Department of Industrial Technology

Wireless Sensor Networks for Infrastructure Monitoring

Tech transfer summary

A wireless sensor network was implemented in a secondary road bridge to monitor bridge stresses. The application of wireless sensor networks in infrastructure monitoring is feasible and effective.

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RESEARCH PROJECT TITLE
Wireless Sensor Networks for Infrastructure monitoring

SPONSORS
Iowa Highway Research Board
The Iowa Department of Transportation
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OBJECTIVES

The goals of this project were to evaluate the technical feasibility and cost efficiency of wireless sensor networks for transportation infrastructure monitoring.

A wireless sensor network was implemented in a secondary road bridge to monitor the structural health of the bridge. Based on the field test experience, the suitability and scalability of these technologies for practical deployment in other bridges were studied. The major activities include: 1) Investigate sensor and data acquisition technologies salient to the physical quantities to be monitored and select likely technologies for field implementation; 2) Establish the needed characteristics of mobile computers and wireless communication adapters and based on these characteristics select a best fit; 3) Deploy a prototype test-bed unit in the field; 4) Acquire data and observations from this unit under a variety of conditions.

PROBLEM STATEMENT

According to the data from Federal Highway Administration, over 26.9% of all bridges are deficient in the State of Iowa, including 5153 bridges that are structurally deficient and 1320 bridges that are functionally obsolete in 2009. Traditionally infrastructure inspection is performed via infrequent periodic visual inspection in the field. Most mandated bridge inspections are conducted by state workers who visually examine structures or perform hands-on tests. This traditional way of infrastructure inspection may not be efficient due to limited inspection time, infrequent visit, and human mistakes. Improved inspection and monitoring methods are critical to prevent the loss of human lives and property due to accidents.

There has been a growing interest in applying sensing

technology to infrastructure monitoring. Systems have been deployed to monitor the bridge structure using wired FBG sensors, data acquisition card and PC on the site. The major disadvantage of a wired structure health monitoring (SHM) system is that the cables have to run all over the bridge, which not only makes the installation of the system expensive and very time-consuming, but also increase the system failure probability due to cable bending or failures.

Wireless sensor networks have drawn great attention recently because of its advantages and numerous potential applications. Networking the sensors wirelessly to empower them with the ability to coordinate on a larger sensing task can greatly improve the infrastructure monitoring. Along with the recent advances in novel sensor technology, low-cost infrastructure monitoring has become possible. We expect that integrating such systems for the development of intelligent transportation system will help to improve driving safety effectively.

RESEARCH DESCRIPTION

A prototype test bed was implemented in the field to evaluate the technologies of wireless sensor networks in Iowa's environment. At the core of the system is a low-cost, low power wireless strain sensor nodes whose hardware design are optimized for structural monitoring applications. The key components of the systems are the control unit, sensors, software and communication capability. The extensive information developed for each of these areas has been used to design the system. Wireless sensor nodes used in the experiments are shown in Figure 1.

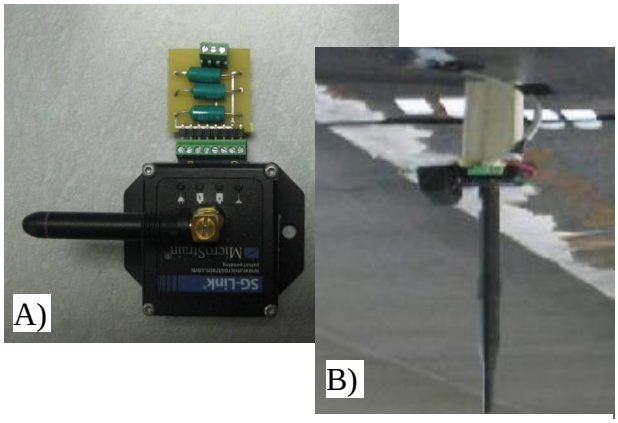

Figure 1 A) a wireless sensor node (Size: 2.3″× 2″×1″) B) node installed on the I-Beam under a bridge on Ansborough Avenue, Blackhawk County, IA

Energy efficiency is critical for practical deployment. Various scenarios were tested to obtain the power consumption results. Our results indicated that a pair of the Lithium AA batteries could last from 6 months to more than 1 year for low duty cycle with sample rate less than 1 Hz. When the sample rate is high (for example 125 Hz for strain gages), nodes must turn on all the time and the lifetime is very limited.

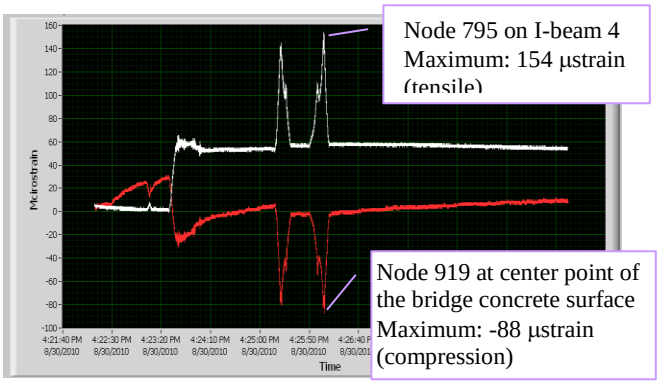

Figure 2 strain results on I-beam and concrete for one load test

The performance and reliability of the proposed wireless monitoring system is validated on a 34 feet span composite beam in slab bridge in Black Hawk County, Iowa. LabVIEW program was developed to provide easy configuration and user interface. Some test results are shown in figure 2.

OUTCOMES

- Implemented the first wireless sensor network system for bridge monitoring in Iowa and useful first hand experience has been gained.
- Investigated the energy efficiency of the wireless sensor nodes
- Identified the limitations of the system and future research directions to address the issues

RECOMMENDATIONS

- Wireless sensor networks are more suitable for low sample rate sensor such as vibrating wire gages to minimize the energy consumption and achieve long lifetime.
- Small scale energy harvesting from ambient environment based on vibration, strain, and thermal energy is the next step to implement the self-sustainable system for the long term remote monitoring.