Ubiquitous Sensor Network for Hazard Mitigation

Narito KURATA, Kajima Corporation, K1 Building, 6-5-30, Akasaka, Minato-ku, Tokyo
B. F. SPENCER, Jr., University of Illinois at Urbana-Champaign
Manuel RUIZ-SANDOVAL, Universidad Autonoma Metropolitana-Azcapotzalco

The vision of “Ubiquitous Sensing and Computing” is a new Information Technology Paradigm that is expected to come to fruition in the next ten years, substantially impacting civil engineering society. In this paper, risk monitoring of buildings for natural and man-made hazards mitigation using the Ubiquitous sensor network “Berkeley Mote” is discussed. Performance of the Mote is investigated through shaking table tests of a two story steel structure. The feasibility of risk monitoring for buildings by using the multi-hop routing network is also discussed.

Key Words: Ubiquitous Computing, Wireless Sensor Network, Risk Monitoring, Hazard Mitigation, Structural Health Monitoring

1. Introduction

An application of a smart, network-enabled, wireless sensor based on the Berkeley Mote platform to the next generation of structural health monitoring and control was proposed. In this paper, the performance of the MICA2 Mote as a wireless sensing tool for risk monitoring in buildings is tested.

2. Risk Monitoring and Hazard Mitigation

Buildings are subjected to natural hazards such as severe earthquakes and strong winds, as well as man-made hazards such as fire, crime, and terrorism. To mitigate these hazards, monitoring various risks in a building employing a “Ubiquitous” sensor network is necessary. The ubiquitous sensor network could measure acceleration, displacement, strain, etc. The risk to buildings includes degraded structural performance, fatigue, damage, gas leaks, intrusions, fires, etc. According to the risk monitoring results, appropriate risk control measures (e.g., structural control, maintenance, evacuation guidance, warnings, alarms, fire fighting, rescue, security measures, etc.) can be applied (see Fig. 1).

3. Wireless Sensor Network MICA2 Mote

The Mote has been developed by research group at the University of California at Berkeley. It is an open hardware and software platform for smart sensing. The MICA2 is the latest version of the Mote (see Photo. 1) and consists of ATmega 128L processor, 315/433/868/916 MHz transceiver, TinyOS (TOS), plug-in sensor boards and attached AA battery pack. TOS is a distributed, open-source operating system and includes radio messaging, message hopping from Mote to Mote, low-power modes, sensor measurements and signal processing. An MTS310 Sensor Board, which was used in this research, has acceleration, magnetic, light, temperature, and acoustic sensors, as well as a sounder (see Photo. 1). Other sensor boards can be designed and manufactured freely for specific purposes. For example, the “Tadeo sensor board” which is equipped with a high-sensitivity acceleration sensor has developed and tested for civil engineering applications.

Figure 1. Building risk monitoring and hazard mitigation.

(a) MICA2 Mote
(b) MTS310 Sensor Board.

Photograph 1. MICA2 Mote and MTS310.
4. Performance Test

Application software developed by the Open Systems Laboratory, the University of Illinois at Urbana-Champaign, was installed on the MICA2. It runs on the TinyOS version 1.0 and has a re-try function for sending the information to the base station from each MICA2 by ad hoc and multi-hop communication. Shaking table tests were conducted to investigate the performance of ad hoc network monitoring of the MICA2. Photo 2 shows the two story test structure considered with elasto-plastic beams and columns. The columns and beams are made with aluminum for columns and beams. The MICA2 and a reference accelerometer were attached to the top and base of the test structure B as shown in Photo 2.

The input excitation was the JMA-Kobe (NS) earthquake. Fig. 2 shows the measured accelerations for the test structure using both the reference accelerometer and the MICA2 for the case of an input peak acceleration of 371 cm/sec^2. Accelerations from the MICA2 sensor units were sent wirelessly to the base station which was attached to the notebook PC. Maximum rate of data loss was 30 percent in previous experiment using the MICA and “oscilloscope” software of TinyOS version 0.6. However, only 0.5 percent of data were lost during the test because of the retry function used for the wireless communication. Accelerations measured by the MICA2 at the top and base of the test structure agree with results by reference accelerometer. The accuracy of the measurements using the MICA2 was also recognized.
Damage detection tests for test structure were carried out using the shaking table. The peak value of the input acceleration was 428 cm/sec². Photo. 3 and Fig. 3 show the damage process for the test structure, and the measured top-floor acceleration and strain in the columns, respectively. The first story collapsed at stage 2 and 3 of the process; subsequently the second story collapsed at stage 4, as shown in Photo. 3. Comparing measured results between the reference accelerometer and the MICA2, the MICA2 was able to measure the response of the structure with only 0.5 percent data loss and detected its damage wirelessly. The information about such large acceleration response can be used as an indication of damage in the actual building, and evacuation guidance control in large earthquakes.

5. Conclusion

The feasibility of risk monitoring for buildings using a ubiquitous sensor network was discussed, and the performance of the MICA2 Mote as wireless acceleration sensors was tested. The results showed the MICA2 has a promising future as an effective tool for risk monitoring in buildings. Further research on more effective modes of real time communication that facilitate no data loss is needed to achieve a ubiquitous sensor network for building risk monitoring.

Acknowledgement

The authors would like to express their gratitude to Prof. G. Agha and Mr. K. Mechitov of the Open Systems Laboratory, the University of Illinois at Urbana-Champaign, for development of the communication software for the MICA2. The authors would like to express their gratitude to Dr. Y. Miyamoto, Dr. Y. Sako, and Mr. T. Watanabe of Kajima Corporation for implementing the shaking table tests. The authors gratefully acknowledge the partial support of this research by the CUREE-Kajima Joint Research Program V.

References