Evolution of wireless sensor networks and necessity of power management technique

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***Abstract*—Wireless sensor networks interfere in a growing number of applications ranging from simple environmental monitoring like temperature detection to complex calculation such as video processing. This last type of application requires a high load at the sensor level and leads to a problem of optimization. It is critical to design algorithms and protocols in such a way to use minimal energy. This paper provides a survey of WSNs technologies, main applications and hardware evolutions. In the other hand, we will provide an insight about the latest trends of the technique to reduce the power consumption within the WSN that could possibly make this emerging technological area more useful than ever.**

***Keywords*—Wireless Sensor Networks; Power consumption; Platforms; Applications; Dynamic Voltage and Frequency Scaling; Dynamic Power Management.**

I. Introduction

Sensor area is growing at an accelerated pace, attracting more and more people to its use, and is becoming one of the subjects of predilection of researchers. The imminent progress made in MEMS (Micro Electro Mechanical systems) coupled with wireless communication and digital electronic has led to the massive deployment of tiny size, low cost, low power, multifunctional and high performance sensor nodes[1]. Thus, the network technologies of wireless sensor have become a global trend in communication, mobility and research of flexible implementation. The first challenge of a wireless sensor network is to ensure optimal performance for users and to save the energy consumed by sensor nodes [2]. Widespread in hostile environments and equipped with limited resources, this network sees reducing its performances and confines itself to some applications. Once deployed, it is often impossible or inappropriate to recharge sensor nodes or replace their batteries [3] [2].

Recently, wireless sensor networks (WSN) are expected to carry out high functionalities in various scopes. It's more evident now to support heterogeneous WSN's applications with different sensors: temperature, pressure, image, sound, video instead of sampling temperature and sending the value to a base station. Unfortunately, energy remains the major handicap in front of this progress due to limit capacity of node's batteries. Therefore, the energy optimization becomes more and more a necessity for sustaining a sufficiently long network lifetime [4]. Since most systems require much longer lifetime, significant research has been undertaken to increase lifetime while still meeting functional requirements. There are many techniques to reduce power consumption [1]. This paper presents an overview of some of the key areas and research in wireless sensor networks related to energy savings.

The remainder of the paper is organized as follows: we use examples of recent work to portray the state of art of the evolution those networks. In particular, we discuss the progress made in the fields of application, the architecture and the platforms in the second section. Besides we give a glance about the progress known by the architecture and the platforms of WSN. We have proposed also many innovative applications of wireless sensor networks. We also attempt an investigation also into pertaining energy constraints. Section 3 states the deployment of the power management technique to meet the best of our needs. We conclude in section 4.

II. Evolution of WSN

Wireless sensor network (WSN) is an exciting new technology that has attracted extensive interest. The WSN is subject for various resource constraints which are memory, processing ability, bandwidth, and mainly energy efficiency [2]. To overcome those many possible architecture and new platforms have been defined offering more reliability and broadening the spectrum of deployment of these networks. We try to provide next an overview of the recent advances of architecture, in the platforms and the field of application.

A. Hardware architecture

A Wireless Sensor Network is a self-configuring network of small sensor nodes communicating among themselves using radio signals, and deployed in quantity to sense, monitor and understand the physical world [4]. A sensor node is typically made up of four basic components which are the sensing unit, the processing unit, the transceiver section and the power supply unit as illustrated in figure 1. The motes or the sensor nodes have to provide information anytime and anywhere to a final user, by collecting, processing, analysing, and disseminating data [5]. The recent advances of wireless sensor networks create new opportunities for innovative applications, but poses new technical challenges for constructing such applications. In fact, new types of sensors are now commercially available and could be broadly classified as pressure, temperature, light, biological, chemical, strain,

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fatigue, tilt sensors, humidity, vibration, microphone, camera and so on[6].

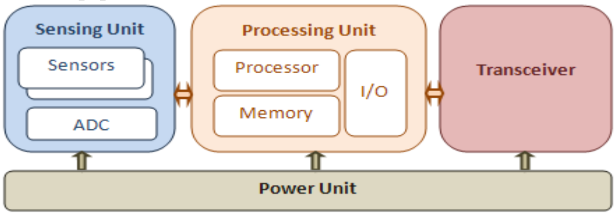

Figure 1 A sensor node components

Today, the lack of appropriate tools and methodology that are able to handle the imminent progress made in WSN is an obstacle to potential uptake. That's why this progress requires inherent evolution in the hardware architecture of the motes. The nodes forming the WSN are now equipped with more processors and are more powerful (4Mhz mica, 12Mhz with Imote2) and a greater memory. As it is shown in Table1, new platforms have 32Mbyte as RAM memory and the same capacity as flash memory. In addition, they support dynamic voltage and frequency scaling (DVFS) technique thanks to the range of frequency of processor.

Table 1. Evolution of hardware resources of motes

	WeC	Dot	Mica2	Imote1	Imote2	Shimmer [7]	Cookies [8]	Egs [9]
development	1999	2001	2003	2005	2007	2008	2008	2010
Processor (MHz)	4		7	12-48	13-400	8		96
Flash	8K	16K	128K	512K	32MB	48KB +external memory 2GB	4 Mbit	256 KB +external memory 2GB
RAM	0.5K	1K	4K	64K	32MB	10KB	4 Kbytes + 62 Kbytes	52KB
Transceiver	RFM		ChipCon	Bluetooth	Zeegbee	Bluetooth and 802.15.4 (WML-C46A, CC2420)	ETRX2 TELEGESIS	CC2520 : 802.15.4 and 2 Bluetooth modules
µC	Amtel			ARM 7TDMI	XScale PXA271	MSP430 processor	ADUC841 + Spartan 3FPGA	ARM Cortex M3

The heterogeneity of the nodes in the WSN as well as the power resources, help not only to improve the capabilities of the WSN, but also to limit its lifetime. The lifetime of a node may be determined by the battery life. The network lifetime is defined as the maximum number of times a certain data collection function or task can be carried out without any node running out of energy [4]. This is why implementing dynamic power management techniques become more and more obligatory.

B. Platforms of Sensor Networks

The WSN platforms (mica2, micaz, etc.) used to contain just a temperature or pressure sensor and they were restricted to the transmission of the captured information to a third element. Recently, the proliferation of the WSN has led to new generation of platforms that are equipped with a camera, a microphone, an earpiece for dedicated applications that integrate audio or video treatments. Also treatment has become increasingly complex and requires more resources and mainly better power management than sleep-policies. In this context, new platforms (imate2) are equipped with processors with management policy dynamic frequency and voltage (DVFS). Indeed, the functioning of a processor is not constant; it consists of treatment periods that require computing variable power.

C. Applications of Sensor Networks

WSN have become an equipment key in many industrial applications. Indeed, WSN have proved their efficiency in monitoring, tracking, or controlling phenomena where wiring is difficult or cost-prohibitive. In terms of areas of application, sensor networks have been extremely successful, because they hold a potential which revolutionized many sectors of our economy and our daily life, such as the monitoring and preservation of the environment, the industrial manufacturing, passing through the automation in the sectors of transport and health, modernization of the medicine, the agriculture, the telematics, and the logistics [10]. Also they invade military and many other different scoops that were unthinkable several decades ago such as cellular phones, GPS units, television satellite, remote sensing and the internet [5]. Far away from simple application, WSN set up today applications more complex with heterogeneous sensors. We have attempt next to give a glance about the latest trends of application of WSN.

1) *Habitat Monitoring:* As an example, we cite an application for firefighters proposed in the project GEODE, comprising nodes for sampling temperature, smoke detection and motion as well as cameras in a building. On the other hand, we can also equip firefighters with their nodes to determine areas where there are people in danger or simply determining the output once it is in the building on fire[11].

2) *Agriculture:* In addition, WSNs have the potential for widespread application in precision agriculture, particularly in the areas of crop and irrigation management, planned fertilization and pest control, variable rate chemical input application and modeling crop performance[12].

3) *Civil infrastructures:* Once deployed in offshore fields, the use a low-cost WSN presents a major advantage when it comes to feeding measurement and communication equipment data to central units. The WSN can be retrofitted on offshore platforms that have hundreds of pumps, fans, and other motor driven devices requiring permanent maintenance[13].

4) *Medicine:* Bio-sensors are implanted in the human body to monitor the patient's physiological parameters such as heart beat or blood pressure. The data so collected is sent regularly to alert the concerned doctor on detection of an anomaly[2].

5) *Environment monitoring:* These sensors are very useful for environmental applications also. As a network, they have been used to detect environmental hazards such as earthquakes and floods. Some motes have even deployed to analyse remote locations, observing the motion of a tornado,

or detecting fire in a forest [5]. Sensors that are used also for satellite oceanographic observations, records the amount of incident energy returned from the imaged surface. This application provides a wealth of information on a diverse range of geophysical and biological parameters and phenomena [14].

6) Logistic: The WSN nodes are attached to goods which are mostly food due to their perishable nature. The goods are loaded from a warehouse to a freight vehicle, in which their nodes need to self-organize and form a network of nodes, which can deliver information of the goods' state to the outside world using a gateway [15].

III. Technique to reduce the energy consumption

WSN are subject to many resource constraints which are mainly closely related to the energy consumption. The nodes contain a conventional battery, supplemented by a renewable source that generates power using scavenging techniques (vibration, solar, EM, piezoelectric, radioactive, etc.)[16]. However, a sensor node powered by 2 AA batteries can last for up to three years with a 1% low duty cycle working mode [4].

To extend the autonomy of a system, only two methods exist: increasing the capacity of the on-board energy or reducing the consumption of the system. The first solution is a subject of research related to the field of batteries. However, it is always difficult to increase the capacity of a battery without increasing the weight, volume and price. Notwithstanding, the battery technology is not progressing fast enough to satisfy those requirements [2]. The second solution has also led to several researches in the field of electronics and computer science. Different techniques can minimize the energy consumption of WSN. In the literature, there are several methods that allow us to get a system with low consumption. Typically, they are divided into three categories.

A. Hardware Level

In fact, the power being proportional to the square of the voltage, we can think that the most effective one is to lower it [16]. However, lowering this parameter also leads to a reduction of the threshold voltage V_{th} which increases the leakage current and therefore the static power. Because our system is often in standby mode, it is therefore necessary to find a compromise between the reduction of the supply voltage and the threshold voltage. On the other hand, we can reduce the output capacity at the layout level, to the sizing gates level and also at the architectural level [17]. There is also the opportunity to try to reduce the frequency of activation at the architectural level partitioning the circuit block, enable those who are necessary for the application and put the rest in standby mode. It is possible to add solar cells or scavenge energy from motion or wind[16].

B. Software Level

Numerous system software techniques have achieved to extend the WSN lifetime such as duty-cycling subsystems, batching operation, reducing redundancies, low-power software approaches[18].Given that the number of instruction is proportional to the consumption, the techniques of code's optimization can help to minimize this consumption by reducing the number of access to the external memory. But as the optimization of these codes is manually difficult to implement, we can use other techniques for automatic optimization that intervenes at the level of the code generator. Among the automatic optimization techniques, we can cite inlining and loop method (copy the code in a function where it is mentioned instead of using a procedure of function call) and the unrolling technique(Copy the code several times)[3].At the level of communication, we can cite low power listening, communication scheduling, power-aware routing etc. At the operating system level, the Operating System (OS) for sensor nodes could implement a low-power task-scheduling which take advantage of nonlinear battery effects to reduce energy consumption. At the computation level, the operating system powers down the processor between events when idle which reduces considerably the wasted energy[19].

C. Hybrid

At the software level power management solutions are targeted to minimize the communications since transmitting and listening to messages is energy expensive, and to create sleep/wake-up schedules for nodes or particular components of nodes [2]. Indeed, this power manager allows us to adapt the energy resources in an automatic way and to reduce the power consumption of the WSN. Dispose of this utility offers various advantages such as a structure in which nodes can intelligently manage their own power and a module which has a global view across the network, the power and the sensor nodes states. Each component in the node can have different power modes. A task can be active, slowed down, or in sleep mode: radio can transmit, receive or in standby or other mode [20]. Each sleep state of the node corresponds to a particular combination of components of power. An interesting aspect of this concept is to take advantage of the static and dynamic resources management algorithms. Those policies refer mainly to the DPM (Dynamic Power Management) technique and to DVFS (Dynamic Voltage and Frequency Scaling).

1) *DPM:* The basic idea of DPM is to stop devices when they are not required and to wake them up when they are. Test-bed developed in cooperation with the start-up company SeNet s.r.l. for agricultural monitoring has shown that in sleeping mode, node consumption is only 0.5 mA, whereas during the activity mode the overall consumption is 30 mA[17]. Currently, the DPM is done thanks to the ability of the hardware to support mechanisms of sleep state ranging from total activity of the system up to full sleep implementation or disconnection of the system. Indeed, idle state transitions and implementation cost is running a bit expensive in the point of view of energy. In addition, the node must have a progressive quality scalability of energy so that its lifetime will be extended if the application requires, this is achieved at the expense of accuracy[3].

2) *Dynamic voltage and frequency scaling:* Approaches to deal with the reduction of energy consumption are various. We will give a synthesis of those methods. Pillali article [16]

introduced the dynamic management of tension as a key for the physical characteristics of the processor to reduce the energy dissipation by minimizing the supply voltage and the frequency. These algorithms have proved their effeicency by offering a considerable energy gain, while ensuring the performance of the real time embedded system. Notwithstanding this, we can not deny their impact in the execution time. Thus, taking into account the time constraints is necessary. Consequently, he introduced a new algorithm "Real Time Dynamic Voltage Scaling" which modifies the operating system real time and task management. The article written by Sinha and Chandrakasan [21] proposes the use of power aware methodology. They employ a micro incorporated operating system to reduce the energy consumption of the node by exploiting the node sleep state and active power management.

The appearance of variable voltage processors has led to greater autonomy and energy savings. Dynamic voltage and frequency scaling (DVFS) is an effective technique for reducing CPU energy. The DVFS tries to combine the performance and the lifetime of the battery. Lowering only the operating frequency can reduce the power consumption but the energy consumption remains the same because the computation needs more time to finish. Lowering the supply voltage can reduce a significant amount of energy because of the quadratic relation between power and voltage. Lowering the supply voltage and operating frequency reduces the power and energy consumption further[19]. A number of modern microprocessors such as Intel's XScale and Transmeta's Cruso are equipped with the DVFS functionality[3]. The first feature of this technique provides high performance only for a short time reduced, while the rest of the time a low CPU power is largely sufficient [16] [20]. Most micro-processor systems are characterized by a time-varying computational load. DVFS exploits the CMOS property that a linear reduction in the supply voltage results in a cubic reduction in the power consumption at the expense of a linear slow down in the processor frequency [21]. It is better thus to run the processor at the weakest frequency compatible with the necessary performance level. When used at a reduced frequency, the processor can operate at a lower supply voltage. As wireless sensor networks interfere in a growing number of applications ranging from simple environmental monitoring like temperature detection to complex calculation such as video processing. This last type of application requires a high load at the sensor level and leads to a problem of optimization. It is in this perspective that EDF DVFS technique justifies itself.

IV. Conclusion

Wireless sensor networks have been widely used in many areas. They provide endless opportunities, but at the same time pose several challenges, such as the fact that energy is a scarce and usually non-renewable resource. The aim of this paper is to discuss some of the most relevant issues of WSNs, from the application, design and technology point of view. We covered also the techniques reducing the power consumption within the nodes. We focused also in the DVFS and DPM techniques.

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