RESEARCH ARTICLE

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Smart Monitoring and Controlling of Water Level Based on ZigBee Technology

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Abstract: This paper presents a monitor and a remote control of water level system with automatic operation, this system is considered an application of wireless sensor network. The network of the presented system is consist of two main parts: the main station part which is considered as the gateway node and Raspberry Pi used for this purpose and the second part is the control node which is used Arduino Uno board to control the level of water according to the value of the connected sensor. The ultrasonic sensor is used to detect the water level and a relay board is used to change the state of the water pump. ZigBee technology is used as the wireless communication between the main station and the control node which provided low data rate with low power and low cost. The overall system provided accessing from a remote location by using any web browser and it used a contactless method to detect the water level with increasing the safety and reliability.

INTRODUCTION

Nowadays, the automatic controlling and monitoring of water level in the tank is an essential system that prevents the lack of water in the tank and an overflow of water in the tank. The main function of such system is to manage the level of water in the tank by closing and opening the water pump according to the required level, this function leads to saving water, power and money by restricting the using of electricity and provided more safety and comfort to the user. Therefore, it is necessary to have such system with features of contactless, autonomous, cost less, flexible and reliable.

There are many related works in this type of monitoring system, the researchers of this field of application using different technologies according to their requirements.

Michelle Clifford (2006) proposed a water level monitoring. [1] It is designed using MPXM2010GS pressure sensor, an eight-pin MC68HC908QT4 microcontroller and a dual op-amp instead of using a mechanical switch. This system performed a calibration function, pressure converting function and other functions to determine the levels of water. This system solves the problem of using mechanical switch and detecting the level of water but it uses complex components with many software functions to verify the operation of the system.

Ebere and Francisca (2013) proposed an automatic system to control the water level using a AT89C52 microcontroller. [2] A copper sensor is used to determine the level of water in the tank according to the voltage that transferred to the sensor, this voltage is processed by using comparator circuit. According to the comparator result that fed to the microcontroller which turn the water pump ON or OFF and display the result on LCD screen. It provided improvement on the existing system but it also used a calibrated circuit to determine the water level.

Mani *et al*., presented an indicator of a fully automatic water level. [3] It uses a transistor circuit as a water level sensor to determine the level of water. This value of detecting level is transmit to the microcontroller and then display this value in LCD screen and if the tank is full then a buzzer circuit is beeped to notify the full of water. It also solves the problem of controlling water pump but with limited access and less feature.

Daadoo and Daraghmi (2017) presented smart water detection. [4] The researcher designed a wireless sensor network to monitor the water level and to keep the water resource and provide the ability to control the pump. This system consists of Arduino mega2560 as a microcontroller and sensors to detect the water level. GSM (Global System for Mobile) technology is used as a wireless communication to send SMS (Short Message Service) to the user. The implementation of this system reduced the delay of operation and improved the efficiency but the using of this system consider a high cost due to the price of GSM and sending SMS in each detect state.

In this paper, we proposed a system for monitoring and controlling of water level based on ZigBee technology to verify many issues including the reducing of power consumption, reducing the cost, low maintenance, save man power and provided a two type of operation manual and automatic operation of water pump with contactless method to confirm the safety and reliability.

This paper is organized as follows. Section 2 explains ZigBee technology. Section 3 shows the overall structure of the proposed system. Section 4 shows the hardware and software design of the proposed system including the design of the main station and control node. Section 5 shows the implementation and results. Finally, section 6 presents the conclusion and future works.

ZIGBEE TECHNOLOGY

ZigBee is a wireless technology offered from ZigBee alliance and built on IEEE 802.15.4 wireless standard protocol. It considers a low-cost, low power and an open standard protocol. [5] There are many types of wireless communication technology using in such systems. Each one has specific features and the choice of any one is done according to the factors of the required application such as power consumption, range, data rate and battery life. ZigBee considers the lowermost data rate and provide low power consumption with increase battery life compared with Bluetooth and Wi-Fi. Table 1 shows the comparison among ZigBee, Bluetooth and Wi-Fi. [6]

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Table 1: Comparison between Wi-Fi, Bluetooth and ZigBee [6]

Features	Wi-Fi IEEE 802.11	Bluetooth IEEE 802.15.1	ZigBee IEEE 802.15.4
Application	Wireless LAN	Cable Replacement	Control and Monitor
Frequency Bands	2.4 GHz	2.4 GHz	2.4 GHz, 868 MHz, 915 MHz
Data Rate	1 to 11 Mbps	1 to 3 Mbps	20 to 250 Kbps
Range (Meters)	1 – 100	1 – 10	1 – 75 and more
Battery Life (Days)	0.1 – 5	1 – 7	100 – 7000
Nodes Per Network	30	7	65,000
Topology	Tree	Tree	Star, Tree, Cluster Tree and Mesh
Bandwidth	2 – 100 Mbps	1 Mbps	20 – 250 Kbps
Memory	100 KB	100 KB	32 – 60 KB

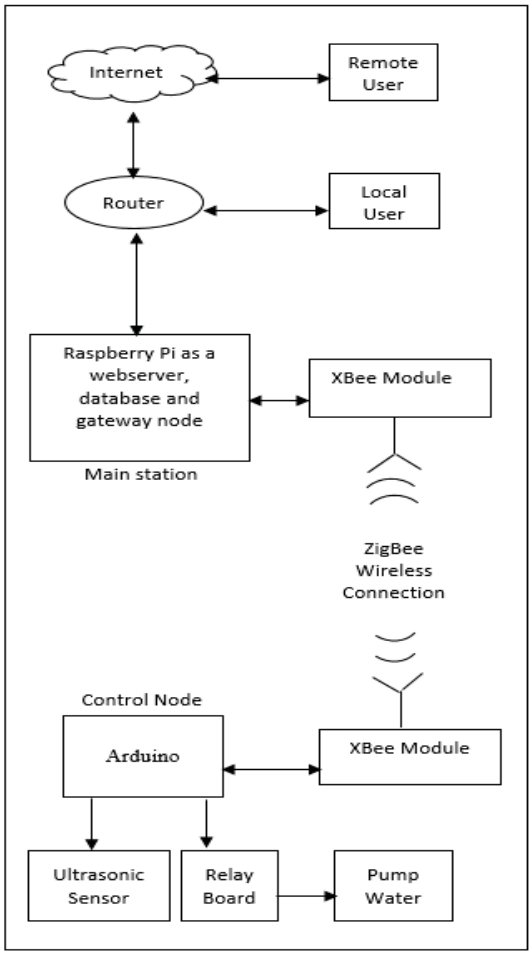

Figure 1: The overall structure of the proposed system

ZigBee devices are divided in to three different type: ZigBee Coordinator device, ZigBee Router device and ZigBee End device. Coordinator device must contain in each ZigBee network and responsible for the management of the overall network, each ZigBee network must not contain more than one coordinator. Router device is responsible to send and receive message and to extend the ZigBee network and finally End device has only the ability to transmit and receive data and can enter to sleep mode when there is no transmitting of data. [7]

ZigBee devices operate in two different mode of operation according to the required purpose, AT (Transparent operation) mode and API (Application Programming Interface operation) mode. AT mode considers the default operation mode in ZigBee devices and it operates as serial line between devices that operate in this mode, any UART data come from DI directly send to the destination RF module. API mode has more features and depending on the frames in send and receive data which provide with destination address, payload data, some specific configuration fields and checksum, it also provided with broadcast and multicast transmission. [8]

PROPOSED SYSTEM

In this paper, we designed and implemented a system for monitoring the water level in the tank and controlling the water pump according to that level. We apply a prototype module of this system in a small tank of home, the overall structure of proposed system is shown in Figure 1. It comprises of two parts: the first part is the main station

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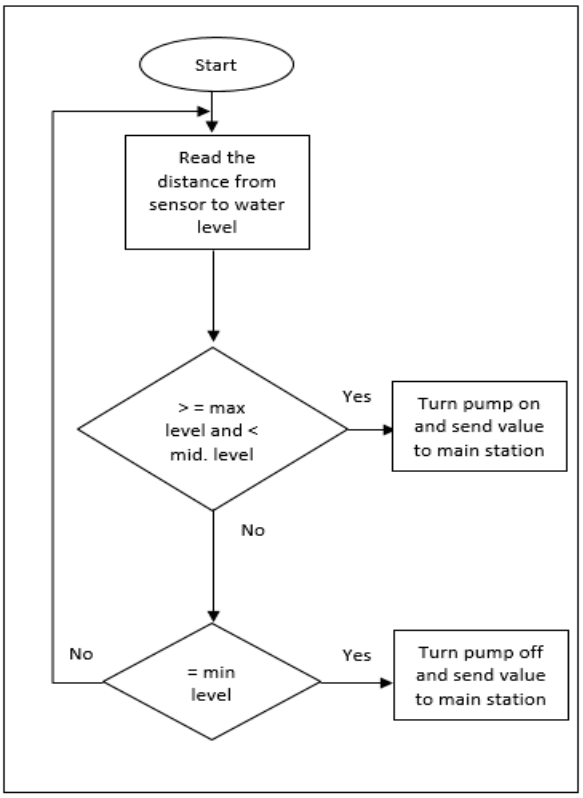

Figure 2: The flow chart of the operation of control node

part which consider the gateway node and contain a webserver and database server on it and we used Raspberry Pi board for this purpose instead of using a dedicated PC server and it connected to XBee module to verify the ZigBee wireless communication to the second part. The second part is a wireless control node which consists of Arduino microcontroller, XBee module for wireless communication to the main station, Arduino XBee Shield, Ultrasonic HC-SR04 sensor to detect the level of water, a water pump as an actuator and a relay board to control on the water pump according to the specific water level. The user can access this system locally from his home or remotely from another location by using the IP address of Raspberry Pi from any PC, tablet or smart phone.

HARDWARE AND SOFT WARE DESIGN OF PROPOSED SYSTEM

Design of Main Station

Raspberry Pi board which considers a low-cost board with an extended GPIO port and small in size with flexibility in use [9-10] was used as main station of the proposed system and it considers the gateway node and contain webserver and database server on it. The wireless connection of main station node to control node is done by using XBee Pro S2 module which offers from Digi and considers a wireless connection depending on IEEE 802.15.4 and ZigBee standard. [11] It operates in 2.4 GHz frequency band and has 20 pins which used as input or output line, also it transmit low data rate with low power and low cost. [11-12] This XBee module is configured as a coordinator device and operates in API mode. The main station is also connected to the home's router through Ethernet port to verify access from local and remote end user to monitor the water level and control the water pump through two different pages: the control page which has the ability to display the current state of water pump and has the ability to change this state, the second page is the display page which has the ability to display a real-time chart of water level in different duration as a monitoring report. The designing of this Graphic User interface is done by using PHP, HTML, CSS and JavaScript for plot the chart of water level data.

Design of Wireless Control Node

The wireless control node is designed as a prototype of control and monitor water level in home. Control node consists of Arduino Uno board as a microcontroller which has many features including an open source software and hardware platform and has 14 digital input/output pins and 6 analog pins. [13] It is connected to main station node wirelessly through ZigBee connection by using XBee Pro S2 module which is configured as an end device and operates in API mode. The XBee module is connected to the Arduino board through Arduino XBee Shield which considers an add on board put on Arduino and then connect XBee module on it to verify the connection between XBee module and Arduino board. [14] Ultrasonic HC-SR04 distance measurement sensor is used to measure the level of water in the tank, it is used an un-contact method to measure from 2 cm to the 400 cm distance between the sensor and an object by sending and listening sound waves at a specific frequency with high accuracy. [15] A water pump is used as an actuator and it controlled by a relay board which considers an electrical switch used to control the appliances by switching their ON and OFF. [16] The value of

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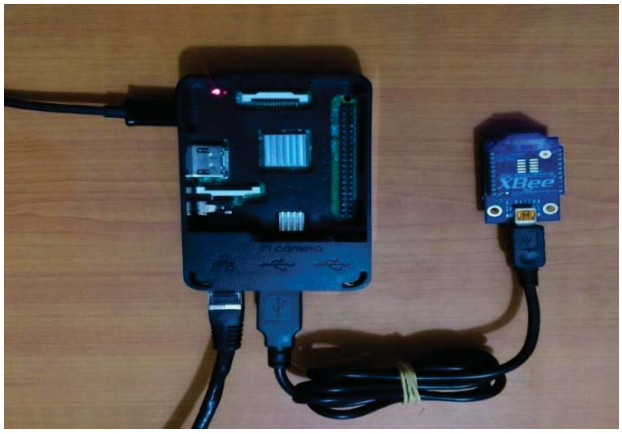

Figure 3: The hardware implementation of main station

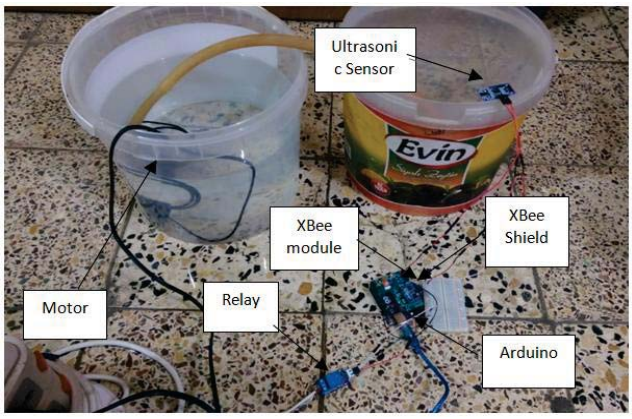

Figure 4: The hardware implementation of control node

maximum level and the minimum level of water in the tank are set according to the depth of the tank. In the evaluation, a small tank of 40 cm is used and by putting the Ultrasonic sensor on the top of the tank and without touching the water, the minimum level of water to turn the motor ON is set to 30 cm (the distance from sensor to the lower water level) and the maximum level of water to turn the motor OFF is set to 10 cm (the distance from sensor to higher water level). In addition, there is a middle level value set to 20 cm to prevent the turning on the pump when decrease the minimum level value in small range, the flow chart of this operation is shown in Figure 2. The value of maximum, minimum and middle level is set according to the length of the tank and according to the requirement of user. This operation is done automatically in Arduino microcontroller and this information is set by the main station through XBee module which is configured as an end device and operates in the API mode. The end-user can remotely control of this node by the accessing the GUI in the main station. The operation of checking the value of water level is done every period of time according to the specification of the tank that is provided by the administrator and during the uncheck state the XBee module go to sleep mode and wake up during the check state, this procedure increases the life of battery for additional years.

IMPLEMENTATION AND RESULTS

The software implementation of the overall main station which included the getaway node, database server and webserver is programmed using an object-oriented Python programming language with some packages and libraries including XBee 2.1.0 package, PySerial 2.7 package and MySQL-python package. [17] My SQL database [18] and Apache web server [19] are installed in Raspberry Pi to store the data of system and verify the server-side access. The hardware implementation of the main station node is shown in Figure 3.

The software implementation of the control node is programmed using C language of the open source Arduino IDE platform. It is responsible for the processes of receive data from XBee module through serial port and analysis it, collect data from the Ultrasonic sensor, do the required action of on or off the water pump and then transmit these data to XBee module. This node uses the contactless method to automatic water level detection in the tank. The hardware implementation of the control node is shown in Figure 4 and the water level output from control node in different period of time is shown in Figure 5 and Figure 6.

CONCLUSION AND FUTURE WORKS

A prototype of the presented system is tested successfully and it provides access the local and remote user to monitor the water level, the control of the water pump operation can be done manually or automatically according to the detected water level. The features of the overall system including low-power consumption due to the sleep mode state of the ZigBee end device which increases the life of battery for additional years, low cost, easy to upgrade and

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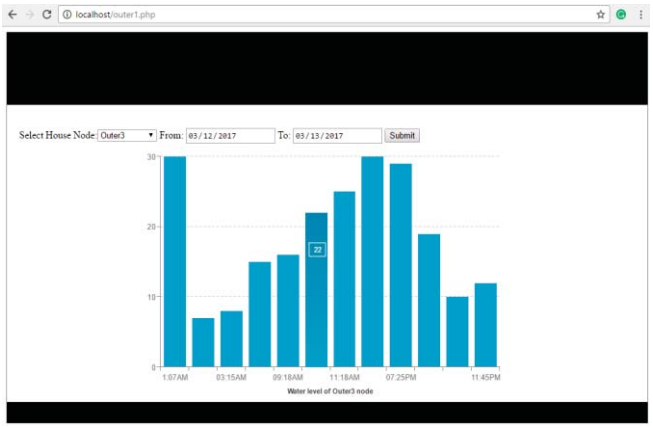

Figure 5: The water level output from control node

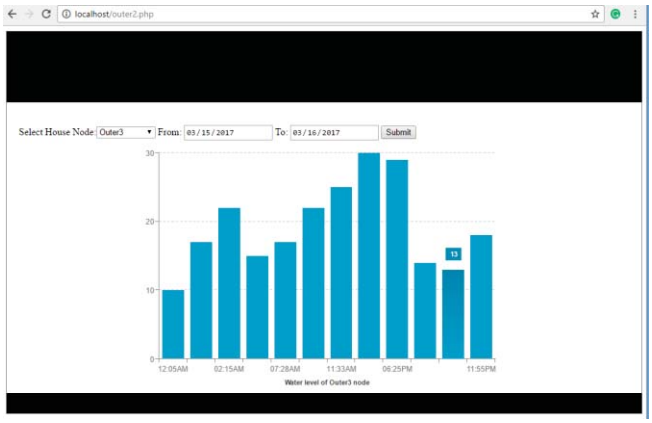

Figure 6: The water level output from control node in different period of time

provide a contactless method to detect the water level which confirm the safety and reliability. There are many future works scoped including expanded the network of this system by adding another control node to verify control and access to more than one tank at home and we can check the quality of water by using another type of sensors. Finally, we are currently studying the adopting of the proposed system for real-time patient monitoring of Saline solution.

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