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A Smart Sensor Interface for WSN in IoT Environment using FPGA

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Abstract:-- **Measurement is an important subsystem of embedded system. Its main function is to collect the information from systems and feed to the processor for controlling the whole system. For collecting data, different types of sensors are used. Each sensor has to write complex and clumsy program code. Most of the control panels available in industries are wired panels and the machines are controlled and monitored by an operator in a room. It leads to the invention of sensor interface device controlled by wireless modules like zigbee, MiWi etc. Microcontrollers, one of the sensor interface device have some restrictions like connect number, sampling rate and signal types of sensors. To overcome these problems Field Programmable Gate Array (FPGA) is adapted as core controller. By using this, data can read in parallel and in real time with high speed from different sensors. MiWi module developed by Microchip is used here as wireless transceiver. But every wireless communication modules have limitations in the range. The concept of Internet of Things (IoT) is applied on the wireless sensor interface device. IoT is a concept of connecting and controlling devices through internet. Wide range of applications is available in IoT like industry, agriculture, environment protection etc. To maintain security in communication, data can send in encrypted form using suitable algorithm. A wireless sensor interface device designed using VHDL and is implemented in IoT environment using Java and C#.**

***Index Terms*—CPLD, MiWi, Internet of Things (IoT), sensor data acquisition**

I. INTRODUCTION

Wireless Sensor Network (WSN) is used to collect data from various applications such as industry, agriculture, environment protection. Researches in communication notices application of Internet of Things (IoT) in different areas in world wide. WSN can be used for lifelong industrial data acquisition in IoT environment. Sensors are used for data acquisition in real time. WSN enables us to understand surrounding conditions. However, in order to collect data in real time from an industry in the IoT, the interface device have to collect multiple sensor data at the same time.

The currently used automation systems, monitoring systems, security systems, etc., can share information over the network and are used mainly to employ an aid real time decision support[2]. The inter device communication in such systems has to maximize the efficiency and convenience in a variety of situations. Intelligent MiWi based wireless sensors have gained significant attention due to their flexibility, compactness and ease of use in remote locations and conditions. These wireless sensor modules are designed to combine sensing and contact less communication into a single, compact device; which provides ease of deployment, operation and maintenance. Large scale wireless sensor networks have different capabilities and are used to monitor real time application needs. Fig' 1 indicates a general wireless sensor network. But the range of wireless communication modules makes issues for big application ends.

Popularly data acquisition interfaces use microcontroller as core controller. Because of its low price and power consumption, also it is easy to implement. But, data acquisition are not parallel in collecting data[1]. Lot of data acquisition equipments are available in market. But each are designed specifically. An adaptive controller is required for changing IoT environment. Here MCUs are replaced with FPGA's because of its reconfigurability, lack of operating system and its dedicated hardware unit for processing logic.

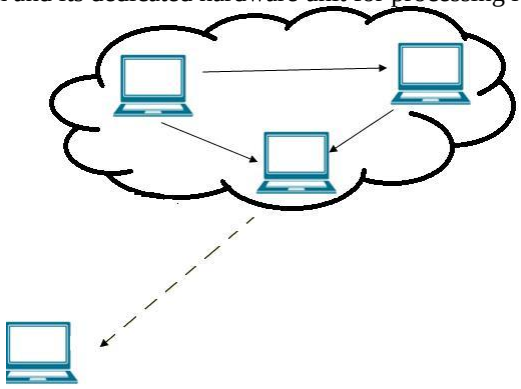

Fig. 1. Wireless Sensor Network

Varieties of complex sensors are presented in the industrial WSNs. For controlling the industrial process, have to collect information up to date and it becomes a challenging issue to the entire team of control unit in an industry. By focusing on the above mentioned issues, an IoT based sensor interface in the WSN generated. This presents the advantages of both WSN based industrial automation and IoT based sensor interface in the WSN. FPGA recovers the restrictions of data acquisition system that is the parallel data acquisition problem got resolved**.** Thus extended a wide range of application in the WSN.

This paper is organized as follows. Design of smart sensor interface for WSN using MiWi module is described in section II, implementation of IoT in section III and detailed hardware and software implementations are described in Section IV. Finally, we conclude our work in Section V.

II. SMART SENSOR INTERFACE FOR WSN

Production of different kind of materials includes an industry. For that, appropriate atmospheric conditions should meet otherwise it may affect the workers or it cause big loss to the manufacturer. Hence the need of maintaining all parameters up to date, hence the importance monitoring parameters inside an industry is very much important. Control unit inside an industry is sometimes not possible such as high temperature areas. In order to avoid that, can establish the control panel outside the industry, but we have to transmit data from indoor to outdoor.

The current generation monitoring systems, have the capability to share information over the network and are use to employ real time decision support. The device communication in such systems should possess maximum efficiency and it should adapt variety of situations. Intelligent wireless sensors based controls have gained significant attention due to their flexibility and ease of use in remote unattended locations and conditions. These wireless sensor modules designed for contactless communication and hence deployment, operation and maintenance becomes easy,. Large scale wireless sensor networks having different capabilities and are being used to monitor real time application.

We designed smart sensor interface for WSN using FPGA, wired and wireless peripherals, communication circuit, power supply of chip, voltage regulator and filter circuit, high speed 8 channel ADC, different analog and digital sensors, an analog extended interface, and digital extended interfaces[3]. The re configurable smart sensor interface device can access eight analog signals. The hardware system can also send and receive data besides the basic sensor data acquisition. Send data to the control room via MiWi wireless module. MiWi wireless communication is enabled through the driver IC PIC16F877A connected with the board through the interface. The sensor network consists of several logical elements, sensors, power

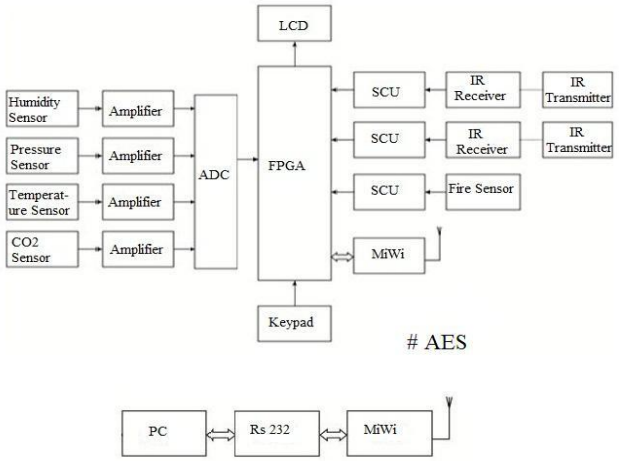

Fig. 2. Wireless Sensor Network

Supply and a wireless transceiver which sends measurements from the sensors to the control panel. Communications are typically based on the MiWi wireless communication due to its focus on low-power communications and simplicity. IEEE 802.15.4 used in gateways for high-speed data transmission. This protocol uses acknowledged data transfer mechanism in MAC layer.

Microchip developed MiWi module is the modified version of IEEE 802.15.4.The modification is done by introducing additional MAC commands. No specific operating system is required. Automatically scan the entire network for detecting peripherals. Thus the use of MiWi based WSN more flexible. User friendly protocol because no need of certification to enable communication. Guaranteed Time Slot (GTS) and beacon networks are not supported. Hence both the sides of the communication cannot go to Sleep Mode simultaneously.

Designed smart sensor interface device that collecting both digital and analog data, processing and finally transmit wirelessly together. The device can be widely used in many application areas of WSN to collect various kinds of sensor data in real time. FPGA coded using VHDL act as core controller in this design, therefore our interface device can automatically discover sensors connected to it, and can collect multiple sets of sensor data parallel and serially with high-speed. For proper transmission and reception using a wireless modules have to first initialize source and destination IDs, should disable interrupts, need to enable read and write operation, have to set output direction, enable serial port

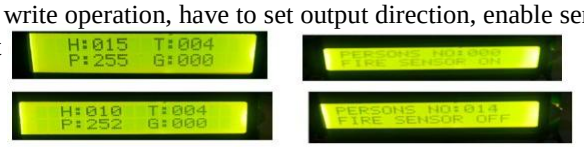

Fig. 3. Sensed Data

Communication moreover have to set baud rate. Zigbee is most popular and the modified version of Zigbee is the MiWi, hence is selected. Depending on the needs mentioned above, MiWi module is configured using embedded C.

The industries like aero engines needs secrecy in data transmission, considering that situation also in this design. To provide security in communication, many cryptographic algorithms are available, from that Advanced Encryption Standard (AES) is used here. It's a simple and most power algorithm which included substitute bytes, shift rows, mix columns, add round key. The standard form is AES -128. Here the data is send as encrypted form and the receiver can decrypt it depends on the authenticity. The received data is connected to the PC through a RS-232 serial peripheral interface.

*abhaafcffaabaaab*abgaafcffaabaaab*abgaaf
cffaabaaab*abgaafcffaabaaab*abgaafcffaabaa
aa*abgaafcffaabaaaa*abfaafcffaabaaaa*abfaa

Fig. 4. Data sending to receiver

III. WSN IN IOT ENVIRONMENT

While wireless technology is not an adequate technology for many applications, it should not be regarded as a unique solution for every networking environment. WSN means it's a centered connection, where all devices connected around a particular network. The data are closely packed inside the range of communication which means wide range of collecting information's has limits, hence Internet of Things (IoT). In IoT, sensors and peripherals are connected each other through a connecting internet.

The hardware implemented in the WSN mode can be retained for IoT platform, but some additional features are established to make it available in worldwide. That is in the WSN method, the data send as encrypted but the user needs original data. The authenticated person can decrypt the data with suitable decryption algorithm, here used is the AES algorithm for both encryption and decryption. The received data is connected to the PC through RS-232 serial interface; after that to the created IoT environment.

Internet of Things proposition starts up a very great extent array of promotion for bearer, tycoon and customer experiences. IoT is about communicating with the gadgets around us; even static and dynamic things and increasing such communications with surrounding as provided by geographic location, time and so on. All connected devices can be linked into the IoT via the smart phone serving as a entrance to the internet. In the case of machine to machine communication into the IoT via the smart phone serving as a entrance to the internet.

Fig. 5. WSN in IoT

In the case of machine to machine communication such as the sensors via Internet Protocol (IP) over wireless or wire line. M2M is a subset of the Internet of Things.

Java is a language which is considered to be very suitable in the internet scenario. Java program are called applications or Java applications The part of web pages are Java programs to be used in the internet scenario. They are called Java applets. So basically Java applets are Java programs which can be embedded within an asp.net page. Applets exist in byte code form on the server and applets are downloaded by the browser executed on the client machine. Here is a web server on which we have a particular ASP.NET web page and there is also a Java program which is stored on the server. This is actually

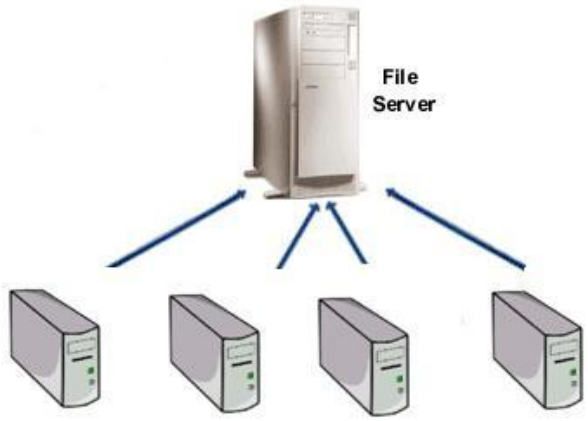

Fig. 6.Data from sensors to file server

Java byte code after compilation and from this .NET file there is a link to this applet. So now what will happen is that a scenario where a page being displayed on a screen with a Java programming

Android is an open source where an app developer can freely use required sections of the android code they might need for their app development, via the Android Software Development Kit (SDK). The main fact is that Android has the highest smart phone user base because it acquires over fifty per cent of the global smart phone market. Hence with such a vast user base, android app developed called MONITOR for real time monitoring of industrial sensor data. The only requirement is internet, for accessing both server connection and app.

IV. IMPLIMENTATION

A. Hardware Architecture

The overall structure of smart sensor interface for IoT consists of sensors (Humidity, temperature, pressure, gas, count and fire sensors),these includes both digital and analog type,SPARTAN-3E FPGA,ADC 3008,transformers,wireless transmission modules,RS-232 serial interface, power supply, LED indicators and 16X2 LCD display.Fig.7 shows the FPGA transmitter hardware physical representaion.

The receiver section of FPGA hardware indicates Fig. 8, which includes MiWi receiver module, voltage regulator, PIC 16F877A driver IC and power supply. The hardware system can send data up to the 100m wireless to the receiver section. It can send data to the control center via MiWi module. MiWi wireless communication module can be connected with the board through the PIC interface and the receiver part get connected with COM port of an internet enabled PC.

The system programmed such that the data received will connect to the server where the data stores in the data base. The

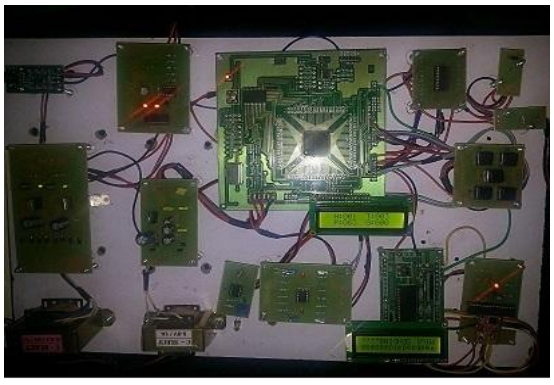

Fig. 7. Transmitter physical map

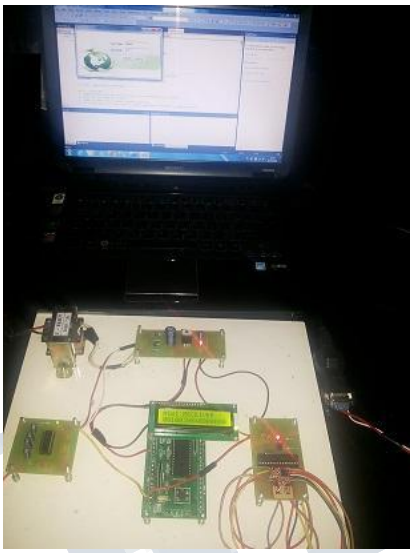

Fig. 8. Receiver physical map

One who authenticated to monitor can access data in real time by proper key, for that provided a user name and password which keeps the privacy of data.

B. Design

One part of the system uses the Very High Speed Integrated Circuit Hardware Description Language (VHDL) design as the basic tool and write related features of the reconfigurable smart sensor interface device for programming SPARTAN 3E FPGA. It distinct's between smart sensor inter-face device and common data acquisition system, which has a considerable result in collecting sensor data.

In this design, ADC3008, a modulus conversion chip produced by Microchip Company is adopted. ADC3008 is connected to FPGA processor through four serial interfaces, including clock line (SCLK), serial data out (DO

UT), serial data in (DIN), and chip select (CS). Here, the data and control signals of the modulus conversion chip are shown in Fig. The second part is programming the interface driver and MiWi configuration based on embedded C language. It mainly coversprogramming of PIC 16F877A driver and configuration of wireless module of the device. The driver IC selected is PIC because the wireless module used is microchip developed,

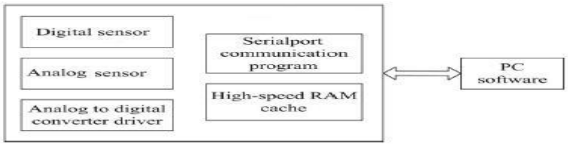

Fig. 9. Overall structure diagram of VHDL part of the system

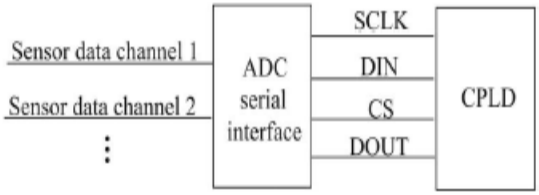

Fig. 10. Data and control signals of ADC3008

Hence peripherals selected also developed by the same company for avoiding complexity.

In this system, the ADC is mainly controlled by writing signal Din from the connected FPGA to operate registers inside the chip. First, the system controls ADC to collect analog signals of sensor input. These digital signals after conversion are first stored in the internal registers of ADC. Then, these digital signals are sent to the FPGA through DOUT port. Here, DOUT port is set to automatically send ADC conversion results on the SCLK clock rising edge. FPGA manages initializing of the ADC, sensor data collection, and data conversion during the entire process. The flowchart is shown in Fig.11.

The third part is developing a website for connecting with the server. For that in ASP.NET in Visual Studio platform. The server will collect data in real time and save in the data base.ASP.NET is a web developing tool, which gives a programming model, a inclusive software base and various applications required to build up booming web applications for both PC and mobile devices.

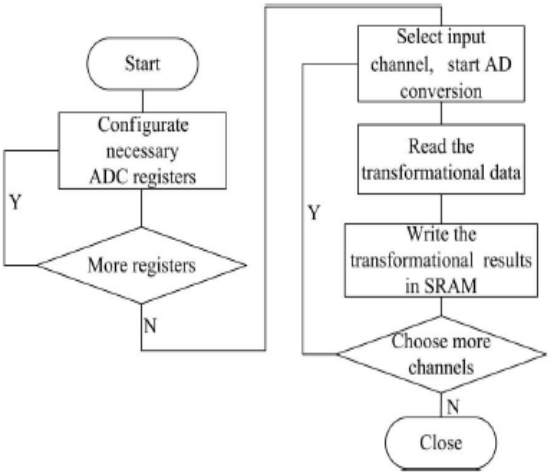

Fig. 11. Configuration ADC3008 program flowchart

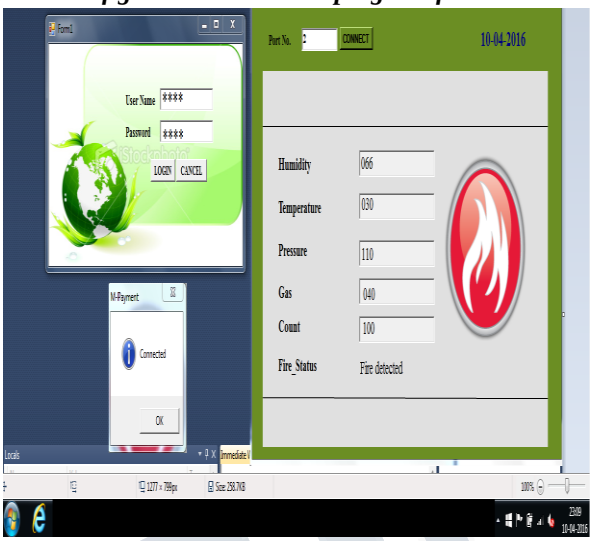

Fig. 12. Data received in the server

ASP.NET application codes can be written in any of the languages such as C, Visual Basic.Net, Jscript,J. Here C# is used.

Fig. 13. Data monitoring in android mobile

The last and final section is developing an Android App for implementing it in the IoT environment. For developing the app, Android 2.1 Eclipse Software Developing Kit(SDK) is used. Most popular language which runs on a virtual machine. Fig. 13 shows the final output of the smart sensor interface for WSN in the IoT environment.

V. CONCLUSION

This paper describes a smart sensor interface for industrial WSN in IoT environment. The system can collect sensor data and transmit it to the entire world through the IoT platform. It was designed based on IEEE802.15.4 protocol by combining with FPGA and the application of wireless communication. It is apt for real-time and additive requirements of the high-speed data procurement system in IoT environment. The appli-cation of FPGA makes the design of peripheral circuit easy, and makes the whole

system more flexible and extensible. Application of IEEE802.15.4 protocol enables the system to collect sensor data wireless. Many sensors can be used as long as they are connected to the system. Main design method of the smart sensor interface device used in industry are described in this paper. We verified that the system achieved good effects in practical application because anywhere in the world can monitor that industry parameters in real time. Many interesting directions are remaining for further researches. For example, here only the data is monitoring through IoT,it will have extent application like controlling can be implement through IoT, if it makes in practical its an added advantage for future scope.

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