Low power wireless sensor networks in industrial environment

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Abstract: - The current situation in Spanish municipal solid waste is a reason of concern for the society because the consumption habits of modern consumer lifestyles are causing a huge waste problem. Last investigations show generation of polluting emissions, not just during the dumping period but enough time later. Try to control these emissions or, even develop a way to recycle waste by generating electricity from landfill waste and pollution needs to have some kind of information.

News technologies allows us to get some different environmental measures, thanks to the great advanced that this area has had in the last years, how they can be temperature, pressure, light, etc.. To be able to realize a processing in the right moment and condition inside landfill, can depend on measures read and whether it can be used later correctly.

To get some information from the environment doesn’t mean that it can be able to be processed and managed. It is necessary to locate each sensor in the correct place where you would like to have a right measure, and of course, it is necessary to know in what moment you take this. To install a complex sensor system that can report events to a central base station, which can take appropriate action, in geographical locations and under environmental adverse conditions, similar those that can be found on solid waste landfills, can be an expensive and complicated task.

In those situations is where new devices called micro-electromechanical systems (MEMS) joined to network wireless technologies are going to help us resolving our problem doing wireless sensor networks (WSN). These low cost and low power devices are going to allow us to have some sensor connected between them without needing to do a wired infrastructure, since it won’t be necessary neither to transmit data nor to give them energy.

The goal, besides saving all those problems in the installation, is to carry out a collection of data of several physical magnitudes, store them in a central base station and after analysis of this information, a qualified person can make decisions about the most convenient action to do a correct management of landfill.


1 Introduction

Nowadays it is necessary to carry somewhere all municipal solid waste that have been generated by human being, and it has driven us to make landfills. Spain is one of European countries where landfills more have been used to resolve the problem with municipal solid waste. However, only a little part of those belongs to the group of the controlled landfills.

In spite of the great quantity of existent landfills and the efforts carried out by the governments to try to palliate the environmental effects and to be able to obtain a reuse from landfill, like it can be the control of biogas to generate energy, they are still few landfills that they make a control.

So that they are controlled correctly, besides having to follow the correct methodology when you treat waste inside the landfill, as including methods of contention of grouts, or doing a compression of the garbage to increase their density, or covering this to
avoid their dispersion, you need information of system if you want to manage situation correctly.

These days some landfills have gas extraction systems, where can get gas from biodegradable materials. In those systems gas is pumping outside of landfill using perforated tubes and later it will be burned in a gas motor to generate energy. Burn this gas is better solution than release it directly to atmosphere, since this way methane consummation is carried out, that it is a greenhouse gas much more noxious than dioxide of carbon.

To help to do these tasks, obtaining some measurements that can give environmental information of the area like can be temperature, atmospheric pressure, quantity of light and other variables that allow detecting the quantity of certain gases like can be the methane or O₂, can be really important when you have to make decisions.

2 Wireless sensor network (WSN)
A sensor network is a flexible and powerful instrument that allows monitoring complex systems, where to locate the sensors can be impossible in any other way. The aim of data gathering for sensors in monitoring is the obtaining of data having as only limitation sensors features.

Traditionally the obtaining of data coming from the monitoring was carried out by an individual installation located in a concrete place that picked up data every sort period of time. When it was considered that the number of samples was the appropriate one, a person was moved to the location and stored data were picked up for its study.

Then this technology appears and not just allows picking up the data, but also allows processing and transmitting them to other place without necessity of making a movement. Besides thanks to that each node can be programmed, these can be adapted to the conditions that environment demands them. And against what can seem, this technology is less expensive than old system.

A WSN is a network with several devices distributed widely that use sensors to control diverse conditions in different points. Each node is typically equipped with a wireless communication device, a small microcontroller with a little memory and some measurement elements, which allow having the ability to observe and to react to events and phenomena in a certain environment.

There are four basic components in a sensor networks:
- A group of located and distributed sensors.
- An interconnection network, in our case a wireless network.
- A central station where information are sent.
- And certain computational resources where be able correct data, make consultations in order to see the state and even apply mining of data.

Environmental monitoring represents a kind of sensor network applications with enormous potential benefits, which is a highly active area of research devoted to developing the tools and techniques needed for monitoring. There are a lot of projects that work in this research [1] [2] [3] [4].

3 MicaZ technology.
In a study of the available possible technologies to develop a WNS, the Micaz technology was chosen. This decision was made because this family was the one that more accessories had to carry out the work, besides it had very good features.

![Fig. 1 Wireless device MicaZ](image)

MicaZ nodes have a chip from chipcon, model CC2420 that works under IEEE 802.15.4 standard. It also has a low power microcontroller, an Atmega128L, where programs can be executed from available internal flash memory [5].

It is an evolution of mica technology and as it has an in/out connector with 51 pines, many applications and sensor boards available for this family can be used for MicaZ.

These devices have been designed to work with feeding of batteries, specifically with two type AA batteries, however other sources can be used whenever feeding is between 2.7 and 3.6 VDC. The given batteries are alkaline with a load of 2000 mAh.
4 Sensor boards
As it was said before, MicaZ technology has one of the widest ranges of sensors, and here we have studied several of them.

With all these boards and with the sensors integrated in them, we can obtain useful measures that can be used for our aim. The problem appears when we want to make measures with other sensors and that they are part of our sensor network.

<table>
<thead>
<tr>
<th>Sensor board</th>
<th>Sensors and features</th>
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<tbody>
<tr>
<td>MTS310CB</td>
<td>Light, Temperature, Acoustic, Sounder, Dual-Axis Accelerometer and Dual-Axis Magnetometer.</td>
</tr>
<tr>
<td>MTS400CB</td>
<td>Ambient Light Sensor, Relative Humidity &amp; Temperature Sensor, Dual-axis Accelerometer and Barometric Pressure Sensor.</td>
</tr>
<tr>
<td>MTS420CC</td>
<td>The same five basic environmental sensing parameters than MTS400CB and an GPS module.</td>
</tr>
<tr>
<td>MDA100CB</td>
<td>Light, Temperature and general prototyping area.</td>
</tr>
<tr>
<td>MDA300CA</td>
<td>Light, Relative Humidity an extremely versatile data acquisition board.</td>
</tr>
</tbody>
</table>

The boards studied with capacity to connect sensors are MDA100CB and MDA300CA. In MDA100CB besides having sensors integrated in it, we have a prototyping area where we can connect external sensors. This area supports connection to all eight channels of the Mote’s analog to digital converter (ADC0–7). It also has more holes without connection that are used for breadboard of circuitry if it was necessary [6].

A problem that can be found is the difficulty of finding sensors that have features that data acquisition boards need. It is not possible to connect signals that are greater than VCC (3V) or less than 0 V to any of the holes, because it could damage that board.

Not only obtained tension from sensor is a problem for sensor board, the tension that the mote should give to the external sensor so that it works correctly fed, is also limited because this tension will be obtained from feeding system of the mote, in this case two type AA batteries.

With MDA300CA happens something similar. It is possible to connect analogical sensors that will go to different channels of the converters, as digital sensors that will connect to the digital channels.

This board has a greater tension range from 0 V to 5 V. Can be used a greater range of sensors, but it continues having the same problems, because it is complicated to work in those tensions ranges.

5 Low power networks
In these kinds of networks, it is important to keep in mind the energy consumption, mainly for getting that life of devices be highest. So our network nodes won’t be connected to a power system and their work mainly with batteries, it has tried to reduce and to optimize energy consumption inside the node. In spite of this, should be kept in mind how long our node will be correctly fed and when it will stop to work.

To make an energy consumption study in a sensor network by means of direct measure is not feasible, due to the great number of nodes and different consumption level in each of them. Investigations made on this area are rather few and most is based on software simulations [7].

Some energy consumptions in these type wireless devices are:

<table>
<thead>
<tr>
<th>Processor operating current</th>
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<tbody>
<tr>
<td>Normal operation</td>
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<tr>
<td>Full operation</td>
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<tr>
<td>Sleep operation</td>
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<tr>
<th>Transmission system operating current</th>
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<tbody>
<tr>
<td>Receive mode</td>
</tr>
<tr>
<td>Transmission mode -10 dBm</td>
</tr>
<tr>
<td>Transmission mode -5 dBm</td>
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<tr>
<td>Transmission mode 0 dBm</td>
</tr>
<tr>
<td>Idle mode</td>
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<tr>
<td>Sleeping mode</td>
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<tr>
<th>Memory operating current</th>
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<tbody>
<tr>
<td>Write</td>
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<tr>
<td>Read</td>
</tr>
<tr>
<td>Sleep</td>
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<table>
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<tr>
<th>Sensor operating system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Humidity</td>
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<tr>
<td>Light</td>
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<td>Gas</td>
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The MicaZ technology incorporates a fed module that uses two batteries type AA. The batteries usually express in mAh, which means that a battery of 1000 mAh should support a consumption of 10 mA during 100 hours, although in the theory it is a little less.

Technologies in that batteries are based can be several, alkaline, lithium, nickel-metal hydride. To understand the cycle of life of the node is necessary to see the graph of life of an alkaline battery [8], since for defect the nodes MicaZ come with this kind of batteries.

To solve fed problem is chosen solar energy and it work system. At the moment, a solar panel can give more than 15 mW for square centimetre and if this energy is stored correctly it would be enough to consume at night that it stored during the day.

The device selected to solve the problem is one from Atla Labs and it is called Heliomote. This device is a system of solar feeding for small devices and low power. Its main purpose is to harvest energy from the sun, store the energy in two AA NiMH batteries, and supply power to the sensor node.

This device is housed in an environmentally strong, IP-67 rated enclosure, which is shockproof, dust-proof, and water-proof up to 6 ft. of water. This enclosure allows the Heliomote to survive in the harsh, outdoors conditions [9].

MicaZ technology can adapt perfectly to this device, being connected through its connector of 51 pins because it has a material that avoids the static, protects to the node and adapts it to the size and position of mote.

The figure 5 shows the Heliomote solar panel at various insolation conditions ranging from moderate night to bright day. The peak power output of the solar panel is 94mW. In a given day the Heliomote will supply approximately 1800J of energy. A MicaZ at full operating power is approximately 0.3W. The problem is that a MicaZ at full power consumes more power than a Heliomote can produce. It is necessary optimize the software on the mote so that it doesn't consume more than it can generate [10].

6 Base Station

Inside our sensor network it is necessary to have a device that can pick up data generated by sensors and can also store them in order to use them later.

Making a study of the possible available technologies, Stargate SPB400 from Crossbow was chosen. It is a powerful single board computer with enhanced communications and sensor signal processing capabilities [11].
This device has a Linux operating system that can run software that allows reading all the picked up data from sensors. These data are analyzed and stored in a database for their later study.

The Stargate also has connection to the exterior, which makes possible to consult data from any place, only having an Internet connection.

**7 Data examples**

In the following graphics is observed a sample of the data picked up for several of studied sensors.

**Fig. 7 Temperature from MTS310**

**Fig. 9 Microphone from MTS310**

**Fig. 10 Barometric Pressure from MTS400**

**Fig. 11 Relative Humidity from MTS400**

**Fig. 12 Light from MTS400**
8 Conclusion

Nowadays, the use of wireless sensor networks is increasing considerably thanks that every day these devices have low cost and better features.

Every day sensors, wireless communications devices and processors are integrated in smaller devices and consume less energy, what allows using this technology in new applications where before it could not be used.

Technologic developments, like bigger duration in batteries life or the possibility of harvesting energy from environment with solar panels, make that nodes life can be considerably longer.

In spite of high quantities, these data can be stored and used later. Thanks to the advances in computation, it is possible to pick up and study as many data as the application needs.

All this joined makes that the future of monitoring goes unavoidably by the wireless sensor networks and one of these applications can be monitoring a landfill.

References: