Comparison of Different Wireless Sensor Network Node Technologies

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Abstract –**In this paper a comparison of different hardware architecture of several wireless sensor nodes is presented. The type of the sensor node that would be used depends on the application and should represent a compromise between the size, cost and power consumption. So, a review of several nodes compared under a number of different parameters is examined.**

Keywords –**Hardware architecture, Review, Size, cost, Power consumption.**

I. Introduction

A wireless sensor networks consists of sensor nodes deployed over a geographical area for monitoring physical phenomena like temperature, humidity, vibrations etc. Typically, a sensor node is a tiny device that includes few basic components: a microcontroller, transceiver, power source and one or more sensors which can be internal or external connected to the sensor board. The measurement system is usually consisted of one of more base stations and a lot of end devices connected between them in a network, where the main task of all the nodes is data logging, data transmitting and processing of sensor information from the environment to the base station and makes a decision according to which the nodes perform appropriate tasks.

Recent advances in wireless communications and electronics have enabled the development and production of low-cost, low-power and multi-functional sensors that are small in size and communicate in short distances. Cheap, smart sensors, networked through wireless links and deployed in large numbers, provide enormous opportunities for monitoring and controlling homes, cities and the environment.Wireless sensor networks are a modern technology which integrates the knowledge of sensors, automation control, digital network transmission, information storage, and information processing.

Wireless sensor nodes are used in different applications, like medicine, agriculture, home automation etc. One typical example where the wireless sensor nodes are implemented is in industry,where the sensors can be used for detection of the presence of toxic and other hazardous materials, ensuring detection and identification of leakage or discharge of chemical or biological agents before the occurrence of any serious damage.

For the purposes of medicine, small portable wireless oksimeters (Photoelectric instrument for measuring oxygen in the blood) are developed. These devices collect data for the heartbeat speed, oxygen saturation and EKG data and transmit these data over wireless communication usually for short distances (up to 100m) to any recipient who can be laptop, PDA, or terminals ambulances. The data can be displayed in real time or can be saved in the patient's personal data.

Precision agriculture [1, 2] is a new modern solution for traditional agriculture based on environmental parameter monitoring and control. Monitored data is used to derive the optimal decision for control and adjustment of environmental parameters with the aim to obtain better production yield while optimizing use of resources. Three tasks are essential for achieving precision control of the production environment: 1) monitoring parameters such as temperature, humidity and illumination, as these parameters are the main factors that influence the product yield and quality; 2) analyses of monitored data and decision making supported by optimization; and 3) applying the control mechanisms [3, 4].

The type of the sensor node that would be used depends on the application and should represent a compromise between the size, cost and power consumption.

In this paper we present a review of several wireless sensor nodes compared under a number of different parameters. The comparison between the other hardware architectures can be made according on general parameters, processor and memory, communication capabilities, sensor support and power consumption. In this paper we will discuss for 6 currently available node platforms.

TelosB – wireless sensor nodes developed at UC Berkeley and currently are available from Crossbow technology.

MicaZ – second and third generation wireless nodes networking family from Crossbow technology.

SHIMMER – SHIMMER (Sensing Health with Intelligence, Modularity, Mobility and Experimental Reusability) is a wireless sensor platform designed for wearable applications.

Sun SPOT – the Sun Small Programmable Object Technology (SPOT) is a wireless sensor node from Sun Microsystems. In this type of platform both the hardware and software are open-source.

EZ430-RF2480/2500 – EZ430-RF2480 and EZ430-RF2500 wireless solutions from Texas Instruments incorporate the MSP430 microprocessor and CC2480/2500 radio transceiver on each board. These kits are the most inexpensive node solution reviewed in this paper and are explained in section III.

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II. COMPARISON OF HARDWARE ARCHITECTURE

A. General parameters

Choosing the right sensor mote is an important consideration for any WSN deployment. The first physical parameter which can influence in the node selection is its physical size especially in applications where the nodes are components of mobile unit or are integrated into wearable health monitoring solutions. Another parameter that is also important and should be considered is the price.

Current pricing information of some of the most used sensor nodes is presented in table I.

TABLE I
COST PER NODE

Node platform	Price	comment
TelosB	€77	low powered MCU and optional sensor suite
MicaZ	$150	two 900MHz motes
SHIMMER	€199	2 boards
Sun SPOT	$399	two free-range (with processor, radio, sensor board and battery) and one base station (with processor and radio)
EZ-RF2480	$99	3 nodes, one is a USB interface
EZ-RF2500	$58	2 nodes

TABLE II
MICROPROCESSOR AND MEMORY SPECIFICATIONS

Name of node	microcontroller	Data memory	External memory	Frequency range
TelosB	TI MSP430	10K RAM	48K	2.4-2.4835GHz
MicaZ	ATMEGA128	4K RAM	128K	2.4GHz
SHIMMER	TIMSP430F1611	10K RAM	48K	2.4-2.4835GHZ
Sun SPOT	ARM920T	512K RAM	4MB	2.4-2.4835GHZ
EZ-RF2480/2500	TI MSP430F2274	1K RAM	32K	2.4-2.4835GHZ

TABLE III
RADIO CHIP SPECIFICATION

Radio Module	Frequency (MHz)	Modulation	Data rate	TxPower (dBm)	Rx Sensitivity (dBm)
TI CC1000	300-1000	FSK	76.8 kBaud	-20-10	-110
TI CC2420	2400-2483.5	OQPSK	250kbps	-24-0	-95
TI CC2500	2400-2483.5	OOK, MSK, GFSK	500kBaud	-30-1	-108
TI CC2480	2400-2483.5	OQPSK	250kbs	-55.8-0	-92
Atmel AT86RF230	2405-2480	OQPSK	250kbs	-17-3	-101

In the table II are explained some of the board specifications – name of microcontroller and its memory, frequency range and data rates. There is a wide variation here in available memory sizes and types for the different nodes.

B. Communication capabilities

The IEEE 802.15.4 protocol has been adopted as a communication standard for low data rate, low power consumption and low cost. Most of the mote platforms use this standard for communication between the motes. TelosB, Sunspot are IEEE 802.15.4 compliant motes. The MicaZ mote uses the Texas Instruments CC1000, the EZ430-RF2500 uses the Texas Instruments CC25000 while the EZ430-RF2480 uses the CC2480. The CC1000 [8] and CC2500 [9] are both bit level radios and the CC2480 is a Zigbee compatible packet level radio.

Table III gives the operating specifications of the six radios and table IV gives the power consumption of each radio in sleep mode/switched off, idle/receive mode and when transmitting at the specified power level.

TABLE IV
RADIO CHIP POWER CONSUMPTION

Radio Module	Sleep	Idle/Rx	Tx (mA)
TI CC1000	0.2µA	74µA -7.4mA	10.4(0dBm)
TI CC2420	0.02-426 µA	18.8mA	17.4(0dBm)
TI CC2500	400nA-160 µA	13.3-19.6mA	21.2(0dBm)
TI CC2480	0.3-190µA	26.7mA	26.9(0dBm)
Atmel AT86RF230	20nA	40mA	60(0dBm)

The CC2420 [6] is a very popular chip for use, being used on four of the nodes considered here. The CC2420 was the first 802.15.4 radio chip to be widely available in the market. 802.15.4 is very suitable for use in wireless sensor nodes due to its very low power and flexibility.

The CC2500 [9] also operates in the 2.4GHZ frequency band, but unlike the CC2420 and CC2480 does not conform to the 802.15.4 standard. A major feature of the CC2500 not available on any of these other radios is a very low power hardware wake up radio function to allow automatic RX polling. This allows the microprocessor to remain in deep sleep mode for more of the time, so provide a significant energy saving.

CC2480 [10] is used to simplify the integration of wireless communication into embedded solutions by handling the entire communication stack on the radio chip. The fact that entire communication is handled on the radio chip is reflected in the higher power measurements.

C. Sensor Support

TelosB offers a set of onboard sensors, for humidity, temperature and light sensors. Light intensity is measured with a photo-diode connected to the 12bit ADC available on the MSP430.

MicaZ do not have onboard sensors. But, Crossbow offers an extensive set of sensor boards that connect directly to mica nodes and are capable of measuring light, humidity, temperature, barometric pressure, acceleration, acoustics, magnetic fields and GPS position.

SHIMMER device incorporates 3 axis accelerometer and allows connection of other sensors through its expansion board.

Sun SPOT has also possibility for extension connection of tri-axial accelerometer, temperature and light sensors.

Ez430-RF2480/2500 has no on-board sensors, but a break out connector provides 10ADC lines an SPI and I2C interface.

D. RF Transceiver and OS comparison

In this paper majority of the considered nodes are programmed via the TinyOS operating system as it is shown in Table V. Typical programs for these nodes are written in nesC, a derivative of the C programming language. The TI Ez430-RF2480/2500 nodes do not support Tiny OS. Another exception to the Tiny OS programming interface are the Sun SPOT nodes. Sun SPOT uses a small J2ME which runs directly on the processor without an OS. Squawk and the sun SPOT code are open source.

TABLE V
RF TRANSCEIVER AND OS OPERATING SYSTEM

node platform	Transceiver	Operating System
TelosB	TI CC2420	Tiny OS, MANTISOS
MicaZ	TI Chipcon CC1000	Tiny OS
Shimmer	TI CC2420	Tiny OS
Sunspot	TI Chipcon CC2420	Squawk Java ME
EZ-RF2480	CC2480	Do not support TinyOS
EZ-RF2500	CC2500	Do not support TinyOS

E. Power Specifications

TelosB are powered from an external battery pack containing 2AA batteries. The voltage must be at least 2.7 when programming the microcontroller flash. Total active power is 3mW.

MicaZ sensor nodes use the same battery configuration as the TelosB nodes. Voltage requirement is minimum 2.5V and active power is 33mW.

Shimmer mote is typically powered by a 250mAh battery, while sunspot uses a 3.7V rechargeable 750 mAh lithium - ion battery, nominally operating with a 30 nA deep sleep mode.

The EZ430-RF2XXX application boards must be externally powered for operation in a standalone environment. The expansion pack takes 2 AAA batteries to power the wireless board. Standard supply voltage for the board is 3.6V.

III. EZ430-RF2500 HARDWARE ARCHITECTURE

The low power WSN is built from wireless nodes type eZ430-RF2500, from Texas Instruments (TI), shown on fig. 1. These nodes integrate MSP430 family of ultra–low power microcontrollers and CC2500 low-power wireless radio frequency (RF) transceivers which are suitable for low power, low cost wireless applications.

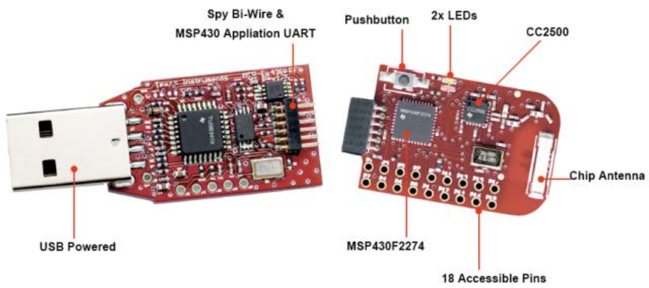

Fig. 1. eZ430-RF2500 Wireless nodes

The eZ430 - RF2500 [5] consists of MSP430F2274 microcontroller and CC2500 2.4GHz wireless transceiver, which are the two core components and all the hardware and software required for them. The MSP430F2274 microcontroller consists of 16-MIPS performance with a 200-ksps, 10-bit ADC and 2 op-amps, while the CC2500 multichannel RF transceiver is used for low-power wireless applications. The ez430-RF2500 target board is an out-of-the-box wireless system that may be used with the USB debugging interface, as a stand-alone system with or without external sensors, or incorporated into an existing design. The new USB debugging interface enables eZ430-RF2500 to remotely send and receive data from a PC using the MSP430 application UART, referred to as the application backchannel. EZ430-RF2500 features highly integrated, ultra-low power MSP430 MCU with 16MHz performance, two general-purpose digital input/output pins connected to green and red LEDS for visual feedback, 21 available development pins and interruptible push button for user feedback.

The eZ430-RF2500 application [5] uses SimpliciTI protocol which is low-power radio frequency protocol for small RF networks, i.e. network with less than 100 nodes. The simplicity network protocol is designed for easy implementation with minimal microcontroller resource requirements.

Small low-power RF networks typically contain battery operated devices, which require long battery life, low data rate and low duty cycle, and have a limited number of nodes communicating pair wise. With the simpliciTI network protocol, the microcontroller resource requirements are minimal, resulting in low system cost for low-power RF networks. A simpliciTI base station manages the network and is always on, receiving sampled data from one or more simpliciTI sensor nodes. The communication between the base station and the sensor nodes is established in regular time frames which can vary from few seconds to several hours. The duration of the period between two consecutive communications depends on the application requirements, i.e. the requirements for measuring and collecting data over time. However, the frequency of the data measurements by the sensors and the send/receive configuration of the RF module influence the battery lifetime, therefore, all of these parameters should be chosen carefully in order to create an optimal system. The sensor nodes of the wireless sensor network contain the sensors that implement the end-application for the network and most of the time are in low power mode (LPM3), waking up once a half hour to sample the environmental parameters and battery voltage and send the results to the network's base station.

IV. Conclusion

In this paper a review of currently available node technologies has been presented. For the different nodes, a series of 5 categories have been considered, like general parameters, processor and memory specifications, communication and sensor capabilities and power consumption. Sun SPOTnodes are best option in the applications where high computational tasks and processing power are required. SHIMMER nodes are good solution for wearable applications such as health monitoring. Ez430-RF2500 development boards are the cheapest, low power and fair performance nodes reviewed in this paper. The comparison can be made according on general parameters, processor and memory, communication capabilities, sensor support and power consumption.According to these parameters they offer best cost/performance ratio for the application.

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