International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

# Evolution Of Wireless Sensor Technologies And Energy Resource Management Of Microcontroller Used In Wireless Networks

B N Suresh Kumar, Adapa

Rajesh, Tammu

Tarak RamaKrishna, Pamidi

Dept. of Electrical Engineering, Blekinge Tekniska Hogskola(BTH)

***Abstract*—This paper is a brief survey that presents the evolution of wireless sensor networks (WSN) over time and how they are optimized and made reliable in power aspects of design. The research question of this paper is to reduce power consumption in a sensor node. Since most applications of WSNs are in areas of wilderness, power consumption is vital to make them work for long time. Microcontroller (MCU) is heart of any sensor node. Now our focus is on power controlling techniques and issues in microcontrollers. This paper describes the energy consumption techniques to reduce overall power of WSNs that are main attributes to modern day wireless technologies. It also briefly discusses about the states of the MCU and reducing the power consumption in these states. This paper also discusses about reducing the power of MCU in sleep mode via Brown out Detector (BOD). Finally, the AVR Pico power technology and design tailored microcontrollers for application specific sensor network node (ASIC) are also presented.**

***Index Terms*— Wireless sensor networking, AVR Pico power technology, resource management, ASIC microcontroller, sensor node, Brown Out Detector.**

## I. INTRODUCTION

Owing to wireless technology every corner of world is aligned with intelligence. The evolution of wireless network started as *"smart dust"* by Dr.Kris Pister and Co as they defined it a network of microcomputers built into whatever we need, such as buildings, bridges and etc. The processing features such as sensing, computation and communication in small package, are right now integrated in a size of grain. These nodes record information about the surroundings and send it to a neighbouring computer or to the user for monitoring. These low power and relatively inexpensive tiny specs of networks can manage even a larger size city. This discovery of smart dust led made us to understand more about our surroundings. For example, automatic opening and closing of doors by motion sensors, detecting the seismic activity by vibration sensors, automatic fire alarm by heat sensors etc. The wireless sensor networks are a subclass of wireless ad-hoc networks that uses sensor nodes for sensing, communicating and computing operations that are monitored using a networked distributed sensor network.

Technologies have not developed parallel and at the same level for all WSN components. Since the networks are powered by batteries careful monitoring has to be done to prevent out of service nodes. Also the radio transceiver module used for wireless communication consumes lots of power i.e. it uses power of 1000 cycles of CPU for one bit of data [1]. Hence, efficient use of energy is necessary in areas of low power reserves.

It is to be noted that wireless sensor networks are erroneously classified as a special case of wireless ad-hoc networks, but the truth is the algorithms and protocols used for ad hoc networks are incompatible to WSNs [2].

## II. PROBLEM STATEMENT AND MAIN CONTRIBUTION

Micro controllers are employed at the core of sensor nodes which consume most of the sensor energy. We discuss about various factors that influence the power consumption in a MCU of a sensor. In this paper we mainly focus on various methods adapted to lessen to the power consumption of a microcontroller in a sensor node. We relate the concept of AVR pico technology with MCU to reduce the total power consumption of the sensor node. The concept of Application Specific Integrated Circuits (ASIC) is used so as to evolve the concept of tailored MCUs to reduce the power.

In the first section (III) the paper deals with evolution of WSNs and its optimization to adapt with technology demands. In the second section (IV) the focus is how to deal with power consumption issues in microcontrollers that used in sensor nodes.

## III. EVOLUTION OF WSNS AND OPTIMISATION WITH TECHNOLOGY AND RELIABILITY ISSUE

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or connected to the other networks (e.g. the Internet) through a gateway. [1]

The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not i.e. similar sensors node are connected to another or not respectively. "On one hand, WSNs enable new applications and thus new possible markets, on the other hand, the design is affected by several constraints that call for new paradigms"[1].

At the end of 20th century the idea of combining MEMS technology, Morse coding together with the communication revolution gave rise to the emerging wireless sensors

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

technology under the name of *"dust networks"* [2]. As the reliability is the main concern of any emerging technology, it had taken time to achieve 99.9% reliability. Protocol reliability, i.e the challenges a sensor network to withstand with RF environment is main concern. It started as a single hop network usually emerged as multi hop network along with some protocols to work with it. Dust Network employs TSMP [3](Time Synchronized Mesh Protocol) to keep the nodes awake at particular instants of time and also manage the energy consumption and multi path interference in a manner that data from no single node is dropped [2]. Also the path loss of various nodes in the system is calculated and it shows fair results [2]. In case of high path loss that interrupts data packet to be properly transferred, a mechanism to switch the operating channel is developed. Adaptation of the operational channel based on channel quality is similar to Zigbee to Zigbee Pro development. As the result, the described designed intelligence in MAC (Media Access Control) or Application layers constructs a reliable system.

The next concern about a sensor node is physical size. In the course of sensor evolution the size of a node had changed from a shoe to a small grain in series of steps. In some applications such as medicine and security the need for even smaller size is demanded. Hence, striving is in a direction of achieving microscopic or nanoscopic sensor nodes which is the research area of future.

## IV. POWER CONSUMPTION IN MICROCONTROLLER HIERARCHICALLY

Fig.1 provides the intuitive understanding that in a sensor node most of the power is consumed by MCU (Micro Controller Unit) since most of functionalities is controlled or performed by MCU

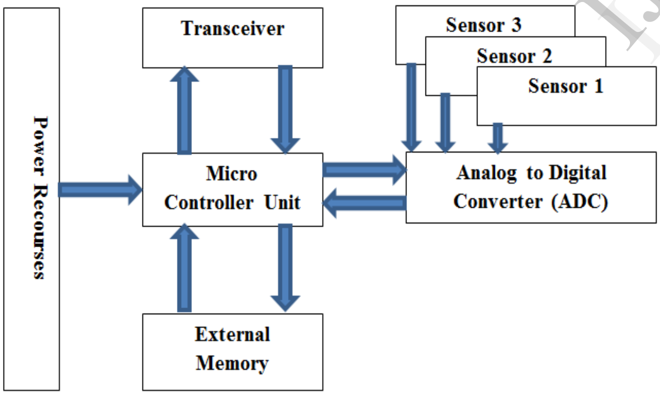


Fig. 1. Functional diagram of a wireless sensor.

Earliest inventions such as "smart dust" proved unreliable from life time point of view since the controller is powered on even when the sensor is not transmitting any data. Later the query had been solved by novation of Time Synchronized Mesh Protocol (TSMP)[3]. "This communications protocol for self-organizing networks of wireless devices called motes. TSMP devices stay synchronized to each other and communicate in timeslots, similar to other TDM systems. Such deterministic communication allows the devices to stay extremely low power, as the radios only turn on for the periods of scheduled communication. The protocol is designed to operate very reliably in a noisy environment. It uses channel hopping to avoid interference the packets between TSMP devices get sent on different radio channels depending on time of transmission.[7]" In addition, TSMP allows the WSN to stay in sleep mode more often than wakeful mode i.e. it has a low duty cycle and the focus is then drawn to save power in sleep modes. A duty cycle of a microcontroller is the percentage of its active state in one time period. It is intuitive that a typical WSN node has a duty cycle of about < 1% because of their applications. For example a temperature sensor calibrates once in every 10 minutes, a vibration sensor placed in an earthquake prone area wakes up once in very long time. So, it is intuitive that its active state is very less than that of its sleep state. So considering the power saving methods in sleep mode may reduce overall power. Low power is dependent on many factors such as crystal oscillator frequency, temperature, operating voltage with peripherals running. "In many applications, the processor does not run continuously and peripherals may be idle much of the time. The overall power consumption can be reduced by taking advantage of various sleep modes available virtually on all processors. The most common sleep modes are Power Down (PWD), Power Save (PS) and Idle. In Power Down mode everything is shut down, including the clock source"[4]. In Power Save mode everything is turned off except a 32 kHz clock running from a crystal to keep track of the time. Idle mode is a shallow sleep mode where only parts of the device are shut down but the main parts of the microcontroller are active [4].

The main consumption of power occurs in a MCU during its sleep mode is Brown Out Detector (BOD). BOD function is to check for the voltage levels of MCU while MCU is about to wake up. If the power is less than the required threshold level, BOD resets the device [4]. Since BOD has no functionality when the MCU is ON, a part of the power is consumed without any notable advantage. So zero power BOD is a research interest. However, reduction of the power level of BOD decreases the accuracy of analog devices. In addition, it is important to consider that the power specification on data sheets of a MCU is given without considering active peripherals.

Then Atmel designed AVR Pico power technology overcomes all the described disadvantages. It has been designed to work with very low power oscillators, functional MCUs at operating voltage with an algorithm for BOD to be switched ON/OFF in case of requirement [4].

The next step of power saving is to design Application Specific Integrated Circuits (ASIC) to be used in WSNs. The question that arises from a critic when named application specific MCU is "why to limit the usage of MCU?". In this case the sensor networks have the best answer. Usually once deployed these networks work for their life time provided enough power sources. Hence there is no drawback in designing ASIC for sensor networks. The main theme behind

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

ASIC is to reduce the hardware utilization into a suitable level according to the certain application instead of using the off the shelf microcontrollers. A survey had been conducted among MCUs from Atmel, TI and PIC. Among them MSP430 from TI proved to be reliable and efficient than the others. The design of these MCU is more based on applications. According to application useless hardware is removed. After selecting the right amount of features, MCU uses conventional low-power techniques like clock gating to reduce the dynamic power [6]. Clock gating is extensively used in microcontroller design. The ALU (Arithmetic Logic Unit), fetch-execute pipeline, RAM, ROM, instruction decoder and program counter are all supplied gated clock inputs to prevent unnecessary transitions and reduce dynamic power consumption. Static power, which becomes dominant in sleep mode [4], is improved by employing low-leakage FLASH for the ROM and low-leakage SRAM for RAM, as these are the largest portions of the actual hardware and consume lots of leakage power [5].

.

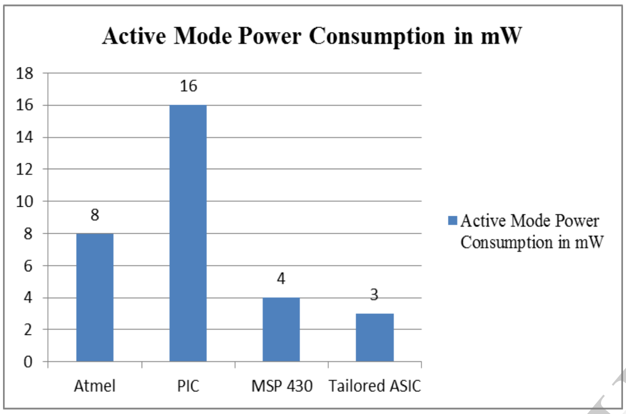


Fig. 2. Active mode power consumption at 10Mhz in mW.

(D. Singh, S. Sai Prashanth, S. Kundu, and A. Pal, "Low-power microcontroller for wireless sensor networks)[5]

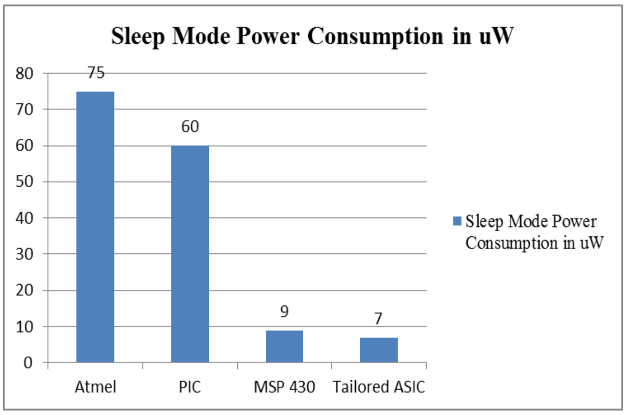


Fig. 3. Sleep mode power consumption in uW.

(D. Singh, S. Sai Prashanth, S. Kundu, and A. Pal, "Low-power microcontroller for wireless sensor networks) [5]

As a result, the power of flip-flops, multiplexers and etc. that are not a part of application can be switched off according to the design. The simulation shows outstanding results in a way that this design proved remarkable efficiency than MSP430 [5]. Fig.2 and Fig.3 respectively illustrate the power consumption comparisons in both active and sleep mode between different designs.

The simulation results are intuitive that the tailored design of MCU yields better results than using the off the shelf MCUs. Fig 2 depicts the results in the active state of microcontroller and tailored MCU always consumes less power. Fig 3 represents the sleep state power consumption and the power consumed by tailored ASIC is less when compared to other MCU's. The simulations are done using 180nm CMOS technology. The present trend of CMOS technology is 22nm CMOS technology since the technology scales 76% for every 2-3 years[10]. Simulation using this technology could yield far better results.

Our paper deals with only MCU power issues of a node. Since a node is made up of many other components energy management in other areas such as radio transceivers, Analog to digital converters, power sources etc is also significant. Many algorithms had been deployed till date such as PEACH[8], energy efficient clustering algorithm for data aggregation[9] etc.



## V. CONCLUSION AND FUTURE WORK

The vastly acceptable wireless sensor technology needs to be much more reliable in every field. The life time of the wireless node should last for long times. Many factors have influence on them. The paper discusses optimal and reliable employment of power levels in microcontrollers. In conclusion, as the power levels are reducing, the applications for WSNs are in increasing trends.

The main concern with sensor nodes of realistic size has its disadvantages in medicine, military etc. So, future work in the field of WSNs would be concentrated around building up of microscopic or nanoscopic sensor nodes with reduced power as trade off and increased reliability. Since the design of tailored MCUs yields better results than off the shelf MCUs, the hardware should be designed for ASIC MCUs. ASIC MCU can be used to reduce the size of sensor nodes. However, the disadvantage of design of tailored MCUs is that, it is asynchronous. Therefore, lot of work should be done in near future to overcome the synchronous problem, which is another important factor for power consumption.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

## VI. References

[1] C. Buratti, A. Conti, D. Dardari, and R. Verdone, "An Overview on Wireless Sensor Networks Technology and Evolution," Sensors (Basel), vol. 9, no. 9, pp. 6869–6896, Aug. 2009.

[2] Based on a talk by Dr.Kris Pister about "smartdust" http://www.youtube.com/watch?v=PVH1K1Eocz0 (2007)

[3] K. S. J. Pister and L. Doherty, "TSMP: Time Synchronized Mesh Protocol," in In Proceedings of the IASTED International Symposium on Distributed Sensor Networks (DSN08, 2008)

[4] Innovative Techniques for Extremely Low Power Consumption with 8-bit Microcontrollers Arne Martin Holberg, AVR Project Manager and Asmund Saetre, AVR Marketing Manager (Atmel white paper) 2008

[5] D. Singh, S. Sai Prashanth, S. Kundu, and A. Pal, "Low-power microcontroller for wireless sensor networks," in *TENCON 2009 - 2009 IEEE Region 10 Conference*, 2009, pp. 1 –6.

[6] Piguet C., Masgonty J. M., Arm C., Durand S., Schneider T., Rampogna F., Scarnera C., Iseli C., Bardyn J. P., Pache R. and Dijkstra E., "Lowpower design of 8-b embedded CoolRisc microcontroller cores." In IEEE Journal of Solid-State Circuits, vol. 32, no. 7, Jul. 1997.

[7] Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/TSMP, Accessed on 14 October , 2012.

[8] PEACH: Power-efficient and adaptive clustering hierarchy protocol for wireless sensor networks Sangho Yi, Junyoung Heo, Yookun Cho a, Jiman Hong b[2007]

[9] Energy efficient clustering algorithm for data aggregation in wireless sensor networks SHA Chao1, WANG Ru-chuan, HUANG Hai-ping, SUN Li-juan(2010)

[10]http://en.wikipedia.org/wiki/180_nanometer[updated2012]