International Research Journal of Innovations in Engineering and Technology (IRJIET)

Volume 1, Issue 1, September-2017

Employing wireless sensor networks for early prediction of volcanic earthquake and eruptions

[1]Rupavathi.N

[1]Associate Professor, Dept. of ECE, JCET, Dharmapuri, Tamilnadu, India

Abstract* – The monitoring of volcanic activity from mountains for disaster management has employed single sensors till date. This system makes the monitoring work complicated, not flexible and efficient enough to be adopted for various volcano environments. The accuracy of volcano monitoring and coverage of observations has now been a possibility due to the development of networked wireless sensors. Here we propose a prototype for remote data logging and volcano monitoring by deploying wireless sensor nodes. Using a real time (RT) system that can launch a volcanic warning with effectiveness within a most possible short time has been realized. With these settings a key role will be played by using wireless sensor networks for volcano monitoring. The aim of this proposal is to satisfy the metrics of RT requirements by deploying optimum number of multiple sensors. Here we have combined the test bed and simulation results implemented in a controlled environment. In this paper we perform detailed study of test bed results including simulation analysis to provide valuable and accurate information for specifications to be implanted in permanent real time volcano monitoring solutions.

***Keywords*:** WSN, monitoring system, sensor nodes, volcano, volcanic analysis, IEEE 802.15, Zigbee.

I. INTRODUCTION

Volcanic eruptions have become a major threat to human societies worldwide. Wireless communication technology has been developing in recent years at an extraordinary speed. The instrumentation of the world with wireless sensor networks has been emerging as result with intelligent sensors equipped with sensor module. For field deployment there are many types of sensors that have become developed. The sensors like seismic, acoustic and gas sensors that are capable of sensing environmental parameters precisely have been in use along with a digital microprocessor for quality processing of sensor signals, a radio communication module and performing network protocol functions with a battery to provide power supply for operation [1]. These varieties of smart senor nodes are designed to be able to perform better in all kinds of various environments under rugged and touch operating regions around world all round a year continuously.

a) Remote Sensing of Volcano Monitoring

The main key role of a volcano monitoring system is to estimate the risk of eruption by measurement of the released gas evolving from the magma tank. Traditionally the gas samples are taken manually from the crater surface which is a very dangerous method by which many people have loosed their precious lives every year. Any how the volcano scientists have invented a safe and better way for remote sensing using spectroscopic imaging [2]. With this method the HCL and SO2 concentration can be calculated far away though spectrum taken from the volcano crater. Hence by analyzing these two gas concentration emitted by the volcano, their inside activity can be studied. The developments of cheaper, compact, cost effective and multi-functional sensors have enabled the growth of embedded systems and electronic technology [3]. The ideas of sensor networks are leveraged by these kinds of sensor nodes consisting of data processing, sensing and communicating components. Due to the development of micro-level wireless communication technology the sensors will no longer be deployed separately. The processing information from the monitoring field is made easier and more efficient to collect by using these kinds of sensors connected to wireless sensor network. In many fields wireless sensor networks are being emerged for usage replacing other technologies. The kind of sensors can be deployed in areas where environmental parameters like temperature, humidity are unstable which may be in sea or in air or on the ground. Due to this features the wireless sensors are said to be dynamic [4].

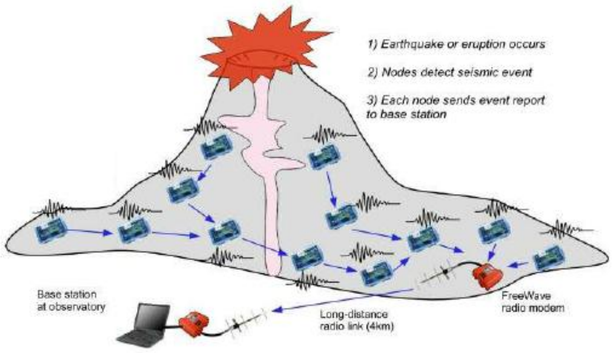

Figure 1: WSN deployment in a Volcano Mountain

In such kind of environments the bandwidth for communication and energy are significantly more limited other than in a tethered environment. To adapt over time for system stimuli and changing connectivity is one of the major requirement for a dynamic system. In most of the application areas of sensor networks, the network operation unit is left unattended due to harsh environmental conditions.

b) Deploying a Wireless Sensor Network

Instead of being designed to work in worst case scenarios there is a need to design for current conditions since the worst case conditions requires more operating power levels than the average condition with advancement in technology [5].

The design for a micro sensor wireless network should be:

- Easy to deploy in the networks and to enable self configuring.
- To extend the system life time and be energy efficient in operation.
- Passing information quickly to the end user and to get latency aware.
- The nature of the sensor network quality should be cognitive and application specific in nature.

In order to compare qualitatively the two types of systems a seismic signal analysis from registered set of events from the proposed WSN system can be performed to estimate the differences between them.

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II. OVERALL DESIGN

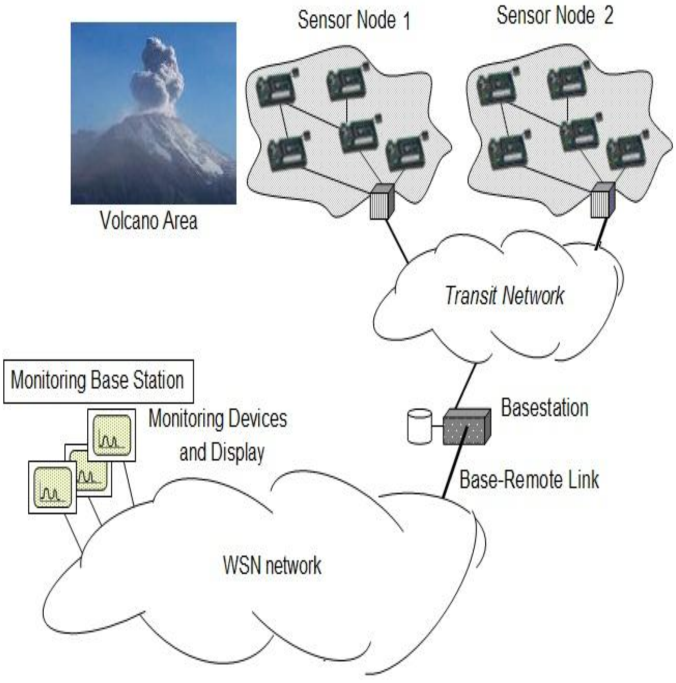

Figure 2: Wireless Sensor Network

The scalability of the system can be increased to a wide range by lighter and fast to deploy hardware which helps in addressing the scientific data beyond the limitations of current reach. Typical data collection station in volcanic places involves power hungry hardware components which are bulky, heavy, portable difficult and require an automobile battery for power backup. Such kind of systems is known to deliver long term suitability in challenging environments in a successful manner.

In network real time quality assured data collection is an issue that has not been addresses to the best of our knowledge [6], [7].

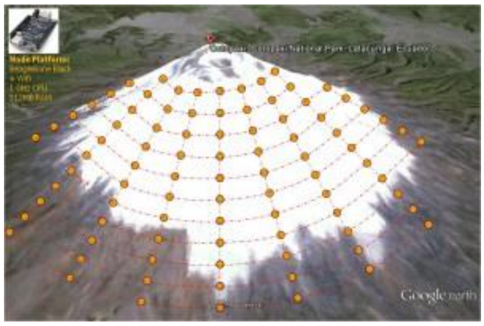

Figure 3: Arranging Method of Sensor Nodes

Above figure clearly displays the arranging methods for all the sensor nodes to be placed in the volcanic area in a connected bus method of topology. A tree topology method is commonly connected in this system of sensor nodes. A zigbee based wireless sensor network is used in this paper to send all encoded data to the base station after converting from analog reading to digital ones.

III. SYSTEM DESIGN AND DESCRIPTION

For the transmission of sensory data from the wireless sensor node to a centralized processing unit of base station, the earlier prediction of seismic and earth quake events can be detected and forecasted. A number of distributed sensors are utilized on the volcano comprised of a base station for data forecasting [8].

Here used is the vibration sensors based on peizo electric for detecting seismic vibrations and earth quakes. The gases constantly released by a volcano comprises of carbon di oxide, sulphur di oxide and carbon mono oxide [9]. MQ2 and MQ6 gas sensor modules are used here for measuring the chemical gas levels respectively. AT mega16 microcontroller is used to receive all sensor data through its inbuilt 7 ADC channels.

The program inside the microcontroller continuously converts the analog sensor voltages in to 10bit digital values and sends the data to serial UART communication port. Each sensor is connected to the multiple ADC pins to receive signals. The base station receives the data transmitted from the microcontroller UART through a wireless RF data modem. Another ATmega 16 microcontroller is connected to the base station to read the sensor values obtained from the serial ports and each sensor data are then identified and separated. Received sensor values are processed, converted and calibrated and then displayed in a LCD or any PC or laptop at the base station [10]. Parallel the microcontroller cross checks the received values with the preset reference values and if any values are found to cross the threshold limits then the controller sends a signal to the warning system. Thus an audio visual alert is produced immediately alerting the people about volcanic activity.

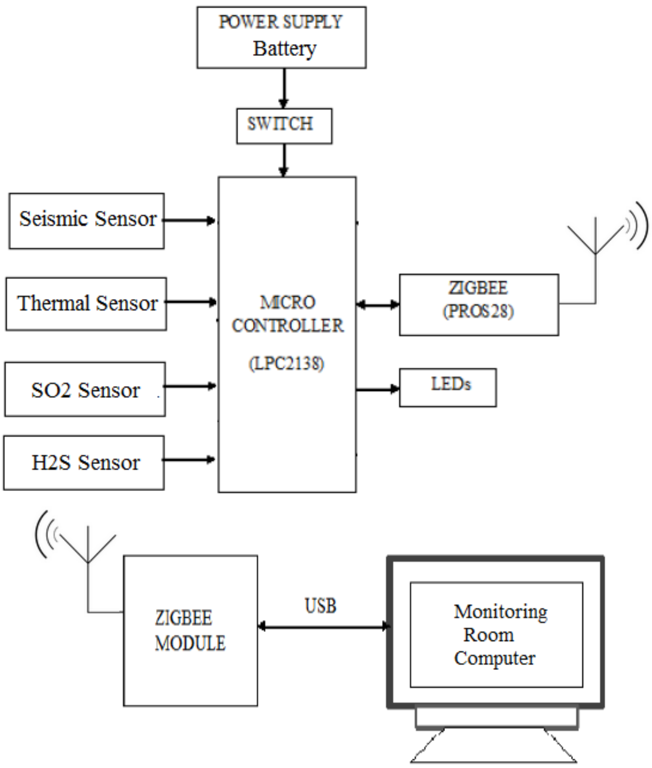

Figure 4: System Monitoring Design

Thus a highly dynamical approach for detecting volcanic earth quakes with a quality driven method based on collaborative signal processing is presented. To minimize energy consumption of sensors is the particular aim subject to quality sensing requirements.

IV. REQUIREMENTS AND METRICS FOR HARDWARE

For practical application of this system the environment surrounding the volcano in wild terrain has to be taken into consideration and lacking of supply for implementation of WSN taken into account.

a) Zigbee CC2500

CC2500 RF transceiver module is a easy to use RF communication module operating at 2.4 GHz. It can receive and transmit data at 9600 baud rate to and from any standard CMOS TTL sources.

Figure 5: Zigbee CC2500

It requires no extra hardware and special coding to work in a Half Duplex mode and it is a direct replacement for any serial communication since it requires communication in both directions but at only one direction at the same time.

b) Gas Sensors MQ- 2 & MQ-6

Gas sensor modules MQ2 and MQ6 are highly sensitive in detecting gases and are used majorly in equipments for gas leakage in domestic and industrial applications. These can detect wide range of gases like iso-butane, methane, propone, hydrogen, smoke and LPG. SnO2 substrate material which is highly sensitive with lower conductivity in clean air is used in MQ6. The conductivity of the sensor will be higher with increase in gas conduction during the presence of combustible gases. An op-amp based is used to amplify the sensor signal while the gas sensor produces conductivity of gases into proportional voltages.

c) Vibration Sensor

A peizo electric based transducer is used for converting mechanical displacement form neutral axis into electrical output. Then bending in sensor produces a strain within the peizo electric element which is converted into voltages. These kinds of sensors are highly sensitive to vibrations and are majorly used in security practices and in vibration detectors. When a vibration is detected, it send a signal to the data acquisition board which consist of the instrumentation amplifier which boosts the signal levels to required voltages. A major advantage of this sensor is its highly sensitive omni directional detection gain [11]. Additionally it most suitable for flexibility measurements, touch and impact detection. The module design is PZT film based sensor technology. During forward and backward motion a certain voltage levels will be created by the voltage comparator with low and high output levels. In spite of this fact it exhibits a wide dynamic range (0.001Hz~1000MHz) and also guarantees an excellent measurement performance with high receptivity for strong impacts. The sensitivity of the transducer can be adjusted by varying the position of potentiometer screw for various levels of required sensitivity. Thus it makes versatile for seismic vibration measurements.

Figure 6: Vibration Seismic Sensor

d) Precision Temperature Sensor- LM35

LM35 is a IC based precision temperature sensor module which is compact with less pin count with only 3 pins in transistor type package. It produces a voltage proportional to the temperature in Celsius scale. The circuitry of this sensor is completely sealed and so it is not subjected to oxidation and other environmental changes [12]. Unlike thermistor the measurement of LM35 is more accurate and also possesses low self heating and does not rise more than 0.1 degrees Celsius temperature rise in still air. The output of this sensor varies by 10mV in response to every one-degrees Celsius raise or fall in ambient temperature. The operating range of this sensor will be from -55°C to 150°C. Output voltage scale factor is 0.01V/ °C.

e) ATMEGA16 Microcontroller

Here ATmega16 based low power CMOS 8-bit microcontroller is used as the processing unit. This is an AVR family of microcontroller with enhanced reduced instruction st (RISC) based architecture. ATmega16 achieves high processing speed by executing instructions at 1MIPS per MHZ. Thus this design provides optimized power consumption with high processing speed.

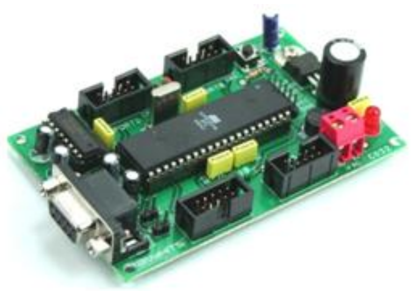

Figure 7: ATMEGA16 microcontroller

V. REQUIREMENTS OF SOFTWARE

The software used to simulate the performance of volcano monitoring system and its functional analysis is Proteus7.0. Many embedded system developers dismiss the method of creating PCB layout and hardware based testing since it is a time consuming and more complicated and also wastage of money and labor. Without hardware testing proteus software offers a new automation window for component placement and routing and the computer designing can most effective testing methods with real time simulation results. Additionally graphical representation of the output and real time data values can be monitored in different time slots using a serial port terminal emulator window.

VI. SIMULATION RESULTS

In this article we have simulated the output results of the wireless sensor network in volcano monitoring applications using proteus schematic design. The system components are drawn into schematic and the embedded software code is compiled and merged with the design. The c source code is compiled to get a 'hex' file and uploaded into the microcontroller code memory. Proteus design is executed and during automation the inputs for sensors are varied and output results are cross checked through the terminal software emulator window which shows the serial data sent and received by the zigbee module. Also additionally y a LCD display is used for viewing the results of the sensor node outputs. The real time performance of the volcano monitoring system can be displayed in simulation window and any errors or modification of data can be done with ease through proteus platform.

a) Schematic Design

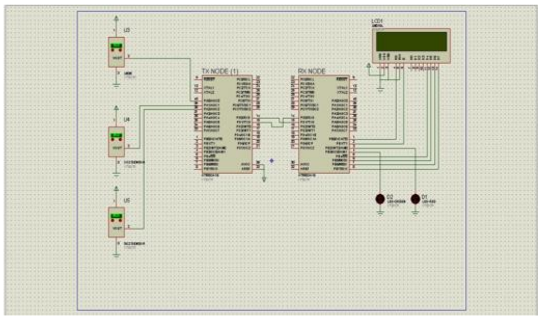

Figure 8: Schematic Design in Proteus

b) Execution- Temperature Sensor Response

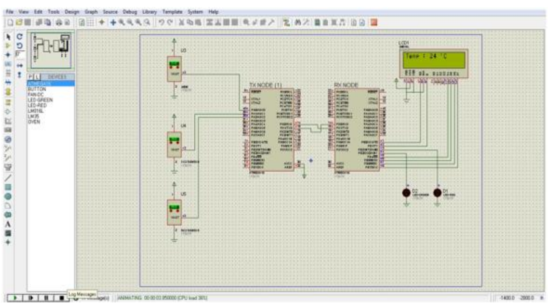

Figure 9: Temperature Sensor Response

c) Execution- Gas Sensor Response-SO2

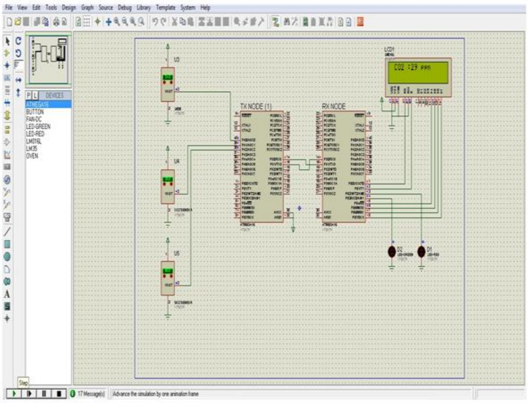

Figure 10: Gas Sensor Response-SO2

VII. CONCLUSION

The volcano monitoring system is designed and simulation is conducted through Proteus software with the schematic design for real time continuous monitoring of volcanic activity. Thus a successful attempt in understanding wireless sensor network based monitoring of seismic activity is done for sensor network in communication the data to the base stations. A scientific instrumentation approach for volcanic monitoring are evaluated to yield a high data fidelity for real time sensor network deployment. All challenges that remain in the validating the accuracy and instrumentation are solved in this system. In considering the scientific, social and technical aspects the proposed system design can be robust and emphasis a reliable network platform for remotely managed long distance technology.

VIII. FUTURE WORK

The future work of this model will be the life extension of sensors with reduced power consumption for extended life time of network reliability. The choice of batteries foe reduced bandwidth requirements for increased scalability of large sensor arrays.

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