ZigBee Based Wireless Sensor Network for Flood Monitoring and Control

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Abstract

This paper presents a simple, very cost effective, efficient, low power and low data rate application of ZigBee technology for flood monitoring and control. The paper discusses the hardware and software aspects of Zigbee sensor network with bidirectional communication and inter-node data reception. For complex wireless network, the basic condition is to establish a point-to-point communication link. To achieve this, star topology of ZigBee network is used. Hardware enhancements and improvements are made to the transmitted power and the receiver sensitivity. In software aspect, very simple BASCOM compiler is used for programming and Visual Basic is used as the GUI for display in the control room.

Keywords— *Control devices, Flood monitoring, Microcontrollers, Sensors, Traffic management, WSN, WPAN, Wireless, ZigBee*

I. INTRODUCTION

Emergency measure personnel who plan flood relief operations require reliable information for decision making. Accurate and timely information of flood extent is useful for planning purposes such as where to evacuate, where to deploy resources to minimize infrastructure damage and to carry out search and rescue operations. There is a need of putting in place a Flood Monitoring System (FMS) that would generate digital and hard-copy map products displaying the extent of flood and provide statistics necessary to determine impact on infrastructure and the land use/ land cover.

Current flood monitoring approaches involve deploying depth and flow sensors in flood prone areas and feeding the collected data to grid-based computational models which predict flood events. This system issue general warnings over a large area for people to take preemptive action. This systems rely on sparsely-distributed sensors which send information to a central point for analysis.

It can be seen that there is a considerable scope for improvement in such scenarios by shifting the prediction model of flood monitoring to the Wireless sensor network (WSN). The new system based on a network of intelligent sensors acting as a 'Mini Grid' can be placed in flood-prone areas to issue rapid warnings to this site. The whole system is low power and cost effective as the sensors are able to adjust their power consumption according to dry days and rainy days.

II. WIRELESS SENSOR NETWORKS

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions such as temperature, sound, vibration, pressure, motion or pollutants at different locations. Recent advances in wireless communication and electronics have enabled the development of tiny, low-cost, low power multi-functional sensor nodes [1]. These sensors have the ability to sense, process and communicate information over short distances in an un-tethered fashion. They are densely deployed to form a wireless sensor network to collect high resolution data and perform complex information gathering and dissemination tasks as shown in Fig.1.

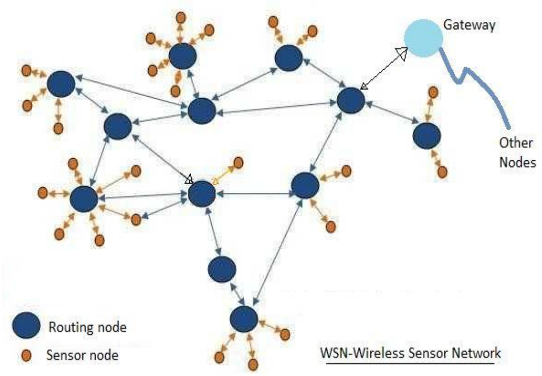

Fig. 1 Wireless Sensor Network (WSN)

The sensor nodes are constrained by energy and computational capabilities. It is required that the sensor networks are scale able, robust with respect ot frequent node failure, self -organized and have a long overall network lifetime. It is required that the protocol and application algorithm are light weight, resulting in larger network lifetime without compromising in performance.

III. ZIGBEE MODULE

ZigBee technology is a low rate, low power, low cost wireless networking protocol used for automation and remote control application. ZigBee is a home- area network designed specifically to replace the proliferation of individual remote controls [2].

ZigBee was created to satisfy the market's need for a cost-effective, standards-based wireless network supporting low data rates, low power consumption, security and reliability.

A. Need for ZigBee

Multitude of wireless standards ranging from mid to high data rates for voice, PC, LANs, video etc. are available. Besides, there are multitude of proprietary wireless system manufactured to solve issues that does not require high data rates but do require low cost and very low current drain. These proprietary systems were designed because there were no standards that met their requirements. These legacy systems are creating significant inter portability problems with each other and with newer technologies. Also, sensors and controls do not need high bandwidth instead they need low latency and low energy consumption for long battery lives as well as for large device arrays. There was a need to develop a unique wireless network standard that meets the needs of low data rate and low power systems and devices.

B. Features of ZigBee

Low Cost in terms of device, installation and maintenance. Simple implementation with low power consumption. ZigBee/ IEEE 802.15.4 has only two modes; active or sleep. ZigBee uses the IEEE 802.15.4 PHY and MAC standard that allows network to handle any number of devices[3][4]. This attribute is critical for massive sensor arrays and control networks.

IV. ON-SITE AND MAIN STATION ZIGBEE MODULES

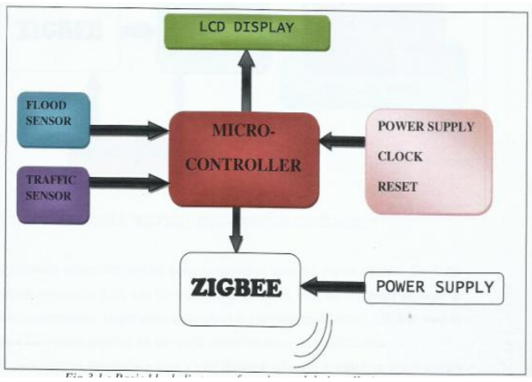

Fig. 2 ON-Site ZigBee Module

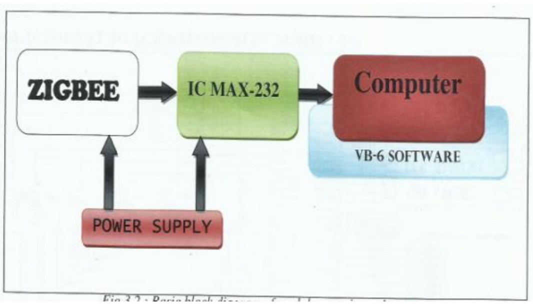

Fig. 3 Main Station ZigBee Module

The on-site module as shown in Fig.2 require flood sensing transducer that converts water level changes to its electrical equivalent signal. The measured signals are processed by the microcontroller and displayed on a LCD display. Also, these values are transmitted by the on-site ZigBee to the main station controller through mesh network of ZigBee.

The ZigBee at the main station as shown in Fig.3 receives the measured signals. The signal from Zigbee at the main station is to be fed to the main station computer using serial communication. Since, ZigBee is a low power module operating at 3.3V. The boost in the voltage is provided by IC MAX-232 for serial communication via RS 232 cable.

The graphical map of all places where the modules are installed is displayed on the computer at main station. Algorithm is written to communicate with on-site micro-controller for remote sensing and controlling.

V. THE ON-SITE CIRCUITRY

A. Circuit Explaination

The power supply unit is designed using 12V/ 1Amp transformer and regulators to provide 5V DC to the microcontroller, 3.3 V to the ZigBee and 12 V to the relay circuit to drive the motors. The 11.059MHz Crystal Oscillator along with 22pF capacitor connected to the microcontroller provides the necessary clock signal to the controller. Power on Reset circuit comprising of a resistive-capacitive network is interfaced to the reset pin of the microcontroller. Port 0 of the microcontroller is interfaced with 16x2 LCD Display. To adjust the brightness of the display preset pin connection is provided by the port. A 10KΩ pull up resistor is used which pull up all the pins of port0 to 5 Volts to provide sufficient driving voltage and current.

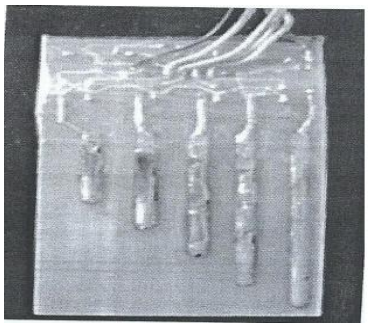

Fig. 4 Flood Sensor

The Flood Sensor shown in Fig.4 is designed using BC549 NPN transistor connected in Common Emitter mode. The base of all the transistors are connected to the solder line that indicates different levels of flood levels. Collector terminals of all transistors are pulled up using 10KΩ pull up resistor. The collector terminals of the transistors are connected to the Port1 pins P1.0 to P1.3 of the microcontroller to carry the signal of flood level to the microcontroller.

B. Working Principle

The segment from the right to the left indicate the different flood levels from zero on wards. When the water level is less than or equal to the rightmost zero level segment, all the transistors are in off state and logic level 1 is read by the microcontroller on all the port 1 pins. This condition indicates 'No Flooding'. As the water level rises up to the second segment level, the first segment and the second segment gets short, turning ON the second transistor. This makes the corresponding port pin logic 0 and is read by the microcontroller. The level of flooding along with the area is then displayed on the LCD at the On-site module. Also, this information is transmitted through ZigBee routers to the Main station. The Main station compares the current water level with the threshold flood level. If the water level has crossed the threshold flood level, the main station controller issues a command to the on-site ZigBee to turn on the relay circuit which in turn starts the pump for evacuating the water.

C. Trans Receiving using ZigBee

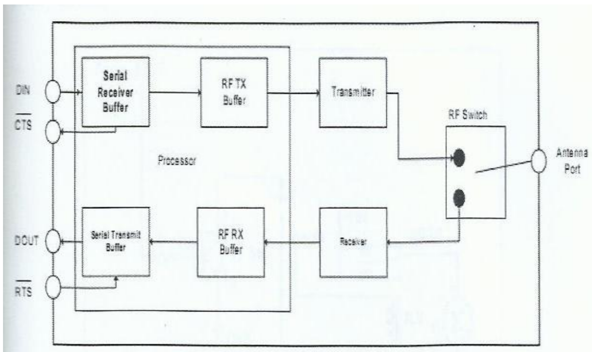

Fig. 5 Trans Receiving using ZigBee

When serial data enters the RF module through the DIN pin, the data is stored in the serial receive buffer until it can be processed[2], [5] . Under certain conditions, the module may not be able to process data in the serial receive buffer immediately. If large amounts of serial data are sent to the module, CTS' flow control may be required to avoid overflowing the serial receiver buffer.

When RF data is received, the data is moved into the serial transmit buffer and sent out to UART. If the serial transmit buffer becomes full enough such that all data in a received RF packet would not fit in the serial transmit buffer, the entire RF packet is dropped.

If CTS flow control is enabled, when the serial receive buffer is 17 bytes away from being full, the module de-asserts CTS to signal to the host device to stop sending serial data. CTS is re-asserted after the serial receive buffer has 34 bytes of space.

If RTS flow control is enabled, data in the serial transmit buffer will not be sent out the DOUT pin as long as RTS is de-asserted. The host device should not de-assert RTS for long periods of time to avoid filling the serial transmit buffer. If RF data packet is received, and the serial transmit buffer does not have enough space for all of the data types, the entire RF data packet will be discarded.

D. Relay Circuit

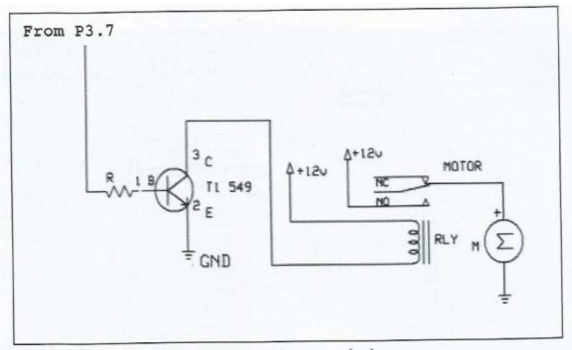

Fig. 6 Relay Circuitry

As shown in Fig.6, the output from port 3 pin 7 is given to the transistor base terminal via current limiting resistor. On reception of signal from port to the base terminal set the transistor ON and hence it magnetize the coil in the relay circuit leading to closure of the switch and start of the motor/pump etc. If the supply ceases off the coil de-magnetizes and pump/motor stops. Here the relay is of 12V electromagnetic (SPDP) that works in both ON and OFF modes.

VI. THE MAIN STATION MODULE

A. Circuit Explaination

The data sent by the transmitter reaches the receiver using the ZigBee mesh network. The objective is to send this data to the computer through RS232 cable. To maintain compatibility between the RS232 and the ZigBee module, IC MAX 232 is used.

The power supply circuitry is similar to that explained in the transmitter. It provides 5V supply to the IC MAX23and 3.3V supply to the ZigBee module.

B. Working Principle

The MAX 232 receives the data from ZigBee having operating range from 0 to 3.3V. However, MAX232 needs to communicate through RS232 which operates at -10V to 10V. The MAX 232 along with four 10µF capacitors will step up the voltage to desired level required for the RS 232 communication.

The RS232 cable sends the data to the computer in the control room. The information or data from all the on-site ZigBee modules is observed on the map of the computer screen. The map consists of the areas where on-site modules are located. The area code and the level of the flood/ water is displayed on each of these locations on the map. Depending on the received information, the relays of the on-site module are controlled remotely to control the flood. Visual Basic 6 is used as the GUI in this case for the representation of the data on the map of the computer screen.

VII. CONCLUSIONS

The paper shows simple, cost effective, efficient and rapid way of flood monitoring and control using ZigBee as a wireless sensor network. Using ZigBee, the distance between the size and the control room can be largely increased because ZigBee supports different topology using which we can form grid networks. By attaching a motor to the relay circuit at the receiver or on-site module, we have shown that larger pumps can be used to evacuate water from the flooded area. The existing ZigBee network can also be used for road traffic control by placing the on-site modules accordingly and appropriately. Also, a messenger service can be created by which the people can get messages from the control room regarding flood and traffic.

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