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Structural health monitoring of River bridges using Zigbee technology

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ABSTRACT

The river bridges are the main connective parts of most of the places in the world. The deterioration or damage of the river bridges occurs due to natural disasters, environmental conditions
or may be changes takes place under the piers. It causes loss of connectivity, loss of lives, excessive repairs at times. Therefore it is important to monitor the structural health of river bridges. One of the major cause of the structural health degradation is scour. There are other parameters like vibration of bridges, vibration near pier which also affects structural health of bridges. This proposed work consist the various existing scour monitoring techniques. The existing methods for scour monitoring have limitations that it could not be estimate failure of bridges accurately. To improve this system the Wireless sensor networks Structural Heath Monitoring has been designed to overcome problem which will monitor scour and vibration of River bridges. The system is built using ARM controller with Zigbee Digikey module. Hence in this project low cost wireless sensor network based solution to monitor the structural health.

Key words: Piezoelectric sensor, Scour, Structural health monitoring, Ultrasonic distance sensor, Vibration sensor, Wireless sensor networks, Zigbee.

1. INTRODUCTION

The structural state of our nation's infrastructure is deteriorating, so it is the ability of the nation to pay for its continual maintenance and repair. In the case of catastrophic events including earthquakes, tsunamis, and terrorist attacks, it is essential that emergency responders have available to them real-time information regarding the condition and safety of the structures for which they are responsible.

1.1 Structural health monitoring of river bridges

The structural health monitoring estimates the state of structural health as current condition of structures, modal analysis or detecting the changes in structure that effect the system performance at every moment during the life of structure. The goal of SHM is to improve safety and reliability of infrastructure by detecting damage before it reaches a critical state [1]. A SHM system consists of sensors, data acquisition and transmission systems, database for effective data management and health diagnosis (including data processing, data mining, damage detection, model updating, safety evaluation and reliability analysis) [2].

1.2 Wireless sensor networks

As bridges and other structures such as buildings age, they naturally develop cracks, concrete deterioration, and steel corrosion that can impact the safety of the bridge or the structural integrity of the building. Wireless sensor network enables low-cost sensing of environment [3]. As compared to the wired techniques, wireless network have low equipment cost, low installation cost, low maintenance cost, low duty cycle, low power consumption. The wireless sensor system enables remote damage detection and structural health monitoring for bridges and other structures.

A)Zigbee technology: IEEE 802.15.4 is the basis for the ZigBeee specification. Zigbee builds upon the IEEE 802.15.4 standard and defines the network layer specifications and provides a framework for application programming in the application layer. ZigBee builds upon the physical layer and medium access control defined in IEEE standard 802.15.4 (2003 version) for low-rate WPANs. Zigbee is the result of the demand from industry and consumer for wireless applications that demand for lower data rate, longer battery life, simple design, shorter range, low power consumption and low cost solutions.
Zigbee is a Low data rate, Low power consumption system operates in Unlicensed Bands. Zigbee ISM 2.4 GHz Global Band operates at 250kbps [4].

2. SCOUR

Scour in watercourses and drainage paths causes significant damage to the environment and engineering infrastructure. In order to minimize the long term costs, infrastructure must be designed and protected from scour. Scour is the transport of bed material by the flow of water and is present to some degree where the river bed or seabed is formed of granular material. Scour increases as flow rates increase and therefore the actual collapse of structures due to scour often occurs during periods of extreme flow, due to flooding. The scour occurs due to its different types and takes various forms. The loss can be major which depends on the type of scour. Hence there is necessary to reduce such type of loss [5]. Scour monitoring can be completed by either fixed or portable instruments. Fixed instruments are those that are installed and left at the bridge and typically involve a sensor for making the scour measurement, a power supply and a data-logger [6].

The most common cause of bridge failures is from floods scouring bed material from around bridge foundations. Scour is the engineering term for the erosion caused by water of the soil surrounding a bridge foundation (piers and abutments) [5]. There are so many bridges failure due to scour in the different part of the world. So scour monitoring is necessary.

2.1 Mechanism of scour

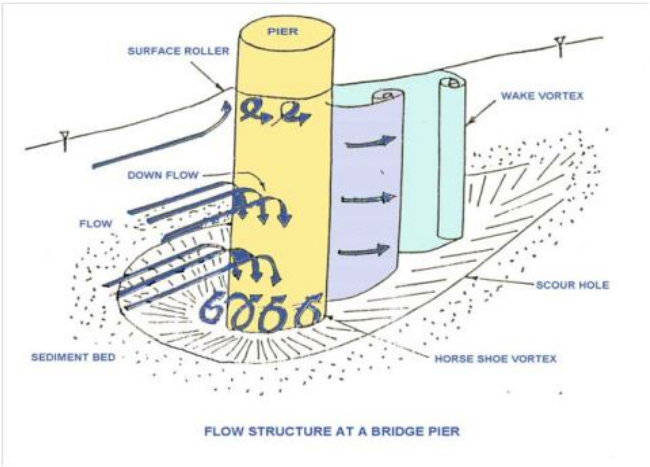

Figure 1: Mechanism of scour

2.3 Scour monitoring instruments

A) Sonar: Sonar instruments measures distance based on the travel time of a sound wave through water. Sonar is an acronym for SOund NAvigation and Ranging. The sonar transducer is connected to the sonar instrument or directly to a data logger.
The sonar instrument measures distance based on the travel time of a sound wave through water to the stream bed and back to the transducer. The data logger controls the sonar system operation and data collection functions and can be programmed to take measurements at prescribed intervals. Sonar sensors normally take a rapid series of measurements and use an averaging scheme to determine the distance from the sonar transducer to the streambed. These instruments can track both the scour and refill (deposition) processes [7]. The sonar instruments can provide an accurate depth-structure model of the steam bottom, but the measurement results are vulnerability to noises (multiple reflection and echoes from riverbed or piers), therefore they cannot work well in debris or ice environment [8]. It is affected by aerated flow and bed load. It is able to measure the current level of scour so information on the refilling is collected. This type of sensor device is not structurally robust, but the device may be mounted in a variety of elevations out of the way of debris.

B) Piezoelectric Film Devices: A piezoelectric film sensor is a passive electric sensor that turns deformation into an electric signal. The device uses an array of film sensors to detect the location of the bed. When a sensor is buried, it does not move and does not output a signal; when unburied the sensor is moved by the flow and outputs a small current. Thus, they can measure aggradation and degradation of surrounding soil. These devices are typically very sensitive which can lead to false measurements [7].

3. PROPOSED SYSTEM

A proposed system is based on ARM7 and zigbee technology for solving problems of the scour monitoring system. Zigbee module is used as an interface between ARM controller and pc is used to send information to the Control room.
The system is designed for monitoring the structural health of bridge wirelessly and sends the information of bridge continuously to control room. So based on that necessary action can be taken for monitoring the structural health of river bridge. Basically system having two parts, transmitting section and receiving section.

3.1 Bridge Area

This area is a transmitting section. This area of system consists of ARM7, Ultrasonic distance sensor, Vibration sensor, Zigbee module, LCD, Power supply.
A) Arm7(LPC2138): The LPC2138 microcontrollers are based on a 16/32-bit with real-time emulation and that combine the microcontroller with 32 kb, 64 kb, 256 kb and 512 kb of embedded high-speed flash memory. The ARM controller LPC2138 is programmed such that it accurately takes the measured distance which is sensed by ultrasonic distance sensor and detection of vibrations by vibration sensor. The ultrasonic distance sensor is interfaced to ARM controller through UART serial port. The zigbee module is interfaced to ARM controller and using this it displays the water depth on LCD. All the programming part of this system comes under this. It having 8-channel 10-bit ADCs provide a total of up to 16 analog inputs, with conversion times as low as 2.44 ms per channel. Also having single 10-bit DAC provides variable analog output.

B) Ultrasonic distance sensor: Its compact size, higher range and easy usability make it a handy sensor for distance measurement and mapping.
· Minimum range 10 centimeters
· Maximum range 400 centimeters (4 Meters)
· Accuracy of +-1 cm
· Resolution 0.1 cm
· 5V DC Supply voltage
· Modulated at 40 kHz
· Serial data of 9600 bps TTL level output for easy interface with any microcontroller. This band can be used to Control of lights, switches, thermostats, appliances, etc.

C) Vibration sensor: It is used to detect the vibration of bridges at pier. It is placed inside the pier of bridges. It gives Digital high output whenever vibration is detected. The two contacts of sensor are not connected in idle condition. When external force is acted upon either my movement or vibration, the sensor's two contact pin are closed and contact is made between the two pins.

When the force is removed the sensor terminals returns back to open contacts. Sensor is made up of a small spring mechanism, which makes the contact ON when the applied vibration force is at above a certain threshold. Vibration sensor output pin is connected to Port Pin 40 of LPC2138 controller. When bridge capacity exceeds then bridge column capacity violated will display on visual basic 6.0 tool.

D) Piezoelectric sensor: A piezoelectric sensor is a device that uses the piezoelectric effect, to measure changes in pressure, acceleration, temperature, strain. Two main groups of materials are used for piezoelectric sensors: piezoelectric ceramics and single crystal materials. Here it is used to detect the vibration of bridge. Piezoelectric sensor is connected to Port Pin 44 of LPC2138. When bridge capacity exceeds then "Bridge vibration level beyond threshold" will display in visual basic 6.0 tool which means bridge is overloaded.

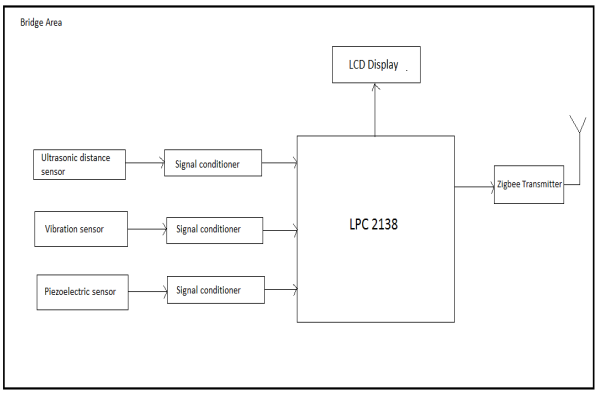

Figure 1: Block Diagram of Bridge area

E) Zigbee transceiver: Zigbee is the result of the demand from industry and consumer for wireless applications that demand for lower data rate, longer battery life, simple design, shorter range, low power consumption and low cost solutions.

Zigbee is a Low data rate, Low power consumption system operates in Unlicensed Bands. Zigbee ISM 2.4 GHz Global Band operates at 250kbps. In this system zigbee module is attached to the ARM controller and then according to range of zigbee module sends the information of sensors which are placed on bridge to the receiver zigbee module side.

3.2 Control room area

In this section, all the transmitted data will be received and based on information about bridge condition, further action can be taken. This area is also called as receiving section. This section consists of PC, Zigbee module.

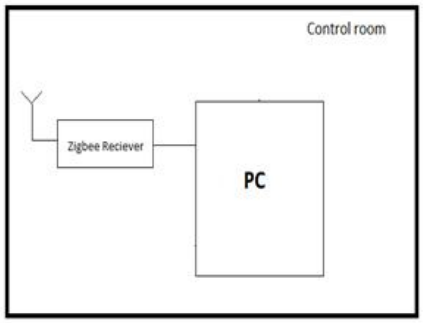

Figure 2: Block diagram of Control Room side

4. RESULTS

The ultrasonic distance sensor output is displayed in Visual basic tool. Following figure shows the corresponding sensor output when the bridge is under normal condition. Firstly, the data transmission is done by using zigbee technology and corresponding data transmitted is shown in Docklight software.

Figure 3: Ultrasonic distance sensor output

When distance between bridge deck and river-bed goes beyond level then scour possibility will be there. So scour is detected in Visual Basic 6.0 tool. The results is shown in Figure 4.

When distance between bridge deck and river-bed goes beyond level then scour possibility will be there. The results for this condition in Docklight software is shown in Figure 5.

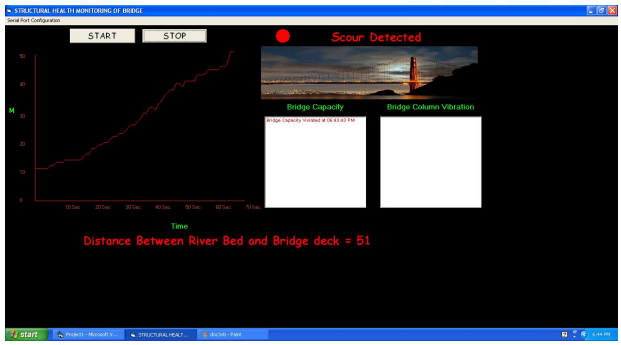

Figure 4: Ultrasonic sensor output when scour is detected

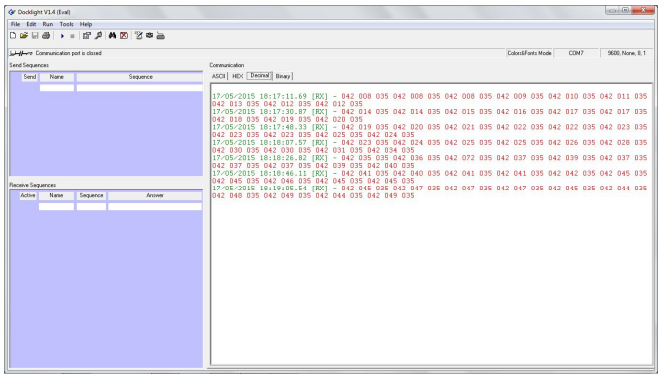

Figure 5: Ultrasonic distance sensor output

The ultrasonic sensor output when there is possibility of scour and also vibration sensor output and piezoelectric sensor output is shown in Figure 6.

Figure 6: Vibration and piezoelectric sensor output

5. CONCLUSION

Bridge health condition monitoring in real time has been popular issue. The sensor technology is continuously advancing and condition monitoring has never been accurate and easier before. With the help of the wireless technology many problems due to data cables and expensive optical cable are now minimized and eliminated. ZigBee is proved to be excellent solution in short distance wireless data communication.

The bridge scour monitoring is absolutely important for prior warning or signs of damage of bridge structure. The main objective of this paper is to ensure the structural health of bridge, its function and reduce the probability of bridge collapse during the scour. No *single* methodology or instrument can be utilized to solve the scour monitoring problems for all situations encountered in the field. Considering the wide range of operating conditions necessary, it is obvious that several instrument systems using different approaches to detecting scour will be required.

In this paper, three kind of bridge monitoring devices are used such as ultrasonic distance sensor, vibration sensor, piezoelectric sensor. The ultrasonic distance sensor is used for scour monitoring of bridge. The vibration sensor is used to detect the pier near vibration and the corresponding output for ultrasonic distance sensor and vibration sensor is displayed in Visual Basic 6.0. The piezoelectric sensor is used to detect the vibration of bridge deck and its output is displayed in Visual basic 6.0. The cost effective zigbee wireless sensor network technology is used. Hence structural health monitoring of bridges is monitored by using this technology.

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