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A Wireless Sensor Network Based Automated Water Pump Control System for Multiple Overhead Water Tanks

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Abstract

This paper presents the design and implementation of a wireless sensor network based automated water pump control system to monitor and control the level of water in heterogeneous configurations of overhead water tanks. The purpose of the research was to solve the problems of energy wastage, water wastage and water pollution caused by inadequate human supervision and management of overhead water tanks in residential areas. The system was designed to have units for water level sensing, water pump interfacing, display, valve control and communication. A wireless sensor network (WSN) with central node placed close to the water pump and sensor nodes positioned close to the water tanks was designed. A PIC16F863A microcontroller was used to implement the control of the nodes while wireless communication between nodes was achieved using HT12E and HT12D RF modules. The SIM900 GSM module was used to transmit status of the pump and water level from the WSN nodes to a remote mobile phone via SMS. The prototype developed was shown to effectively determine the level of water for each tank and automatically turn ON or OFF the water pump accordingly. The state of the water pump at every point in time and other outputs of the system could be accessed onsite using an LCD screen and remotely through an SMS to the mobile phone of the user.

1. Introduction

Water finds application in all works of life some of which include agriculture, industry, and domestic consumption [1]. One way of making water available for domestic use is to store it in overhead water tank by pumping out water from underground water reservoir using a water pump. Water pumps can be traced back to the 1700s where wooden pumps existed and they were used to empty the bilges of ships. They were made from bored logs with wooden pistons to create suction. In the turn of the early to mid-1800s metal piston type pumps driven by steam were built [2].

Today, electrically driven pumps are common and this development has made it possible to utilize automated and intelligent equipment for water management. However, the common method of water management in many homes in developing nations where private boreholes are used is simply to start the water pump when the water in the tank is low (or empty) and allow it to run until the tank is full or until enough water is available the water tank [3]. This approach could lead to problems such as water overflowing from tanks and energy wastage due to inadequate human supervision; when the water in a tank is at the lower level the human cannot tell except it is completely empty. Similarly, when it's at a high level of the tank it is completely unknown to the human supervisor unless it starts spilling to the ground. A control system could address this problem by monitoring the level of water at the overhead water tanks and regulate the flow of water such that water is always supplied to the consumer when available. It needs to be completely autonomous requiring no user input beyond the initial installation. Users need an affordable system that draws little power to ensure low running costs. The system must function accurately so that resident's tanks can fill as much as possible. Not every pump system requires the same power source, so the control system must support various pumps as well as common voltage source [8]. In addition, the system should be able to cater for needs of various tank arrangement, connections, volume and quantity. Thus, the need for smart and efficient techniques to monitor the level of the water in the tanks and to also effect the necessary control to either ON/OFF the pump is required in order to curb this wastage and save the electrical power has become necessary.

The "Wireless Sensor Network Based Automated Water Pump Control System for Multiple Overhead Water Tanks" presented in this paper was designed to monitor the level of water in the tanks. The system also has an automatic pumping system attached to it so as to refill the tanks once the water gets to the lower level of the tanks, while turning the pump OFF once the water gets to the higher level of the tanks. This was made possible by the use of wireless sensor network (WSN) that has not really been explored in water storage systems especially in developing countries.

1.1 An Overview of Wireless Sensor Network

Wireless Sensor Networks (WSNs) has drawn much attention for their broad practical application. These network systems have been widely considered as one of the most important technologies for the twenty-first century [5]. It is a group of specialized transducers with a communications infrastructure for monitoring and recording conditions at diverse locations. A sensor network is an infrastructure that comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment [6]. There are five types of WSNs, they include: terrestrial WSN, underground WSN, underwater WSN, multi-media WSN, and mobile WSN [7]. The basic components in a sensor network are as shown in the block diagram of Figure 1.

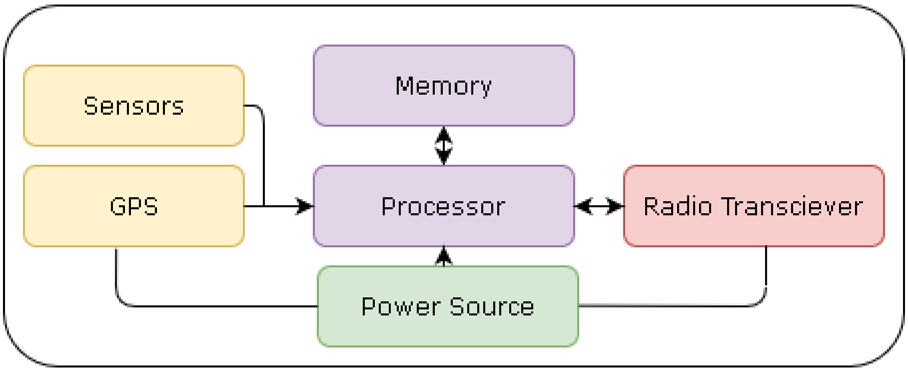

Figure 1: Components of Wireless Sensor Network Node

A WSN is usually characterized by a large number of low - cost, low - power, and multifunctional sensor nodes that are deployed in intended region of interest. The sensor nodes are usually small in size, but are well equipped with sensors, embedded microprocessors, and radio transceivers, which gives them not only sensing capability, but also data processing and communicating capabilities. They communicate over a short distance via a wireless medium and collaborate to accomplish a common task [5]. WSN applications can be classified as monitoring and tracking. Monitoring applications include indoor/outdoor environmental monitoring, health and wellness monitoring, power monitoring, inventory location monitoring, factory and process automation, and seismic and structural monitoring. Tracking applications include tracking objects, animals, humans, and vehicles [7].

1.2. Related Works

This section briefly describes some of the related works that make use of WSNs in automating various control system. Reza, [3] developed a microcontroller-based water level sensing and controlling system. This system introduces the notion of water level monitoring and management within the context of electrical conductivity of the water. Abang [1] designed and constructed an automatic water level controller. The system determines the level of water in a tank. It displays the level of water and when it is at the lowest level; a pump is activated automatically to refill the tank. When the tank is filled to its maximum capacity, the pump is automatically de-energized. Madli [8] designed and constructed a Web-based system for intelligent irrigation control. The system automates the irrigation process by sensing primary agricultural parameters such as soil moisture, soil PH, temperature and humidity. It uses a phone as server and Bluetooth module for communication, reduces the cost involved in processing and communication. Suhasini [9] developed a GSM and Wireless Sensor Network Based Smart System for real time sensing and control of an irrigation system. Other similar attempts at solving irrigation problems were made by Gunturi, (2013). Similar techniques and GSM communication has been used for a different application which involve monitoring of the health of oil wells and control of oil pump unit [10]. Ref. [2] carried out a research on automatic water level control system by embedding a control system into an automatic water pump controller through the use of different technologies in its design, development, and implementation. The system used microcontroller to automate the process of water pumping in an over-head tank storage system and has the ability to detect the level of water in a tank, in order to either switch ON or OFF the water pump accordingly or display the status on an LCD screen. One of the motivations for this research work was to deploy computing techniques in creating a barrier to wastage in order not to only provide more financial gains and energy saving, but also help the environment and water cycle which in turn ensures that water is saved for future use. Other attempts have been made to monitor the water level using IoT and similar techniques [11-13]. An automatic water pump control systems was developed by [4] to automatically regulate water pumping into the overhead tanks for storage, by the use of water level sensors to monitor the water level at both the top and bottom of the tank for the purpose of transferring the pumping to the next empty tank. Once the supply of water decreases down to a point of concern, roughly 10% of the tank capacity, the controller turns 'ON' the water pump. This prevents the water pump from siphoning air which can result in the water pump's malfunction or complete breakdown. Similarly, the controller turns off the water pump if the rooftop tank reaches a water level of greater than or equal to 95%. This prevents the tank from overflowing and wasting water. This remedies the current issues faced in water level and storage management.

The objective and approach used in the last two works reviewed are similar to the current work presented in this paper. This paper attempts to use both GSM, RF and WSN to realize these objectives. A significant difference is that unlike in the previous works, this paper adequately considered multiple arrangements (and complex configurations) of water tanks.

2. Methodology

The approach that was used in this work is a modular design approach that involves breaking the overall design into functional block diagrams where each block in the diagram represents a section of the circuit that carries out a specific function. The units which include water level sensor unit, control unit, display unit, power unit and communication unit shown in the block diagram of the system presented in Figure 1.

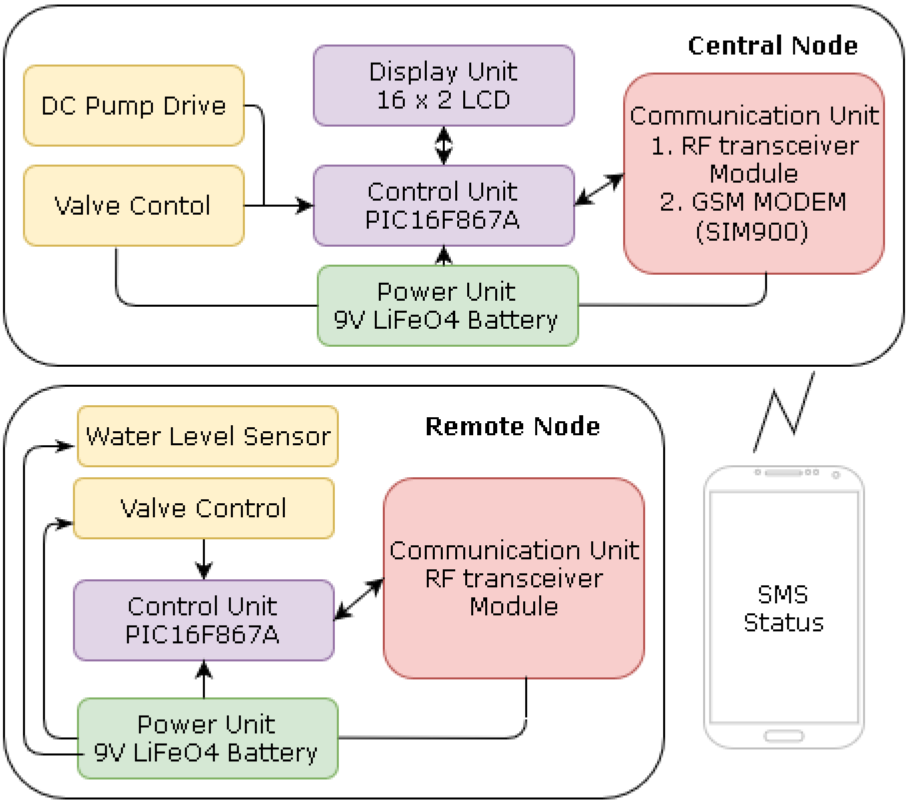

Figure 2: System Block Diagram

The block diagram in Figure 2 shows that the system consists of the central node and the remote nodes. The central node is located very close to the water pump and it receives signal from the level sensors at the remote nodes and sends signal to the GSM modem for SMS alert which displays the status of the DC pumping machine. The units designed in each node are: the level sensors unit, pump control unit, the display units GSM module unit, value control unit and communication unit.

2.1 Level Sensor Unit

The water level sensors unit detects when the level of water in the tank drops below half level and when the tank is filled. The level switch sensor employed in this work is an electromechanical device that consist of a floater that makes contact with the water in the tank and the electronic circuit that controls it encased in a waterproof plastic casing. The sensor operates like a switch by turning ON or OFF when the water in the tank is at a preset level or not. The appropriate signal is then transmitted to the central node through the communication unit of the remote node which is directly interfaced to the level switch is connected to.

2.2 The Control Unit

The control unit receives signal from the sensor nodes as generated by the level sensors, process this signal and then carry out the appropriate action. The control unit is implemented with the PIC16F876A Microcontroller. The digital signal from the water level sensors is interfaced with the Microcontroller at PORTB which is configured as an input port. The RF Module and the GSM MODEM are interfaced with microcontroller at PORTC. The microcontroller uses UART protocol to communicate with the GSM MODEM and the RF Module. The control software was implemented using Mikro BASIC programming language and uploaded into the microcontroller using TopWin programmer.

2.3 Display Unit

The display unit is used to give the output of the system, in this project two different devices were used as a means for the system output the LCD at the control unit and the user's cell phone. The LCD screen is connected to PORTB.21- PORTB.26 and also PORTB.1. of the microcontroller, and it display the level of the water in the tank at a particular time and also the state of the pumping feed. The second output device relies on the inbuilt SMS application on the user's mobile phone.

2.4 Communication Unit: The central node has two components in its communication unit namely SIM900 GSM module and RF module while the remote nodes are fitted with only the latter. SIM-900 GSM Modem that was used in this project is a compatible Quad-band cell-phone that works on a frequency of 850/900/1800/1900MHz and which can be used not only to access the internet, but also for SMSs. The GSM MODEM was connected to PORTC of the Microcontroller to facilitate SMS notification about the water level in the tanks and the state of the water pump. The RF Module that was used for this implementation is the HT12E and the HT12D. They were used to facilitate communication between the nodes and the central nodes since all the nodes are equipped with processing power, the signals are coordinated in a decentralized manner.

2.5 Tank Configurations and Sensor Node placement

Different tank configurations for overhead water tank storage system could be accommodated by the design by placing the appropriate number of remote nodes and valves. Examples of designed considered include a number of tanks step up at different levels such that the lower level tanks are filled from the topmost tank; the tanks are at the different levels and filled simultaneously, however the lower level tanks will get filled first before the higher level tanks; unequal sizes of tanks at different levels, each tank is connected to the pump independently as shown in Figure 3. A star topology was used for the wireless sensor network.

2.6 Testing

Tests were carried out at each design phase of the project and depending on the results, minor implementation changes were made. Specific tests carried out include output voltage of power supply of nodes, RF signal coverage of the RF transmitter in the communication units of nodes, level sensor operations, central node coordination of nearby remote nodes and communication between nodes and GSM phone. A general test of the system was also carried out on the system to check for its performance.

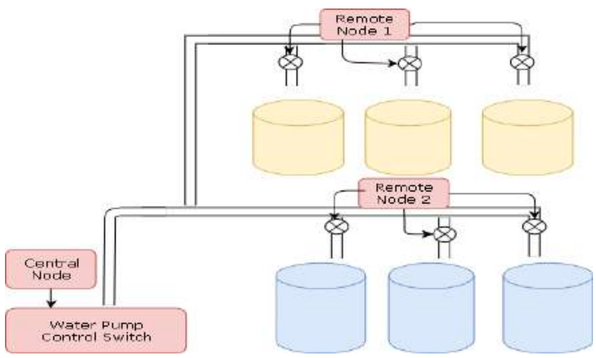

Figure 3: Sensor node placement

3. Results and Discussion

The developed prototype is presented in Figure 4. Plastic cans were used to represent water tanks in and water reservoir. A submersible water pump was placed inside the water reservoir and connected to the central node. Each remote node was used to control 3 valve and a separate node is used to control the level sensors. The system provides the advantage of using different tank arrangement (configurations) such that pumping can continue even if one or more tanks are full but some are not yet full. The use of buckets in the prototype is similar to what was done in [4] but mounting brackets and pipes were not used for the current research. A significant difference between [4] and the current research is that configurable and self-contained WSN nodes were used to control the valves and level sensors. A drawback of this system is the use of a floater in the level sensor that makes contact with the water. This can easily be replaced with a non-contact level sensor similar to that used in [4]. Priority schemes can be implemented whereby a particular water tank is configured to close all valves except the valve to the tank with highest priority. When the high priority tank it is full, the tank with the next highest priority is filled and so on until all the tanks are full. Previous works surveyed did not consider priority schemes.

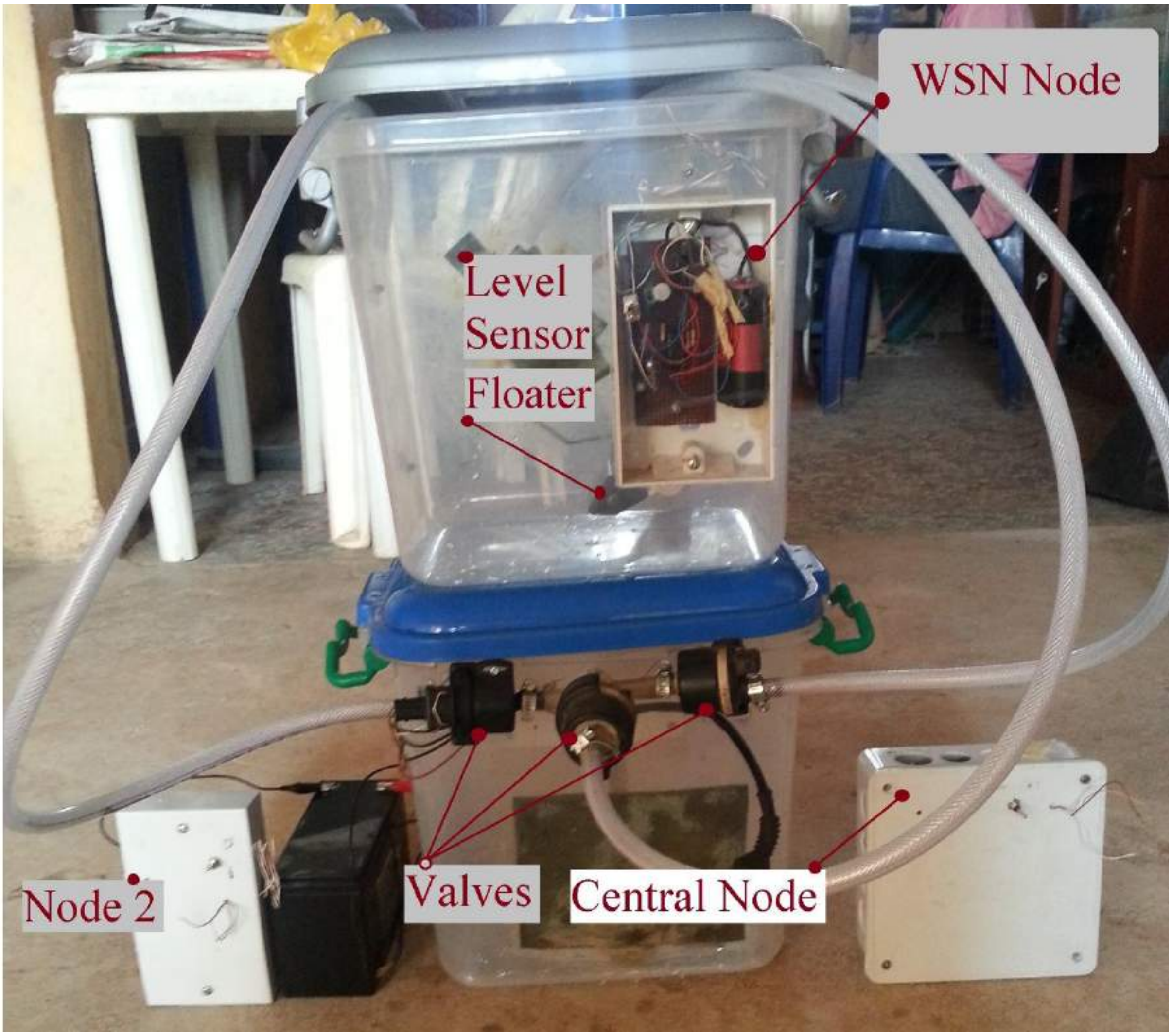

Figure 4. Prototype showing a central node, 2 remote nodes and 3 valves

Figure 5 shows the central node of the system. the state of the system can be read off from the LCD screen.

Figure 5. Central node with state of three valves (T1-T3) displayed on LCD

Result of test carried out revealed the average power supply voltage of the nodes is 4.96, the level sensors operated as expected, the system responded to the different water level by sending SMS messages and RF signal to the remote receiving unit to indicate the status of the DC pump. Although, previous works such as [9] used a mobile phone, Bluetooth was used rather that SMS. While Bluetooth has the advantage of running at no cost to the user, its major drawback is the coverage area. Effective remote monitoring is essential for this application because users who may forget to put off the water pump before going to work can receive SMS notifications at work. The effective coverage range of the RF transmitter was observed to be approximately 800m radius with bit rate of 9600bps. This coverage area makes the system very flexible and suitable for applications where the water pump is in one building but some of the water tanks are in another building.

4. Conclusion

The goal of the paper was to present a system that utilizes a wireless sensor network to automatically control pumping of water into various overhead water tanks. The prototype presented in this paper and the results of tests carried out on it shows that the system achieved the goal of this paper. The developed system will help to reduce wastage because reliance on human supervision ability for the overhead water storage system will only worsen the current shortage in electricity supply which is required to pump water into overhead tanks in residential buildings. However, with a good monitoring and automated water pump control system home electric power wastage will be eliminated in the big cities of this part of the world. This project has also solved the problem of water wastage by overhead water tanks and has proffered an affordable, decentralized and sustainable solution to environmental pollution by water flowing from filled overhead tanks.

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