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Conference Paper

Monitoring and Maintenance of Highway Bridges Using Wireless Sensor Networks

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Usage of wireless sensor network increasing and becoming cost effective now days. Many real-time applications using this network system. One of the example for 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 (PIC18) and is transferred to the receiver node at the management center using the transmitter node at the transmitter end whenever the fault occurred. CC2500 module is used as a wireless node in this paper. 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 along with the exact location where fault occurred in bridge. The proposed system can be used efficiently with low cost.

Keywords: Accelerometer, flex sensor, load cell, wireless sensor node, alert system using raspberry pi.

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 river. There are five long rivers in Indonesia where a 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 maintenances. 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 need 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 (Jivesh Kumar and Ramansh Bajpai, 2012). These basic techniques are failed to get the bridge safety because it's not providing the enough knowledge to avoid bridge collapsing (Yang Wang et al., 2007). As the wireless sensor networks are evolving now a day, they are becoming cost effective and user friendly. Recent studies were developed wireless sensor nodes and platforms for health monitoring of a bridge (Bo Chen and Wenjia Liu, 2010). Among others, used an RFID based wireless sensors for energy

conservation during bridge monitoring system (Jerome P. Lynch and Kenneth J. Loh, 2006). Also, cable-stayed bridge status monitoring using smart sensor networks and using deployment evaluation techniques are described in (Shinae Jang et al., 2005). Latter system consists of Development of a Prioritization Methodology for reducing data cleansing (Jonathan Gokey et al., 2009). Also, other system was developed which consist of micro-electro mechanical systems, micro controllers, cloud monitoring and fuzzy logic for data analyzing (Amro Al-Radaideh et al., 2015).

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 PIC18 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.

SYSTEM BUILDING BLOCKS

To design the wireless bridge monitoring system, it should use cost effective components. The proposed system consists of 3 main functional blocks.

a) Sensor Network Location and Wireless Transmission.
b) Intermediate Module.
c) Management Centre.

TABLE1: SELECTED HARDWARE COMPONENTS

Requirements	Model name	Descriptions
Microcontroller	PIC18	Microchips PIC18 40-pin Controller.
RF module	CC-2500	2.4GHz RF Transceiver Module for communication link between WSN.
3-axis Accelerometer	MS3A001	Structures acceleration in 3-axis Measurements.
Flex sensor	Spectra symbol 00216	For sensing the bending in a Bridge.
Load cell	Model: CZL601	Overload detection
Others	Raspberry pi External power	For alert system 5V Power supply

A. Sensor Network Location and Wireless Transmission.

The wireless transmission system consists 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.

Whenever jerks occur in 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. These three values from 3 sensors are given to PIC ADC pins and transfers the data to intermediate module through UART TX pin of controller to the cc22500 RF module.

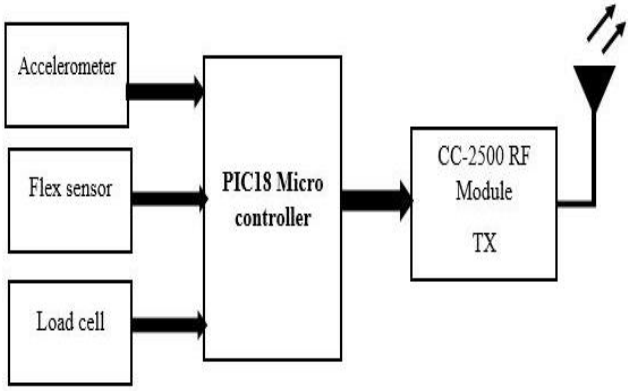


Fig 1: Sensor network and wireless transmission

B. Intermediate Module

CC-2500 receiver module which will be receiving the continuous data sent by 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 LAN connection. In case operator is not present at management center after few time pi will send a SMS to operator's mobile number along with location of error occurred.

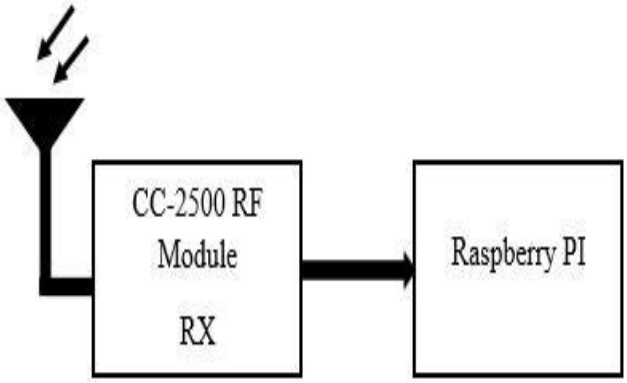


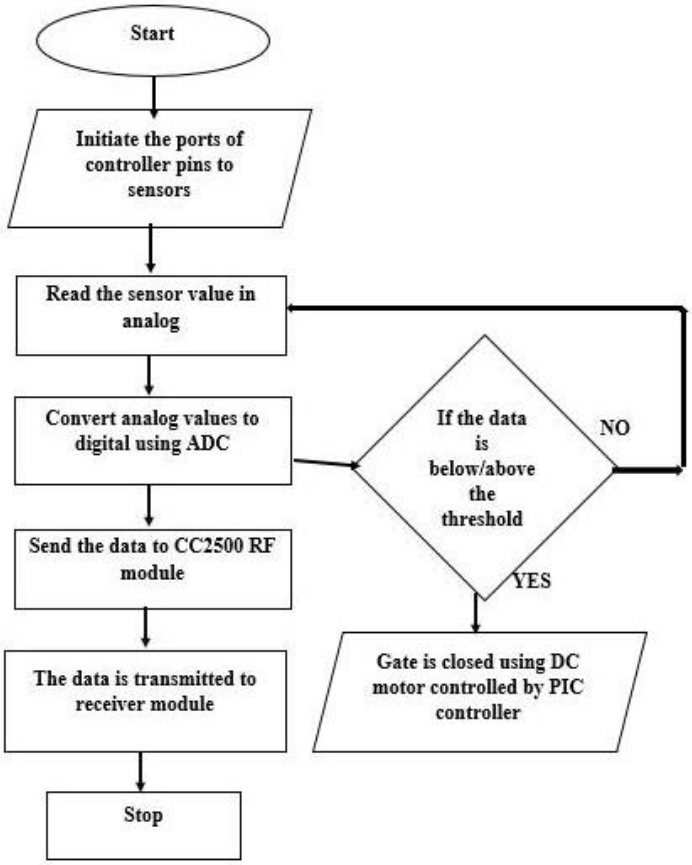
Fig 2: Intermediate Module

C. **Management Centre.**

The alert with complete error information will be sent by Raspberry pi through LAN. The pop-up will appear on computer screen in management center. Until operator clicks OK button in pop-up, intermediate center won't get any acknowledgement from management center and it send an SMS to operator mobile number.

FLOW CHART

The Sensor network location and wireless transmission



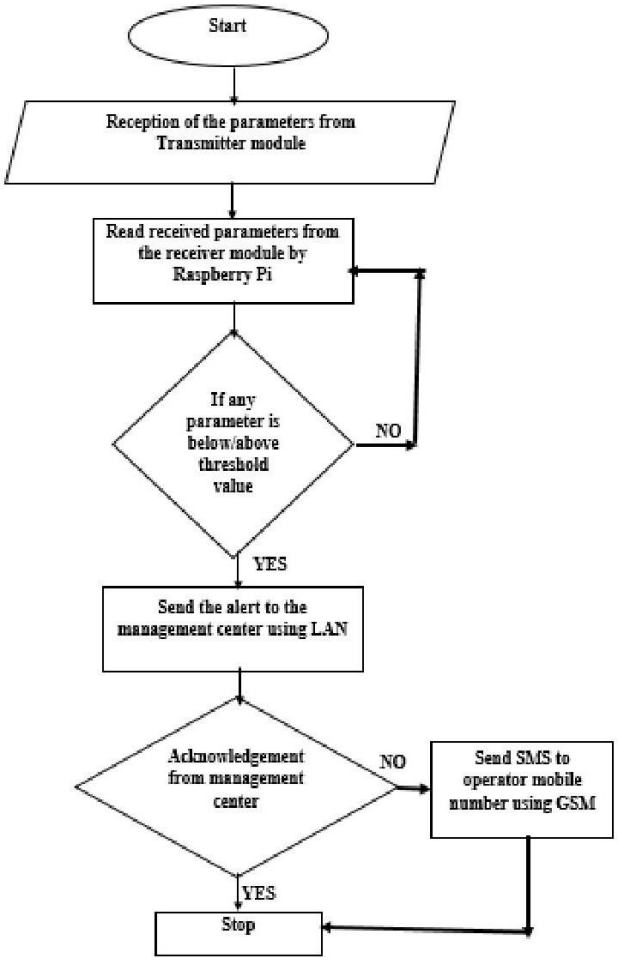
When model is powered up, sensor values are sent to ADC pins of PIC controller. DC converts analog values of sensor to digital and sends to CC2500 RF module through UART TX pin of controller. When data exceeds the threshold values the gate will be closed in either side of the bridge in order to stop the vehicles.

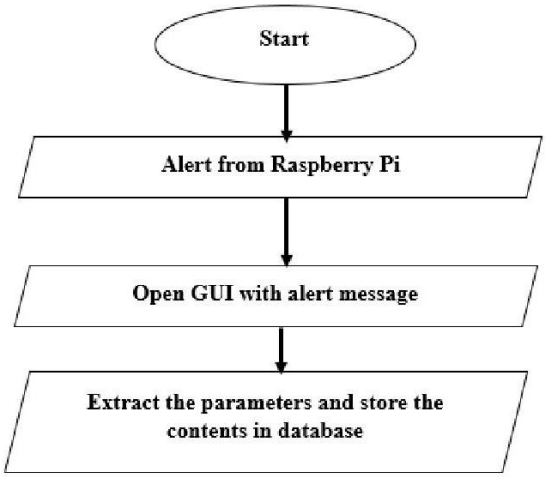
B. Intermediate module

CC2500 receiver gets the data from transmitter and gives the same values to raspberry pi. Whenever parameter exceeds threshold values it sends an alert to the management center using LAN connection. Once the operator receives and opens the alert pop-up, it sends back an acknowledgement to intermediate module. In the case of no acknowledgement pi send an SMS to operator mobile number using GSM.

C. Management center

Receives alert with all the details of fault and location of fault. Sends back an acknowledgement when operator open alert message and content will be stored in database.





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.

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