AGRICULTURAL WIRELESS SENSOR AND ACTUATOR NETWORK DESIGN

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ABSTRACT

Agriculture is a challenging area where newly emerging wireless sensors based on Micro and Nano technologies can be applied in order to increase the safety and quality of alimentary products. The European GoodFood project focuses on this aspect of factory automation and tries to develop new distributed systems which ensure the respect of main principles of WSANs.

I. WIRELESS TECHNOLOGIES

Wireless technology is increasingly used in agricultural environments. It allows the production optimization, and it improves the management system reducing costs.

A large number of agriculture automation devices are composed of proprietary (many) or standard (some) wireless systems, instead of or in combination with wired systems. The main aim of our idea is neglect proprietary solutions, which can be used in a limited number of contexts. The most interesting solutions are those based on standard communication protocols. Bluetooth [1], IEEE 802.11 [2], IEEE 802.15.4 [3, 4] and the recent WirelessHART standard [5] are currently the main wireless standard technologies for process control networks.

The ZigBee protocol [6] is a standard recently developed suitable for mesh-topologies, based on IEEE 802.15.4 mac protocol; this protocol is not suitable for our purpose because it has a low bit rate. Wireless HART[7], is an extension of the HART protocol primarily used for monitoring and control, which is based on IEEE 802.15.4 and it is suitable for use in mesh networks, but it is not a flexible protocol, in fact is not adaptable to topology's changes.

The 802.11 is the most used wireless technology and it uses frequencies between 2.4 and 5.4 GHz, but the CSMA/CA protocol doesn't guarantees delay times when multiple nodes compete for the channel. Bluetooth protocol, developed by Ericsson, is a protocol for Wireless Personal Area Network (WPAN) common used for a low number of nodes, however it has a low area coverage (1 – 10 meter). Another available technology is the Ultrawideband (UWB) [8], which is a type of wireless technology for short-distance transmissions.

However wireless networks introduce the problem of electromagnetic interferences with the consequently risk of loss of information and general performance degradations. Some recent papers [9, 10] have shown their researches developed to analyze these problems and reduce the percentage of deadlines miss in a real-time factory environment.

Because of the need of a real-time control of agricultural systems, and the need to act quickly by issuing commands to the actuators on the basis of data collected by the sensors, it was decided to work with a Wireless Sensor and Actuator Network (WSAN).

A WSAN consists of a group of sensor and actuators linked by a wireless technology to carry out some tasks.

The paper is organized as follows. In section 2 we will discuss about the requirements of IWSN; in section 3 we will present a case study about agricultural sensor network and in section 4 we will show the results obtained in terms of energy consumption.

II. SOME AGRICULTURAL SYSTEMS REQUIREMENTS

An agriculture environment needs these following requirements:

1. Low cost and small size of the nodes: in very large environments, both cost and size have a significant importance. It is very useful to have the large coverage using small size devices.
2. Scalability: in the agricultural landscape there is very often the need to add or remove items to the network without this involves a malfunction of the network itself; it is also very important the use of efficient protocols to limit the transmission delays.

3. Low energy consumption: it is necessary to reduce the energy consumption of each node to maximize the life cycle of the node itself.

4. Self-configuration and self-organization: it is an important feature that reduces any outside operation on the network.

5. Security: It concerns data integrity, resistance to false positives and protection against unauthorized external tampering.

6. Wide areas coverage: Agricultural systems are extended in wide areas, is therefore necessary to ensure full coverage, including through the use of redundancies.

7. Low environmental impact: The technologies used must ensure the minimum environmental and visual pollution and must also have a low dispersion of electromagnetic waves.

To satisfy all this requirements we suggest using technologies based on IEEE 802.15.4. This standard describes the Physical (PHY) Layer and Medium Access Control (MAC) Layer for low-cost and low-rate networks. Fig. 1. shows the simplified structure of a zigbee frame and, as we can see, the payload size is between 2 and 127 byte, which guarantees a lower delay.

The small size of the frame provide a higher percentage of packets received without errors

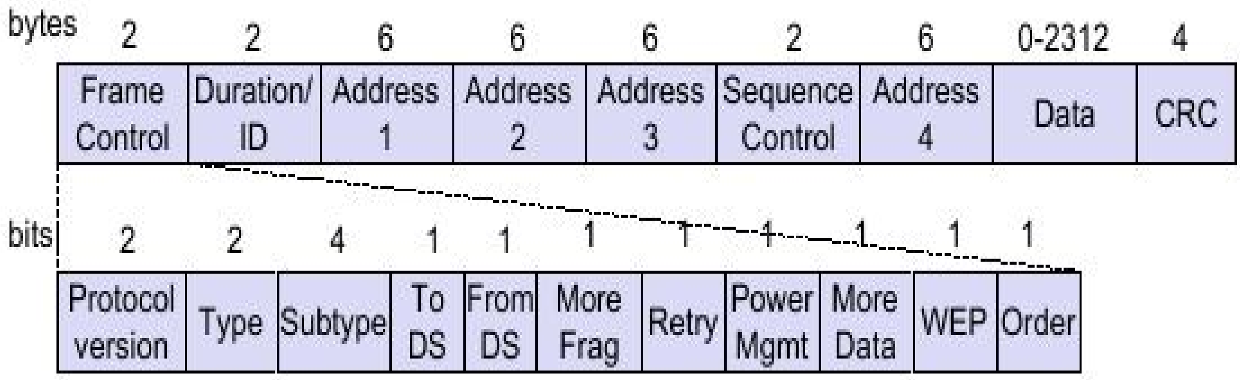

Fig. 1. Example of 802.11's frame

III.

IV.

V. CASE OF STUDY

In this section, we propose to analyze a case of study of a WSAN in agriculture, to monitor temperatures and rainfall, and to manage the use of sprinklers under certain environmental conditions. The network simulated consists of a set of sensor nodes that collect data, and some actuators that will be involved in certain cases. The nodes are connected to a coordinator who manages the communication between themselves. Every coordinator sends the collected data to a Central Unit. It is planned to build a network where there are 10 nodes, including 2 sensors and 8 actuators. The generic scheme of the expected network is the following:

We have a temperature sensor and a precipitation sensor. They will be activated every 8 and 24 hours respectively. Referring to the data of metereologic Sicily's center collected by Kore University we obtain the following graphs of the temperatures and rainfall during the months of January (Fig. 3), April (Fig. 4), July (Fig. 5), and October (Fig. 6) at Sicily – Italy(En). In January we observed temperatures below 15°C and low rainfall.

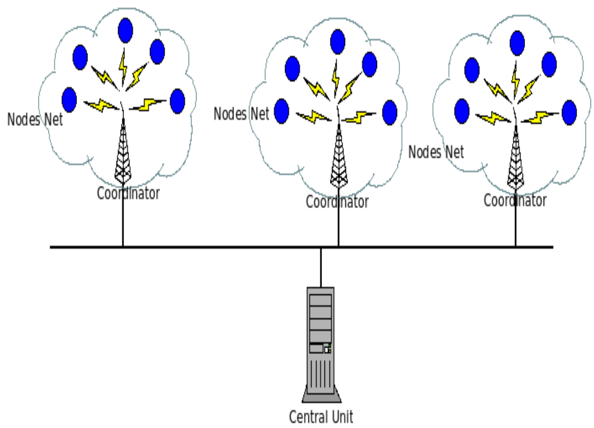

Fig. 2. Structure of a typical WSAN network

In April temperature is higher than January and vary between 15°C and 26°C. Rainfalls are at the end of the month.

July presents the highest temperature and rainfall are almost absent, instead the month of October has temperature more variables and rainfall in the middle of the month.

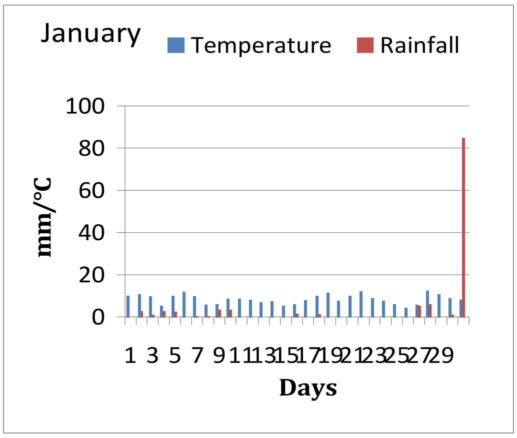

Fig. 3. January temperature and rainfall graph

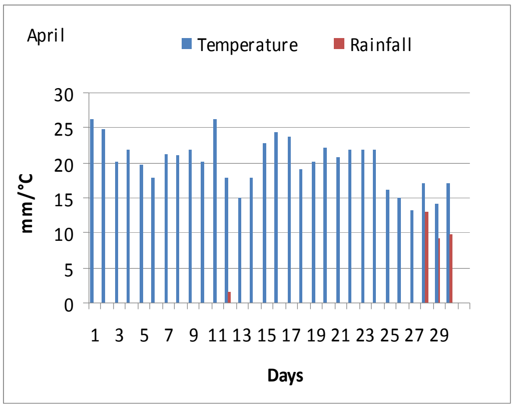

Fig. 4. April temperature and rainfall graph

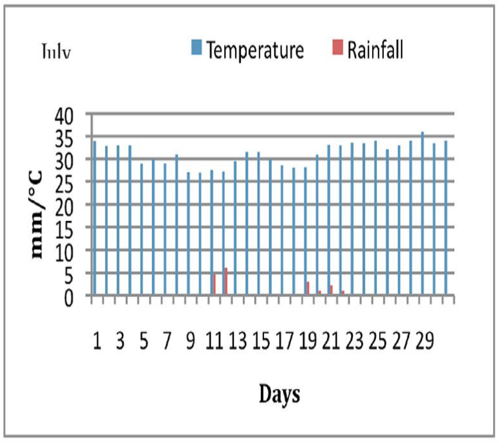

Fig. 5. July temperature and rainfall graph

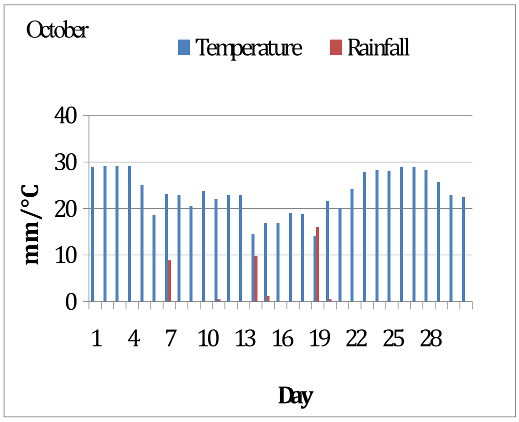

Fig. 6. October temperature and rainfall graph

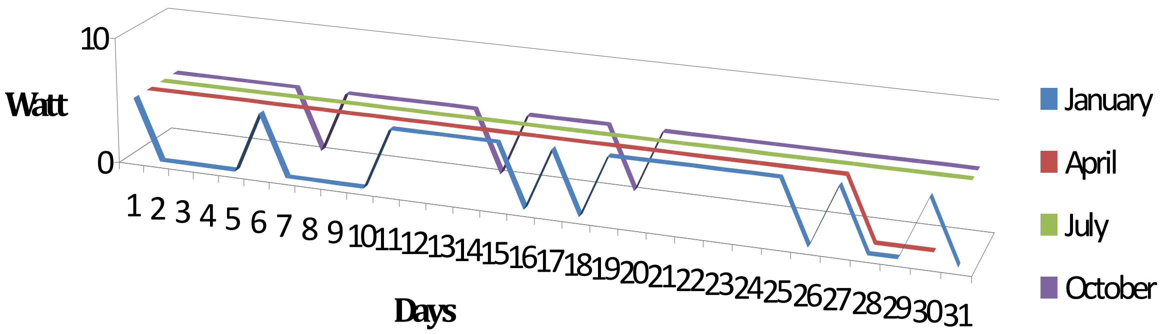

Fig. 7. Power consumption of a single actuator

VI. SCENARIO EVALUATION

Considering the temperature and rainfall graph and considering that both the sensors and actuator have a consumption of 3µW in standby and 81mW in transmission, we obtain the daily consumption of 7,55W for temperature sensor and 2,69W for rainfall sensor respectively. The actuators are will be activated in two cases. When the measured temperature is less than 15° C, the actuators are activated whenever the rains are not detected. However, when the temperature is above 15°C actuators will be activated when the sensors detect less than 7 mm of rain. When there is no need to activate the actuators, the daily energy consumption is 0.2592W, instead, when the actuators are activated the daily consumption is 5.119W.Then we get the graph in Fig. 7 of energy consumption, we will have the maximum consumption on January, and the minimum on July. We note that this consumption fully meets the requirements described above and therefore this technology can be applied for this scope.

VII. CONCLUSIONS AND FUTURE WORK

In this paper we discussed the use of wireless technologies in agricultural production, focusing on the aspect of energy consumption. This kind of system could substitute the use of wired and traditional wireless system.

One future scenario could include the use of data collected by sensors in order to improve the weather forecasting system providing real-time data on larger areas of study.

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