Bringing real world applications for wireless sensor networks into the classroom: Telemetric monitoring of water quality in an artificial stream

UNT Research Experiences for Teachers on Sensor Networks - Summer 2013

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Abstract

This research uses a wireless sensor network (WSN) using Zigbee protocol to remotely monitor water levels, pH, dissolved oxygen (DO), and temperature in an artificial aquatic system. Along with being able to monitor these factors, we are using a control system to help maintain a suitable water level, and other water quality factors, necessary to a healthy stream system. Field tests were conducted at University of North Texas Water Research Field Station using water tanks to simulate a model stream. Measurements were recorded every 10 seconds for water level, pH, DO, and temperature over a period of 24 hours. If the variables changed to an unsuitable level then valves were opened to either fill, drain or flush the tanks.

Introduction

There are a wide variety of reasons why one may wish to monitor the quality of water in a stream, lake or river. Considering the breadth of the topic it is unsurprising that there are many experiments, both completed and ongoing, focused on monitoring key aspects of these environments and attempting to relate them to the health of the system and perhaps implement controls on the system. Most of these experiments are using expensive equipment that is in situ and must be collected to retrieve data. Probes that transmit data wirelessly are becoming more common but such systems tend to be expensive. When operating on a research budget it is preferable to keep each piece of the project as cost effective as possible.

Methodology

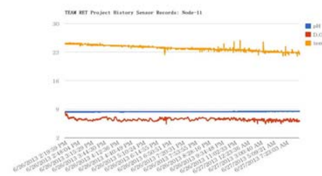
The focus of our research was the development of a wireless sensor network to monitor stream health parameters and engages a control system in response to stresses in the system.

We began by testing the Atlas Scientific probes we would be using individually. Once we showed they were effective we used a PCB to connect them all and then wired them to an Arduino microprocessor. We built and tested five sensor clusters, and one controller, in the lab. We then installed them in the artificial stream system at the Water Research Field Station site. The clusters collected data for 24 hours as a proof of concept.

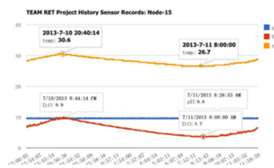
Once the wireless sensor network was functioning properly with multiple nodes we focused on developing a control system. The choice was made to control all factors through the use of adjustments to the water in the system. Water can be added, removed or the tank can be flushed by doing both simultaneously. The system evolved to include a small aquarium pump to remove water and an electronic sprinkler valve to add water. The pump and valve are controlled by an Arduino that is set up as a sensor cluster with the inclusion of an ultrasonic sensor to judge water level and a Liquid Crystal Display for ease of monitoring.

Results

The sensor clusters were able to produce consistent data under controlled lab conditions. We set up the sensor clusters and had them run overnight. All five clusters sent viable data for the entire testing period. The resulting graphs presented data that matched expectations. There was a concerning amount of variance in some of the data but, upon further research, we discovered that this is a known error that is an artifact of the microprocessor and could be corrected easily with existing code.



After successfully testing the sensor clusters in the lab we proceeded to deploying the WSN in the field. We used the artificial stream system that exists at the UNT Water Research field site. Due to an ongoing experiment we were limited to passive monitoring with no control system in place at the site.



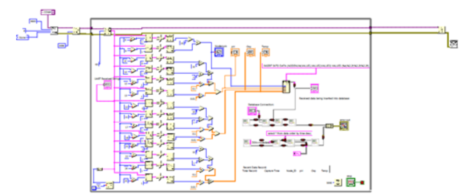
The data that we retrieved from the field site shows that all five sensor clusters remained connected and streaming over the entire 24 hour period. Further, the data is consistent with expected norms based on the conditions in which they were located. The range of the WSN was more than sufficient to cover the area required and could be expanded further as each device functions as both an end user and router as part of the ad hoc WSN.

The control system was installed in a 30 gal. tub under lab conditions. It was not possible to install the control system in the field as it would interfere with current projects going on there. The water level monitoring system functioned well. The control structure for flushing the tank in the event of alarms related to pH, DO and temperature were more problematic. Unexpected interference forced a redesign of the circuit and the logic in the code underwent several revisions before the system was operational.

The remote video system is functional and has been tested in a closed system. It is possible to capture streaming video wirelessly and to broadcast the signal over the internet. We were successful at sending the video to laptops and cell phones that were all linked to the same WiFi signal via router. We were not able to install the video system at the field site because the fiber optic connection was not completed in time and we were not able to obtain the necessary permissions to connect the unsecured wireless signal to the University network.

Hardware

Software



Summary

Over the course of two summer programs we were able to take inexpensive off-the-shelf components and use them to create a functional wireless sensor network to remotely monitor key water quality/stream health indicators. The probe cluster we designed focused on pH, dissolved oxygen and temperature, though this could easily be expanded to include other indicators with the addition of appropriate probes and few lines of code. The sensor cluster functioned well and produced comparable results to commercial systems that are already in place at a fraction of the cost. The addition of a control system designed to monitor the water quality indicators and use the addition and removal of water to the system to maintain optimal conditions expands the use of this system from passive monitoring for research to include applications in industry, water treatment and commercial fisheries. The video monitoring system allows for oversight of the WSN remotely to visually inspect anomalies in the system with out the need to visit the physical site.

For Further information visit our blog at:
http://untret2.blogspot.com/

RET (Research Experiences for Teachers) Site on Sensor Networks, Electrical Engineering Department, and Institute of Applied Sciences, UNT, Denton, Texas. This material is based upon work supported by the National Science Foundation (NSF) under Grant No. 1132585 and the IEEE Control Systems Society (CSS) Outreach Fund. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF or the IEEE.