Impact of Algorithm Complexity on Energy Utilization of Wireless Sensor Nodes

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***Abstract*— Nowadays wireless sensor networks are implemented in a variety of fields to obtain real-time measurements. These networks are comprised of small, low cost devices called wireless sensor nodes (WSN). There are different types of wireless sensor nodes available in the market. Based on the requirements, wireless sensor nodes can be selected for each application. Power consumption is a major aspect in developing wireless sensor applications. In this paper, analysis of power consumption in different sensor nodes is conducted based on algorithms with different complexities. The experimental analysis results show that at a particular input current limit, Waspmote consumes 15% less power than MICAz mote in the case of O (1), 11.04% less in the case of O (n), 7.6% less in the case of O (n2), 3.9% less in case of O (log n) and 18.06% less in case of O (m+n)complex algorithms.**

***Keywords*— mote; algorithm analysis; complexity; power consumption**

I. INTRODUCTION

Wireless sensor nodes are small, low powered devices equipped with limited sensing, computing and wireless communication capabilities. Wireless sensor nodes differ in many performance criteria such as operating system, energy consumption, speed, radio frequency, radio range, energy consumption, etc. Wireless sensors are advanced devices that are used to sense and act in response to signals. Sensors are devices that detect almost all types of signals such as physical, chemical, and biological and provide a route for those signals to be measured and recorded. A sensor senses many parameters such as pressure, humidity, light, temperature, etc., and converts them into a signal which can be measured electrically. There are certain characteristics such as accuracy, environmental condition, range, calibration, resolution, cost and repeatability which have to be considered while selecting a sensor for a particular application. The basic architecture of a wireless sensor node [8] is shown in Fig.1.

Different types of sensors and wireless sensor nodes are available in the market. A wireless sensor node is constructed with four subsystems. The sensing subsystem consists of sensors whose response is sent to the processing subsystem, where processing of signals is done with a microcontroller. The communication subsystem consists of antenna which acts as transceiver and last is Power subsystem which consists of batteries. Since their size is small, the lifetime of a wireless sensor node also decreases. The different communication technologies used in WSN are ZigBee, WiFi, WiMax and Bluetooth. This paper describes the analysis performed of wireless sensor nodes based on different algorithms. The power consumption was taken as the main goal in this analysis. It will estimate how much power each wireless sensor node consumes for the implementation of a particular algorithm. This will give an idea of how different parameters of a wireless sensor node performs with algorithms of different complexities.

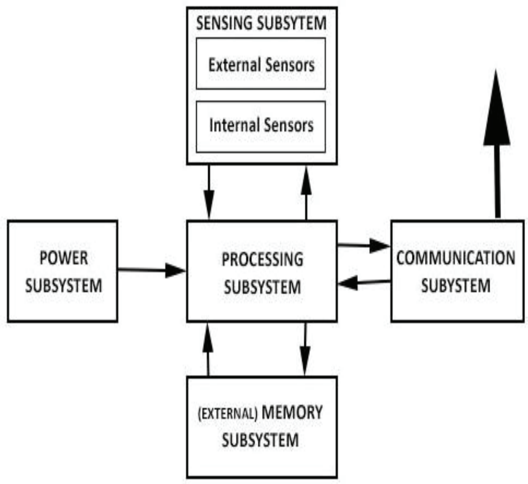

Fig.1 Architecture of a wireless sensor node

This paper is structured as follows. Section II describes the details of referred papers. Section III discusses the complexities of different algorithms. Section IV describes the experimental setup and the details on measurement of power. Section V provides the results of practical measurements and their values. Finally the conclusion and future work section informs the reader about the best choice between two wireless sensor nodes and gives scope for future work.

II. RELATED WORK

A study was conducted on different wireless sensor nodes available in the market and its comparison based on power consumption with respect to programs with different complexities.

A comparative study on performance characteristics of few commonly used wireless sensor nodes are discussed in [1]. They found that for an application requirement with low cost, limiting processing power, best transmitting range and outdoor coverage, the TinyNODE wireless sensor node was the best option. The authors also suggest that SunSPOT has excellent memory.

[2] discusses comparative analysis of mote technologies mainly focused on features such as memory, cost, power consumption, processor and their advantages and disadvantages had discussed in [2]. They also suggests that with minute form factor and integrated 3D accelerometer sensors, SHIMMER suits best for wearable applications mainly healthcare monitoring. While considering cost, MICAz and TelosB are the inexpensive among all. Due to increased range of coverage, IRIS wireless sensor nodes can be used for long distance communication.

Gajjar et al. did research work [3] comparing of wireless sensor nodes on the basis of LEACH protocol. This work was done on different parameters such as software support, storage, computational power, radio modules and onboard sensor support. They found that for power consuming applications, SunSPOT was the best choice. Wasp mote provided a big range of radio modules and different models with integrating up to sixty sensors. The EZ430-RF2XXX wireless sensor nodes were the low-cost and best suited for applications requiring sensor data to be provided from external source(s).SHIMMER wireless sensor nodes were developed for wearable applications such as monitoring human physiological data, human health etc. For node technology, it is more essential to reduce energy consumption and cost.

[4] Discusses a survey paper done based on performance and parametric analysis of different motes. This paper mainly concentrates on power consumption and RF module based parametric survey. They analyzed various technical and implementation parameters like frequency, data rate, TX etc... Shingal and et.al did research work [5] on estimating the power consumption and lifetime of a wireless sensor node based on a humidity monitoring system. In this work, they used an oscilloscope and a 10 Ohm resistor to measure the power across each sensing state.

III. ANALYSIS OF POWER CONSUMPTION IN WIRELESS SENSOR NODES ON DIFFERENT ALGORITHM COMPLEXITIES

The area of wireless sensor networks needs a variety of algorithms and protocols to obtain full-fledged functionalities. Some of them are related to energy management, power management, data collection, data aggregation and so on. In this paper, algorithms with different complexities are taken and tested with each type of wireless sensor node. After running each program with different wireless sensor nodes, the. corresponding energy and power is analyzed. The comparison of MICAz and Waspmote [7] based on certain features are discussed in Table 1.The figures of MICAz and Wasp mote are shown in Fig 3.1 and Fig 3.2 respectively.

Fig.3.1. MICAz mote

TABLE 1. GENERAL ANALYSIS OF MOTE PERFORMANCE

Features	MICAz	Wasp mote
RAM(KB)	4	8
FLASH(KB)	128	128
Data rate(kbps)	250	250
Release	2004	2011
Manufacturer	MEMSIC	LIBELIUM
Power Supply	2.7V-3.3V	3.3V-4.2V
Weight(gm)	64	20
Transmission Power consumption (mW)	52.2	165
Reception Power consumption (mW)	56.4	148.5
Power consumption Sleep/idle	1.28mW	33µA
Modulation	O-QPSK	PWM
Transmit power	-24dBm	-10dBm
Radio chip	CC2420	XBee-802.15.4

Complexity is considered as the maximum number of primitive operations that a program may execute. Complexity specifies the order of magnitude within which a program perform its operations[5]. In this work, the power consumption of each mote is done based on O(1),O(n),O(n2),O(m+n) and O(log n).

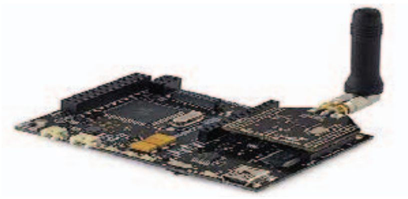

Fig 3.2. Waspmote

The MICAz mote is boarded on a MIB520 gateway for burning the program. This gateway can make a MICAz node to function as a base station when connected to it. In addition to data transfer, MIB520 also acts as a USB programming interface.

IV. EXPERIMENTAL SETUP

The power consumption of each algorithm is measured by the product, SMU (Source/Measure Unit) which is shown in Fig 5.1.This is a product from Keysight Technologies [9]. This instrument is built with the capability to either source or measure both current and voltage .Thus for a particular input current and the voltage, it will return its corresponding power consumed. In this work, the voltage is a measured input and current is a sourced input. After burning each program to the mote, power of each mote is switched on and will be connected to the SMU using the probes. It will measure the corresponding power consumption with respect to the voltage used for running the particular program and the sourced input current.

In this research we aim to find the power consumption rate at two different motes with exactly same program with same logic and same number of execution steps. So we had taken simple programs such as blinking LED for O (1),finding prime numbers for O (n), and nested loop program for O (n2) and so on. Two different variations of C programing are used in programing motes. MICAz is programmed in NeSC language and Waspmote is programmed in Waspmote IDE which uses extension of C++ language.

Fig 4.1 Precision Source/Measure Unit [9]

V. RESULTS

In this paper, we conducted an analysis of wireless sensor nodes with different algorithms. We analyzed the performance of wireless sensor nodes based on algorithms of different complexity. Various algorithm complexities are discussed in [6]. Performance with various algorithms are discussed in this paper.

In this paper ,only two wireless sensor nodes, namely MICAz and Wasp mote, were analyzed. The power consumption of each mote was analyzed based on algorithms of different complexities with respect to a particular current limit. In Fig 5.1, the rate of power consumed by both wireless sensor nodes based on algorithm of complexity O(1) was analyzed. It is observed that MICAz mote consumes more power compared to that of Waspmote for a specific current limit. In Fig.5.2, the amount of power consumed by each mote for executing a program of complexity O(n) was analyzed. In both cases, it was clear that MICAz wireless sensor nodes consumed more power than Wasp mote.

The power consumption status of both wireless sensor nodes with respect to an $O(n^2)$ complexity algorithm is shown in Fig.5.3. In this case too, Wasp wireless sensor nodes consumed less power than the other one. The power consumption status of both wireless sensor nodes with respect to an O(log n) complexity algorithm is shown in Fig.5.4. Here also, Wasp wireless sensor nodes consumed less power than the other one. The power consumption status of both wireless sensor nodes with respect to an O(m+n) complexity algorithm is shown in Fig.5.5. In this case too, Waspmote consumed less power than the other one. Over all we can see that when a particular current limit is taken, the percentage increase in power consumption decreases as shown in Table 2.

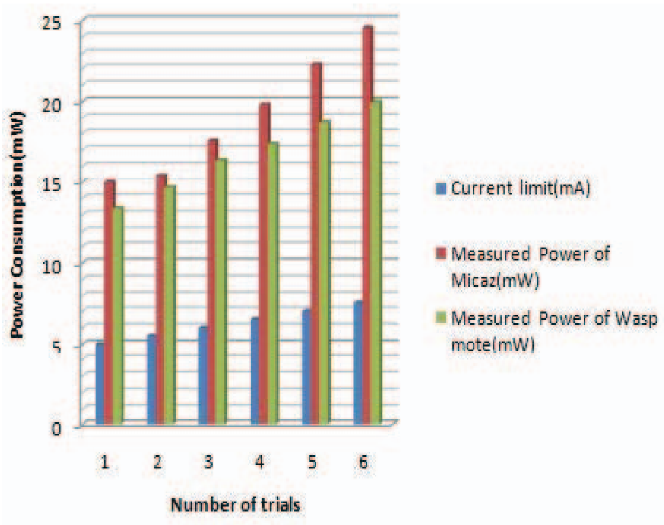

Fig.5.1 Power consumption analysis of wireless sensor nodes based on algorithm with complexity O(1)

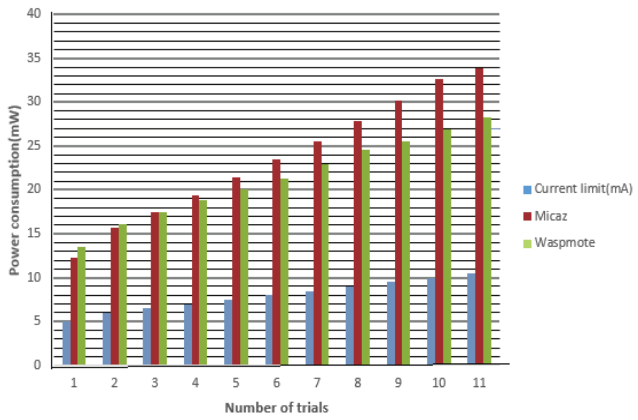

Fig.5.2 Power consumption analysis of wireless sensor nodes based on algorithm with complexity O(n)

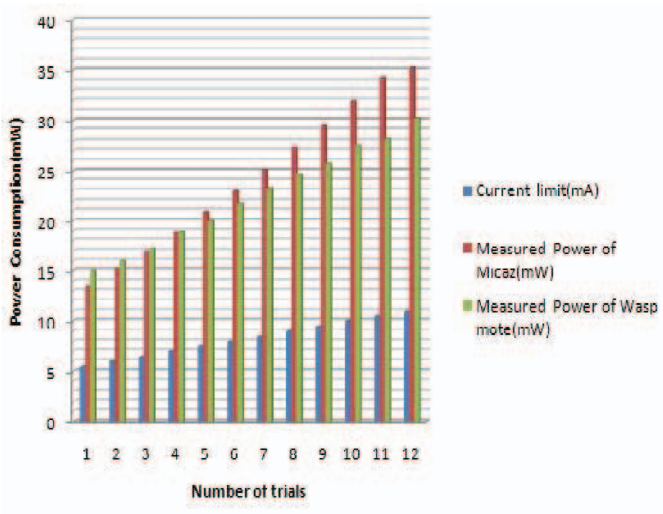

Fig.5.3 Power consumption analysis of wireless sensor nodes based on algorithm with complexity O(n^2)

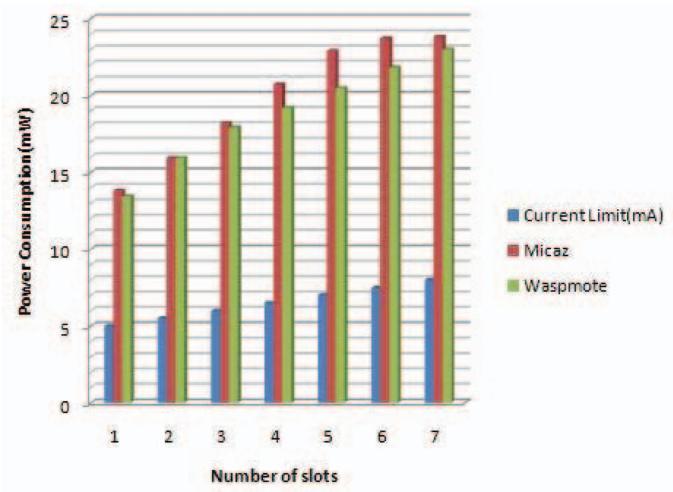

Fig.5.4 Power consumption analysis of wireless sensor nodes based on algorithm with complexity O(log n)

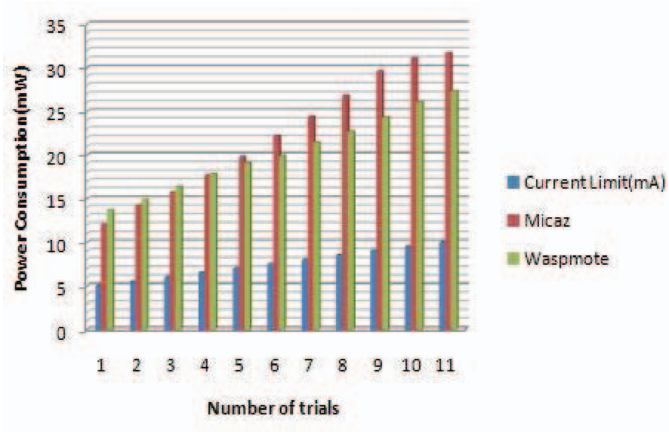

Fig.5.5 Power consumption analysis of wireless sensor nodes based on algorithm with complexity O(m+n)

TABLE 2. EXPERIMENTAL ANALYSIS OF MOTE PERFORMANCE

Complexity	Type of Mote	Base Current Limit(mA)	Power consumed (mW)
O(1)	MICAz	8.5	26.44
	Waspmote	8.5	22.98
O(n)	MICAz	8.5	25.54
	Waspmote	8.5	23
O(n2)	MICAz	8.5	25.09
	Waspmote	8.5	23.31
O(log n)	MICAz	8.5	23.9
	Waspmote	8.5	23
O(m+n)	MICAz	8.5	26.8
	Waspmote	8.5	22.7

In all cases, the MICAz mote and Wasp mote had a power limit beyond which for any input current, it gives constant power values. For a MICAz mote, the power consumption varies up to about 8.5 mA and about 20 mA in the case of a Waspmote. If too much current is given, it may affect the mote and board. All these experiments were done with the help of a SMU(Source Measure Unit),a Keysight Technologies product, which could give accurate measured values for current, voltage and power. As the complexity growth increases, the power consumption of wireless sensor nodes decreases.

V. CONCLUSION

This paper describes a comparative power consumption analysis of different wireless sensor nodes. The study was conducted based on algorithms with various complexities. Only MICAz mote and Wasp wireless sensor nodes were used in this paper. After the experimental measurements and analysis, we concluded that MICAz wireless sensor nodes consume more power than Wasp mote. Furthermore, the range of power values varies in each complexity case.

FUTURE WORK

For experimental analysis, only two types of wireless sensor nodes were considered in this paper. As a future work, the same experimental analysis can be extended with other types of wireless sensor nodes. This will give a practical analysis of mote measurements.

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