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REAL TIME VOLCANO MONITORING USING WIRELESS SENSOR NETWORK

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Abstract— The objective of this paper is to monitor the hazardous areas like volcano by means of WSN and PC. This serves as a safety barrier to detect and to identify potential threats and dangers, such as volcanic eruptions, earthquake etc. Alarm system is included in this design so that the people living around such areas can be evacuated and the lives and premises can be protected. Sensors detect all the volcanic events and the collected volcanic data is transmitted to the receiver section situated far from the field. This data received is stored in the database and forwarded to the internet and any user who is having internet access can get this volcanic data. The distributed users can not only view but also download the current and historical data. If any abnormal event is detected, the alarm system will work and the alerting messages or mails can be sent to the scientist in charge. Sustainability and reliability of sensor networks in extreme environments remain a major research challenge. Network connectivity is unstable which result in data loss. To overcome this problem, RSS based network is designed.

Keywords—Wireless sensor networks

Abbreviations—Wireless Sensor Network(WSN),Received Signal Strength(RSS)

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I. INTRODUCTION

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring etc

The WSN is built of 'nodes' – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning 'motes' of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi hop wireless mesh network.

Wireless sensor networks have broad range of applications including environmental monitoring, habitat monitoring and structural monitoring. In the last 15 years, volcanic eruptions have killed more than 32,000 people and caused billions of dollars in damage. WSN has the capability to monitor the hazardous areas like volcano and it is able to run continuously with zero maintenance for a long time in volcanic environment. This interdisciplinary project is investigating the use of wireless sensor networks for monitoring eruptions of active and hazardous volcanoes. Wireless sensor networks have the potential to greatly enhance our understanding of volcanic activity. The low cost, size, and power requirements of wireless sensor networks have a tremendous advantage over existing instrumentation used in volcanic field studies. This technology will permit sensor arrays with greater spatial resolution and larger apertures than existing wired monitoring stations.

In the past, in the case of temporary geophysical monitoring deployments, stand-alone data loggers were often used to record signals to a ash memory card or hard drive and later retrieved manually every several weeks, involving significant human effort. Permanent installations, on the other hand, sent their data to an observatory via analog or digital telemetry. The amount of data transmitted is limited by bandwidth of the hardware, and computational and storage limitations at the observatory. As a result, even many threatening and active volcanoes (e.g., Mount St. Helens) maintain networks of less than ten stations. Scientists frequently lack of sufficient real-time and high-fidelity data for volcano analysis and eruption prediction. Wireless sensor networks have the potential to greatly enhance the understanding of volcano activities by allowing large distributed deployments of sensor nodes in difficult-to-reach or hazardous areas. Wireless communication permits sensor nodes to communicate with each other and to a central base station via a smart self-healing multi-hop network, allowing intelligent real-time data reduction as well as retaking the sensor array after deployment. Battery is the only reliable energy source, because solar panels do not work during the long rainy season in the Northwest region. There is a compelling need for real-time raw data for volcano eruption prediction research.

II.RELATED WORKS

2.1 FIDELITY AND YIELD IN THE VOLCANO MONITORING SENSOR NETWORKS

It presents a science-centric evaluation of a 19-day sensor network deployment at Reventador, an active volcano in Ecuador. Each of the 16 sensors continuously sampled seismic and acoustic data at 100 Hz. Nodes used an event-detection algorithm to trigger on interesting volcanic activity and initiate reliable data transfer to the base station. During the deployment, the network recorded 229 earthquakes, eruptions, and other seismoacoustic events. The science requirements of reliable data collection, accurate event detection, and high timing precision drive sensor networks in new directions for geophysical monitoring. The main contribution of this work is an evaluation of the sensor network as a scientific instrument, holding it to the standards of existing instrumentation in terms of data fidelity (the quality and accuracy of the recorded signals) and yield (the quantity of the captured data). They describe an approach to time rectification of the acquired signals that can recover accurate timing despite failures of the underlying time synchronization protocol. In addition, they perform a detailed study of the sensor network's data using a direct comparison to standalone data logger, as well as an investigation of seismic and acoustic wave arrival times across the network. Limitations include node failure, message loss, and inaccurate time synchronization.

2.1.1 SENSOR HARDWARE

Nodes were interfaced to either a single-axis seismometer or three seismometers in a triaxial configuration. Both sensors are passive instruments; ground motion generates a voltage which is amplified and digitized by the sampling board. In addition, each node was attached to an omnidirectional microphone. This microphone has been used in other infrasonic monitoring studies. Each node was equipped with an 8.5 dBi omnidirectional antenna mounted on 1.5m of PVC pipe. This permitted line-of-sight radio range of over 1 km without amplification; nodes were typically placed 200-400 m apart in our deployment. Nodes were powered by two D-cell batteries with a lifetime of approximately 1 week. Each node was enclosed in a weatherproof Pelican case. Several other pieces of hardware complete the system. Free Wave radio modems provided a long-distance radio link between the sensor array and the volcano observatory, 4.6 km away. A laptop located at the observatory logged data and was used to monitor and control the network. They used a single Crossbow MicaZ mote interfaced to a GPS receiver . The GPS receiver provided a 1 Hz pulse that is accurate to GPS time within 1 μs, and acted as the root of the network time synchronization protocol

2.1.2 EVENT DETECTION AND DATA COLLECTION

Because of the high data rates involved (600-1200 bytes/sec from each node) it is infeasible to continuously transmit all sensor data. Rather, nodes are programmed to locally detect interesting seismic events and transmit event reports to the base station. If enough nodes trigger in a short time interval, the base station attempts to download the last 60 sec of data from each node. This design forgoes continuous data collection for increased resolution following significant seismic events, which include earthquakes, eruptions, or long-period (LP) events, such as tremor. The download window of 60 sec was chosen to capture the bulk of the eruptive and earthquake events, although many LP events can exceed this window (sometimes lasting minutes or hours). To validate the network against existing scientific instrumentation, the network was designed for high-resolution signal collection rather than extensive in-network processing. During normal operation, each node continuously samples its seismic and acoustic sensors at 100Hz, storing the data to flash memory. Data is stored as 256-byte blocks in the flash. Each block is tagged with the local timestamp corresponding to the first sample in the block. This timestamp is later mapped onto a global time reference. The 1 Mbyte flash is treated as a circular buffer storing approximately 20 min of data. In addition, nodes run an event detection algorithm that computes two exponentially-weighted moving averages (EWMA) over the input signal with different gain settings. When the ratio between the two EWMAs exceeds a threshold, the node transmits an event report to the base station. If the base station receives triggers from 30% of the active nodes within a 10 sec window, it considers the event to be well-correlated and initiates data collection. The reliable bulk-transfer protocol, called Fetch, operates as follows. The base station waits for 30 sec following an event before iterating through all nodes in the network. The base sends each node a command to temporarily stop sampling, ensuring the event will not be overwritten by subsequent samples. For each of the 206 blocks in the 60 sec window, the base sends a block request to the node. The node reads the requested block from flash and transmits the data as a series of 8 packets. After a short timeout the base will issue a repair request to fill in any missing packets from the block.

2.2 AIR-DROPPED SENSOR NETWORK FOR REAL-TIME HIGH-FIDELITY VOLCANO MONITORING

This work presents the design and deployment experience of an air-dropped wireless sensor network for volcano hazard monitoring. The deployment of five stations into the rugged crater of Mount St. Helens only took one hour with a helicopter. The stations communicate with each other through an amplified 802:15:4 radio and establish a self-forming and self-healing multi-hop wireless network. The distance between stations is up to 2 km. Each sensor station collects and delivers real-time continuous seismic, infrasonic, lightning, GPS raw data to a gateway. The main contribution of this paper is the design and evaluation of a robust sensor network to replace data loggers and provide real-time long-term volcano monitoring. The system supports UTC time synchronized data acquisition with 1ms accuracy, and is online configurable. It has been tested in the lab environment, the outdoor campus and the volcano crater. Despite the heavy rain, snow, and ice as well as gusts exceeding 120 miles per hour, the sensor network has achieved a remarkable packet delivery ratio above 99% with an overall system uptime of about 93:8% over the 1:5 months evaluation period after deployment. Their initial deployment experiences with the system have alleviated the doubts of domain scientists and prove to them that a low-cost sensor network system can support real-time monitoring in extremely harsh environments.

Aiming to replace data loggers for volcano monitoring, the system design mainly focused on achieving real-time high fidelity, online reconfigurability, and a high-degree of robustness. The high data yield of our deployed system proves its robustness. The presented system design and deployment experience clears the doubts of domain scientists and proves that the low-cost sensor network system can work in extremely harsh environments.

2.2.1 SYSTEM DESIGN

The USGS scientists specified the following system requirements:

i. Synchronized Sampling: To utilize the temporal and spatial correlation of volcano signals, the earth scientists require that all stations perform synchronized sampling and timestamp recorded signals with precise UTC time, with error no more than one millisecond.

ii. Real-time Continuous Raw Data: There are no existing algorithms or models are widely accepted to predict volcano eruptions, thus the scientists need real-time continuous raw data to study the behaviour of volcanoes.

iii. One year Robust Operation: The sensor network must be able to collect raw data continuously for one year, despite the extreme weather conditions and routine volcanic activities.

iv. Online Configurable: The OASIS system aims to integrate complementary space and in-situ elements and build an interactive, autonomous sensor web. The sensor network shall respond to external control from the NASA Earth Observation satellite USGS science softwares, and adjust its behaviours accordingly .The command and control needs to be delivered reliably in real time.

v. Fast Deployment: In the past, installing a single monitoring station required significant human intervention, which is not just costy, but also risky. It is strongly preferred that the sensor stations can be air dropped and self-form a network to reduce the deployment cost and associated safety risks. To meet these requirements, we comprehensively designed the system architectures, hardware, sensing and networking softwares, such as robust communication stacks, intelligent sensing algorithms, hybrid time synchronization protocols and light-weight network management tools.

III. METHODS

Sensors like temperature sensors, LM 35 and MEMS vibration sensors are used to detect the volcanic events in the field. PIC microcontroller processes these measured values and transmitted to the receiver section. If the measured values are above the threshold value, alarm system can send messages to the scientist in charge. In receiver section, all the received data are imported into the data base for future reference. Simultaneously, these measured values are uploaded into the internet so that the people anywhere from the world can not only view but also download the volcanic data and this will be very useful especially for Geologist to predict and analyse the behaviour of the volcanoes. Sustainability and reliability of sensor networks in extreme environments remain a major research challenge. GPS receiver is included so that the exact location where the event is triggered can be identified. Network connectivity is unstable which result in data loss. To overcome this problem, Received Signal Strength (RSS) based network is designed. The main modules in each node are shown below. The modules shown in the block diagram form a node in the wireless sensor networks. Such nodes are embedded throughout the hazardous areas like volcanoes so that they can collect volcanic data from many different sites. These nodes can communicate each other and send the collected data to the receiver section situated far from the field. Communication process takes place with the help of ZigBee. It is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks. ZigBee devices are often used in mesh network to transmit data over longer distances, to reach more distances.

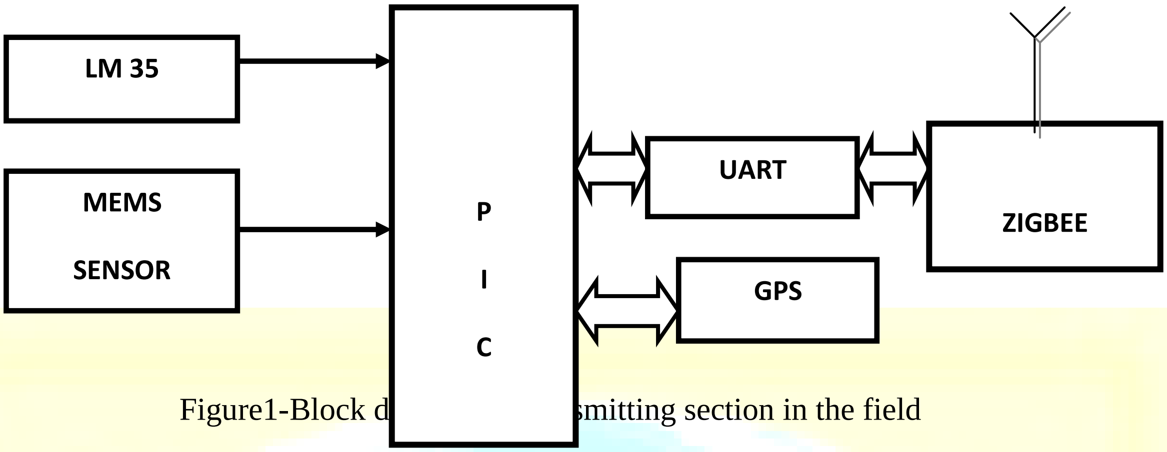

Figure1-Block d smitting section in the field

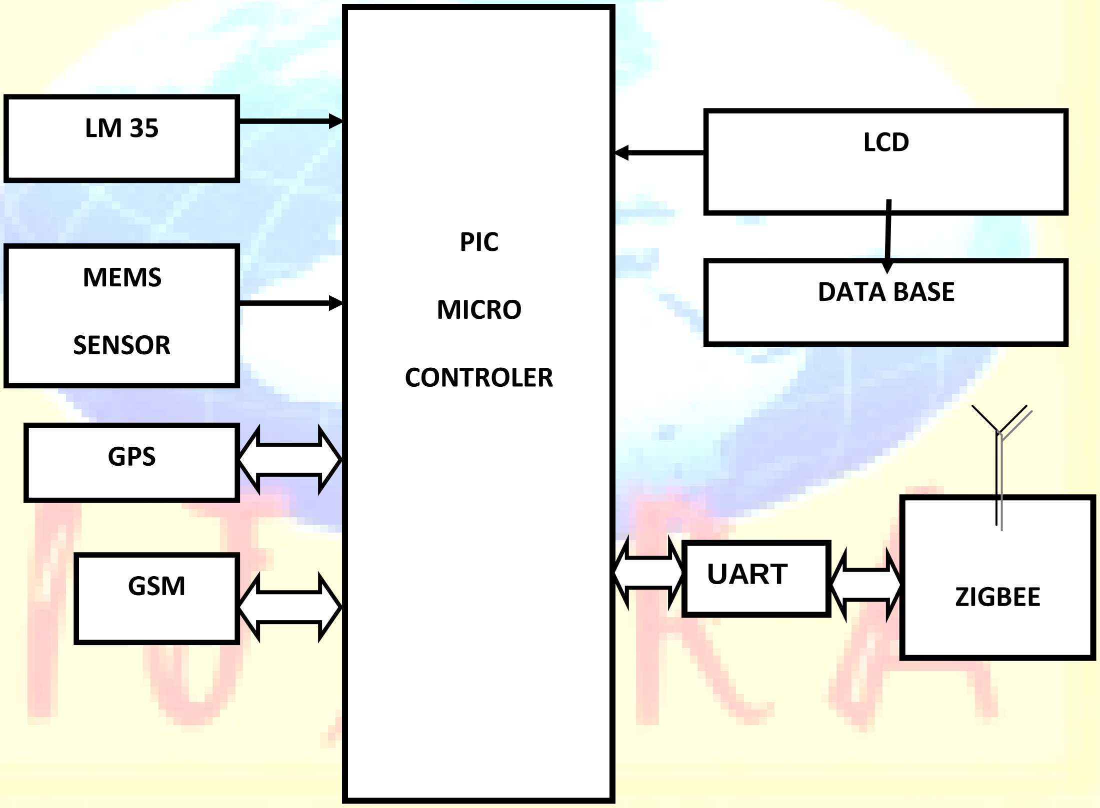

Figure 2- Receiver Section in the Office

IV. RESULT

Since PIC microcontroller is using as a main component in the hardware implementation, embedded C programming is written and debugged using MP LAB cross compiler and the circuit is designed and simulated using Proteus design software. The result obtained in each stage is listed below.

1. LCD is interfacing with PIC microcontroller and displayed the word "kit" as per the program.
2. Using a temperature sensor temperature is continuously measured and displayed in the LCD module. The measured analog value is converted into digital by the ADC in the PIC microcontroller.
3. Temperature and vibration are continuously measured and displayed in the LCD display. If vibration is above a particular level, it is displayed as "vibration over" otherwise "normal".
4. The measured parameters are sent to the receiver section and it is stored in the database for future analysis and study.
5. Using a GPS receiver, the system can pinpoint the exact location where the event is detected. The received values are uploaded to the internet and the distributed users can not only visualize but also download the volcanic data. This makes feasible study on volcanoes and their behaviour especially for geologists. The alerting mails or messages are sent to the scientist in charge if any abnormal event is detected so that the authorities can take necessary steps like evacuating the surrounding areas to protect the lives and premises.
6. After completing the simulation, circuit is designed, tested and hardware implementation is done.

V. CONCLUSION AND FUTURE ENHANCEMENT

A variety of precursory signals are generated by the many processes that occur as molten rock (magma) forces its way up through miles of the Earth's crust before eruption at the surface. Many of these signals are extremely subtle and complex, and consequently require expensive arrays of sensitive instruments to detect and scientists with years of experience to interpret Just as doctors monitor patients' potential future health risks by studying their medical histories and interpreting results of lab tests over time, so, too, do volcanologists learn about the possibility and size of future volcanic activity by studying a volcano's historic activity and measuring and evaluating the signals it generates over many years. Doctors and volcanologists both know that routine monitoring over time is the best way to detect potential future problems early, when they are most easily dealt with. While patients can go to laboratories for tests, volcanologists can only assess the state of volcanoes in the field by placing monitoring instruments on and near them. Ideally, complete networks of monitoring instruments are put in place while potentially active volcanoes are still quiet. By missing the earliest signals of restlessness, volcanologists risk losing critical early data needed to establish “baseline” trends and accurately estimate the size of a possible eruption

The number of nodes can be increased to capture more volcanic data from different sites. ARS algorithm can be implemented to autonomously recover from local link failures to preserve network performance. By using channel and radio diversities in WMNs, ARS generates necessary changes in local radio and channel assignments in order to recover from failures. Next, based on the thus-generated configuration changes, the system cooperatively reconfigures network settings among local mesh routers.

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