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# Remote Monitoring and Reconfiguration of Environment and Structural Health Using Wireless Sensor Networks

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**Abstract**

In the era of Internet of Things, there has been an increasing interest in the adoption of emerging sensing technologies in the real-time applications such as Structural Health, environmental and Traffic Monitoring Systems. The wireless monitoring is gaining popularity as there is no wiring is required between the sensors and data acquisition systems. Recent improvements in GSM and micro controller technologies have led to the development of various Structural Health Monitoring (SHM) systems. The SHM should observe the context and provide reliable information about the integrity of the structure. There is a need for an embedded system with dynamic reconfiguration mechanism which can adapt itself to the unstable and ever changing environments of structural and traffic monitoring. The implementation of dynamic reconfiguration is still challenging for real time embedded system control software. The proposed framework should also support the combined deployment of two heterogeneous applications on the same WSN. The fundamental aim of this paper is to develop a real-time embedded system, which provides flexible and robust mechanism for monitoring and reconfiguration of environment and SHM.


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*Keywords:* : *Remote Monitoring; Structural Health Monitoring; Internet of Things; GSM; dynamic reconfiguration; Heterogeneous System; Control Software*

## 1. Introduction

The Structural Health Monitoring (SHM) is a process which monitors and detects the damages to an engineering structure. The damage to a structure could be due to the changes caused to the material and geometric properties of a structural system. The changes caused to the boundary conditions and system connectivity could adversely affect the


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system's performance. The SHM system collects the periodic response measurements from an array of sensors. The damage-sensitive features are extracted from the data collected and a statistical analysis is conducted to determine the current state of system health. In case of emergency, the reconfiguration process should patch the differential image of the sensor software. The Fig.1. shows the generic view of Structural Health Monitoring.

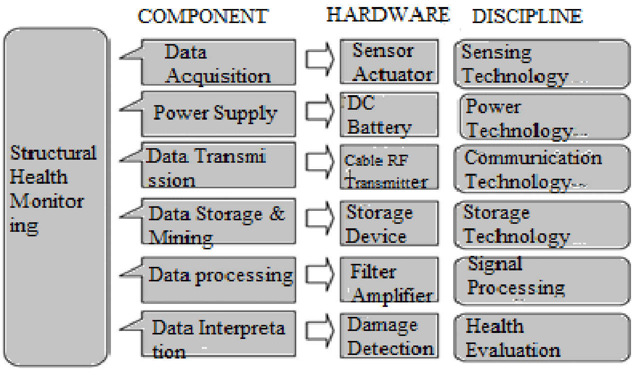


Fig.1.Generic View of Structural Health Monitoring System.

If any changes are to be incorporated into the working model then the running software of the system should be stopped, modification should be done and the new reconfigured code has to be flashed on to the devices. It may cause high overhead and damage to the user.

Connectivity between IOT devices and other IOT gateways or servers can be provided by using different kinds of wireless technologies such as Wi-Fi, ZigBee and Bluetooth or other standard wireless technologies. The limitation of the Bluetooth technology is that it can be used in an applications like Home Appliances, which works within a short distance.

## 2. Related Work

In[1], Jerome Peter Lynch et.al proposes a signal conditioning circuit to amplify and band-pass the voltage output of structural sensors. For sensors whose intrinsic noise floor is below the quantization noise of the ADC, the signal conditioning circuit can amplify the sensor output so that the noise floor of the sensor controls the quality of the measured data.

In [2], Vallidevi Krishnamurty, et.al describes the reconfiguration as a generic approach for building adaptive software systems. Service Oriented Architecture (SOA) represents an open, agile, extensible, federated, composable architecture comprised of autonomous, QoS-capable, vendor diverse, interoperable and potentially reusable services, implemented as web services.

In [3], Andreas Rasche and Andreas Polze, presented a framework Adapt.NET for runtime adaption of component-based applications, including a runtime infrastructure for dynamic reconfiguration and monitoring, targeted for mobile and desktop environments. The complex component-based real-time applications can be adapted to changing environmental conditions, continuously meeting all tasks deadlines during dynamic reconfiguration.

In [4], Zeeshan Abbas and Wonyong Yoon has provided a comprehensive survey on energy conserving issues and solutions for battery-operated IoT devices from wireless networking aspects. The extant solutions have tackled various operational aspects of IoT devices, including the adjustment of duty cycles, collision/congestion avoidance schemes, mechanisms to manage device sleep time by switching off radios or increasing a standby time, efficient radio resource scheduling, the intelligent selection of heterogeneous radio interfaces.

In [5], R. Andrew Swartz et.al, designed wireless sensors explicitly for structural health monitoring of civil engineering structures. The automated, on-board interrogation of the data can make it more manageable and give officials and the public an immediate warning in the case of possible damage or deficiency in a civil infrastructure system such as a bridge, skyscraper, or levee. The extension of wireless sensing to wireless real-time feedback control allows the structure to react to external stimuli such as earthquakes in order to reduce the effects of undesirable vibrations.

In [6], John Caffrey et.al. describes a wireless data acquisition network, including the methods of storing and transmitting the data. A damage detection scheme is described that uses extremely low transmission bandwidth, and is shown to be effective in detecting damage in a simulated structure. Finally, a large-scale structural Testbed that is being used for the project is described.

In [7], P.Susmitha, G.Sowmyabala, proposed an embedded system to design a weather monitoring system which enables the monitoring of weather parameters in an industry. The system contains pair of sensors like temperature, Gas and humidity will be monitored and uses LPC1768 microcontroller (ARM9). The data from the sensors are collected by the microcontroller and also microcontroller sends the sensors data in to the LABVIEW by using the Serial Communication and this module will keep the data in excel page & also user can get the SMS in the mobile with the help of GSM module.

In [8], Matthew J. Whelan, et.al have developed an advanced wireless sensor system, at Clarkson University, which allows for Structural Health Monitoring (SHM) of bridge structures. A short-span integral-abutment bridge located in New York State is instrumented with a wireless sensor system measuring acceleration, strain and temperature to monitor the behaviour of the structure under various loading conditions.

In [9], Yang Wang1, et.al, designed a wireless sensing prototype system specifically for structural monitoring applications. The wireless sensing units are also programmed to locally process their measurement data in real-time using an embedded fast Fourier transform algorithm. The Fourier response spectra are then wirelessly transmitted to the wireless network server. Robust software and hardware designs enable low-cost and reliable data collection and interrogation from a network of autonomously functioning wireless sensing units.

In [10], Xu Li, Wei Shu have proposed two types of traffic status estimation algorithms, the link-based and the vehicle-based algorithms. These are introduced based on data basis. The results from large-scale testing cases show that the traffic status can be fairly well estimated based on these imperfect data.

## 3. Problem Statement

The environmental changes and the traffic constraints are going to affect the structures. The damage may cause changes to the material or geometric properties of a structural system. This also includes the changes to the boundary conditions and system connectivity, which adversely affect the system’s performance. The remote monitoring and data collection can be done using Bluetooth technology, using zigbee. But, the main drawback is that they can work only within a shortest distance. There is a need for a system to monitor bridges, buildings and roads in a better way. The framework should be designed to support the combined deployment of two heterogeneous applications on the same WSN.

## 4. Design and Implementation

The proposed work monitors the engineering structure and also helps to take precautionary measures before the occurrences of earthquake and bridge collapse. The work includes the State Monitoring and Data Reconfiguration of environmental, traffic and the engineered structure. This system is based on the structural modular design concept and is mainly composed of a microcontroller and sensors. A program is embedded within the microcontroller, that helps to take the action based on the input provided. The data will be updated to server via GSM for every few seconds and the data can be monitored remotely using an android device.

The Fig.2. shows the block diagram of the components of the Structural Health Monitoring System. The SHM system consists of a Microcontroller, Accelerometer, Pressure Sensor, Temperature Sensor, Moisture Sensors which are placed at different places of an engineered structure.

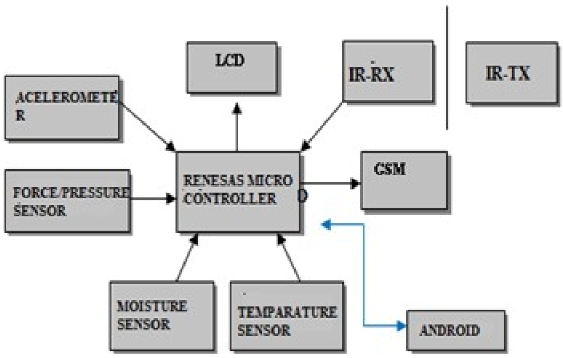


Fig. 2.Components of Structural Health Monitoring.

- An Accelerometric sensor is used to measure acceleration forces. Such forces may be static, like the continuous force of gravity or, to sense movement or vibrations in building**.**
- The Moisture sensor U25 monitors the water absorption time of the road or wall.
- The Pressure sensor U33 senses the pressure or force applied on the bridges or walls of the building
- The Temperature sensor is mainly used to find temperature variations in an environment.
- The IR Obstacle LM358 is used to detect the obstacles and the temperature is sensed by the temperature sensor LM35.
- Renesas (RL78) is 16 bit architecture, it has 64I/O pin (R5F100LE). It has eleven I/O ports, 64KB ROM, 4KB RAM, watch dog timer,I2C protocol, three UART's, 10 bit ADC, eight Timers, on chip debug function, high speed on-chip oscillator.
- A liquid crystal display (LCD) is a flat panel display, electronic visual display, based on Liquid Crystal Technology liquid crystal display consists of an array of tiny segments (called pixels) that can be manipulated to present information

- IR (TX-RX) is mainly used to find the number of vehicles crossing the bridge.

- SIM900 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS 1900 MHz SIM900 features GPRS multi-slot class 10/ class 8 (optional) and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4.

- AT Commands can be used to get information in SIM card. The SIM interface supports the functionality of the GSM.

### *4.1. Software Tools*

- **Cube Suite** is an integrated development environment for microcontrollers, integrating the necessary tools for the development phase of software into a single platform. By providing an integrated environment, it helps to perform all development tasks, without the use of many different tools.

- **Eclipse Kepler** is an integrated development environment (IDE) used in computer programming. It contains a base workspace and an extensible plug-in system for customizing the environment. The Eclipse Kepler is used to develop an android application to send the information to admin.

### *4.2. Algorithm for GSM Module*

- Step 1: The configuration of GSM is done.
- Step 2: The sensor information is read from microcontroller.
- Step 3: The Application is launched.
- Step 4: The information is send to a stored number.
- Step 5 : If (message sent successfully)?
- Step 6: Transaction complete
- Step 7: else sends the message again and the loop repeats

### *4.3. Algorithm for Android Application*

- Step 1 : Start the Application.
- Step 2: Start the Registration of number.
- Step 3: The Verification of the number is done.
- Step 4: If (valid number)?
- Step 5: The sensor information is sent through the GSM.
- Step 6: If (Threshold value)?
- Step 7: Send notification to the stored number.
- Step 8 : else get information from sensor

In the case of emergency, the controller would send the continuous message to the Admin. The Admin can reconfigure the parameter of measurement to the required time interval and obtain the data in the required format.

## 5. Results

Initially, the microcontroller sends the command to all the sensors to start functioning. The microcontroller initiates the SIM for functioning of GSM. For every 30 seconds the sensor information is sent to the microcontroller. The Fig.3.a shows the working model of SHM and Fig.3.b. shows the Registration process.

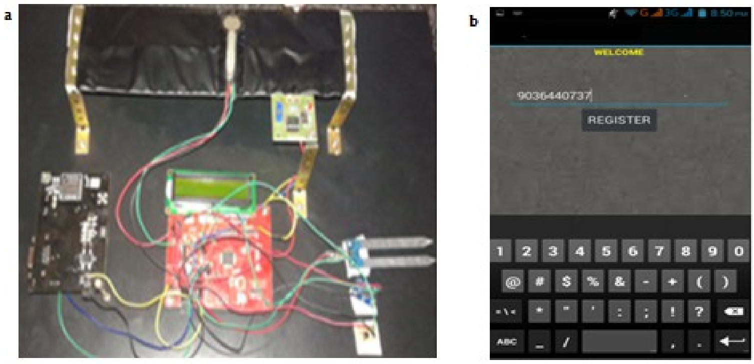


Fig.3.a) Working Model; b) Registration.

The admin has to get registered to an android application. As soon as the verification of number is finished, the GSM sends the collected information to the admin through an android application. An android app contains a database called SQLite where the information will get updated for every 30seconds of duration. The Fig.4.a. shows the fetched measurement details from each sensors. The Fig.4.b. shows the normal message sent to the registered phone number.

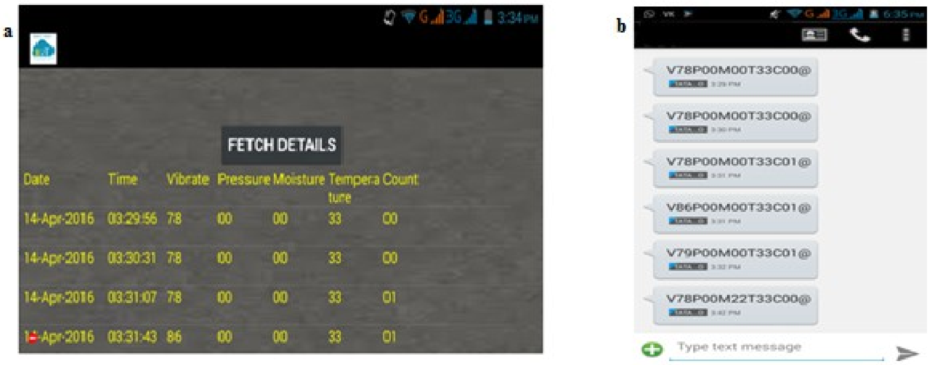


Fig. 4.a) Fetch details of sensors; b) Normal Message.

The credentials used to represent the sensor parameters are - 'V' is used to represent vibrations, 'P' is used for pressure, 'M' for moisture and 'C' for taking a count of number of vehicles. All the sensors in the system are provided with some threshold values. Once the threshold is reached a notification is sent to admin's android device and the information will get updated in the SQLite database of an android application. The first data sensed from various sensor V78P00M00T33C00 indicates the sensors measurements as Vibration-78, Pressure-00, Moisture-00, Temperature- 33, count of Vehicle-00. The data sample varies with the change in the context.

## 6. Conclusion and future Enhancements

The State Monitoring and Reporting Mechanisms are implemented for the Structural, Environmental and Traffic Monitoring Systems. The work is to investigate the Run-time reconfigurations of an Indoor/Outdoor environment of WSN. The measured data is collected from the sensors and updated to an android application. The experimental result shows the importance of monitoring the structures with reliability and low cost. The system is scalable and efficient of handling the data collected from the different sensors. This technique can be applied in various fields where there is a need for remote state monitoring and reporting mechanisms. The proposed framework also support the combined deployment of two or more heterogeneous applications on the same WSN. An efficient code update mechanisms and security techniques need to be incorporated to the existing system.

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