An Efficient Cluster-based Reliable Power Aware Scheme (RPAS) for Network Longevity in WSN

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Abstract - This experimental work is mainly focused on designing a new wireless sensor networks (WSN) node called WSNMSP430 with increased life time. The developed node was based on the analysis of the various low power components available in the market and also an energy model was created for processor, transceiver & sensor for predicting the life time of the WSN node. Utilizing low power features supported by processor and transceiver a reliable power aware scheme was developed for the node to transmit and receive the packets. An appropriate experimental setup was employed for transmitting and receiving the packets to various WSNMSP430 nodes in different places. And also the same node was compared with cross bow motes like Telosb, Mica2 & Micaz for estimating the life time through various real time scenarios. From the experimental test results it revealed that newly developed node had good impact on the improved life time.

Key-Words: - Wireless Sensor Networks (WSN), Clusters, Energy model, life time estimation

1 Introduction

A WSN is a collection of tiny wireless sensor nodes and each node comprised of Processor (MCU), RF Transceiver, Sensor, Peripherals, and Power supply unit (Battery)[1]. A small operating system integrated with an application program is also embedded in the sensor nodes which will take care of sensing (measuring), computing, and communicating with neighbor nodes that gives an administrator the ability to instrument, observe and react to events and phenomena in a specified environment [2]. Wireless sensor networks are widely used in the commercial and industrial areas such as environmental monitoring, healthcare, process monitoring and surveillance. Modern wireless sensor networks are made of a large number of inexpensive devices that are networked via low power wireless communications. Since WSN nodes operate on battery power which is often deployed in a rough physical environment changing the batteries is therefore a complicated task, as some networks may consist of hundreds to thousands of nodes. Such large physically distributed networks increase the difficulty of changing batteries and makes almost impossible for recharging during operations and also the failure of one node can interrupt the entire system or application. Hence Low power consumption is a key factor for ensuring long operating horizons for non-power-fed systems [2]-[3]. This problem has forced node, network and system developers to make changes in the basic WSN architecture to minimize the power consumption in order to make the long life WSN.

The power management scheme can be classified under the two heads:

1. Network Level -Choice of communication methods and protocols to minimize energy consumption.

2. Device Level -Hardware component selection and their configuration to achieve low energy consumption in a wireless sensor node.

In the network level, a variety of energy efficient protocols were developed in the recent years. The routing protocols in WSN are classified under three main heads: data centric protocols, location based protocols and hierarchical protocols. This experimental work mainly focusing on hierarchical protocol which deals with organizing WSN in to a set of clusters. Each cluster is formed by grouping of sensor nodes (cluster nodes) and consists of a central node called cluster head (CH).The responsibility of the cluster head in each cluster is to carry out the following tasks. The first task is to collect the data from the cluster nodes periodically and then the cluster head aggregates the data in an effort to remove redundancy among correlated values [10]-[14]. The second task of a cluster head is to transmit the aggregated data directly to the base station through multi-hop and finally the third task is to generate a Time Division Multiple Access (TDMA)-based schedule through which each node of the cluster is assigned a time slot that it can use for transmission. Since CH role is more energy consuming, implementation of power management strategy to CH and cluster nodes is becoming essential to develop a long life WSN. This experimental work suggests an ultra-low power sensor node component for the cluster head and cluster nodes and proposes an efficient power aware scheme for the wireless sensor networks.

This experimental report is organized as follows: Section 2 explains the selection of sensor node components such as Processor, Sensor, and Transceiver and describes their energy model with several adjustable parameters. Section 3 describes Cluster-based Reliable Power Aware Scheme. Section 4 confers the experimental setup and results. Section 5 presents Node life time estimation and comparison with crossbow motes. Eventually, Section 6 concludes with future enhancement of this work.

2. WSN Node Energy Modeling and Energy Estimation Techniques

Energy Modeling plays a major role for designing an energy efficient WSN [4]. This section presents the energy model of WSN node components of the Processor, Transceiver and Sensor to establish the different energy states and state transition energy from one state to other.

2.1 Energy Modeling of the Processor

The MSP430 family is a 16 bit ultra-low power microcontroller of Texas Instruments, designed specifically for ultra-low-power applications and high performance. Its flexible clocking system, multiple low-power modes, instant wakeup from sleep modes make this processor more suitable for designing a low power WSN node.

Flexible clocking system: The MSP430 Microcontroller Unit (MCU) clock system has the ability to enable and disable various clocks and oscillators which allow the device to enter various Low-Power Modes (LPMs). The flexible clocking system optimizes overall current consumption by only enabling the required clocks when appropriate.
Instant wakeup: The MSP430 MCU can wake-up instantly from LPMs. This ultra-fast wake-up is enabled by the MSP430 MCU's internal Digitally Controlled Oscillator (DCO), which can source up to 25 MHz and be active and stable in 1µs. Instant wake-up functionality is vital important in ultra-low power applications since it allows the microcontroller to use the CPU in very efficient manner and spend more time in LPMs.
Low Power Modes: The MSP430 family microcontrollers have one Active Mode (AM) and five low-power operating modes which can be selected by software according to requirements of application. They are LPM0 (low power mode 0), to LPM4. For example, the application requires a timer and ACLK running when it is in the low-power mode. Clearly, the LPM3 is selected and then the bit SCG1, SCG0, OSCOFF, CPUOFF in status register should be set as "1101", so that the MCU will enter the LPM3 with only ACLK and counter working. Consequently it enables to save more energy to prolong the lifetime in WSN. When the MCU need to return to active mode, it can be waken up by an external interrupt signal in less than 1µs.The current consumption in different modes is between 0.1 to 340µA and 1.6µA in standby mode [5]. Under normal circumstances CPU can be placed in the standby mode or in LPM3 mode. Fig 1 presents various operating modes, status of CPU as well as the clock and current consumption of various modes when the MCU is powered by 3 V and 2.2V respectively and runs at 1 MHz

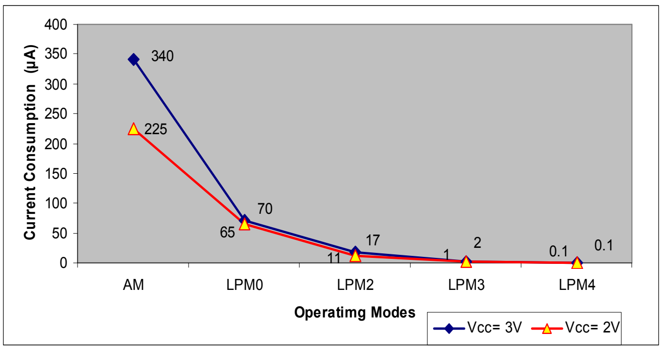

Fig 1: Current Consumption of MSP430

The most common method for a processor to enter in to a low power mode with the interrupts enabled. Interrupts can only bring an MCU out of a low-power mode and wakeup the system. For Example consider the following pseudo code which is used to set the bit in the status register in MSP430:

// BIS_SR(LPMx_bits + GIE); //
Here the SR represents status register, x represents LPMs from 0-4 and GIE is Global Interrupt Enable. In addition to enable or disable the CPU and clocks in the low power modes, turn on and turn off the

specific peripherals may further reduce total current consumption of the individual modes. This method enables the system programmer to combine both the techniques to design a low power WSN.

2.2 Energy estimation of the processor

Processor energy consumption (E_{MCU}) is the sum of state energy consumption (E_{SE}) and state transition energy consumption (E_{TE}) as expressed in Equations 1 and 2.

$$E_{MCU} = E_{SE} + E_{TE} \quad \text{--------- (1)}$$

$$E_{MCU} = \sum_{i=1}^{n} P_{CS}(i) * T_{CS}(i) + \sum_{j=1}^{n} N_{CC}(j) * e_{cc}(j) \quad \text{--------- (2)}$$

Where, $P_{(CS)}$ (i) is the power consumption of the various states of the processor like AM, LPM0 to LPM4 and $T_{(CS)}$ (i) is the time spent during the various CPU states. $N_{(CC)}$ (j) is the frequency of state transition j and $e_{(CC)}$ (j) is the energy consumption of one time transition.

2.3 Sensor Energy Model

In this investigation sensing module is integrated within MSP430F149 and consists of sensors and analog-digital converters (ADC), be responsible for the information collection and digital conversion. The energy consumption of the sensing module come from multiple operations, including signal sampling, AD signal conversion, and signal modulation, etc.

Table 1: Current consumption of the sensor

Parameter	Test conditions		Nom	Max
I_{sensor}	REFON = 0, INCH = 0Ah, ADC12ON = NA TA = 25°C	2.2 V	40 µA	120 µA
		3.0 V	60 µA	160 µA

ADC12 module has 12 bit resolution and allows sampling and conversion of up to 8 external channels. Each channel can be assigned an individual reference voltage and one out of four clock sources can be selected [18]. Table 1 represents the current consumption of the sensor when the then supply voltage is 2.2 and 3V.

2.4 Energy modeling of the Transceiver

In WSN, Transceiver consumes the majority of the available energy during data transmission and reception [6]. Hence optimization in this field can result more impact in the energy saving methods[7]-[9]. A transceiver used here is Ultra-Low-Power (ULP) transceiver nRF24L01 by Nordic semiconductors. This transceiver is a packet oriented radio chip working in the 2.4 GHz ISM band with a net data rate of 2 Mbps. It consists of a fully integrated frequency synthesizer, a power amplifier, crystal oscillator, demodulator, modulator and Enhanced Shock Burst protocol engine [10].

Table 2: Operating modes of Transceiver

nRF24L01 states/ transition		Current consumption	Power (mW)
Power down mode		0.9 µA	0.002
Standby mode		22 µA	0.066
Crystal oscillator startup		285 µA	0.855
Transmission- (TX) Mode	0 dBm	11.3 mA	0.034
	-6 dBm	9.0 mA	0.027
	-12 dBm	7.5 mA	0.022
	-18 dBm	7.0 mA	0.021
Receiving- (RX) Mode	1 Mbps	11.8 mA	0.035
	2 Mbps	12.3 mA	0.037
Average current during TX settling		8.0 mA	0.024
Average current during RX settling		8.4 mA	0.025

In addition, the nRF24L01 also offers an innovative on-chip hardware solution called 'MultiCeiver' that can support up to six simultaneously communicating wireless devices with unique address. Table 2 lists various operating states, current consumption within each state at a system voltage of 3.0V. This transceiver stands out by very low energy consumption and a small protocol overhead compared to other frequently used WSN transceivers as the CC2420.

2.5 Energy estimation of Transceiver

Similar to the processor energy function, Transceiver Energy consumption (E_{Trans}) is the sum of state Energy consumption (E_{SE}) and state transition energy consumption (E_{TE}) as expressed in equations 3 and 4.

$$E_{Trans} = E_{SE} + E_{TE} \quad \text{------------- (3)}$$

$$E_{Trans} = \sum_{i=1}^{n} P_{TS}(i) * T_{TS}(i) + \sum_{j=1}^{n} N_{TC}(j) * e_{TC}(j) \quad \text{--------- (4)}$$

Where,

$P_{(TS)}$ (i) = The power consumption of the different states of the Transceiver in Tx mode at different RF output power and Rx mode at different data rates

$T_{(TS)}$ (i) = The time spent during the particular state of the Transceiver

$N_{(TC)}$ (j) = The frequency of state transition j

$e_{(TC)}$(j) = The energy consumption of one time transition.

3. Reliable Power Aware Scheme (RPAS)

This section deals with reliable power management schemes of WSN nodes to achieve the following energy saving methods and the results of power estimated based on the low power WSN MSP430 hardware platform.

1. Transmission power control
2. Power Saving modes

3.1 Transmission power control

In hierarchical clustering most of the research work deals with energy efficient cluster head selection mechanism but fails to focus on non-cluster head nodes. The proposed scheme describes the efficient power management scheme for both CH and cluster nodes so that overall network lifetime would be enhanced. This research work assumes that already cluster was formed and cluster head was elected by any one of the clustering approach [12]-[13].

In clustering frequent communication is in between cluster head and cluster nodes. The basic idea of the proposed scheme is to modify transmission power between CH and cluster nodes according to the distance estimated between them. In order to achieve this power control mechanism, the nodes need to identify the optimal power before sending the data. Here the CH sends a packet to nearby cluster nodes, which measures the received power. Based on the Friis transmission equation as shown in equation 5, each cluster node estimate the distance with CH.

$$\frac{P_r}{P_t} = \frac{G_r G_t}{F_t}\left(\frac{\lambda}{4\pi d}\right)^2 \qquad \text{------------ (5)}$$

Where

d - Distance between two nodes

P_t - Output power of transmitting antenna

P_r - Power received by receiving antenna

G_t - Transmitting antenna Gain

G_r - Receiving antenna Gain

λ - Wavelength and L is the system loss factor

In nRf24L01, the data packet format can be configured as shown in fig 2 and each item can be configured by setting the corresponding registers when initializing nRf24L01 transceiver.

1 byte	3 byte	9 bit	0-32 byte	2 byte
Preamble	Address byte	Packet control field	Payload	CRC word

Fig 2 Data packet format

Based on the experimental results discussed in the table 3 each node constructs a look up table which consist of node id, distance between the nodes and RF o/p power in dbm. The RF output power of nRF24L01 can be programmed and the PA control is used to set the output power from the nRF24L01 Power Amplifier (PA). By setting the bits in the RF_PWR Reg the RF output power can be varied. In Tx mode PA control has four programmable steps. The PA control is set by the RF_PWR bits in the RF_SETUP register. Power down mode is entered by setting the PWR_UP bit in the CONFIG register low.

By setting the PWR_UP bit in the CONFIG register to 1, the device enters standby-I mode.Standby-I mode is used to minimize average current consumption while maintaining short start up times. In this mode part of the crystal oscillator is active. This is the mode the nRF24L01 return from Tx or Rx mode when CE is set to low.The air data rate is the modulated signalling rate when the nRF24L01 transmitting and receiving data[10]. The air data rate can be 1Mbps or 2Mbps. The 1Mbps data rate gives 3dB better receiver sensitivity compared to 2Mbps. The air data rate is set by the RF_DR bit in the RF_SETUP register. In this study transmitter and a receiver was programmed with the same air data rate as 1Mbps.The program was developed for various transmitting power and tested in the sensor node hardware.

3.2 Power Saving modes

This section introduces four different modes of WSN node used to save energy based on the application requirement. At any instant the sensor node may be any one of these following modes:

Communication mode (Tx mode): The node is assumed to be an intermediate node in which it just transmit the data to other nodes. In this mode sensor would be switched off. The current consumption is the sum of MCU (I_{MCU}) and Transceiver at Tx mode (I_{Trans}).

$I_{Tx} = I_{MCU} + I_{Tx\text{-}Trans}$ --------- (6)

Communication mode (Rx mode): The node is assumed to be an intermediate node in which it just receive the data from other nodes and sensor would be switched off. The current consumption is the sum of MCU (I_{MCU}) and Transceiver at Rx mode (I_{Trans}).

$I_{Rx} = I_{MCU} + I_{Rx\text{-}Trans}$ --------- (7)

Sensing mode: In this mode Sensor sense, MCU process the data and Transceiver Transmit the data. The current consumption of this mode is the sum of the current consumption of the Sensor (I_{Sensor}), MCU (I_{MCU}) and Transceiver (I_{Trans}).

$I_{SM} = I_{Sensor} + I_{MCU} + I_{Tx\text{-}Trans}$ --------- (8)

Power down mode: In this mode, sensor is in off mode, MCU is in Low power mode 3 (LPM3) and Transceiver in power down mode. The current consumption of this node is the sum of MCU (I_{MCU}) at LPM3 mode and Transceiver (I_{Trans}) at power down mode.

3.3 Pseudo Code for the proposed RPAS

Initialization Phase:

```
Sensing module ();
Processing module ();
Communication module ();
MSP430 Basic Clock Setup ();
Port Initialization ();
SPI Initialization ();
nrf24L01 Initial Register Setup
Configure Register (CRC enable, power-up, Rx mode)
Pipe0 Address{5,6,7,8,9}
Pipe1 Address{0,1,2,3,4}
Transmitter Address {5,6,7,8,9}
Payload width of Pipe0 (1)
Payload width of Pipe1 (1)
```

Transmission and Reception Phase:

```
Call NRF_Txt (0xab)
Initialize stack pointer
WDTCTL = WDTPW + WDTHOLD; Stop WDT
BCSCTL1 &= ~XT2OFF;
Port Initialisation ();
NRF_send
NRF FUNCTIONS ();
CSN_HIGH;
CSN_LOW;
CE_HIGH;
CE_LOW;
SPI Send Command with address
Initialise SPI Interface and chip NRF24L01
NRF_init();
NRF_PREPARE_FOR_RECIEVE
/ * After sending a byte  set the device to RX mode
Void NRF_prepare For_Receive (void )
Setting for RX device
Write CONFIG register -> 00001010 - CRC enable, power-up, RX status =
SPI_Send_command_with_ADDR
(W_REGISTER,CONFIG_REG_ADDR, 0x0B);
/* Receive one byte from the air via chip nRF24L01. Addresses are hardcoded */
NRF_receive (unsigned char *const byte)
Read STATUS status register
Set high when new data arrives RX FIFO
Chip enable low
CE_LOW();
Read payload data
Clear RX_DR bit in status register
```

Power estimation phase:

```
Distance Estimation ();
{
Compare with look up table;
Distance D = Look table values;
}
/* Estimate RF output power */
{
If (D< 4)
Set RF_PWR as 00
Else if (4<D<7)
Set RF_PWR as 01
Else if (7<D<9)
Set RF_PWR as 10
Else if (D≥9)
Set RF_PWR as 11
}
Go to Transmission and Reception Phase.
```

4 Experimental Setup and Results

Fig 3 Experimental setup

The Experimental setup is made such that male terminal of the Parallel port cable is connected to PC, female terminal to Flash Emulation Tool (FET) and one end of JTAG cable is connected to FET, another terminal to WSN MSP430 as shown in Fig 3.

Table 3: Settings in WSN-MSP430 for Tx and Rx Mode

	Transmission mode (Tx)			Receiving mode (Rx)		
Node Distance (m)	RF_PWR Reg	RF o/p Power in (dbm)	Current Consump tion (mA)	RF_DR Reg	Air data rate (mbps)	Current consumption (mA)
0-4	00	-18	7.00	0	1	11.8
4-7	01	-12	7.50	0	1	11.8
7-9	10	-6	9.00	1	2	12.3
9-11	11	0	11.30	1	2	12.3

The IAR C/C++ Compiler and Integrated Development Environment (IDE) tool provides programming environment for WSN nodes which is freely downloaded from IAR website [11]. The WSN nodes are arranged as a network as shown in figure 3. Here CH node indicates the destination node which is connected to PC. The data from the network is processed and displayed by this computer. The Node lifetime depends upon the power consumption of MSP430, Tx and Rx mode current consumption of nRF24L01 along with sleep and active times.

A simple wireless sensor network was constructed with six nodes (N1-N6) in which CH node (N1) is connected with PC. The remaining five nodes (N2-N6) are configured as cluster nodes and are placed wirelessly in various distance with different RF o/p power. The CH (N1) is configured as transmitting node and made -18dbm RF o/p power by setting RF_PWR register as 00.The Data Rate is kept at 2Mbps when the node is transmitting with higher power levels (i.e., at 0dBm and -6dBm) and 1 Mbps when transmitting at low power levels (i.e., at -12dBm and -18dBm). Table 3 shows the settings made in WSN MSP430 (Tx and Rx mode) to obtain the node distance for the different RF O/P power and the corresponding current consumption. A measurement test was performed in order to evaluate the distance for the data transmission between the two nodes in which CH (N1) is connected fixedly with PC and cluster node (N2) was placed wirelessly with various distance. This experiment was carried out in an open space within B.S.Abdur Rahman University campus with good line of sight.

4.1 Packet Loss Measurement

Nine thousand packets were transmitted from the CH node and the number of received packets was calculated at the node N2. The WSN MSP430 target board could be operated on frequencies from 2.40 to 2.525 GHz. Transmit the RF signal from the CH and the node N2 will demodulate.

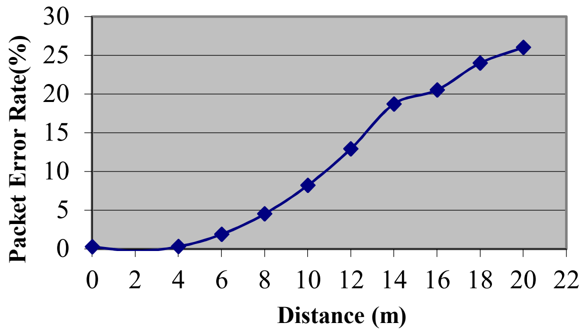

Fig 4 Packet Error Rate versus Distance

The node was programmed in such a way that the CH node gradually increase the no of packets to be transmitted and the error rate was calculated at the receiving end node N2. Figure 4 represents the relationship between packet error rate (PER) and distance. PER is the number of packet loss over the total number of transmitted packets.This figure 4 also shows that the PER is less than 5% for distance less than 7m.

5. Node life time calculation

Based on the experimental results obtained from the Table 3, node life time was calculated by taking the current consumptions of MSP430, nRF24L01 and sensor by assuming the sensor node is in low-power mode in majority of its lifetime and spends only a very short period of time in collecting and transmitting data[12]. The assumption was also made that the measurement cycle is an hour and made active for 10 sec for every hour.The remaining time the MCU was made in LPM3 by setting the SR (status register) with _BIS_SR (LPM3_bit+GIE) instruction to enter LPM3 and Transceiver was forced to be in the power down mode by setting PWR_UP bit in the CONFIG register low. Even when the nRF24L01 enters Power Down mode the MCU can control the chip through the SPI and the Chip Enable CE) pin.

Table 4: WSN MSP430 life time calculation

WSN MSP430 Mode Setting	Average current consumption (mAhr) for 1 hr	Node life time (Years)
Sensing mode : MCU + Sensor on + Radio (Tx+Rx)	0.057162	2.795867
Tx Mode 1: MCU + Sensor off + Radio (Tx+Rx)	0.056995	2.804059
Tx Mode 2: MCU + Sensor on + Radio (Tx)	0.023448	6.81582
Rx Mode: MCU + Sensor off + Radio (Tx)	0.023281	6.864712
Power Down Mode: MCU + Sensor off + Radio (Rx)	0.036614	4.364925

Table 4 exhibits the average current consumption for 1 hour and node life time in years for WSN MSP430 under different modes like Sensing, Tx, Rx and power down mode. For instance, in the sensing mode, for each ten second in an hour , WSNMSP430 node components like MCU, Sensor and Radio were made active and during the remaining periods the MCU was in LPM3 mode and Radio was made in power down mode. For the sensing mode, the average current consumption was calculated by assuming the node is sensing, processing, transmitting and receiving the data with neighbouring nodes for each ten sec in an hour. The average current consumption and node life time for the sensing mode was estimated theoritically by the following calculation:

The average current consumption =
$(10*(60*10^{-3} +340*10^{-3} + 7) +10*(340*10^{-3} + 11.8)) /3600 + ((3580*2*10^{-3}) + 3580*0.9*10^{-3})) / 3600$
= 0.057162 mAhr, and

Expected life time of the node is about 1400/0.057162 = 24491.79 hour≈*2.795867* years

Similar assumption and calculation was also made in other modes such as Tx mode 1, Tx mode 2, Rx mode and Power down mode

Table 5: Configuration of Telos, Mica2 and Micaz motes

Operation	Telos	Mica2	Micaz
Minimum voltage	1.8V	2.7V	2.7V
Battery current rating	1400 mAh	1400mAh	1400 mAh
Mote Standby	5.1 µA	19µA	27 µA
MCU Idle (DCO on)	54.5 µA	3.2mA	3.2mA
MCU Active	1.8 mA	8 mA	8 mA
MCU + Radio (Rx)	21.8 mA	15.1mA	23.3 mA
MCU + Radio (Tx)	19.5 mA	25.4mA	21.0 mA
MCU + Flash Read	4.1 mA	9.4 mA	9.4 mA
MCU+ Flash Write	15.1 mA	21.6mA	21.6 mA
MCU Wakeup time	6µs	180 µs	180 µs
Radio Wakeup time	580µs	1800 µs	860 µs

Table 5 presents the configuration of three commonly used WSN nodes such as Telos, Mica 2 and MicaZ with different parameters. Table 6 represents the average current consumption and node life time for the Telos, Mica 2 and MicaZ nodes when the similar assumption was made in WSN MSP430 node.

Table 6: Crossbow Motes Life Time calculation

Mote Settings		Average current consumption (mAhr) for 1 hr	Node life time (years)
Telos	MCU + Radio (Rx)	0.065641	2.434718
	MCU + Radio (Tx)	0.059253	2.697203
	MCU + Radio (Tx+Rx)	0.119794	1.334101
Mica2	MCU + Radio(Rx)	0.04703	3.3982
	MCU + Radio(Tx)	0.075641	2.11284
	MCU + Radio(Tx+Rx)	0.117572	1.359315
Micaz	MCU + Radio(Rx)	0.069808	2.289384
	MCU + Radio(Tx)	0.063419	2.520023
	MCU + Radio(Tx+Rx)	0.128127	1.247335

While comparing Tables 4, 5 and 6, it reveals that the average current consumption for WSN MSP430 node is low and node life time is improved when compare with Telos, Mica2 and MicaZ motes. Significantly it is to be observed that, in WSN MSP430 node, the current consumption of the microcontroller and transceiver chips in low-power mode is very small and the corresponding wake-up time is very short, so the sensor nodes are suitable for long-time sleeping applications and can response to emergencies very quickly.

6. Conclusion

Low power consumption is an essential requirement for wireless sensor networks. The embedded software running on sensor nodes should strive to optimize power consumption at node and network level. Most of the existing energy models only analyze the energy status of communication module, being deficiency of studying the overall energy consumption from the view of nodes. By modeling the energy consumption of different node components in different operating modes and state transitions, this experimenatl research work proposed a new node energy model. The proposed RPAS also saves the power to a great extent when the communication range varies with the transmitting power. By assigning the suitable transmitting power according to application requirement the node life time will be further increased. This work can also be used to analyze the energy status of WSN nodes and systems in both node and network level, to evaluate the node life time and deploy nodes and construct WSN applications. Such ultra low power design can be effectively adopted for applications such as environmental monitoring, Industrial automation and Car park management system.

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References :

[1] I.Akyildiz, A survey on Sensor Networks, *IEEE Communications Magazine*, vol. 40, Issue: 8, pp.102-114, August 2002.

[2] KazemSohraby, *Wireless Sensor Networks Technology, Protocols, and Applications,* Wiley India, 2010.

[3] Fabiano Salvadori, Monitoring in Industrial Systems Using Wireless Sensor Network With Dynamic Power Management, *IEEE Transactions on Instrumentation and Measurement*, Vol. 58, No. 9, September 2009.

[4] Muhammad Mahtab Alam, A Hybrid Model for Accurate Energy Analysis of WSN Nodes, *EURASIP Journal on Embedded Systems*, Article ID 307079, Volume 2011.

[5] http://www.ti.com/product/msp430f149

[6] V. Konstantakos, Energy Consumption Estimation in Embedded Systems*, IEEE Transactions on Instrumentation and Measurement,* Vol. 57, No. 4, April 2008.

[7] O. Landsiedel, Accurate Prediction of Power Consumption in Sensor Networks, *IEEE Workshop on Embedded Networked Sensors*, pp. 37–44, Sydney, Australia, 2005.

[8] Deokwoo Jung, An Energy Efficiency Evaluation for Sensor Nodes with Multiple Processors, Radios and Sensors, *IEEE, INFOCOM Proceedings,* 2008.

[9] Konstantin Mikhaylov, Optimization of Microcontroller Hardware Parameters for Wireless Sensor Network Node Power Consumption and Lifetime Improvement, *International Congress on ultra-modern Telecommunications and control systems and workshop , (ICUMT),*2010.

[10] http://www.nordicsemi.com/eng/Products/ 2.4GHz-RF/nRF24L01

[11] www.iar.com.

[12] Chang and Ju , An efficient cluster-based power saving scheme for wireless sensor networks, *EURASIP Journal on Wireless Communications and Networking,* 2012.

[13] Dali Wei, An Energy-Efficient Clustering Solution for Wireless Sensor Networks, *IEEE Transactions on Wireless Communications,* Vol. 10, No. 11, 2011.

[14] Jinsuk Baek, Dynamic Cluster Header Selection and Conditional Re-clustering for Wireless Sensor Networks, *IEEE Transactions on Consumer Electronics*, Vol. 56, No. 4, 2010.

[15] Lei Wang, A Wireless Biomedical Signal Interface System-on-Chip for Body Sensor Networks, *IEEE Transactions on Biomedical circuits and systems*, vol. 4, no. 2, April 2010.

[16] Cesare Alippi, A Robust, Adaptive, Solar-Powered WSN Framework for Aquatic Environmental Monitoring, *IEEE Sensors Journal*, Vol. 11, No. 1, Jan 2011.

[17] Bryan N. Hood, Estimating DoA From Radio-Frequency RSSI Measurements Using an Actuated Reflector, *IEEE Sensors Journal*, Vol. 11, NO. 2, Feb 2011.

[18] Raja Jurdak, Adaptive Low Power Listening for Wireless Sensor Networks, *IEEE Transactions on Mobile Computing,* Vol. 6, NO. 8, August 2007.

[19] Hao Guo, Optimizing the Localization of a Wireless Sensor Network in Real Time Based on a Low-Cost Microcontroller, *IEEE Transactions on Industrial Electronics*, Vol. 58, No. 3, March 2011.

[20] Stevan J, Nano-Power Wireless Wake-Up Receiver with Serial Peripheral Interface, *IEEE Journal on Selected areas in Communications,* Vol. 29, No. 8, Sep 2011.

[21] N. Kawadias, Measurements Analysis of the Software-Related Power Consumption in Microprocessors, *IEEE Transactions on Instrumentation and Measurement,* Vol. 53, No. 4, August 2004.

[22] Stevan Jovica Marinkovic, Energy-Efficient Low Duty Cycle MAC Protocol for Wireless Body Area Networks, *IEEE Transactions on Information Technology in Biomedicine*, Vol. 13, No. 6, Nov 2009.

[23] Wei Dong, Providing OS Support for Wireless Sensor Networks: Challenges and Approaches, *IEEE Communications Surveys & Tutorials*, Vol. 12, No. 4, Fourth Quarter 2010.