International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Real-Time Bridge Health Monitoring System Using Wireless Sensor Network

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Abstract

Wireless sensor networks are becoming the essential part of the sensing, automation and process control systems. The structural health monitoring of aging highway bridges is important from the point of preventing economic losses, catastrophic failures and loss of human life. This paper presents real-time bridge health monitoring system for an urban Seven Hill Bridge in Aurangabad using fixed wireless sensors. The system collects the vibration data caused by seismic waves or external force such as running vehicles through wireless sensor network and then analyze the data.

The system includes a fixed wireless sensor mesh network based on IEEE 802.15.4/ZigBee technology for real-time urban structural health monitoring.

Keywords: Seismic Waves, Wireless Sensor Network, IEEE802.15.4/ZigBee Technology, Structural Health Monitoring.

I. Introduction

sA wireless sensor network (WSN) is a collection of large number of tiny sensor nodes called as motes which are deployed inside or very close to the phenomenon. A linear sensor network is a special type of sensor network which is used in many applications such as monitoring roads, bridges, railway tracks, etc. The ideal wireless sensor is network is scalable, consumes very little power, smart, software programmable, capable of fast data acquisition, reliable, accurate over the long term, costs less to purchase and install.

Recent advances have resulted in the ability to integrate sensors, radio communication, and digital electronics into a single integrated circuit (IC) package. This capability is enabling networks of very low cost sensors that are able to communicate with each other using low power wireless data routing protocols. A wireless sensor network (WSN) generally consists of a base station (or “gateway”) that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection [1].

II. Related Work

As interest in the smart wireless sensors is increasing in the civil, mechanical, and aerospace engineering fields the number of smart wireless sensor platforms has been developed. Straser and Kiremidjian, in 1998 first proposed a design of a low-cost wireless modular monitoring system (WiMMS) for civil structures by integrating a microcontroller with a wireless radio [2]. Then a more powerful wireless modular monitoring system dual-core was designed by Yang Wang, Jerome P. Lynch and Kincho H. Law, in 2001, but the wireless module in this system was high-power consumption; which consumes 750mW when transmitting and 250mW when receiving, and in the topology of star type the transmission distance is very short [3].

Recently, Nagayama and Spencer 2008 have been working on the realization of monitoring and autonomous performance evaluation of full-scale bridges using a network of Imote2s. A new sensor board for Imote2 that is tailored to the requirements of Structural Health Monitoring applications has been designed Rice 2008, and an open-source software library for Structural Health Monitoring applications of Imote2, Illinois Structural Health Monitoring Services Toolkit has been developed with a service oriented architecture to allow easy implementation of Structural Health Monitoring algorithms on smart sensor networks Nagayama 2008 and Rice [4]. Bridges are critical to the national economy and public safety. Built environment of civil infrastructures undergoes gradual deterioration over its life span due to corrosion, fatigue, scour, etc. Thus, periodic monitoring is necessary to provide information of structural health and civil infrastructure [5].

The proposed system presents a real-time bridge health monitoring system for an urban Seven Hill Bridge in Aurangabad using fixed wireless sensor. The aim of this system is to get continuous real time vibration data from Seven Hill Bridge using wireless accelerometer sensor, and monitor it using .NET framework. The technology advances in wireless communication networks make it possible to implement a low cost, fast, and reliable wireless sensor in bridge monitoring.

Section I includes an introduction of real time bridge monitoring system and wireless sensor network. Section II describes the related work of Wireless Sensor Network. Section III describes proposed system and its basic operation. Section IV explains laboratory test results of real-time vibration data of Seven Hill Bridge, Aurangabad along with its GUI. Section V summarizes the results along with conclusions.

III. Proposed System Design

The proposed Real-time Seven Hill Bridge Monitoring System Based on Zigbee Technology is useful for obtaining and monitoring real-time vibration data continuously. The entire real-time bridge monitoring system is battery operated. The accelerometer sensor is deployed at girders of seven Hill Bridge under permission of Maharashtra State Road Development Corporation (MSRDC), Aurangabad. The obtained data is useful for civil engineers to make further diagnosis of bridge; if incase of vibrations exceed above certain limit.

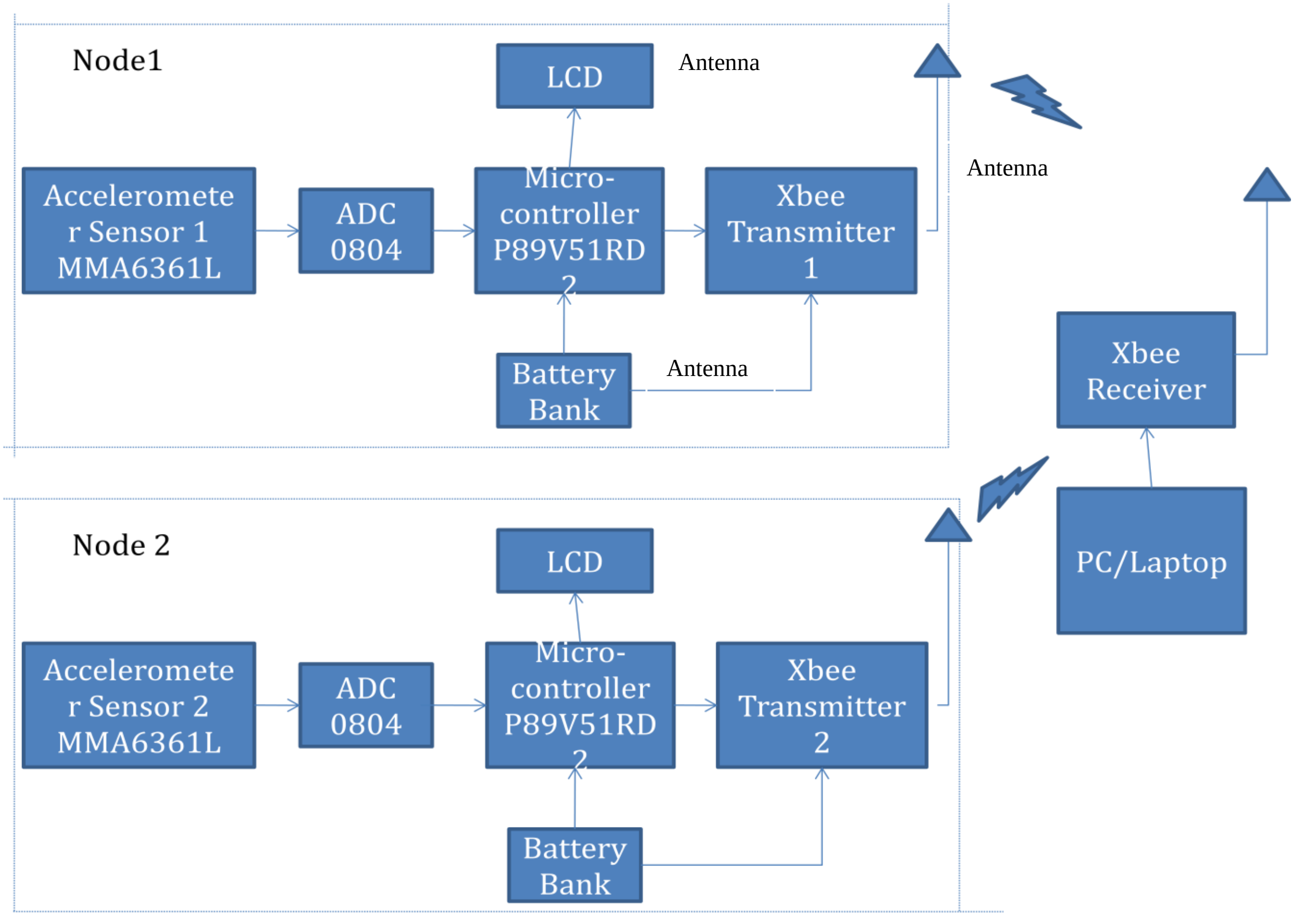


Figure 1: Block Diagram of Microcontroller based Real time Bridge Monitoring System

Bridge monitoring system has three main parts; sensor technology, signal conditioning, and wireless network module: sensor used is accelerometer sensor module, signal conditioning is done using A to D Converter, radio frequency Module Xbee is used as a wireless communication module. While second part consists of RF module is directly connected to PC via serial cable.

A. Basic Operation

Accelerometer Sensor MMA6361L is capacitive micro machined accelerometer sensor with built-in signal conditioning. It is used to convert the physical quantity vibration into voltage. Analog-to-digital converter ADC0804 is 8-bit parallel Analog to digital converter. The analog signals from accelerometer sensor are converted into digital numbers so that micro-controller can read and process them. Micro-controller P89V51RD2 is 8-bit microcontroller. This is an electronic circuit which has the intelligent feature to sense the vibrations and transfer it serially to Zigbee as well as LCD. LCD displays digital vibration data obtained from accelerometer sensor, whereas Zigbee Transceiver is RF module that meet IEEE 802.15.4 standard operate within 2.4GHz frequency band and is used to transmit as well as receive data wirelessly. The data from Xbee Receiver is transferred serially to PC/Laptop. PC then manipulates the packet and displays waveform in the form of GUI using .NET framework.

IV. Laboratory Testing Results

The system was placed on the bridge for real-time monitoring and the results were observed on the Laptop in the form of GUI. It is observed that maximum vibration is up to 27Hz; this indicate that bridge is intact and there exist no corrosion.

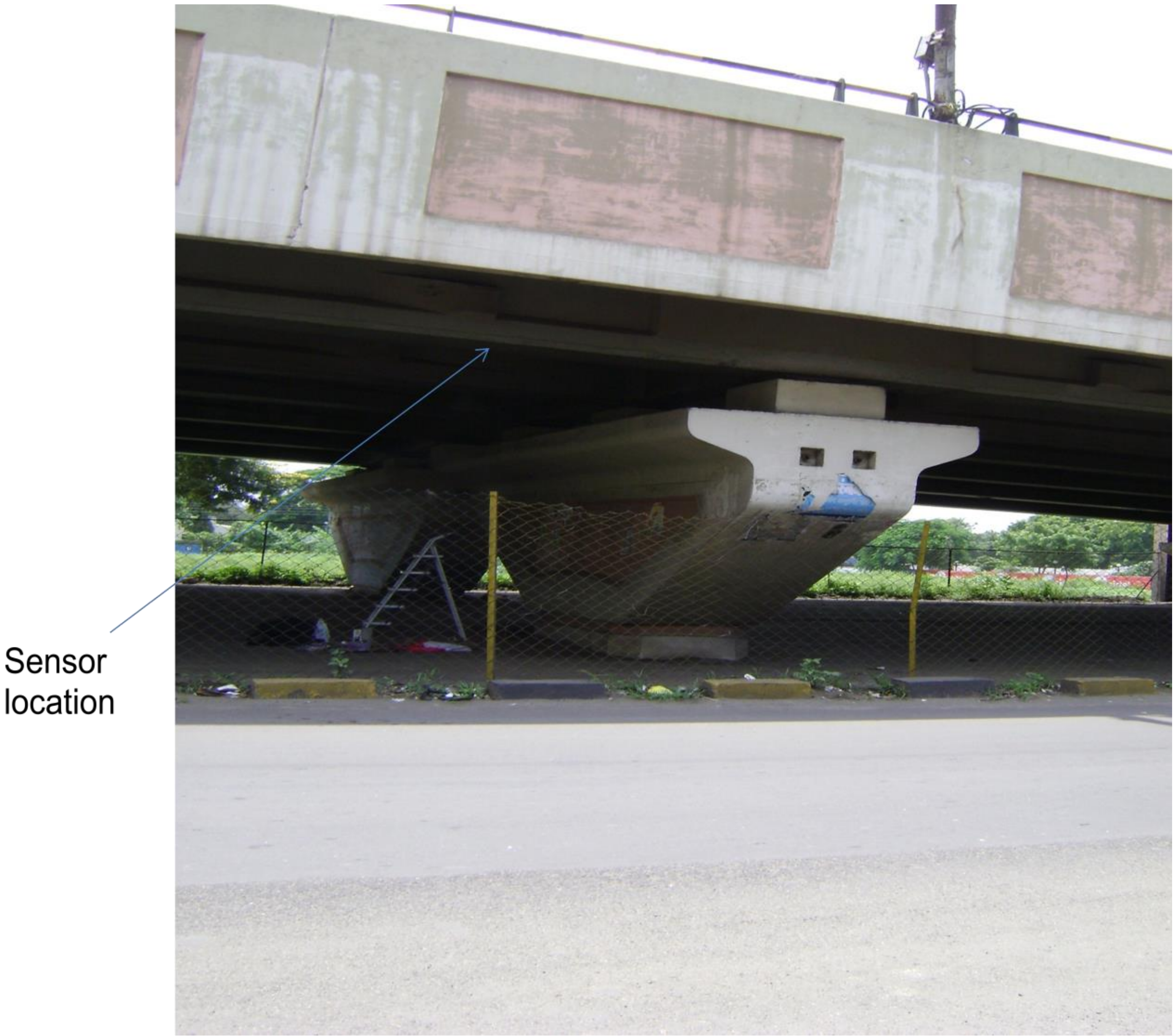


Figure 2: Sensor location on Seven Hill bridge

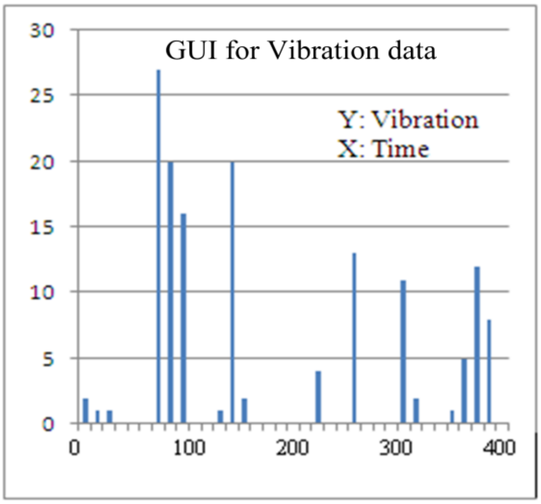
(i) **Vibration data of Seven Hill Bridge, Aurangabad Day 1 – 03/09/2011, Time- 11-12p.m**

Table 1: Vibration data on Day 1 between 11-12p.m

Vibration (Hz)	Buses/Trucks	Cars/Three-wheelers	Mopeds
2	-	-	✓
1	-	-	✓
1	-	-	✓
0	-	-	-
0	-	-	-
0	-	-	-
27	✓	-	-
20	✓	-	-
16	✓	-	-

0	-	-	-
0	-	-	-
1	-	-	✓
20	✓	-	-
2	-	-	✓
0	-	-	-
0	-	-	-
0	-	-	-
0	-	-	-
0	-	-	-
4	-	-	✓
0	-	-	-
0	-	-	-
13	✓	-	-
0	-	-	-
0	-	-	-
0	-	-	-
11	✓	-	-
2	-	-	✓
0	-	-	-
0	-	-	-
1	-	-	✓
5	-	✓	-
12	✓	-	-
8	-	✓	-
0	-	-	-

(ii) GUI- Day1 on 03/09/2011, Time- 11-12p.m



Graph 1: GUI for Vibration data on Day 1 between 11-12p.m

V. Conclusions

Two-day data at different time intervals are shown in the form of GUI. Thus, from the results obtained: hammering test, visual check, and section test by a concrete core in the structure can be performed. But, since maximum vibrations obtained due to running vehicles is 27Hz; hence it is concluded by civil engineers that currently the bridge is intact and free from corrosion. Thus, diagnosis technology is developed to understand the phenomena like deterioration and corrosion of a bridge through the measurement result. So the diagnosis system can evaluate health condition and conduct a comprehensive deliberation on repair and reinforcement work on the basis of measurement data.
The wireless communication protocol IEEE802.15.4/Zigbee used in this project uses the channel contention mechanism of data transfers i.e. CSMA/CA so that even if both the sensors transmit vibration data simultaneously yet collision will be avoided.

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