Design and Development of a Wireless Sensor Mote Prototype for Laboratory Usage

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***Abstract*—Although newly designed motes currently available in the market have recently been focusing on adding extra flexibilities and capabilities into their designs, certain limitations (e.g., limited number of sensor interfaces and wireless communication protocols available) still remain. This makes it unsuitable for laboratory usage.**

This paper discusses the design of a multi-propose wireless sensor mote prototype. In our proposed platform, the mote utilizes an 8-bit Atmega microcontroller with 128 KB of flash memory and 16 KB of RAM. Wireless communication is based on Xbee protocol. Due to the integration of CC2500 chip in our platform, it is possible for those who wish to self-implement the communication protocol. Sensor interfaces has been designed to support both analog and digital sensors (e.g., UART, SPI and I2C).

Keywords— Wireless Sensor Node, Hardware Design, Protocol Testing, WSN

I. Introduction

Recently, wireless sensor networks (WSNs) have drawn attention from researchers as well as industries because of their wide number of applications. Typically, sensor nodes are small devices working collaboratively to form a large scale network. This network is capable of gaining information from physical environment, performing simple processing on the extracted data and transmitting it to remote locations [1]. WSNs are highly resource-constraint, in terms of power supply, processing speed, bandwidth availability and memory capabilities [2-3]. Among all these constraint, power consumption is one of the major concerns in WSN design. This is because although re-charging the battery is possible, it can be highly difficult or even impossible for applications that are deployed in a hostile environment.

To form a WSN, a special type of node called mote is widely used in number of wireless sensor applications like measuring physical phenomenon such as temperature, seismic events, humidity, pressure etc. There are typically four principle components of a mote which are (1) processing subsystem, (2) communication subsystem, (3) sensor subsystem and (4) power subsystem, which are responsible for processing, communication, data acquisition and powering the system, respectively. Design and testing of WSN can be done using computer programs but in realizing a real network is crucial [4]. Commercially available motes have some hardware limitations which will be discussed in Section 2. To overcome these limitations, we proposed a new prototype and the architectural design can be found in Section 3. The comparison of the proposed prototype and of-the-shelf motes are discussed in Section 4. The motivation behind developing a new prototype is that it can fit well for requirements of various applications in the domain of WSN.

II. Protocols in Literature

As mentioned in the previous section that there are number of motes available in the market but they lack certain features which are essential for WSN environment. Hardware limitation is the biggest challenge which needs to be addressed. Waspmote [5] is a sensor mote that can be used in various applications in wireless sensor network. Different sensor boards can be installed on Waspmote which makes it a good choice to be used in a number of applications like agriculture monitoring, environment monitoring and smart building etc. Users can select radio transceiver from available Xbee modules such as Xbee Zigbee, Xbee 802.15.4 and Xbee 900. However, use of a Waspmote is still limited in certain applications for example radio. Users cannot use other radio transceiver because it is designed for transceiver from a specific hardware manufacturer. Communication sockets are designed explicitly for Xbee footprint (cannot be used for proprietary radio transceiver) and also lack of Serial Peripheral Interface (SPI) bus creates difficulties while interfacing it with other devices.

PanStamp AVR [6] is an open source project created for users who are ambitious for telemetric applications like automatic meter reading [7]. It is a small device that contains microcontroller and radio transceiver. The main advantage of using PanStamp AVR is that a new device and wireless network can be formed by adding few lines of code in the existing libraries. This is indeed very convenient to the end user. The disadvantages associated with PanStamp AVR are as follows:

- It cannot be used as a standalone device. It requires additional circuits to become operational such as power supply board, sensor board and USB-to-serial converter board. Although the above mentioned circuits can be purchased off-the-shelf but then user needs to do wiring to these boards which brings inconvenience.

- It requires additional circuit for burning the program in the microcontroller. Wiring and detachment may cause malfunctioning of the device in addition to brining inconvenience.

- Lastly radio transceiver is soldered on the circuit board thus changing of radio transceiver is not possible.

WiSense [8] is designed in such a way that each subsystem of the mote is assembled on separate board. These circuit boards are then stacked together to make a mote. Like PanStamp AVR, WiSense also requires additional circuitry to become operational. The problems mentioned in commercially available sensor nodes motives for the development of new prototype for mote suitable for WSN.

III. PROPOSED MOTE DESIGN AND ARCHITECTURE

The proposed mote architecture is divided into four major subsystems i.e. processing subsystem, communication subsystem, sensor subsystem and power subsystem. Fig. 1 shows the association among these subsystems of mote.

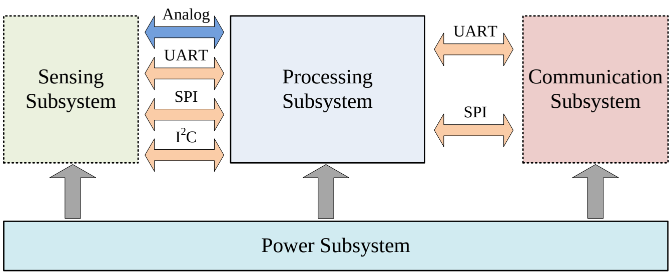

Fig. 1. Block diagram of mote components

A. *Processing Subsystem*

Processing subsystem consists of Atmega1284p, an 8bit microcontroller, Real Time Clock (RTC) module and USB to serial converter. Atmega1284p has been chosen for its distinct characteristics of high performance and low energy consumption (e.g., 128 KB flash memory, 16KB RAM, internal 4KB EEPROM and various sleep modes). Moreover, it can operate in wide voltage range (e.g., 1.8-5.5V) which is desirable for laboratory usage. In addition to its high performance, this microcontroller is a low-cost and a large user community.

DS3231 has been chosen for Real Time Clock (RTC) Module. This is due to its low power consumption, high accuracy and capability of temperature measurement. To add the flexibility in I/O interface, a USB to serial converter is also integrated with this subsystem for of software burning and testing purposes (the mote can be programmed with Arduino Software and Atmel Studio 6 via an USB port or AVR ISP programmer). Moreover, two expansion sockets are provided for communication and sensor interfaces. They support digital interfaces such as Serial Peripheral Interface (SPI), Inter Integrated Circuit (I2C), Universal Asynchronous Receiver Transmitter (UART) and also analog interface. Fig. 2 gives details of the alignment of each interface on the expansion socket.

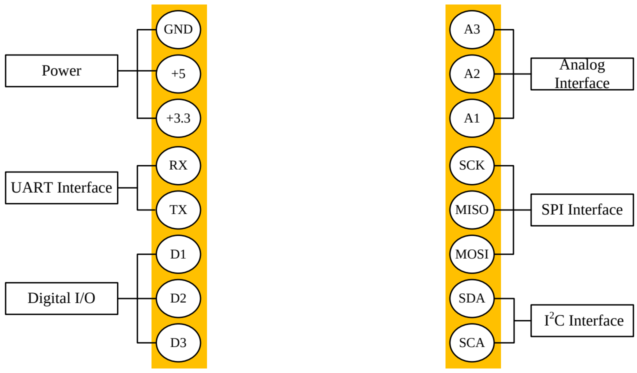

Fig. 2. The alignment of interfaces on the expansion socket.

TABLE I. PURPOSE MOTE SPECIFICATION COMPARED WITH OTHER AVAILABLE COMMERCIAL MOTES.

Mote type	Purposed Mote	Waspmote	Panstamp AVR	WiSense
Microcontroller				
Vendor	Atmega 1284p	Atmega 1281	Atmega 328p	MSP430 G2955
Flash	128 KB	128 KB	32 KB	56 KB
RAM	16 KB	8 KB	2 KB	4 KB
EEPROM	4 KB	4 KB	1 KB	128 B
Speed	16 MHz	8 MHz	8 MHz	32 kHz
Communication				
Radio module	Xbee/ CC2500	Xbee	CC1101	CC2520
Radio interface	UART/SPI	UART	SPI	SPI
Removable	√	√	-	-
Sensor and Interface				
Integrated Sensor	√	√	-	√
Expansion	√	√	-	√
Digital I/O	√	√	√	√
Analog I/O	√	√	√	√
SPI Bus	√	-	√	-
I2C Bus	√	√	√	√
RTC Module	√	√	-	-
Power Consumption				
Active Mode	16.5 mA	9 mA	2 mA	n/a
Sleep Mode	95 uA	62 uA	1 uA	1 uA
Programming				
Interface to host	USB/ AVR ISP	USB	UART*/ AVR ISP	UART*/ JTAG

a. *Required additional circuit board for operation.

B. *Communication Subsystem*

Unlike other commercial sensor motes that typically provide only one radio module (referring to Table I), the communication subsystem of our mote is designed to support 2 wireless radio modules: (1) Xbee and (2) CC2500. By having two available radio modules, it is possible for the mote to serve both users who want to design and implement their own MAC and routing protocols (using CC2500 module) and users who just want to take advantage of the Xbee protocol. Table II shows both Xbee and CC2500 radio module specifications.

TABLE II. RADIO MODULE SPECIFICATION

Module	CC2500	Xbee ZB Pro Series 2
Vendor	Texus Instrument	Digi
Data rate	250 kbps	250 kbps
MAC Layer	none	802.15.4 MAC
Protocol	none	Zigbee
Frequency	ISM 2.4 GHz	ISM 2.4 GHz
Interface	SPI Bus	UART
Powerdown	400 nA	3.5 uA
Tx (0 dB)	21.2 mA	170 mA
Rx	35 uA	45 mA
Cost	$5.87	$38.60

C. Sensor Subsystem

Sensors subsystem provides interface such as SPI, I^2C, UART and analog interface to connect with various types of sensor. Variety of external sensors equipped with sensor board can be installed on the expansion socket which provides freedom to the user to select the sensor. According to Table I, our proposed mote offers more types of interfaces when compared with the commercial motes. These various interfaces make our mote suitable for wide range of sensors.

D. Power Subsystem

The mote can be powered via USB port or alkaline batteries of the range 1.8-5.5V. The MAX1674 is used as a step up DC-DC converter to step up the voltage from power source to maintain working voltage level at 5V. The LP2985-33DBVT voltage regulator is also integrated in order to regulate supply voltage at 3.3V for communication subsystem. The power subsystem and processing subsystem are built on a single board. The detail of the overall system architecture is shown in Fig. 3.

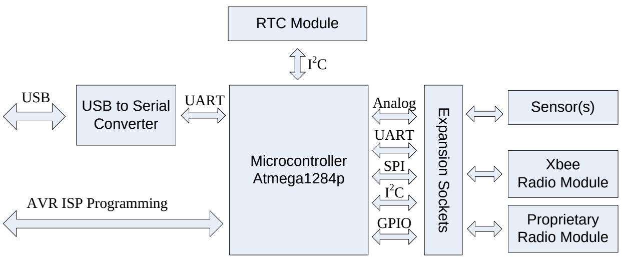

Fig. 3 System diagram of the proposed mote

IV. THE PROTOTYPE AND ITS SPECIFICATION

The first prototype has a dimension of 8.5cm x 15cm. Most of electronic components are surface mounted device (SDM) type. Fig. 4, shows the major functional units on the circuit board. The information presented in Table I confirms that our proposed design is quite flexible for laboratory usage which requires flexibilities in radio communication module and interfaces. Also, various sensor interfaces are made available in the proposed mote so that users have a freedom to choose various types of sensor according to their needs. However, these flexibilities come at a cost of higher power consumption (16.5 mA and 95 uA for active and sleep mode, respectively). In addition, the availabilities of an on-board USB to serial converter, power supply and RTC module eliminate the need of any additional circuit, making it less-hassle when working with the mote.

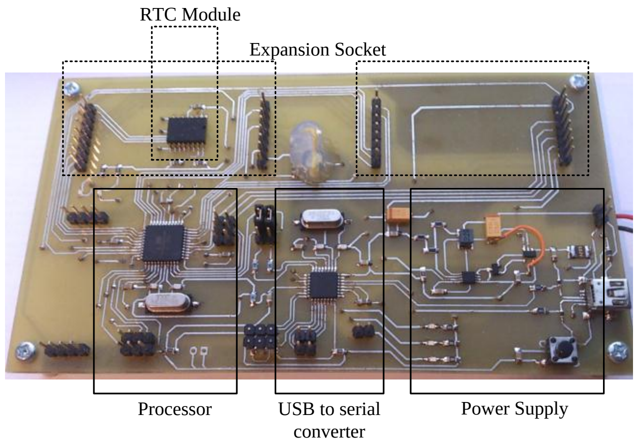

Fig. 4 Prototype with the major functional units outlined.

V. CONCLUSION

In this paper, we proposed a new prototype of mote which is designed to have extra flexibilities and capabilities for laboratory usage. Because of the flexibility on the types of I/O interface, the proposed prototype can be used for multi-purpose wireless sensor network applications. Availability of replaceable proprietary radio module, Xbee radio module, on board USB to serial converter, power supply and RTC, and widely support sensor type interfaces makes it superior to commercially available motes. Our future work will develop application programming interface (API) like functions for users who unpleasing recognize the low-level hardware.

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