ZigBee Wireless Sensor Network for Surface Drainage Monitoring and Flood Prediction

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***Abstract* – A Wireless Sensor Network (WSN) based on the ZigBee is proposed and implemented for the water level detection based on the range scanning using ultrasonic sensor and aim to provide flood prediction. The built sensor nodes reports < 0.52% average error for the distance test within 0.20m to 4.00m. All prototype sensor nodes in this work are powered up by a single standard 3.70V battery and least for operation of ~100 days. Such water level detection capability enables the application of surface drainage monitor and flood detection with simple data analysis approaches. An experiment is setup with variable flow-in water and drainage simultaneously to verify performance of water level detection and demonstrate the flood prediction capability.**

***Index Terms* — ZigBee, WSN, Environmental Monitoring.**

I. Introduction

Benefit from the advance and low cost wireless transceiver in the modern wireless technology, the wireless operation capability of the Wireless Sensor Network (WSN) makes it has higher flexibility, lower operation cost and robustness over the traditional wired counterpart and thus environmental physical parameter can be effectively collected and monitored. [1] Therefore, WSN plays an important role for the remote data sensing, environmental data collections, etc. It is adapted in large numbers of applications for various field sections including civil and environmental engineering, health monitoring, military, security, smart grid [2], transportation [3], etc. Recently, along the research and development of the Internet of Things (IoT), WSNs are considered as one of the effective enabling technologies due to its rich functions of data collection and actuation while the RFID technology is focusing for the low-end object identification and tracking [4].

In the recently years, due to the extreme climates conditions, frequent cloudburst is happened in higher possibility and exceed the design capability of the surface drainage system and probability of the flood in different geographical areas are increased. Hence the surface drainage monitoring and flood detection is concerned by most of the cities and urban areas. In this paper, a WSN architecture based on the ZigBee and WCDMA technologies is proposed and practically implemented for the above objectives.

In section II, the WSN architecture will be described together with sensor nodes design. In section III, an experiment is setup to simulate the surface drainage environment so as to evaluate the sensor nodes and ZigBee network operation. Experimentally results of water level detection, flood prediction will be discussed based on simple data analysis approach. Finally, the conclusions will be drawn in last section.

II. System Architecture of Proposed ZigBee WSN

Fig. 1 shows the system architecture of the proposed WSN, the network mainly consists of ZigBee [5] sensors nodes, network coordinator, and Cloud data storage. In order to visualize the data and analysis results, a remote GUI is developed as well. Based on the proposed system architecture, sensor nodes response to sample the physical parameter to measurable voltage level through corresponding sensors; then ZigBee module digitalizes and codes the voltage level to network data; sent these acquired data to the coordinator through the established wireless links. Coordinator is focusing to network topology maintenance, collect data, and upload the reassemble data to the Cloud data storage using WCDMA transceiver through mobile Internet. Open WSN Cloud data storage platform Xively [6] adapted in this work. The Xively platform offers flexible data collection and visualization, thus ease the support of large numbers of sensor data streams and data processing.

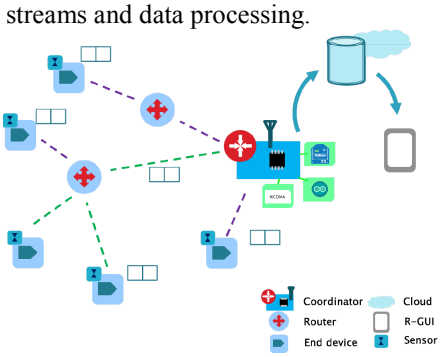

Fig. 1 Proposed ZigBee WSN System Architecture

Sensor node is the key component in this work; it consists of XBee Series 2 [7] module (ZigBee 2007 standard), ultrasonic sensor (XL-MaxSonar-WR MB7060), temperature sensor (TMP36), a standard 3.7 V Li button coin battery, and power control circuity as shown in Fig. 2. Among the above sensors and components, the ultrasonic sensor is the core sensor which can measure a range. The WR7060 ultrasonic sensor used in the work can offer a range measurement between 0.2 – 7.5 m with 1 cm resolution under outdoor rugged environment. Based on the difference between measured range and calibrate value, the actual water level can be determined. The built sensor nodes reports < 0.52%

average error for the distance test within 0.20 m to 4.00 m. All prototype sensor nodes are power up by a single standard 3.70 V battery and least for operation of ~100 days.

(a) (b)

Fig. 2 Photo of Sensor Node (a) Top View; (b) Side View

III. Experimental Setup for Performance Evaluation

As mentioned in the introductory section, the WSN in this project aims to monitor the surface water drainage during rainfall as an application. Relied on the range measurement of the ultrasonic sensor, the water level can be logged and monitor continuously in a wide geographical area. To verify the performance of the proposed WSN, an experiment was setup as shown in Fig. 3.

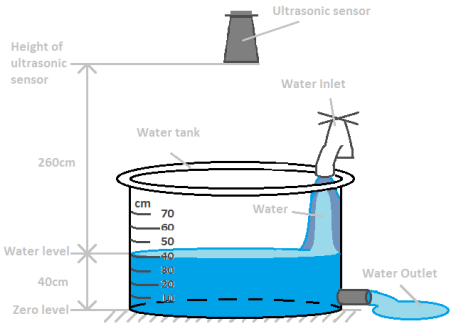

Fig. 3 Experimental Setup

In Fig. 3, a water tank with water outlet is used to simulate surface, then adjustable water flow is feed into the tank through inlet with valve. The sensor node in previous section was fixed 3 m above the tank and zero level was calibrated. Thus when tank is filled with certain level of water, the ultrasonic sensor can detect the range difference and determine the associated water level.

Based on the above setup, water tank was filled with 20 cm water level initially, during the experiment; water was feed into the tank (initial feed rate is 634.90 ml/s) while water was drained thought the outlet simultaneously for 50 mins (initial drained rate is 347.80 ml/s).The sensor nodes readings are reported to the WSN coordinator and recorded in the Cloud storage wirelessly through the ZigBee WSN and WCDMA mobile Internet. The collected data as measured water level are plotted in Fig. 4. In this figure, the water level in the tank can be logged and monitored. It shows the overall water level between 0.2 m to 0.4 m. By control the flow-in water amount in different time instances, the water level was increasing, maintained and decreasing at different time; these can be observed in the points A, B and C in Fig. 4 respectively. However, in this figure, the overall water level was increasing in general.

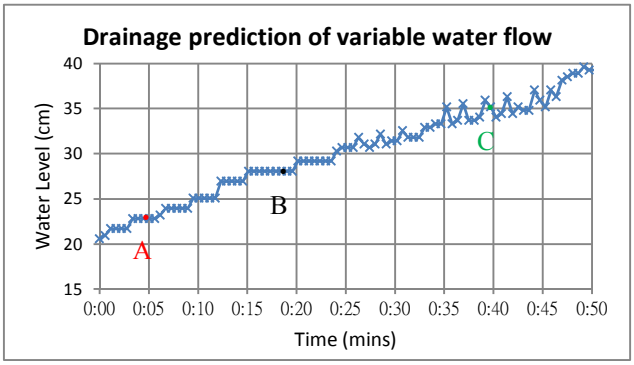

Fig. 4 Measured Water Level of the Experiment

Besides the water level logging, the proposed WSN helps the flood prediction based on the received water level information and its tendency. For a simple approach prediction at point A as an example, based on the previous 5 minutes water level data taken, the water level increasing rate can be determined based on the derivative, such that the predict water level will be increased to 26 cm and 40 cm in coming 5 mins and 30 mins respectively. The proposed WSN, prediction accuracy can be improved with intelligent data analysis algorithms and methods.

IV. Conclusion

A ZigBee WSN is proposed and developed for surface drainage detection using ultrasonic sensors. As an application, it can be applied for the rainfall monitor and flood prediction under cloudburst situation. Based on the experiment verification, accurate water level can be detected and recorded. Basic approaches based on the consecutive data are applied for simple flood detection. On the other hand, intelligent data processing technique can be applied on the proposed WSN indeed.

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