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Real-Time Monitoring and Contamination Detection Sensor Network for Drinking Water Distribution System

Banda Madhu [1], Ujwala Bollampalli [2]

[1] M.Tech student in VLSI & EMBEDDED SYSTEMS, Dept of ECE, SR International Institute of Technology, Rampally, Keesara, R.R.Dist, Telangana, India.

[2] Assistant Professor, Dept of ECE, SR International Institute of Technology, Rampally, Keesara, R.R.Dist, Telangana, India.

Abstract*: This paper presents a holistic approach to the water quality monitoring problem for drinking water distribution systems as well as for consumer sites. Our approach is based on the development of sensor nodes for real time and in-pipe monitoring and assessment of water quality on the fly. The main sensor node consists of several in-pipe electrochemical and optical sensors and emphasis is given on low cost, lightweight implementation, and reliable long time operation. Such implementation is suitable for large scale deployments enabling a sensor network approach for providing spatiotemporally rich data to water consumers, water companies, and authorities. Extensive literature and market research are performed to identify low cost sensors that can reliably monitor several parameters, which can be used to infer the water quality. Based on selected parameters, a sensor array is developed along with several Microsystems for analog signal conditioning, processing, logging, and remote presentation of data. Finally, algorithms for fusing online multisensory measurements at local level are developed to assess the water contamination risk. Experiments are performed to evaluate and validate these algorithms on intentional contamination events of various concentrations of Escherichia coli bacteria and heavy metals (arsenic). Experimental results indicate that this inexpensive system is capable of detecting these high impact contaminants at fairly low concentrations. The results demonstrate that this system satisfies the online, in-pipe, low Deployment-operation cost, and good detection accuracy criteria of an ideal early warning system.

***Key Words:* Wireless sensor networks (WSN), ZIGBEE, and LPC2148.**

I. INTRODUCTION

Microcontrollers as the name suggests are small controllers. They are like single chip computers that are often embedded into other systems to function as processing/controlling unit. For example the remote control is using probably has microcontrollers inside that do decoding and other controlling functions.

Micro-controllers are useful to the extent that they communicate with other devices, such as sensors, motors, switches, keypads, displays, memory and even other micro-controllers. Many interface methods have been developed over the years to solve the complex problem of balancing circuit design criteria such as features, cost, size, weight, power consumption, reliability, availability, manufacturability. Many microcontroller designs typically mix multiple interfacing methods.

In a very simplistic form, a micro-controller system can be viewed as a system that reads from (monitors) inputs, performs processing and writes to (controls) outputs. Embedded system means the processor is embedded into the required application. An embedded product uses a microprocessor or microcontroller to do one task only. In an embedded system, there is only one application software that is typically burned into ROM.

II. PROPOSED WORK

In this article, we present an improved software platform using (GUI) VB.NET & hardware platform, develop a new advanced contamination event detection algorithm and provide an experimental evaluation and validation of system and event detection algorithms in the presence of real microbiological and chemical contamination events.

A limited number of on-line, reagent-free water monitoring systems are commercially available [7] (e.g. Hach HST GuardianBlue [8], J-MAR BioSentry [9], etc), but these systems are bulky (sensors are installed in flow cells located in cabinets) and remain cost prohibitive for large scale deployments (cost tens of thousands of dollars per unit). It is worth mentioning that cost is mostly attributed not to sensing probes but to instrumentation-automation controllers (analyzers) and panels. Such systems can take frequent samples of the water quality at a very limited number of locations.

However, substantial proportion of contamination problems is attributable to problems within distribution systems and due to the limited spatio-temporal sampling, it is impossible for the water companies and consumers to know the quality of potable water delivered to consumer households.

A number of bare multi-parametric sensor arrays have been developed and presented in the literature based on various sensor technologies. A recent review on multi-parametric solid-state sensors for water quality is given [3]. A chemical sensor array for water quality monitoring based on thick film technology is presented in [24], [25], [26], and [27], these sensors are very low cost, though they have limited lifetime (few months) and require a conventional glass reference electrode to operate accurately. Along similar lines, a multi parametric sensor array based on semiconductor ruthenium oxide nanostructures is presented in [3] and [28]. In addition, several water monitoring micro systems (sensor nodes) have been developed for large scale water monitoring, based on wireless sensor networks (WSNs) technology. In a sensor node is developed for monitoring salinity in ground waters as well as the water temperature in surface waters. A WSN and an energy harvesting system (based on a solar panel) to monitor nitrate, ammonium and chloride levels in rivers and lakes.

Energy harvesting techniques along with hibernation methods play an important role in extending the lifetime of sensor nodes. A survey on energy harvesting for WSNs is provided, finally an autonomous boat equipped with water sensors is proposed to collect samples from lakes using the A□ search algorithm. More efficient navigation algorithms for a group of boats with obstacle avoidance are presented in.

Next, we provide a number of academic and commercial efforts aim to develop hardware and software platforms for real-time monitoring of the water distribution systems. WSN is proposed to monitor hydraulic parameters in order to detect events such as leaks, pipe bursts. A cost effective multi sensor probe (Endetec KAPTA 3000-AC4) for monitoring chlorine, conductivity and pressure without any event detection algorithms has been proposed by Endetec in 2012. Finally, an optical interferometric sensor along with an event detection algorithm to monitor refractive index aberrations in water has been developed.

Apart from the on going research towards the design and development of sensors and micro systems another parallel research direction is that of the development of software and algorithms for the detection of water quality anomalies and contamination events. A thorough survey on recent advances in this area is provided in [30]. A limited number of event detection software is commercially available (Hach Event Monitor [8], BlueBox [10]). A currently freely available tool is CANARY software [11] developed at Sandia National Laboratories in collaboration with the USEPA. CANARY indicates possible contamination events by using a range of mathematical and statistical techniques to identify the onset of anomalous water quality incidents from online raw sensor data. Other event detection and data validation methodologies are given in [31] and references therein.

Block Diagram:

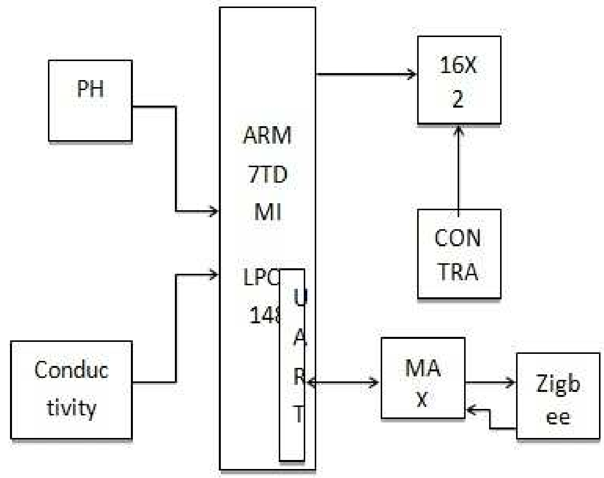

Fig:1 Block Diagram of Project.

2.1 Zigbee Module Interfacing with LPC2148:

The microcontroller output is not compatible with the Zigbee module. To make it compatible we require the DB9 connector and the MAX 232 connector. This will enable the microcontroller to send a message to a predefined when action is performed.

2.2 LCD Interface with LPC2148:

The system also consists of a display system having in corresponding response display information on LCD. LCD module has 8-bit data interface and control pins as shown in Figure 3. One can send data as 8-bit or in pair of two 4-bit nibbles. To display any character on LCD micro controller has to send its ASCII value to the data bus of LCD. For e.g. to display 'AB' microcontroller has to send two hex bytes 41h and 42h respectively.

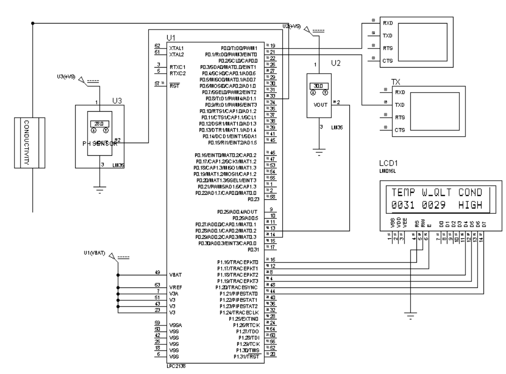

Fig2. LCD interfacing with microcontroller

LCD display used here is having 16x2 sizes. It means 2 lines each with 16 characters.

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2.3 Embedded Processor:

In the proposed work, LPC2148 is the widely used IC from ARM-7 family. It is manufactured by Philips and it is pre-loaded with many inbuilt peripherals making it more efficient and a reliable option for the beginners as well as high end application developer.

The features of LPC214x series controllers 8 to 40kB of on-chip static RAM and 32 to 512kB of on-chip flash program memory.128 bit wide interface/accelerator enables high speed 60 MHz operation. In-System/In-Application Programming (ISP/IAP) via on-chip boot-loader software. Single flash sector or full chip erase in 400 ms and programming of 256 bytes in 1ms. Embedded ICE RT and Embedded Trace interfaces offer real-time debugging with the on-chip Real Monitor software and high speed tracing of instruction execution. USB 2.0 Full Speed compliant Device Controller with 2kB of endpoint RAMS. In addition, the LPC2146/8 provides 8kB of on-chip RAM accessible to USB by DMA. One or two (LPC2141/2 vs. LPC2144/6/8) 10-bit A/D converters provide a total of 6/14analog inputs, with conversion times as low as 2.44 us per channel. Single 10-bit D/A converter provide variable analog output. Two 32-bit timers/external event counters (with four capture and four compare channels each), PWM unit (six outputs) and watchdog. Low power real-time clock with independent power and dedicated 32 kHz clock input. Multiple serial interfaces including two UARTs (16C550), two Fast I2C-bus (400kbit/s), SPI and SSP with buffering and variable data length capabilities. Vectored interrupt controller with configurable priorities and vector addresses. Up to 45 of 5 V tolerant fast general purpose I/O pins in a tiny LQFP64 package. Up to nine edge or level sensitive external interrupt pins available. On-chip integrated oscillator operates with an external crystal in range from 1 MHz to30 MHz and with an external oscillator up to 50MHz. Power saving modes include Idle and Power-down. Individual enable/disable of peripheral functions as well as peripheral clock scaling for additional power optimization. Processor wake-up from Power-down mode via external interrupt, USB, Brown-Out Detect (BOD) or Real-Time Clock (RTC). Single power supply chip with Power-On Reset (POR) and BOD circuits: CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V tolerant I/O pads.

2.4 MAX 232 (Communication Interface):

RS-232 (Fig. 4.) was created for one purpose, to interface between Data Terminal Equipment (DTE) and Data Communications Equipment (DCE) employing serial binary data interchange. So as stated the DTE is the terminal or computer and the DCE is the modem or other communications device. RS 232 is the most widely used serial I/O interfacing standard. In RS 232, a 1 is represented by -3 to -25 v. while a 0 bit is +3 to + 25 v, making -3 to +3 undefined. For this reason, to connect any RS 232 to a Microcontroller system we must use voltage converters such as MAX 232 to convert the TTL logic levels to the RS 232 voltage level, and vice versa.

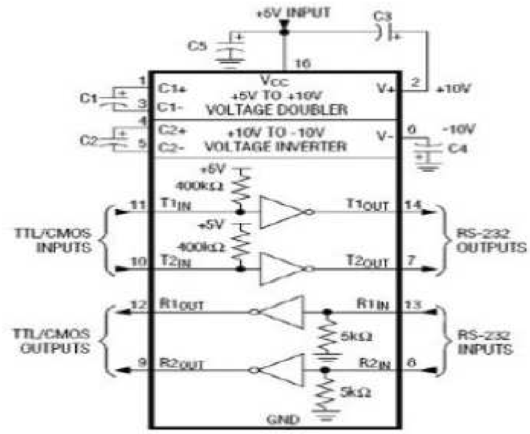

Fig 6. Operating Circuit of MAX 232

This chip is used when interfacing micro controller with PC to check the Baud rate and changes the voltage level because micro controller is TTL compatible whereas PC is CMOS compatible.

III. EXPERIMENTAL RESULTS

a. The main interface:

The main interface of monitor center where users can choose the operation is shown in Fig.4. In the main interface, the serial port should be set. Select the serial port 4, baud rate is 9600bps and take 8 data bits with no parity. After successful set .up, the situation of working node, dormant nodes and the coverage of the water quality will be displayed in the main page after the working of deployment module as shown in Fig.7.

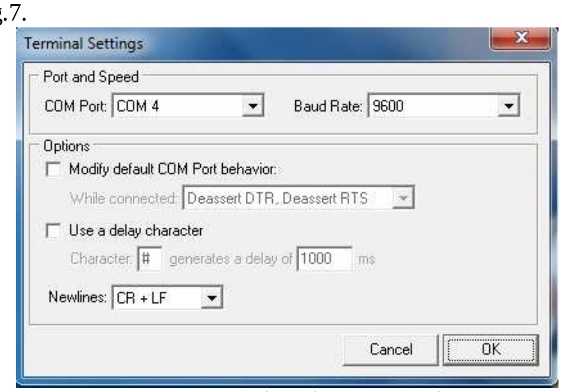

Fig. 7: The main interface of monitoring software

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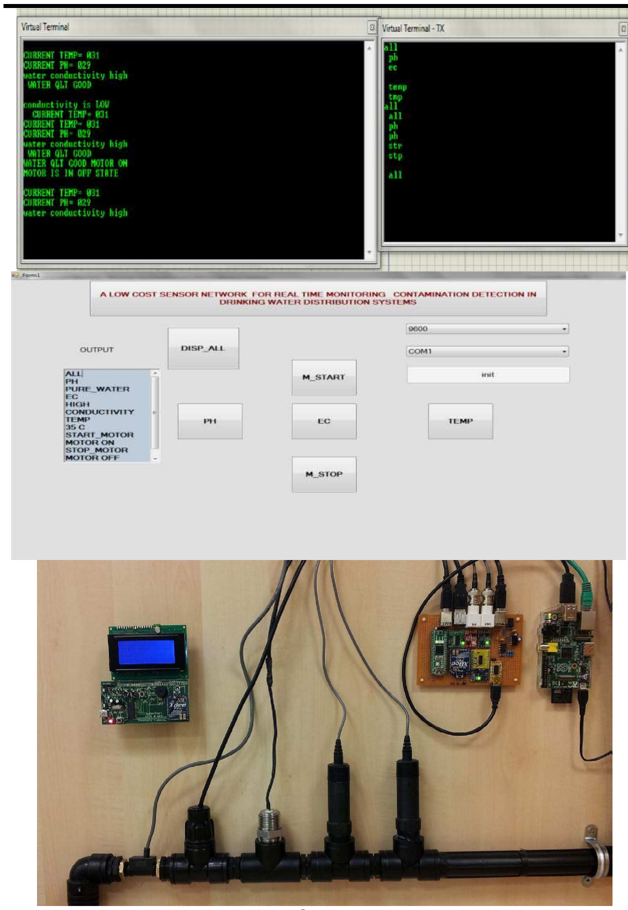

Fig. 8: Complete system output.

Finally we get the value at server section and when it exceeds the threshold values then automatically corresponding sensors alert.

IV. CONCLUSION

In this paper a real-time detection of the water quality monitoring problem for drinking water distribution systems based on wireless sensor network is designed. The system takes modular design, including temperature and PH and Conductivity data collection module, decision analysis module. The system collects current temperature, PH and conductivity in real time under the working of collection model by sensor nodes deployed in the drinking water distribution systems, and it processes the values from collection model quickly with decision module and uploads that values to control center, after evaluation the center can take real-time scheduling in order to distribute the quality drinking water. When the PH or Conductivity is detected fault, then it stops the distribution of drinking water. When the temperature is close to the warning value, and then automatically indicates at the receiving end. All the corresponding sensor values will be displayed on the system at the receiving end.

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BIOGRAPHY

BANDA MADHU M.Tech degree in VLSI & Embedded Systems SR International Institute of Technology,Rampally, Keesara, R.R.Dist. B.Tech from Electronics & Communication Engineering from Vathsalya Institute of Science & Technology, Anantharam, Bhongir, Nalgonda.

UJWALA BOLLAMPALLI received the M.E degree in DIGITAL SYSTEM ENGINEERING from Osmania University, Hyderabad. She is Assistant Professor, Department of Electronics and Communication Engineering at SR International Institute of Technology.

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