Hardware/Software Based a Smart Sensor Interface Device for Water Quality Monitoring in IoT Environment

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***Abstract* — This paper discusses ongoing research being carried out on an Internet of things (IoT) Environment technology. The IoT makes a huge variety of real life objects becomes interconnect via the Internet Protocol. A sensor Interface device is Very important for sensor data collection of industries wireless sensor networks in IOT environments. In this environment, sensors are connected to the device is required to write very complex and cumbersome data collection program code and need external hardware for different application. In this paper, to solve these problems, a new method is proposed to hardware /software based a smart sensor interface for water quality monitoring in Internet of thing environment, in complex programmable logic device (CPLD) is adopted as the core controller. Which causes, data can be read in parallel and in real time with high speed on multiple different sensor data. The standard of IEEE1451.2 smart sensor interface specification is adopted for this design. The device is combined with the newest CPLD programmable technology and the standard of IEEE1451.2 smart sensor specification. Performance of the proposed system is verified and good effects are achieved in practical application of IoT to water environment monitoring.**

***Index Terms* — CPLD, IEEE1451.2 protocol, Internet of things (IoT), Sensor data acquisition interface, VHDL Design, Wireless Sensor Network**

I. Introduction

An emerging technology brought about rapid advances in modern wireless telecommunication, Internet of Things (IoT) has attracted a lot of attention and is expected to bring benefits to numerous application areas including industrial WSN systems, and healthcare systems manufacturing [1], [2]. Wireless sensor networks (WSN) have been employed to collect data about physical phenomena in various applications such as habitat monitoring, and ocean monitoring, and surveillance [3]–[5].WSN systems are well-suited for long-term industrial environmental data acquisition for IoT representation [6]. Sensor interface device is essential for detecting various kinds of sensor data of industrial WSN in IoT environments [7]. It enables us to acquire sensor data.

With rapid development of IoT, there are a lot of data acquisition multiple interface equipment's with mature technologies on the market. But, these universal data acquisition interfaces are often restricted in physical properties of sensors (sampling rate, signal types and number of connect). Now, micro control unit (MCU) is used as the core

Controller in mainstream data acquisition device interface. Micro Controller unit has important advantage of low power consumption, less price and which it makes relatively easy to implement. But, by way of interrupt it performs a poor task, which makes these multisensor acquisition interfaces not really parallel in collecting multisensor data. On the other hand, CPLD has unique hardware logical control, real-time, synchronicity and performance [8], [9].

The remaining of this paper is arranged in a systematic way as follows. The related work is presented in Section II, and the detailed information about platform structure of IoT in Section III. Working diagram of smart sensor interface device described in Section IV. Hardware and Software implementations are described in Section V. Actual effect evaluation of water quality monitoring is discussed in Section VI. And we conclude our work in Section VII.

II. Related Work

Sensor data acquisition surface device is the key part of study on industrial WSN application [10]. In order to standardize a wide range of intelligent sensor interfaces in the market and solve the compatibility problem of intelligent sensor, the IEEE Electronic Engineering Association has also launched IEEE1451smart transducer (STIM) interface standard protocol suite for the future development of sensors [11]. The protocol stipulates a series of specifications from sensor interface definition to the data acquisition [12]. The STIM interface standard IEEE1451 enables sensors to automatically searching the network, and the STIM promotes the improvement of industrial WSN [13]. But, the sensors with the protocol standard have a high cost and still lack popularity in industrial WSN in IoT environment. Nevertheless, at present, examples of intelligent sensors available on the market and compliant with this standard are still limited [14]. To solve these problems, some dedicated hardware interfaces based on the IEEE 1451.2 have been recently proposed, and they are capable of interfacing with different sensor typologies [15]. These interface devices are usually based on relatively complex dedicated electronic boards [16]–[18]. Such restriction should be released [19], and a re-configurable multisensor data acquisition interface with good compatibility and normative interface standard needs to be developed in IoT environment.

By focusing on the above issue, this paper designs and realizes a hardware /software based a smart sensor interface for water quality monitoring in IOT environment. This design presents many advantages as described below.

First of all, CPLD is used as the core controller to release the restriction on the universal data acquisition interface, and realize truly parallel acquisition of sensor data. It has not only improved the sensor data collection efficiency of industrial WSN, but also extended the application range of the data acquisition interface equipment in IoT environment.

Secondly, a new design method is proposed in this paper for multisensor data acquisition interface that can realize plug and play for various kinds of sensors in IoT environment. The design system applies the IEEE1451 interface protocol standard that is used for smart sensors of automatically discovering network. For the sensors not based on IEEE1451 protocol standard, the data acquisition interface system can achieve the function of plug and play. In this paper, this design take full advantage of CPLD characteristics, such as high execution speed, flexible organization structure, IP design could reuse, etc. The design adopts IEEE1451 smart transducer (STIM) interface standards, which makes our device better compatible in the field of industrial WSN in IoT environment.

III. Platform Structure

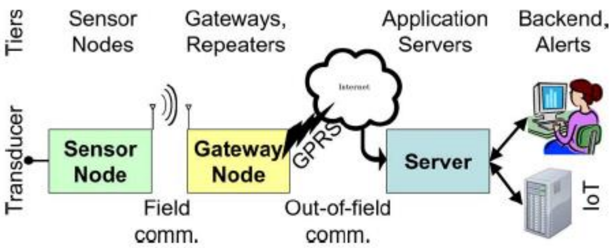

Figure1. Platform Structure of the WSN.

The crucial purpose of the WSN platform is to provide the users of the IoT application and updated view of the events of in the various interest fields.

The tiered structure of the used platform (see Fig.1) was introduced by one of the first long-term outdoor WSN experiments [20] and allows:

The sensor nodes are optimized for field data acquisition using on-board transducers, processing, and communication to gateways using short-range RF module, it may be directly, or it might be through other nodes. The gateways process, store, and periodically send the field data to the application server using long-range communication channels. This application server provides long-time data storage and interfaces for data access and process by end users. The platform should be flexible to allow the removal of any of its tiers to satisfy specific application needs. For instance, the transducers may be installed on the gateways for stream water level monitoring since the measurement points may be spaced too far apart for the sensor node short-range communications.

In the case of seismic reflection geological surveys, for example, the sensor nodes may be required to connect directly to an on-site processing server, bypassing the gateways. And when the gateways can communicate directly with the end user, e.g., by an audible alarm, an application server may not be needed.

In additional elements described above, the platform can include an installer device to assist the field operators to find a suitable installation place for the platform nodes, reducing the deployment cost and errors.

Examples of a new workflow include a water environment monitoring system that adopts sensors to detect pollution and water quality [21]. Water environment monitoring is one of the IoT application fields, where complex water quality information, is used to determine the water environmental quality at the same time. However, currently, there are few data collection devices that are dedicated to water quality monitoring on the market. Such devices can ensure high speed of data acquisition for multiple sensors and adapt to complex and various sensor types well. Thus, we design and implement a WSN data acquisition interface that can be used for water environmental monitoring. Detail of this example is elaborated in Section VI. Other application areas in IoT also need to collect sensor data. If there is a data acquisition interface compatible with the sensor of each application field in IoT. It well greatly promote IoT development.

So this design combines with the standard of IEEE1451.2 intelligent sensor protocol, and we design and implement a Hardware/Software Co-design of a Smart Sensor Interface for Water Quality Monitoring in IoT Environment.

IV. Working Digram of Smart sesor interface device

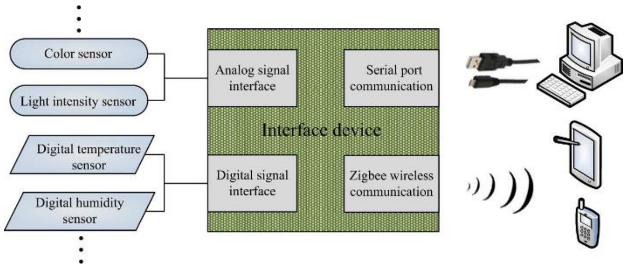

Figure2. Working diagram of the smart sensor interface device

We design a hardware and software based smart sensor interface device that integrates data collection, data processing, and wired or wireless transmission together. The device can be widely used in many application areas of the IoT and WSN to collect various kinds of sensor data in real time.

Fig. 2 working diagram of the hardware and software based smart sensor interface device.

In practice, the designed device collects analog signal transmitted from color sensors, light intensity sensors, and other similar sensors through an analog signal interface. It can also collect digital signal transmitted from the digital sensors, such as temperature sensors, digital humidity sensors, and so on, through a digital signal interface. The Analog to Digital Converter (ADC) module and signal interface on the interface device are controlled by the CPLD, which makes it possible to collect the 8-channel analog signals and 24- channel digital signals circularly, and sets these collected data into the integrated Static Random Access Memory (SRAM) on the interface device. The collected data can be transmitted to the host computer side by way of USB serial wired communication or Zigbee wireless communication, so that the user can analyze and process the data

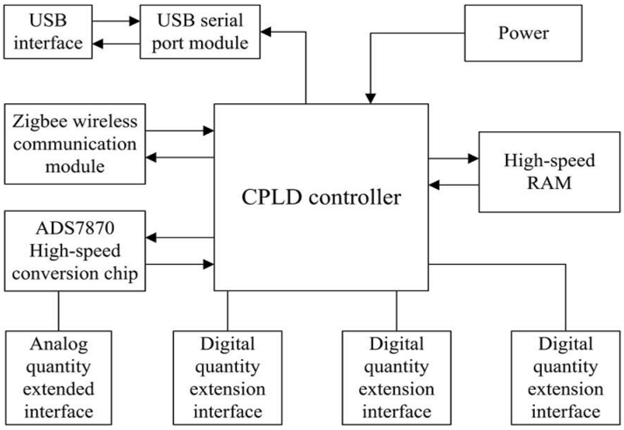

Figure3. CPLD hardware block diagram.

The overall structure of Hardware smart sensor interface consists of CPLD chip (XC2C256 chip), crystals and peripheral circuit, communication circuit for turning USB to serial port (PL2303HXC chips and peripheral circuits), power supply of 1.8 and 3.3 V (LM1117 chip, voltage regulator and filter circuit), an SRAM memory (TC55V400 chip), high-speed 8-channel ADC (ADS7870 chip and peripheral circuit), LED indicator light, an analog extended interface, and three digital extended interfaces. Every extended interface among them can connect eight independent sensors, namely, the smart sensor interface device can access eight analog signals and 24 digital signals. Fig. 3 shows the CPLD hardware block diagram.

V. HARDWARE/SOFTWARE DESIGN

A. Hardware Design:

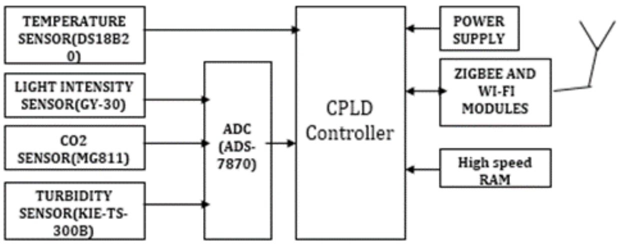

Figure4. System's block function design.

The core module of this system is CPLD-based reconfigurable smart sensor interface device designed by ourselves. It can well meet the requirements mentioned above. Here are the main solutions:

Firstly, we suggest that water turbidity sensor, water proof temperature sensor, CO2 sensor, and light intensity sensor should be used to collect required data; Secondly, Zigbee wireless module connected to the device is adopted for sending and receiving data; Thirdly, 1.8-V battery is offered to supply power for the system, and one battery can work for more than 10 hour. Block function design of the system is shown in Fig. 4.

After combination of the above hardware, the system gain slow cost, low power consumption, small volume, and other characteristics. Compared with the general water quality monitoring system using large equipment, it is more flexible and convenient. It is quite suitable for the project of water quality monitoring. Multi-node monitoring can be realized through Zigbee wireless module. Under the premise of reducing project cost, the system can collect multiple sets of data as much as possible from different nodes and ensures monitoring of the whole water quality environment. Fig. 5 presents the physical map of water quality monitoring hardware.

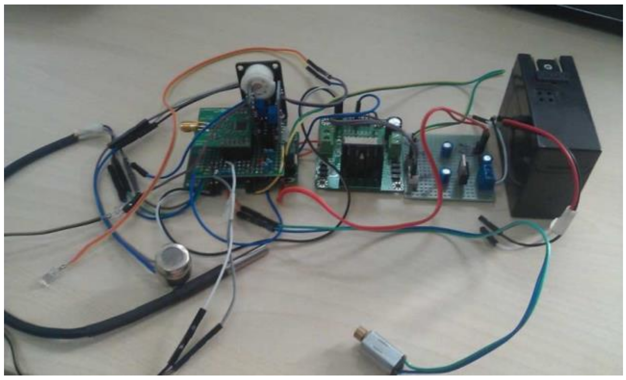

Figure 5. Water quality monitoring hardware physical map. The smart sensor interface device is on the left side and we expand a Zigbee module on it. We use these wires around the device to attach sensors that we have used. Power of the whole system is on the right side. The two pieces of circuit boards are some corresponding configuration circuit in the middle of the figure.

B. Software Design:

Software design of water quality monitoring system also includes two parts.

Firstly, the program uses the hardware description language based on CPLD, to control different sensor data acquisition and the last communication processing. The modular grouping development mode is adopted to develop various functional modules. First, we implement respective functions in the development process, and then summarize the functions to a complete system by way of original instantiation.

Secondly, because the sensor data is defined in the spreadsheet (TEDS), we just simply modify the corresponding sensor data format in spreadsheet according to different application systems. The requirements of data acquisition are met well and the difficulty of modifying the program is solved. CPLD system hardware resource consumption is shown in Fig. 6.

Table 1: Hardware Summary

Summary	
Design name	Top
Fitting status	Successful
Software version	M81d
Device used	XC2C256-TQ144
Date	2-14-2015,3:17PM

Table 2: Resources Summary

Resources Summary				
Microcells used	Pterms used	Resisters Used	Pins Used	Functio -nal Block Input used
224/256 (88%)	50/896 (57%)	203/256 (80%)	15/118 (13%)	390/64 0 (61%)

Figure6. CPLD system hardware resource consumption

What's more, we have programmed a software client, to send control signals through a serial port and obtain the collected data and display the collected data in the window. So far, we have achieved data display in the serial debug terminal. This program still requires further improvement. These data collected from the text are a group of 16 hexadecimal data. The data transmission format is 0xFD + data length +target address + data.

Length of the experimental data can be flexibly adjusted according to the number of sensors connected to the system. The data bit without connected sensors will display 00. After a sensor is connected to the system, the system will automatically search for data format of the equipment through a predefined physical interface and the corresponding relation of the spreadsheet. Then, the system completes standard conversion of the data format automatically. Finally, the transformed data are presented on the serial port terminal.

VI. Actual Effect Evaluation

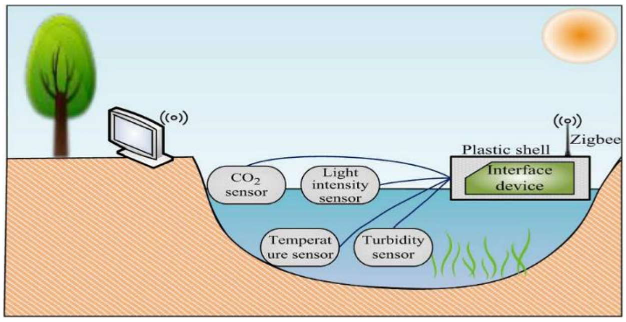

Figure7. Schematic diagram of monitoring equipment installation

As it is the monitoring service of pond water, it includes water turbidity monitoring, temperature monitoring, and carbon dioxide monitoring above the water. The device is put into the pool, so that the turbidity and temperature can be measured by using sensors in the depths of water, and the carbon dioxide sensor and light intensity sensor can be exposed above the water. Therefore, the equipment is covered with a waterproof shell to collect data, and good effects have been achieved. We design the schematic diagram of monitoring equipment installation as shown in Fig. 7.

Through actual test, we learn that the system can immediately collect sensor data when it is connected to power. The system has good compatibility and expansibility for different types of sensors. We have successfully tested different types of sensors on this system.

VII. Conclusion

This paper describes a hardware/software based smart sensor interface device for Water Quality Monitoring in IoT Environment. The system can collect sensor data intelligently. It was designed based on IEEE1451 protocol by combining with CPLD and the application of wireless communication. It is very suitable for real-time and effective requirements of the high-speed data acquisition system in IoT environment. The application of CPLD greatly simplifies the design of peripheral circuit, and makes the whole system more flexible and extensible. Application of IEEE1451 protocol enables the system to collect sensor data intelligently. Different types of sensors can be used as long as they are connected to the system. Main design method of the hardware/software based smart sensor interface device is described in this paper. Finally, by taking real-time monitoring of water environment in IoT environment as an example, we verified that the system achieved good effects in practical application.

For Future work, many interesting directions are remaining for further researches. For example, the IEEE1451.4 protocol can be perfected and the function of spreadsheet should be expanded. It will have a broad space for development in the area of WSN in IoT environment.

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