International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Automatic Bridge Health Monitoring System Using Wireless Sensors

Shachi P.[1], Manjunatha S.[2]

[1]New Horizon College of Engineering, Bengaluru, India
[2]New Horizon College of Engineering, Bengaluru, India

Abstract: ***Usage of wireless sensor network is increasing and becoming cost effective nowadays. Many real time applications are using this network system. One such application is monitoring a highway or railway bridges which plays an important role in transportation. Many bridges in world collapse due to some internal and external factors, those factors must be monitored in order to avoid this collapse. This paper proposes automatic bridge monitoring system using wireless sensor networks. The proposed system consists of three sensors to monitor the bridge condition continuously i.e. accelerometer to detect the jerks in the bridge or in pillar, flex sensor to detect the bend or orientation in the bridge, load cell to detect the overload on the bridge. This data from the sensors will be processed by controller and is transferred to the receiver node at the management center using the transmitter node at the transmitter end whenever the fault occurs. RF module is used as a wireless node in our work. At the receiver side raspberry pi is used to monitor the received data which can also store the database in it. Through the GSM an alert message is also sent to the operator about the fault occurred in the bridge. The proposed system can be used efficiently with low cost.***

Keywords: Bridge, Zigbee, Raspberry pi, jerk, bend, overload

1. Introduction

Transportation plays a major role in today's life. In that bridge is one of the important transportation infrastructure for social and economic activities of country which has a long rivers. There are five long rivers in Indonesia where long suspension bridges are used as transportation over those rivers. The construction of such long bridges must be very strong and structural health status monitoring for such bridges is necessary. Bridges faces structural deficiency because of overloading, ageing, bending and many other improper maintenance. There are more than 89000 bridges are there in world, few of them are managed by regional management, few of them are managed by national management, rest of them are long span suspension bridges.

The fact is these bridges are monitored manually for every 5 years by the management system. And few of them are located in remote area where it is difficult to manage. Because of this random inspection for every few years it is difficult to get the bridge status in the required time. Due to lack of continuous monitoring bridge may collapse. In order to overcome this problem it needs a system which monitors the bridge status continuously and gives the proper alert to the operator at correct time.

At present, visual inspections are becoming most common for the structural health monitoring of a bridge [1].These basic techniques have failed to maintain the bridge safety because it's not providing the enough knowledge to avoid bridge collapsing [2].As the wireless sensor networks are evolving now a days, they are becoming cost effective and user friendly. Recent studies have developed wireless sensor nodes and platforms for health monitoring of a bridge [3].Among others, an RFID based wireless sensors are used for energy conservation during bridge monitoring system [4]. Also cable-stayed bridge status monitoring using smart sensor networks and using deployment evaluation techniques are described in [5].Latter system consist of Development of a Prioritization Methodology for reducing data cleansing[6].Also other system was developed which consist of micro-electro mechanical systems, micro controllers, cloud monitoring and fuzzy logic for data analyzing[7].

2. Proposed Method

Automatic bridge monitoring system using wireless sensor network is proposed in order to replace the above mentioned systems. The system collects the data from sensors and the status is collected by the controller and is transferred to wireless node. This data at transmitter node is sent to the receiver node and is analyzed by the raspberry pi. Analyzed data is sent to the management center and an alert message is sent to the operator mobile number. The proposed system consists of three sensors to monitor continuously for the bridge status, a controller to analyze the monitored data and a CC2500 node to transfer the analyzed data to the receiver node at management center. Raspberry pi also placed at receiver side to store the database of bridge status and an appropriate alert is sent to operator with exact location of fault occurred.

The proposed system consists of 3 main functional blocks.

- Sensor Network Location and Wireless Transmission.
- Intermediate Module.
- Management Centre.

A. Sensor Network Location and Wireless Transmission

The wireless transmission system consist of 3 different sensors i.e. Load cell, 3-axis accelerometer, flex sensor which are interfaced with PIC18 microcontroller and the CC-2500 RF module which is again interfaced with controller. This entire setup will be mounted to bridge. Jerks may occur in the bridge due to over speed of vehicle or because of improper construction or it may be any other reason. At this moment the accelerometer will sense the jerks and gives the acceleration values to the PIC controller. In the same way bridge bending may also happen due to structural defects. In this case flex sensor is used to detect the bending. Also because of overload of a vehicle, bridge may lose its stability. So load cell is used to detect the weight of a vehicle.

B. Intermediate Module

TheCC-2500 receiver module will be receiving the continuous data sent by the transmitter module. This received data will be transferred to pi module which is already interfaced with CC-2500 receiver module. Here this pi will monitor or analyses the data and sends an alert to the management center whenever parameters exceeds threshold values. A clear information about the error occurred will be sent to management center by PI through GSM connection. The pi will send a SMS to operator's mobile number of error occurred.

C. Management Centre

The alert with complete error information will be sent by Raspberry pi through GSM. The pop-up will appear on computer screen in management center. It will also send an SMS to operator mobile number.

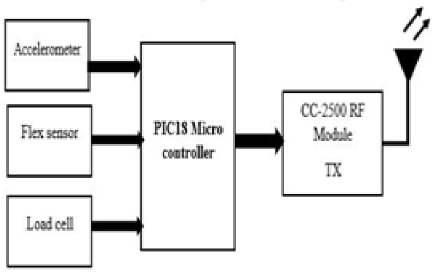

Figure 1: Sensor network and wireless transmission

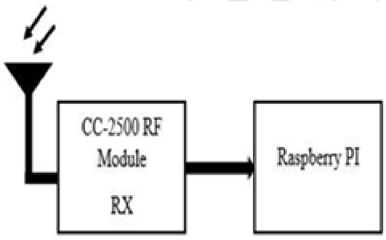

Figure 2: Intermediate Module

I. Hardware Description

A. Sensors

i. Load cell

A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. The various types of load cells include hydraulic load cells, pneumatic load cells and strain gauge load cells.

Figure 3: (a) Load cell

Figure 3: (b) Accelerometer ADXL335

Strain gauge load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. The gauges are mounted in a differential bridge to enhance measurement accuracy. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load.

ii. Accelerometer

An accelerometer is a device that measures proper acceleration; proper acceleration is not the same as coordinate acceleration.

iii. Flex sensor

'Flex Sensor' or 'Bend Sensor' is a sensor that changes its resistance depending on the amount of bend on the sensor. They convert the change in bend into electrical resistance – the more the bend, the more the resistance value. Usually a flex sensor is used in voltage divider configuration. It is shown below:

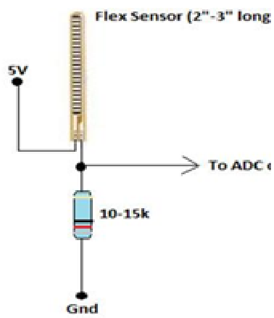

Figure 4: Flex Sensor

B. Raspberry pi

The Raspberry pi is a series of small single-board computers developed in the United Kingdom by the Raspberry pi Foundation to promote the teaching of basic computer science in schools and in developing countries. Several generations of Raspberry pi have been released.

Figure 5: Raspberry pi

C. ATMEGA Microcontroller

The sensors are interfaced to the ATmega328/P microcontroller which detects faults and sensed values to the microcontroller for further decision making. These three values from 3 sensors are given to PIC ADC pins which transfer the data to intermediate module through UART TX pin of controller to the CC22500 RF module.

The Atmel® picoPower® ATmega328/P is a low-power CMOS 8-bit microcontroller based on the AVR® enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328/P achieves throughputs close to 1MIPS per MHz.The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer.

D. Zigbee Transceiver

ZigBee is a low-cost, low-power, wireless mesh network standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications. Low power usage allows longer life with smaller batteries. Mesh networking provides high reliability and more extensive range. ZigBee chip vendors typically sell integrated radios and microcontrollers with between 60 KB and 256 KB flash memory. ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and Australia, 2.5 GHz in India, and 2.4 GHz in most jurisdictions worldwide. Data transmission rates vary from 20 to 900 kilobits/second.

The transmitter unit consists of Tx 433 for transmitting 4bit data through the antenna. The RF transmitter provides an on-off keyed modulation, which can be used to transmit data from any standard CMOS/TTL source up to 1200 baud. The module is very simple to operate; requiring only two connections (see application circuit below). The module is also very efficient, using only 2.3mA which means that it may be driven directly from an encoder I/C or microcontroller.

The receiver receives its input from an antenna, uses electronic filters to separate a wanted radio signal from all other signals picked up by this antenna, amplifies it to a level suitable for further processing, and finally converts through demodulation and decoding the signal. The receiver consists of Rx 433 module. This Receiver Module is Super-Regenerative Version without Decoder using Amplitude Modulation or in other words ON-OFF Keyed Modulation (OOK).

3. Software Description

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

The Arduino/Genuino Uno can be programmed with the (Arduino Software (IDE)). Select "Arduino/Genuino Uno from the Tools > Board menu (according to the microcontroller on your board). The ATmega328 on the Arduino/Genuino Uno comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

Given in figures 6, 7 and 8 are the flowcharts explaining the flow of execution of the program written for the microcontroller.

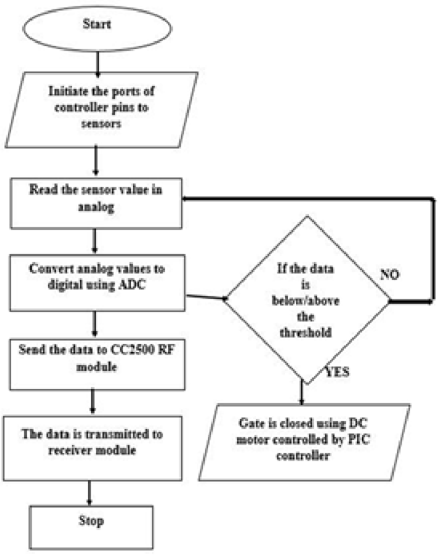

Figure 6: Sensor network location and wireless transmission

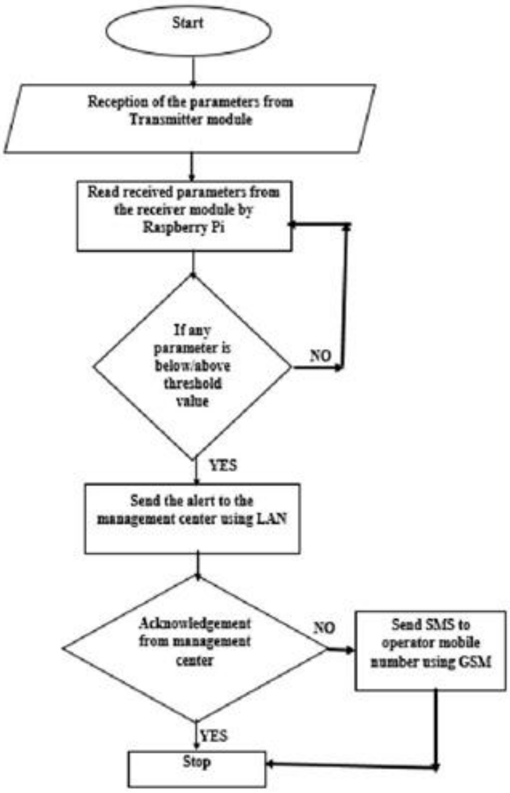

Figure 7: Intermediate module

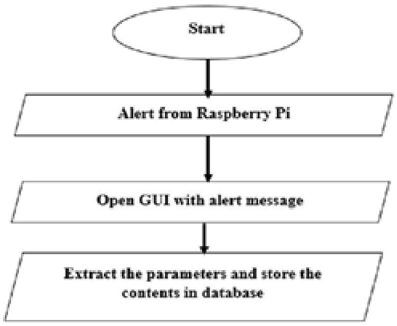

Figure 8: Management center

4. Conclusion

This paper proposed a bridge monitoring system using a wireless sensor network. The system uses a sensor network for data collection and RF transceiver module for communication link between the bridge and management center. The obtained results were matched with acceptable error and that did not change the status of the bridge. The proposed system is low cost and easy to use compared with other similar systems.

References

[1] Jivesh Kumar and Ramansh Bajpai, "Application of Mems in Bridge Structures Health Monitoring," International Journal of Engineering and Innovative Technology (IJEIT), vol. 2, 2012.

[2] Yang Wang, Jerome P Lynch, and Kincho H Law, "A wireless structural health monitoring system with multithreaded sensing devices: design and validation," Structure and Infrastructure Engineering, vol. 3, pp. 103-120, 2007.

[3] Bo Chen and Wenjia Liu, "Mobile agent computing paradigm for building a flexible structural health monitoring sensor network," Computer-Aided Civil and Infrastructure Engineering, vol. 25, pp. 504-516, 2010.

[4] Jerome P. Lynch and Kenneth J. Loh," A Summary Review of Wireless Sensors and Sensor Networks for Structural Health Monitoring," The Shock and Vibration Digest 2006.

[5] Shinae Jang, Hongki Jo, Soojin Cho, Kirill Mechitov, Jennifer A. Rice, Sung-Han Sim, Hyung-Jo Jung, Chung-Bang Yun, Billie F. Spencer, Jr. and Gul Agha," Structural health monitoring of a cable-stayed bridge using smart sensor technology: deployment and evaluation," Smart Structures and Systems, Vol. 6, No. 5-6 (2010) 439-459.

[6] Jonathan Gokey, Nathaniel Klein, and Christopher Mackey," Development of a Prioritization Methodology for Maintaining Virginia's Bridge Infrastructure Systems,"2009.

[7] Amro Al-Radaideh1, A. R. Al-Ali1, Salwa Bheiry2, Sameer Alawnah1," A Wireless Sensor Network Monitoring System for Highway Bridges," 1st International Conference on Electrical and information Technologies ICEIT'2015.

[8] National Bridge Inspection Standard. [Online]: http://www.fhwa.dot.gov/bridge/nbis.htm, 2014.

[9] Whelan, M.J., Gangone, M.V, Janoyan, K.D., and Jha, R. (2009) "Real-Time wireless vibration monitoring for operational modal analysis of an integral abutment highway bridge," Engineering Structures 31(10), 2224-2235.

[10] Vladimir vujovic, Nikola Davidvic, Brankoperisic, "Raspberry pi as internet of things hardware: performances and constraints, "conference paper 2014