

Water Monitoring System using Embedded Technology

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Abstract: Embedded technologies play an important role in the field of Science and Technology. Lots of Research works has been increased in the field of Embedded Systems and a number of papers on wireless sensor networks have increased. All these research works basically deals with the areas of networking concepts, communication systems and other areas. In this paper we are dealing with the application of Embedded systems wireless sensor Networks – Water Monitoring System using Embedded Technology. This Paper is about to find the amount of impurities present in the water. The content of impurities present in the water are sensed and the sensed data is collected and transmitted through Zigbee and GPRS. There are some different techniques are used in the implementation of the system with the help of Tiny OS, LabVIEW and MySQL.

Index Terms— Tiny OS; LabVIEW; PLC; ZigBee; GPRS; Water monitoring

I. INTRODUCTION

In this fast developing world, water pollution is one of the serious problem that distracts the world. To deal with this problem, varieties of water monitoring systems have been developed based on cellular mobile network. These systems with high security will provide environmental protection agencies in providing continuous water monitoring with minimum interaction of man interference. But, with such systems, the rare channel resources and hardware are greatly wasted when the monitoring nodes are distributed in higher density. The hierarchical organization, grouping of the monitoring nodes before transferring the sensor data to higher levels, is one of the mechanisms proposed to deal with that extravagance and is commonly referred to as clustering. This paper is to show a hierarchical architecture, which is low in cost, easy to construct, less dependent upon network infrastructure, is implemented by employing ZigBee and GPRS devices. A general-purpose computer, such as a personal computer, is designed to be more flexible and to meet a large number of user needs. In day today life many devices are controlled by embedded systems. Embedded systems are based on microcontrollers but the microprocessors are also still common in practical use, especially in the complex systems. In both the cases, the processor used may be ranging from a general purpose processor to a specialized processor in a standard class of functions, or even the custom designed application at the other hand. A very common standard processor is the digital signal processor (DSP).The important characteristic is to handle a particular task at a given time. Since the embedded system is dedicated to perform specific operations in a quick time, the design engineers can work to reduce its size and cost of the product and at the same time to increase the reliability and performance. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language developed by National Instruments. LabVIEW software is commonly used for instrumentation processing and control, data acquisition, industrial automation, it works on different platforms including Microsoft Windows, various versions such as Mac Operating Systems, Linux and Unix.

II. THE STRUCTURE AND COMPOSITION OF THE SYSTEM

The hierarchical network is built with one base Station and many monitoring nodes. These monitoring nodes are responsible for sampling the water, single-hopping the data to the base station by ZigBee channel, while the Base Station is set for coordination between the nodes, sending the sensor data which is collected from the nodes to the remote management platform.

The Base Station is made of online monitoring device, GPRS DTU and ZigBee Module (worked as a coordinator, FFD), as is shown in Fig 2. The online monitoring device which uses CP1H PLC made by OMRON as the controller is responsible for testing the concentration of NO₃⁻, PO₄³⁻ and PH value. GPRS DTU implements the transmission of the remote signals by GPRS network. ZigBee module is made up of MSP430 controller and CC2420.

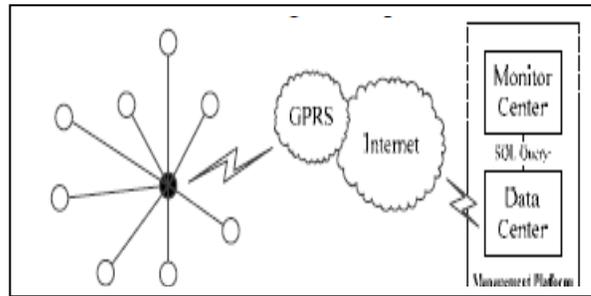


Fig.1. Topology of the network and remote management platform. The disc stands for base station, circle for monitoring nodes.

RF chip. It is used to read the data of the water in PLC, collects the data of water in the other monitoring nodes and exchanges the data with the remote management platform by GPRS DTU. MSP430 MCU is connected to PLC and GRPS DTU respectively through serial cable. Different from the Base Station, the monitoring node, on the other hand, does not include GPRS DTU, and its ZigBee module is a Reduced Function Device (RFD).

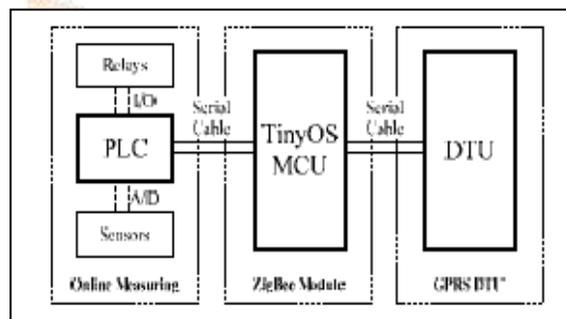


Fig.2. Components of the hardware of the Base Station.

III. ZIGBEE MODEL

ZigBee is new specification for a suite of high level communication protocols used to create personal area networks which is built using small and low-power digital radios. ZigBee system is based on IEEE 802.15 standard. Though low-powered, ZigBee devices usually transmit data over longer distances by passing the data with intermediate devices to send large distances, creating a mesh network. Mesh Network is a network with no centralized control or high-power transmitter or receiver able to reach the overall networked devices. The decentralized nature of these wireless networks make them suitable for special applications where a central node cannot be depend upon. ZigBee is used in different applications that require a very low data rate, good battery life, and highly secured networking process. ZigBee has a fast rate of 250 k.bit/s, with this high speed, it is suited for periodic data or intermittent data or a single signal transmission from a input device or from a sensor. There are plenty of applications include traffic management systems, wireless light switches, electrical meters with displays and other industrial and consumer equipment that requires short range of wireless transfer of data at relatively very low rates. This technology defined by the ZigBee specification is tend to be simple and less expensive compared to other WPANs like Bluetooth or Wi-Fi. ZigBee networks are highly secured by 128 bit symmetric encryption keys. In some home automation applications, transmission distances widely range from 10 to 100 meters line-of-sight, depending on the capacity of the power output and environmental characteristics.

ZigBee module consumes very low power, and it's a low cost wireless mesh network standard. The low cost module allows the technology to be widely used in different wireless control and monitoring applications. Low power consumption gives longer life with smaller batteries. Mesh networking provides a very high reliability and also covers more extensive range. ZigBee module operates in the scientific, industrial, and medical radio bands. Data transmission rates vary from 20 kilobits/second in the 868 MHz frequency band to 250 kilobits/second in the 2.4 GHz frequency band. The ZigBee network layer supports both star networks and tree networks, and generic mesh networks. Each and every network must have one unique coordinator device with some required control parameters with specific task functions and some basic maintenance. In the star networks, the central node is the coordinator. The mesh network and tree network uses the Zigbee routers for a better communication purpose. Zigbee has the media access control and physical layer as defined in the IEEE standard for low rate wireless permanent area networks. The components Application layer, Network layer, Zigbee device objects are added to complete the standard. The important thing in adding high level networks is the introduction of zigbee device objects. The Zigbee device objects plays an important role in performing a number of tasks in a specific time.

Both FFD and RFD are built with TinyOS operating system. TinyOS is an embedded system for wireless network, with a set of components that are included as-needed in applications.

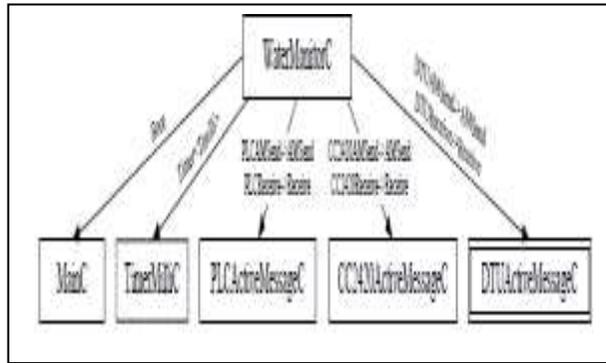


Fig.3. Components used for FFD and RFD.

As illustrated in Fig. 3, WaterMonitorC is composed of five components of which, MainC implements the boot sequence of a node and provides the Boot interface so that WaterMonitorC can be notified when a node has fully booted. In our application, WaterMonitorC needs to sample periodically, so we can use startPeriodic command, which will signal a fired event when time is up. It's worth mentioning that TimerMilliC is a generic configuration which provides code reuse through a code-copying mechanism, so the only way to use TimerMilliC is instantiate it with the new keyword. Furthermore, there are three ActiveMessageC components which look similar but have entirely different responsibilities. For instance, PLCActiveMessageC is used for learning the states of auxiliary relays in PLC and the concentration of NO3-, PO43- and PH value. Communication between FFD and RFDs is the duty of CC2420ActiveMessageC. DTUActiveMessageC, used only in FFD, the coordinator of the sensor network, sends data packets to remote management platform by GRPS channel.

A. RFD

RFD has two main functions: 1. read the concentration of NO3-, PO43- and PH value (as Sensor Data) in PLC; 2. send Sensor Data to the FFD. The Sensor Data is read through HOSTLINK instruction. HOSTLINK is Omron's proprietary protocol, by which the external device can communicate with Omron PLC through serial port. By HOSTLINK protocol, RFD can visit DM (Data Memory), AR (Auxiliary Relay) and other registers in PLC [6].

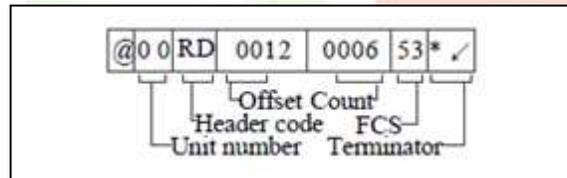


Fig.4. (a) HOSTLINK enquiry

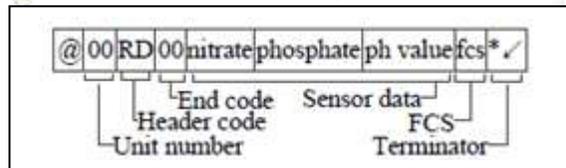


Fig 4. (b) HOSTLINK response

In our system, the Sensor Data, starting from 0012 unit, is stored in the DM area of PLC, each being represented by an 8-byte ASCII. In order to read the Sensor Data, TinyOS will send HOSTLINK instruction, as is shown in Fig 4 (a) below. When a HOSTLINK instruction has been received, PLC will send back a HOSTLINK instruction as response which contains Sensor Data, as shown in Fig 4 (b)

It is to be noted that PLC stores the Sensor Data as a double-byte ASCII because PLC of the C series does not support the float type in IEEE format. Of the 8 bytes only the late half are valid, so that the HOSTLINK response is stored in TinyOS.

Fig 5 (a) is a subset of the RFD state diagram, the advanced operations being elided for simplicity. WaterMonitorC initiates periodic sampling in its booted event by Timer.startPeriodic(60000) command. Timer.fired requests a new PLC sampling by sending HOSTLINK instructions, one time a minute, using the split-phase PLCAMSend interface, and a PLCAM packet stored in a

plc_sensor_data_t packet buffer. The plc_sensor_data_t holds the current Sensor Data after HOSTLINK response arrives. Then we restore the Sensor Data into node_sensor_packet_t (Fig 6), and send the Sensor Data to FFD by CC2420AMSend interface. Thus, the packet is smaller and easier to transmit.

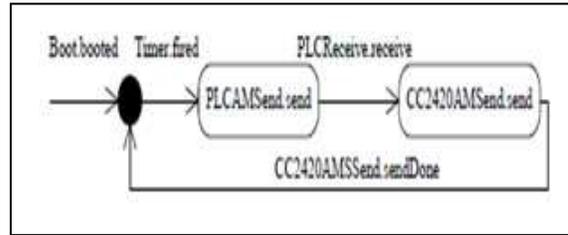


Fig.5. (a) RFD operating scenario

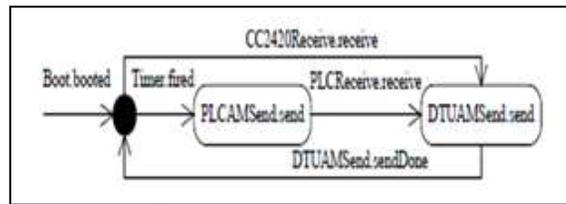


Fig.5.(b) FFD operating scenario.

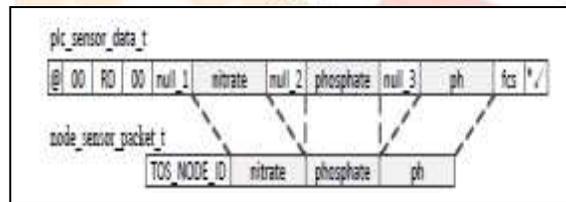


Fig.6. Relationship between plc_sensor_data_t and node_sensor_packet_t.

B. FFD

FFD has functions as follows: 1. receive node_sensor_packet_t variable sent from a RFD; 2. read the Sensor Data in PLC; 3. send every node_sensor_packet_t variable to the remote management platform. The remote transmission function is implemented by GRPS DTU. GPRS DTU is a device for conversion between serial data and IP packet. It has the PPP dial-up and TCP/IP protocol encapsulated in GPRS DTU, enabling transparent transmission between serial devices and remote computers. Different from RFD, PLCReceive.receive does not retransmit HOSTLINK response by CC2420Send interface, but sends the restored node_sensor_packet_t variable to the remote management platform by DTUAMSend interface. When CC2420Receive receives a node_sensor_packet_t variable from RFD, it also sends a node_sensor_packet_t variable by DTUAMSend interface. When this is done, the TinyOS system returns to the original state, waiting for next Timer.fired event. The FFD operating scenario is shown in Fig 5 (b).

IV. REMOTE MANAGEMENT PLATFORM

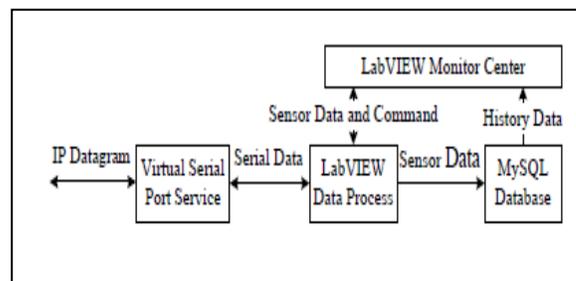


Fig 7. Architecture of Remote Management Platform

A. *Virtual Serial Port Service*

The remote management computer receives the IP packet which contains Sensor Data. For easy operation, the IP packet is converted into serial data by Virtual Serial Port Service. Then the serial data is used to communicate with upper procedures through the virtualized serial port. The Virtual Serial Port Service is composed of the virtual serial driver and the network service procedure. The virtual serial driver is of a standard WIN32, providing a serial port COM5 for the management computer. The network service procedure listens in IP packets on assigned port, converts IP packet to serial data and sends the serial data to the virtualized serial port through the kernel thread.

B. *Data Process Procedure*

The Data Process Procedure of LabVIEW software, is responsible for binding COM5 and receives Sensor Data from GPRS DTU. As float in CP1H PLC is stored as two 16-bit words in ascending order, just like little-endian, LabVIEW must convert the order of Sensor Data before being transformed into float. The obtained sensor data is stored into the database and displayed in the monitoring center. This process is implemented by a producer-consumer pattern. In this way, the Sensor Data can be stored into MySQL database immediately in producer cycle, and is displayed in a constant speed in consumer cycle.

C. *Storage and display of the data*

MySQL, an open sourced relational database with high performance, can run in most operating systems. LabVIEW connects MySQL via Database Connectivity Toolkit and ODBC interface. In addition, the performance of MySQL has to be considered due to the growing records of Sensor Data. So, it is necessary to build up indices in MySQL and to avoid slow query in LabVIEW.

LabVIEW Monitoring Center is not only responsible for displaying the Sensor Data of monitoring nodes in real time but also achieves the functions of historical inquiry and abnormal alarm.

V. CONCLUSION

This system combines the communication technologies of ZigBee and GPRS to set up a complete water monitoring system. Compared to similar studies, TinyOS is first employed in the field of water quality monitoring in our system to achieve the goals of water quality data collection and its remote transmission. The system suggests the component-based programming method and the event-driven operating mechanism, which is independent of network infrastructure, flexible and cheap to be implemented and has a promising prospect. However, the system is far from being perfect. More research is needed concerning hidden terminal, out-of-order packet and other issues in the future.

VI. REFERENCES

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