

BRIDGE CONDITION MONITORING SYSTEM USING WIRELESS NETWORK (CDMA AND ZIGBEE)

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Abstract: Advancements in sensor technology have brought the automated real-time bridge health monitoring system. Many long span bridges in Korea and in Japan have adopted this real-time health monitoring system. However, current system uses complicated and high cost wired network amongst sensors in the bridge and high cost optical cable between the bridge and the management center, which increases the overall cost of installation and maintenance cost of health monitoring system. The complicated wiring also makes the installation and repair/replacement process difficult and expensive. In this paper, a new idea of bridge health monitoring system is suggested. For short distance (among sensors in the bridge) ZigBee wireless network is tested, and CDMA for long distance (between the bridge and the management center) data communication is tested.

Keywords: Bridge Health Monitoring, USN, ZigBee, Wireless Sensor Network

1. INTRODUCTION

Akashi Kaikyo Bridge is not only famous for world longest suspension bridge but also for its advanced health monitoring system. It has a technology called MBM (Monitoring Based Maintenance) that enables the bridge maintenance engineers monitor the condition of the bridge in real time [1]. The sensors installed on main cables, hangers, decks, towers, etc. detect the strain, acceleration, temperature and wind. The sensory inputs are process to represent the condition of the bridge against seismic loads and wind loads. Like Akashi Kaikyo Bridge, there are many bridges that have real time monitoring system in Korea [2]. Sensor technologies have made the monitoring process more accurate and fast.

However, regardless the advancements of the sensor and sensor data processing technologies, there is one thing that has not been changed: data communication is through wires and optical cables [3]. The advancement in wireless technology has provided motives to the authors to develop the wireless network based bridge health monitoring system.

In this research, sensor devices such as accelerometer and strain gauge and ZigBee module are combined becoming u-node where "u" stands for ubiquitous. ZigBee sensor network is designed and tested for wireless communication among sensors. CDMA technology is suggested to send the data to the remote location in which the maintenance office is located.

2. PROBLEMS OF WIRED DATA COMMUNICATION

The current bridge health monitoring system uses cables for data communication. The installation of data cables is a cumbersome job and it often causes the cost increase in sensor installation, maintenance, and repair. The cable based

sensor has many difficulties that might be minimized or eliminated if wireless sensor is used. They are (1) installation cost of communication and power supply cables of the sensors is very high; (2) installation of steel pipelines that protect those cables is also difficult; (3) temperature changes on cables cause sensor data distortions; (4) hard-to-eliminate noises occur at connections between sensors and cables; and (5) it is hard to identify the defects of sensors and cables and difficult to replace and/or repair them.

In this paper, the wireless solution that overcomes these problems is presented. The wireless sensors have the following advantages: (1) the installation cost is low because the sensors do not require wiring; (2) no additional supporting structure such as pipeline for cable is required; (3) sensors are easily replaced when malfunctioning; (4) by using Ad-Hoc and Multi-Hop, re-organizing sensor network is relatively easy. In this research paper, CDMA (Code Division Multiple Access) infrastructure provided by SKTelecom of Korea for long distance communication between sensors and server systems is used, and ZigBee for short distance is used.

3. DESIGN OF SENSOR NETWORK SYSTEM

3.1 Development of u-node (Sensor + ZigBee module)

The output data from the sensors are in a form of voltage, or resistance, or pulse depending on the type of sensors. The sensory outputs are analog data which needs to be converted into digital form. An A/D converter for each type of sensor is developed in this research work. Thus, the A/D converter reads analog data from the sensor and deliver the data to the ZigBee module which sends the data to other the

ZigBee modules wirelessly. A sensor module with the A/D converter and ZigBee module is called u-node in this paper (Fig. 1.) The u-node is powered by battery and solar cell to operate and hard cased for water resistance.

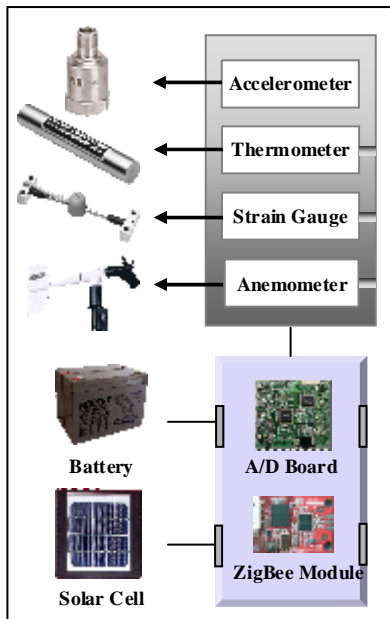


Figure 1. The u-node: Sensor + A/D Converter + ZigBee Module + Battery

3.2 Development of USN (Ubiquitous Sensor Network)

The term USN (or wireless sensor network) is a combination of the wireless communication network and sensor technology. Sensors and network modules are combined into one unit, which often called ubiquitous sensor, and communication network delivers sensor data wirelessly. RFID (Radio Frequency Identification) system is one example of USN.

ZigBee, a standard wireless communication format of IEEE802.15.4 is recently developed and gaining popularity for its flexibility. ZigBee has many advantages over Bluetooth enabling the true idea of USN. Unlike Bluetooth, ZigBee sends and receives data from and to other ZigBee units. Data can be hopped over ZigBee units to reach the server. This feature of ZigBee makes the true USN environment. ZigBee works well in short distance (10 to 20 m) data transfer and with the help of amplifier it sends data further than 1km.

In bridge health monitoring system, sensors and ZigBee modules are combined to be ubiquitous-node (u-node,) which are installed on the members of bridges and sends data to the u-gateway (ubiquitous gateway) that sends data to the management center wirelessly over CDMA technology.

3.3 Design and Development of Test Bed

The authors have chosen Yong-Jong Bridge in Korea for the test bed development. Yong-Jong Bridge is a suspension bridge with the 550 meters of suspension bridge area. It is a double deck bridge: upper deck is for cars and trucks, and

lower deck is for subway train. Yong-Jong Bridge has more than 300 dynamic and static sensors installed and currently operated. The data from the sensors are being transferred over communication cables in the bridge and optical cable from the bridge to the bridge management center.

The authors have done thorough research to determine the optimum number of the dynamic sensors to be installed that optimizes the bridge health monitoring. The optimum number of sensors and locations has been found to test the wireless network and bridge health monitoring. Based on the currently installed sensors on Yong-Jong Bridge, total 66 locations were carefully selected for four types of sensors shown in Figure 1. The sensor locations in the bridge are shown in Figure 2.

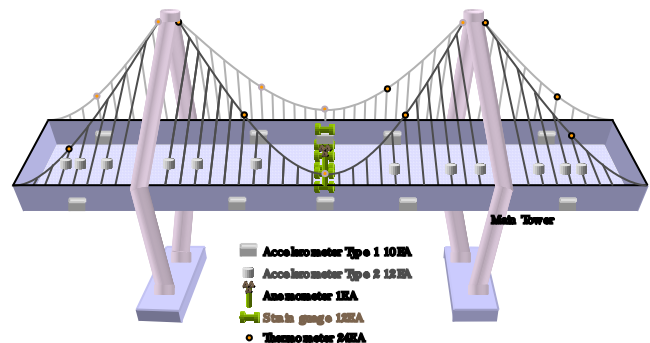


Figure 2. Sensor network locations

3.4 Mesh and Star-Type of Network

Two kinds of sensors are used in bridge condition monitoring. Static sensors send data less than one packet in a second. If a sensor sends more than 30 data packets in a second, it is called a dynamic sensor. There are static and dynamic sensors installed on Yong-Jong Bridge. Dynamic sensors are accelerometers and strain gauges while static sensors are anemometers and thermometers. Depending on the type of sensors star-type ZigBee network, and mesh-type network are used.

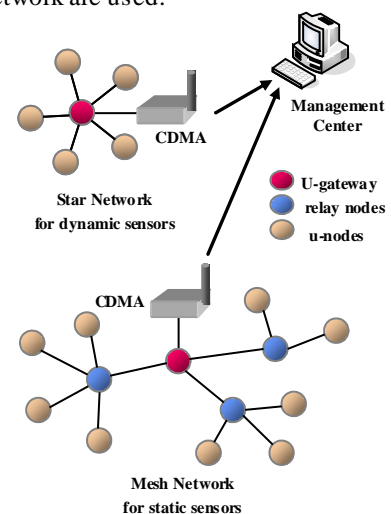


Figure 3. Two types of sensor network

Due to the data transferring capacity, mesh-type ZigBee sensor network is not appropriate for dynamic sensors that produce 100 packets per seconds. For dynamic sensors, star-type network is used the u-gateway connects 8 to 12 ZigBee modules directly. U-gateway collects ZigBee data and send to the management center over CDMA (Fig. 3.)

4. SUMMARY AND CONCLUSIONS

Bridge health condition monitoring in real time has been popular issue. The sensor technology is continuously advancing and condition monitoring has never been accurate and easier before. With the help of the wireless technology many problems due to data cables and expensive optical cable are now minimized and eliminated. Sensor and ZigBee module combined becomes u-node (ubiquitous node). ZigBee is proved to be excellent solution in short distance wireless data communication. For long distance data transferring CDMA which is a mobile phone carrier network in Korea is used instead of optical cable which is expensive in installation and maintenance. The Yong-Jong Bridge used as the test bed is an excellent example to validate the USN technology for bridge health monitoring system because it has already working wire-based sensors. The authors were able to compare the sensor outputs from wired and wireless sensors.

The USN technology presented in this paper covers bridge health monitoring system only. However, there are limitless applications of USN. It is expected to see hundreds of USN application technologies in civil engineering area in near future.

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REFERENCES

- [1] Sumitro, S., Matsui, Y., Kono, M., Okamoto, T., and Fuji, K. (2001), "Long Span Bridge Health Monitoring System in Japan," Health Monitoring and Management of Civil Infrastructure Systems, Proceedings of SPIE, vol 4337, pp. 517-524.
- [2] Park, M. S., Kim, S. G (2000). "Integration of Bridge Condition Monitoring System," KSCE Conference proceeding, KSCE, pp. 503-506.
- [3] Park, C. M., Park, J. C. (2003) "Seo-Hae Cable Stayed Bridge Behavior Analysis Using Sensor Data," KSCE Conference proceeding, KSCE, pp. 571-576.