transmission tool since it is embedded in all smartphones and it can work in the absence of the Wi-Fi connection. Smartphones are the programmable tools to have different kinds of applications that allow communicating with other devices and also gathering, analyzing and verifying data. Investigations by (Aram *et al*., 2012), presents a novel interface by applying a bluetooth-based sensor to sense temperature and Humidity for monitoring of the environmental conditions is using the android-based smartphone. Environmental monitoring is the premise of pollution and it provides scientific basis for environmental management and protection. Based on its advantage of on-line monitoring, biosensor is paid more and more extensive attention in environmental monitoring. The detecting methods and evolution of biosensors are analyzed about in environmental monitoring, especially emphasizes their application in the monitoring of water and atmosphere. The development tendency and prospect of environmental biosensors in the future are predicted by Hu *et al*. (2011). Environment Observation and Forecasting System (EOFS) is a application for monitoring and providing a forecasting about environmental

phenomena (Jung *et al*., 2008) designed an air pollution monitoring system which involves a context model and a flexible data acquisition policy. The context model is used for understanding the status of air pollution on the remote place. It can provide an alarm and safety guideline depending on the condition of the context model. It also supports the flexible sampling interval change for effective tradeoff between sampling rates and battery lifetimes. This interval is changed depending on the pollution conditions derived from the context model. It can save the limited batteries of geosensors because it reduces the number of data transmission.

Air pollution monitoring is extremely important as air pollution has a direct impact on human health and environment (Khemnar *et al*., 2013) introduced a wireless sensor network system for participatory air pollution monitoring. The traditional air quality monitoring system, controlled by the pollution control department is extremely expensive. Analytical measuring equipment is costly, time and power consuming. In contrast to traditional air pollution monitoring stations, the design, implementation and evaluation of low power, low cost wireless sensor based Air Pollution Monitoring System provides real time monitoring of polluted materials at proper locations by using distributed and air pollution monitoring systems.

An overview of remote pavement weather sensing technology and applications for the transportation industry presented by Kelley (1993) describes the components of remote pavement sensing systems and applied applications. Surface sensors embedded in the pavement sense and record pavement temperature and pavement conditions (dry, wet, chemically wet, surface temperature, etc. Atmospheric sensors sense and record air temperature, relative humidity, wind speed and direction, precipitation, etc. Data processing units, data handlers, color enhanced computer workstations and system software provides instant recognition of significant changes in pavement weather conditions. A numerical weather forecasting computer model based on the heat balance equation, developed and refined to support the first centralized weather forecasting facility established solely to provide ice/snow control guidance. Weather instruction and system education for ice and snow control managers. Technology advances continue in weather instrumentation, remote pavement sensing, computer design and function, computer software and communications. Real-time pavement specific weather information provides meteorologists with required data for improved pavement temperature and pavement condition prediction.

MATERIALS AND METHODS

Parametric identification, sensing and measurement of biogases: Bio-sensing means sensing the biological elements in the environment which include humidity, temperature, etc. Humidity plays a very important role in the traffic control. The humidity level in the air should be at a certain level in order to maintain the traffic so as to prevent the accidents because the humidity leads to invisibility and that in turn lead to accidents. Humidity measurement is important because it affects many properties of air and of materials in contact with air. Water vapor is a key agent in both weather and climate and it is an important atmospheric greenhouse gas. Without water vapor we would be 31°C colder on Earth. Huge variety of manufacturing, storage and testing processes are humidity-critical. Humidity measurements are used to prevent condensation, corrosion, mould, warping or other spoilage-highly relevant for foods, pharmaceuticals, chemicals, fuels, wood, paper and many other products.

The temperature in a particular place should be estimated because the people travelling may include small children who may harm them and also the old people who cannot tolerate the temperatures in that area. This temperature measurement can be done using a variety of sensors. The temperature measured should be displayed on the display boards so that the user will be able to decide on the path of travel. Thus the measurement of temperature through the sensors like LM76, LM235, LM135, LM335, LMT85, etc. are useful for the detection and display in the digital form.

The toxic gases by their name are toxic against the health. Toxicity affects the lungs and it sometimes leads to the death of a person. Toxic gases like carbon-dioxide, carbon-monoxide, sulphur dioxide, nitrous oxides, etc., have to be estimated using different methods in order to prevent people from the pollution. This also solves the global problem of preventing the pollution. Hence the toxic gases have to be sensed for the effective traffic management. The various toxic gases sensed through different sensors are oxides of carbon, Sulphur and nitrogen.

The earth vibrations have to be sensed in prior because they help prevent people from great natural calamities. The earth vibrations can be detected in the seismic detectors in order to know in prior about the earthquakes. The vibrations should be detected with the help of specific sensors.

The bluetooth-based temperature and humidity acquisition system consists of a device comprising a sensor and a microcontroller that wirelessly transmits these climatic parameters to a receiver using the bluetooth

communication system. The SHT11 from sensiron company detects the humidity and temperature range from 40 to + 125°C and accuracy of 0.4°C, humidity range from 0 to 100% and accuracy of 3%. The microcontroller acquired temperature and humidity values from the sensor each 10 second and it is connected to a bluetooth module using its embedded UART (Universal Asynchronous Receiver-Transmitter). Bluetooth is chosen as a means of communication for the system due to its simplicity and availability in all conditions. The bluetooth module receives data from the microcontroller through the serial port and transmits the same to the user.

Another, system has been in vogue for detection of humidity and temperature by using smartphone app method which is called "Blusen" which has a display system for displaying readings of the humidity and temperature while the second part deals with data acquisition system. There are certain sensors which can detect the toxic gases. Among them the catalytic sensors are the sensors in which toxic gases are oxidized on a coiled metal wire. This results in the increase of resistance and that in turn results in calculating the concentration of the toxic gases.

The toxic gases like the carbon monoxide (CO) are detected using the constant potential electrolyte sensor, in which the carbon monoxide is reacted with the water to form the carbon dioxide and this in turn results in calculating the toxic gas concentration by amplifying the current produced by the sensor with the help of an external amplifier. The metal oxide semiconductor sensors are used to detect the toxic gases at different levels, in which the detection is done by the change of resistance due to electric response generated when toxic gas comes in contact with it. The detection of the earth vibrations can be possible by the seismic sensors in which the system is programmed in such a way such that it notifies the vibrations changes in the earth and shows it in the Ritcher scale. All the above proposed systems detect the various parameters such as the humidity, temperature, earth vibrations and climatic conditions.

RESULTS AND DISCUSSION

Comparative analysis and connectivity of bio sensing systems in relation to traffic management requirements: Many bio-sensing devices are in existence as on today which are capable of sensing bio gases and convert them to proper ranges before they are transmitted to a local data acquisition system. Traffic management system as such requires the use bio-sensors for different purposes for meeting different kinds of functional requirements which are related to bio-sensing systems. Table 2 shows the extent to which different by sensing systems meets the requirements of traffic management systems. From the table it can be seen that not all sensors would meet all the functional requirements of traffic management system leading to the need for inventing and implementing a composite system that cable of sensing the bio gases but also communicate to different computing locations so that traffic managed in such a way that commuting takes place in less polluted paths.

In typical traffic management system, three major computing locations exists which include signal post system, Local base station and a remote monitoring and controlling system. Typical flow diagram connecting bio sensing systems to signal post, local base station and remote host systems are shown in the Fig. 3 from which it could be seen that bio-sensing systems must be able to communicate using different communication systems and protocols.

Composite bio-sensing system for monitoring and controlling road traffic: Most of the bio-sensing systems that are exiting today does not meet all the requirements of the traffic management systems. A typical comprehensive traffic management system must consider sensing of environmental parameters such as humidity, temperature and various toxic gases existing in the air and transmission of sensed data to various computing stations that after processing the received data initiate various actuating functions. There is a need to consider a combination of existing sensors and integrate them to be able to comprehensively consider most of the environmental factors and carry traffic flow according to level of environmental parameters that affect the traffic.

The device sensiron is used for sensing humidity, quake alarm is used for sensing earth disturbances and the device ST3 x Chem is used for sensing bio gases. To have a total solution to be able to deal with many of the environmental parameters all the three sensors are interfaced into a Raspberry pi board. The board is interfaced with a communication system that communicates with a signal post system using a Wi-Fi system or a local base station using a cellular communication system or with a remote monitoring and controlling system using a satellite communication system. The entire system that provides for bio sensing and communicating to a computing station is shown in Fig. 4. The inputs received from the bio sensors are processed at computing locations and suitable actuating actions are initiated such as controlling the signal system, variable messages and displaying various types

Table 2: Comparison between devices with respect to functional requirements

Functional requirement	LM335	Sensirion	ST3 X CHEM	Quake alarm
Be able to communicate using Wi-Fi communication systems	X	X	X	X
Be able to communicate using cellular communication system	X	X	X	X
Be able to communicate using microwave system	X	X	X	X
Be able to communicate using satellite communication systems	X	X	X	X
Measure temperature and send to controlling stations	√	√	√	X
Measure humidity and send to controlling stations	X	√	√	X
Measure earth vibrations and send to controlling stations	X	X	X	√
Measure toxic gases which include carbon monoxide, oxides of sulphur, nitrogen, dust density and communicate with controlling stations	X	X	√	X

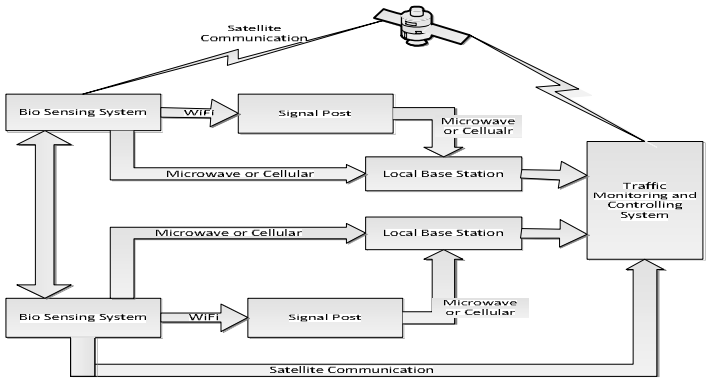

Fig. 3: Connecting bio sensing systems to computing locations

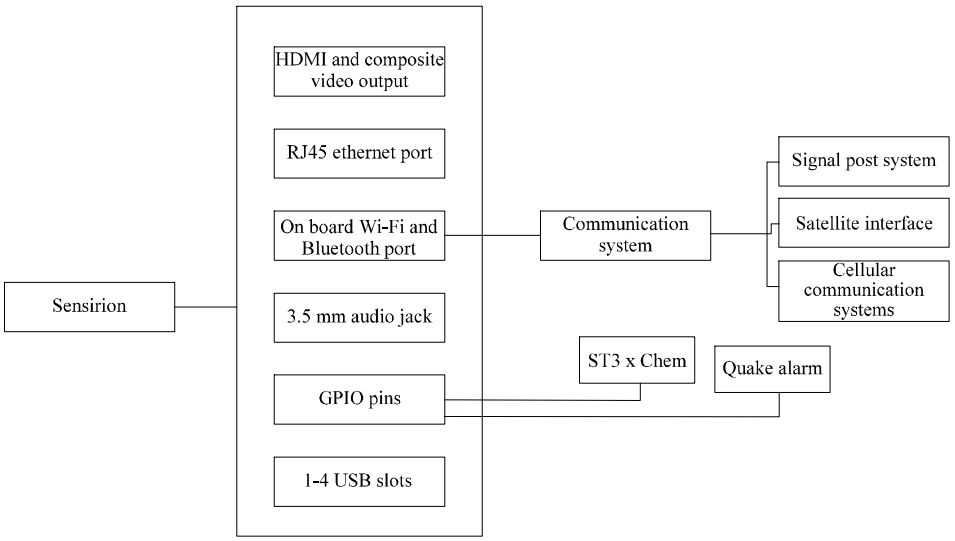

Fig. 4: Composite systems for traffic management systems

of outputs on to the visualization systems. Sensirion (SHT2x), the digital humidity sensor has been used for sensing humidity existing in the air at different levels. ST3 x Chem has been used for sensing electrochemical toxic gases which provide high specificity, fast response and long life. The device can be configured for selectable gas ranges. Quake alarm provides early warning by detecting an earthquake's sound waves before the earthquake's destructive shear wave strikes an area.

CONCLUSION

Bio-sensing system enables sensing of various parameters like humidity, temperature, toxic gas level. Bio-sensing system must receive inputs from sensor through various communication interfaces, protocols and methods. The system presented in this study provides a mechanism of sensing different environmental conditions and based on the level of those parameters the traffic is managed through varying timing the signal system,

controlling the variable signs and also selecting a method to effect the visualization reflecting the traffic condition. The bio-sensing system presented is simple, economical and suitable for implementation within a smart city environment.

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