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RESEARCH ARTICLE

Embedded System for Noise Pollution Monitoring using IoT Platform to create Smart Environment

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Abstract

The emergence of infrastructural, operational and environmental issues such as climate change, noise pollutions, malfunctioning has greatly augmented the need for robust, cheap, operationally adaptable, and smart monitoring systems. In this context smart sensor networks are an emerging field of research which combines many challenges of modern computer science, wireless communication and mobile computing. In this paper a solution for monitoring the noise pollution levels in the infrastructural environment using wireless embedded computing system is proposed. The solution includes the technologies that have been emerging in the field of mobile computing as well as Internet of Things (IoT) because of their vast applicability. Here, the sensing systems are connected to the embedded computing system to monitor the fluctuation of noise pollution parameters, from their normal behavior. This model is scalable and distributive for any infrastructural environment that needs continuous monitoring and behavioral analysis. Performance of the proposed model is evaluated using prototype implementation, consisting of Intel Galileo and sensor boards along with embedded programming. The implementation is tested for two to three parameters and their behavioral patterns with respect to user given specifications that provides a controlled pollution monitoring to make the environment smart.

INTRODUCTION

Innovations in technology mainly focus on controlling and monitoring of different activities. These are increasingly emerging because of the needs of human society. Most of this technology is focused on proficiently monitoring and controlling different activities. Environmental monitoring is required to evaluate the performance of engineered environmental control systems (e.g., temperature, sound and gas control systems) and to assess potential environmental impacts and public health and safety risks from any contaminant releases.

When the environment becomes a self-protecting and self-monitoring environment it is called as smart monitoring system [1]. In such system when some event occurs the alarm is raised automatically. The effects of environmental changes on plants, animals, humans, behavioral and operational changes along with environmental pollution monitoring are also controlled by the smart environmental monitoring. By using embedding ambient intelligence into the environment everyday life of user can be assisted, this is one of the application that smart environment targets.

Necessity of monitoring depends on the type of data that is gathered by the network devices [2]. Spatial Process Estimation (SPE) and Event detection (ED) are the categories to which applications are classified. The sensors are deployed in the first category to detect an event (e.g., a fire location in a building or forest etc.) while the estimation of physical phenomenon (e.g., the temperature variations in a greenhouse, the humidity forecast in a wide area, etc.) is carried out in the second category. Sensing devices are placed in random positions and samples are collected to predict the behavior of the spatial process. The aim of this paper is to design and implement an environmental system in which the required parameters are controlled and monitored remotely using Internet and the data of the sensors are stored in the cloud.

A solution for monitoring the noise levels i.e., any parameter crossing its threshold or ups and downs in the parameter values and ranges, for example temperature in particular region exceeding its threshold level, leakage of gas, etc., in the environment using wireless embedded computing system is proposed in this paper. The model is presented to show the principles and working in an environment and the context in which monitoring is done. The solution also provides intelligent remote monitoring for a particular region. In this paper we present a pollution monitoring system using embedded device. . The device is an integration of sensor networking, wireless communication which provides the users to remotely access various parameters and store the data in the cloud.

The remaining part of the paper is organized as follows: Section II discusses some of the related work and few approaches are described. Section III includes some existing technology and models for smart environment. The section IV discusses the proposed system model. Next in section V implementation based on proposed model is described. Section VI includes the results obtained. Finally the paper ends with summary and conclusion in section VII.

I. Related Work

Some of the research works carried out for pollution monitoring system in wide area for making the smart environment, different techniques and algorithms used are discussed in this section.

Smart Environmental Monitoring using Wireless Sensor networks [1]; architectures, applications, and related design issues are discussed. In this work they highlight how smart environments represent the trend towards increasing automated environmental monitoring with association of the wireless sensing devices to environmental events and phenomena. The environmental behaviors are collected actively as a streaming database to identify the environmental conditions and efficient decision making, dissemination by sensors is provided. A secure access standard and an intelligent remote protocol is delivered which is essential for operating, managing, reprogramming, and configuring the wireless sensor devices, for monitoring the remote or hostile environments using environmental monitoring systems installed for independent operation.

From reference [3] a unified access with respect to the context model and adaptive applications are developed, along with this the executable models is discussed with its state at runtime. A seamless interaction model is developed for user interface adaption and reconfiguration to build context-adaptive applications over a testbed. A layered architecture of sensors and context models is proposed to support context modeling in different phases of development.

Towards a Green Campus with the Internet of Things – the Application of Lab Management adopts the concept of “Internet of Things” and provides the idea of energy-saving by properly managing the computers and air conditioners. The architecture of a green campus and the prototype of the system are demonstrated in [6]. Here the computers and air conditioners are objects of interest. ZigBee device and RFID with temperature module are used to develop along with the wireless sensor network.

In reference [4] the objective is to design and develop efficient, economical, flexible, realistic and real-time wellness sensor networks. The sensor and actuator nodes are deployed depending on the wireless networking technologies and also generate real-time data that is related to the movements of the object and its usage inside the home. The ZigBee based Digi XBee Series 2 is picked up as RF module for monitoring the system. Further the extension from smart home system to smart buildings along with reliability and system performance are demonstrated.

Learning Activity Models for Multiple Agents in a Smart Space for modeling and automating resident activity in multiple-resident intelligent environments, using passive sensors to identify the individuals and their activities in an intelligent environment is presented in [7]. Here the supervised machine learning algorithm is applied to task the mapping sensor events to the resident responsible for the event. The Naive Bayes classifier and a Markov Model are adopted in this work.

II. Existing System Model

Presently, there are many systems designed to monitor the pollution considering different environmental parameters.

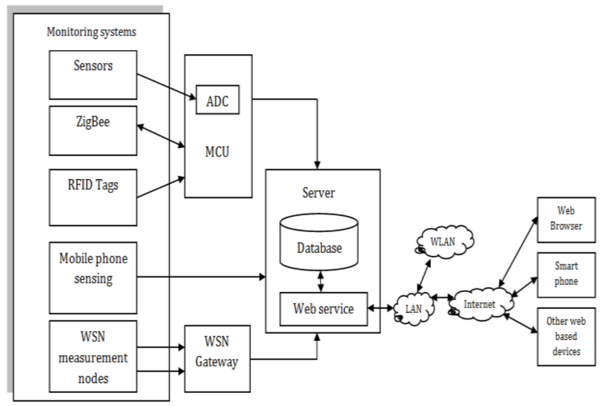


Fig. 1: Existing model for Monitoring System

Existing system presented in figure 1 normally use Zigbee [8] based wireless sensor networks to monitor physical and environmental conditions with thousands of application in different fields. The sensor nodes directly communicated with the moving nodes deployed on the object of interest which avoided the use of complex routing algorithm but local computations are very minimal.

Similarly RFID [9] was used for electronically identifying, location and tracking products, animals and vehicles that are responsible for creating pollution; it is also useful for human health monitoring. In RFID communication takes place between a reader and transponder, which is nothing but a silicon chip connected to an antenna and it is often called as RFID tags. This RFID tags can either be active or passive and are available in various forms but is limited by its distance and computing capabilities.

Mobile phones [10] or smart phones that are enabled with sensors are used for impact on social including how mobile technology has to be used for environmental protecting, sensing and to influence just-in-time information to make movements and actions environmental friendly. Mobile phone sensors were deployed and used on urban areas for monitoring and it was categorized into two major classes, participatory sensing where user is directly involved and opportunistic sensing where user is not involved, but its limitation includes power and static information processing or mobility restrictions.

Wireless Sensor Network [11] can sense, measure and gather information from real-world and it allows measurement of physical environment at high resolutions, and thereby increase its quality and quantity of real world information for applications such as pollution monitoring. For air pollution monitoring various sensors were introduced such as Waspmote to determine the quality of air we breathe, GUSTO to measure volume mixing ratios of certain trace atmospheric gases and Citisense to track pollution levels in real-time, but are limited by its computing capability and adaptability.

The access method of WSN gateway node [16] is convenient because data can be received from a WSN via the gateway at any time and any place. The gateway acts as the network coordinator in charge of node authentication, message buffering where you can collect, process, analyze, and present your measurement data. Wireless sensor network management model consists of end device, router, gateway node and management monitoring center. End device is responsible for collecting wireless sensor network data, and sending them to parent node, then data are sent to gateway node from parent node directly or by router. After receiving data from wireless sensor network, gateway node extracts data after analyzing and packaging them into Ethernet format data, sends them to the server.

A server is a running instance of database software capable of accepting requests from clients and also stores the data and other information required for processing. It also provides web services which is a software function provided at a network address over the Web with the service always on. The services or information in the servers are provided through the Internet that are connected through LAN or WLAN and made available for users via smart phones, web browser or other web browser devices to make the system more intelligent, adaptable and high computational capability.

III. Proposed System Model

Embedded computing device is proposed for noise pollution monitoring to create smart environment. The proposed system shown in figure 2 is a distributive and scalable environmental monitoring system.

Layered architecture is proposed to discuss on the functions and services of individual modules developed for noise pollution monitoring. This layered architecture includes 5 layers that is general environment layer, sensor systems as layer 2, context based decision support as layer 3, sensor data acquisition and aggregation as layer 4 and ambient intelligence environment as layer 5. This layered architecture is shown in figure 2.

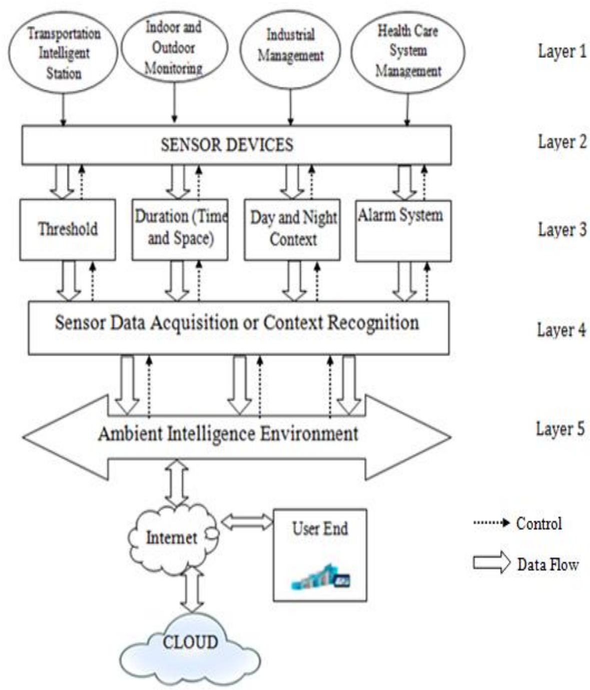


Fig. 2: Proposed model for Monitoring System

Here, the layer 1 provides the details and functionalities of different regions to be monitored for the noise pollution and its control. Layer 2 discusses the sensors with suitable characteristics, features and how each of these sensors are operated and controlled based on their sensitivity as well as the range of sensing.

Depending on the condition layer 3 will decide on sensing and controlling, like fixing the threshold, periodicity of sensing, timings for alert, messages (alarm), etc. These can be referred as parameter fixing elements which can be controlled explicitly or implicitly based on the contextual requirement. For example, based on the data analysis performed in layer 3 and also from previous experiences the parameter threshold values during critical situations or normal working conditions are determined. Using the physical behavior and also the analytics involved in the respective parameters the different context are specified.

Layer 4 describes that, the data is acquired from the sensing system. It also includes the context recognition which specify the condition the data is representing. In our proposed system, the ambient intelligence means to identify the variations in the sensor data and threshold is fixed depending on the identified noise level. The sensor data is analyzed based on the threshold and if the environment is detected as hazardous, controlling such surroundings makes our system intelligent. Finally, the information collected is sent to the users through the web server (using mobile device, PC etc) as well as stored in the cloud.

Analytics on Environmental Parameter

We have included the basic understanding about the sensor parameters to be measured below. Computation of the parameters can be done manually also by using physical behavior and the analytics that relates them. One example for such computing of sound is as follows:

- The common unit of measurement for sound is decibel, dB and its intensity is measured in Sound Pressure Level (SPL).

- The ambient noise levels are measured in the A–weighted (low-level sensitivity) SPL [15], abbreviated as dB (A). Sound of frequencies from 800 to 3000Hz is covered by the A–weighted scale [15].

- If the SPL, L1 in dB is measured at r1 meters, then SPL, L2 in dB at r2 meters is given by

$$L2 = L1 - 20 \log_{10} (r2/r1)$$

- Day – Night equivalent noise levels (Ld_n) of a community can be expressed as [16]

$$Ld_n, dB(A) = 10 * \log_{10}[\ 15/24(\ 10^{Ld/10}) + 9/24(\ 10^{(Ln+10)/10})\ ]$$

  Where,
  Ld = day-equivalent noise levels (from 6AM – 9PM), dB(A)
  Ln = night-equivalent noise levels (from 9PM – 6AM), dB(A)

- Based on intensity, the sound intensity I may be expressed in decibels above the standard threshold of hearing I_0. The expression is

$$I(dB) = 10 \log_{10}[\ I/I_0\ ] \text{ intensity in decibels}$$

Pollution monitoring system adopts the temporal and spatial behavior, threshold and duration based tracking of the fluctuation occurring due to different parameters. Using the values obtained from above calculations, the threshold value can be set to the requirements of ambient and dynamic nature of the environment and to monitor the parameter data through sensors.

Implementation

Based on the framework shown in the layered architecture, we have identified a suitable implementation model that consists of different sensors and other layers, their functionalities are noted as shown in figure 3. In our implementation model, Intel Galileo is used as the embedded device for sensing and storing the data. The Galileo board includes analog pins, micro SD card, Wi-Fi slots and a client port or host port to connect with the system. The sensors can be connected to the board for monitoring, the Wi-Fi connection has to be established to transfer information to the users and also storing data in cloud so that it can be retrieved anytime. All these activities can be performed through the Galileo board and hence fits in our model.

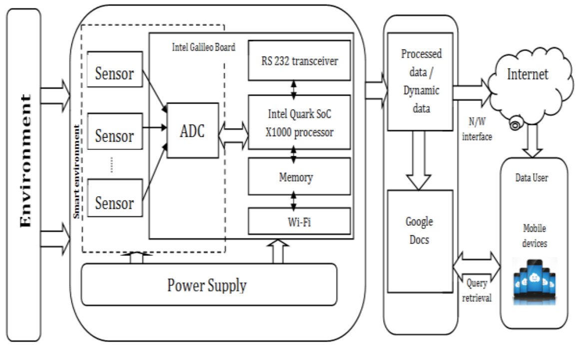


Fig. 3: Schematic representation of implementation model

A model is built for the environmental monitoring system and its actual components are shown in figure 4. The model is placed in one particular region for testing. Temperature sensor TMP35 is placed to record the present temperature in the region. The sound sensor RM0018 detects the intensity of sound around the region and the gas sensor MQ-2 is placed to detect any gas leakage in the considered region, if any leakage is detected then the alarm is raised. The Intel Galileo is placed at one particular place and the mentioned sensors are connected to it.

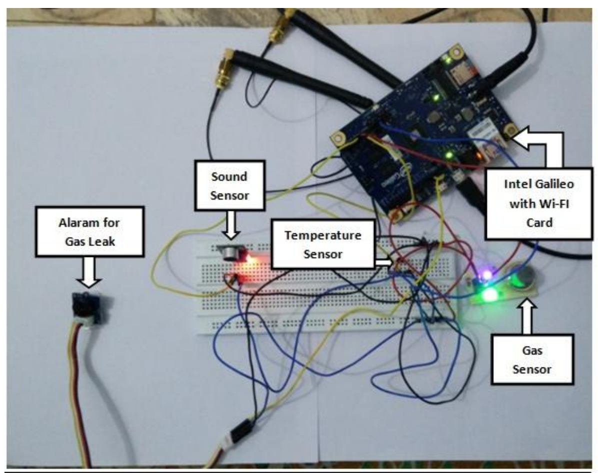


Fig. 4: A model showing the environmental monitoring system

The Wi-Fi is enabled in the Galileo and as the connection is established the sensors for different parameters like p1, p2, p3, etc., read the data. The data is processed and stored in the database for further reference. The essential decisions are made to set thresholds based on the requirements specified for particular condition in the infrastructural environment. The different threshold levels depending on the parameters are set as t1, t2, t3, etc. This data can be analyzed at any point in time and place. Simple adaptable programs for sensing the data are run and if the value of the parameter is greater than the threshold level specified then the respective alarms a1, a2, a3 etc., will be raised and the required actions are taken to control the system.

IV. Results

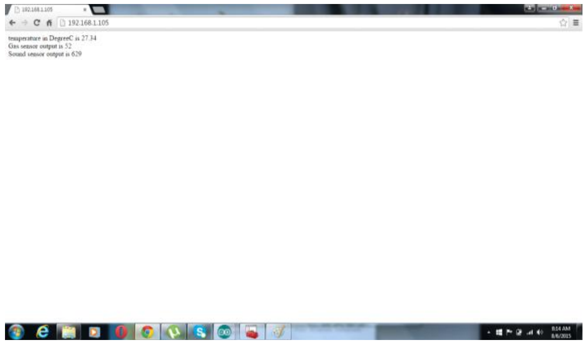
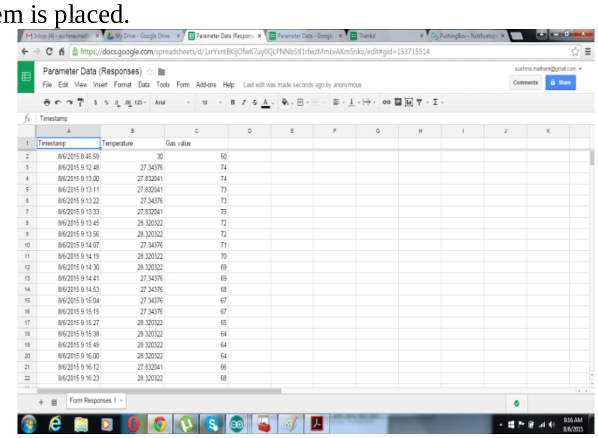


Fig. 5: Web server page

After the successful connection of the server the data of sensor are sent to the web server for the monitoring of the system. The figure 5 shows the web server page which will allow us to monitor and control the system. By typing the assigned IP address in the web browser we will get this web server page. The web server gives the information about the temperature, intensity of sound, and the gas level variations in the particular region, where the embedded environmental monitoring system is placed.



Timestamp	Temperature	Gas value
8/6/2015 8:45:59	30	50
8/6/2015 9:12:48	27.34376	74
8/6/2015 9:13:00	27.832041	74
8/6/2015 9:13:11	27.832041	73
8/6/2015 9:13:22	27.34376	73
8/6/2015 9:13:33	27.832041	73
8/6/2015 9:13:45	28.320322	72
8/6/2015 9:13:56	28.320322	72
8/6/2015 9:14:07	27.34376	71
8/6/2015 9:14:19	28.320322	70
8/6/2015 9:14:30	28.320322	69
8/6/2015 9:14:41	27.34376	69
8/6/2015 9:14:53	27.34376	68
8/6/2015 9:15:04	27.34376	67
8/6/2015 9:15:15	27.34376	67
8/6/2015 9:15:27	28.320322	65
8/6/2015 9:15:38	28.320322	64
8/6/2015 9:15:49	28.320322	64
8/6/2015 9:16:00	28.320322	64
8/6/2015 9:16:12	27.832041	66
8/6/2015 9:16:23	28.320322	68

Fig. 6: Data base of the sensors data stored at cloud

All the required data is stored in the cloud (Gmail). The data is stored for the analysis of the parameter at anytime and anywhere. The figure 6 shows the temperature in degree stored in different time period and also shows the values of gas in the region at regular intervals. All the above information will be stored in the cloud, so that querying will provide the required analysis, and controlling information to tune the parameter threshold, or actuation.

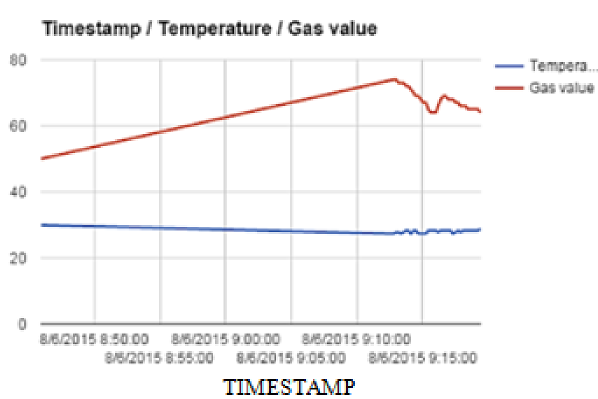


Fig. 7 (a)

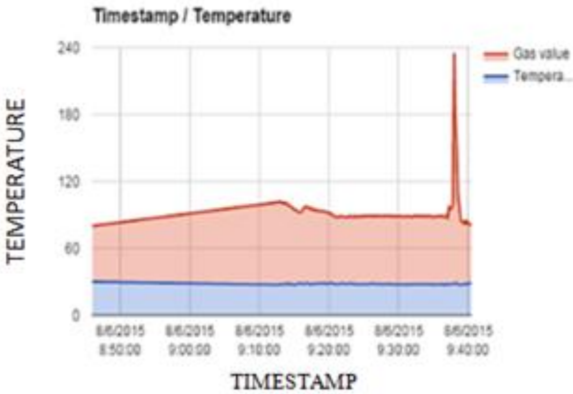


Fig. 7 (b)

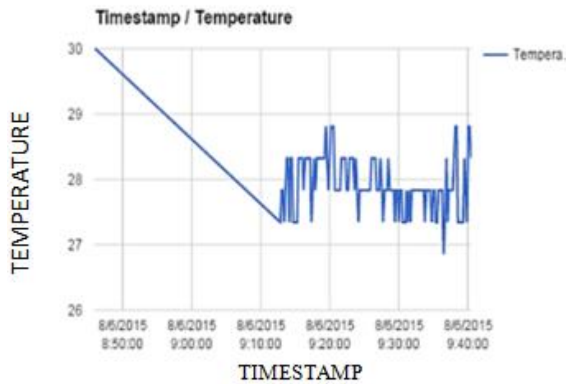


Fig. 7 (c)

The graph in figure 7 (a) shows the analysis of the temperature and gas at different time. From the graph the change in temperature and gas can be noted. The graph 7 (b) depicts the detection of smoke when the value of threshold exceeds. The variation of temperature is shown in graph 7 (c)

V. Conclusion

For smart environmental monitoring, integrating embedded and sensing systems in the environment itself will considerably raise the degree of environmental protection, enabling a lot of new intelligent features for that environment. To implement these features, necessary sensor units were deployed for environmental data collection and analysis. Then the analyzed results were available to the user end like on mobile devices using IP configured embedded device through Wi-Fi.

The concept of smart environmental monitoring along with presenting its different models, applications is addressed in the project. Our proposed model is a 5 layered architecture having different functionalities and services were discussed. The noise pollution monitoring using IOT framework and integration with the embedded device has been experimentally proven to work satisfactorily by connecting few sensing parameter to it and parameters were successfully controlled remotely through Internet. It also stores the sensor parameters in the cloud (Gmail) in a timely manner. This will help the user to analyse the condition of various parameters in the environment anytime anywhere.

Using this system as a framework, the system can be expanded to include various other options which may include home security feature like taking the photo and storing it onto the cloud. Further deployment should be done by building water proof prototype which would help for underwater monitoring and marine environment monitoring.

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Acknowledgement

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