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Low Cost Wireless Sensor Network For Monitoring Soil Parameter In Forest

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Introduction

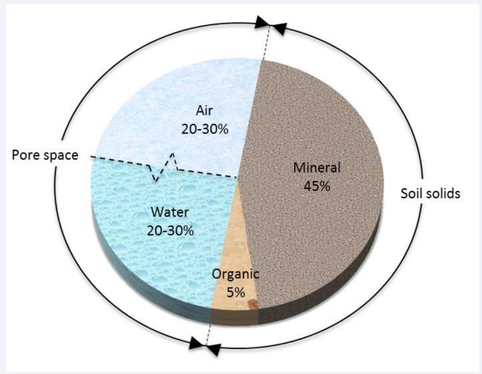
The aim of this work is the development of a low-cost wireless sensor network (WSN) in a forest, for monitoring moisture and temperature by exploiting open source hardware. Commercial solutions are reliable, but quite expensive and not completely customizable. Therefore an ad-hoc solution can reduce the cost, but implies selecting proper hardware components, and integrate them with simple electronics and software. Proposing a low-cost and open source solution facilitates the adoption of the WSN for monitoring a larger sensing area with limited budget.

Background

It is paramount to monitor parameters such moisture and temperature while studying forest soils. The use of a wireless sensor network increases the extension of the sensing area compared with the adoption of dataloggers.

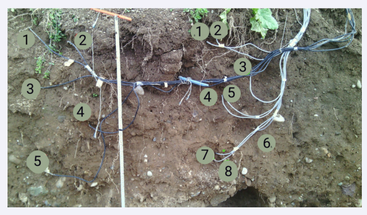
The soil has a complex nonhomogeneous structure. The composition and granulometry of the various particles and the nature of the substance filling the interstices between the solid particles fully characterize the soil at a certain moment.

Not only the water content varies in the ground, but also the temperature changes over time and it has a significant effect on physical, biological, and chemical processes in the soil.



Volume composition of the soil. The broken line between air and water indicates the fluctuations between wet and dry condition. Figure adapted from [1].

Hardware - Design



The sensors are located at different depths in the ground, gathering information about first 50-70 cm of the soil. Positioning several nodes will provide a three-dimensional model of the sensing area.

Moteino specifications.	
Microcontroller	ATmega328p
Transceiver	RFM69, RFM95/RFM96 LoRa, RFM12b
Input Voltage	(VIN pin) 3.6V-16V (up to 12V)
Digital I/O Pins	14+6 (6 PWM capable: marked with)
Analog Pins	8 (2 more than regular Arduinos)
Program Memory	32 KB of which 1 KB used by bootloader
SRAM & EEPROM	2 KB & 1 KB
Lowest power	6.5uA with stock regulator & fuses

Specifications of the Moteino board. Information produced by the manufacturer LowPowerLab.

The design process includes the selection from the choice available on the market for the various parts and integrates those parts with circuitry and software.

Node implementation.

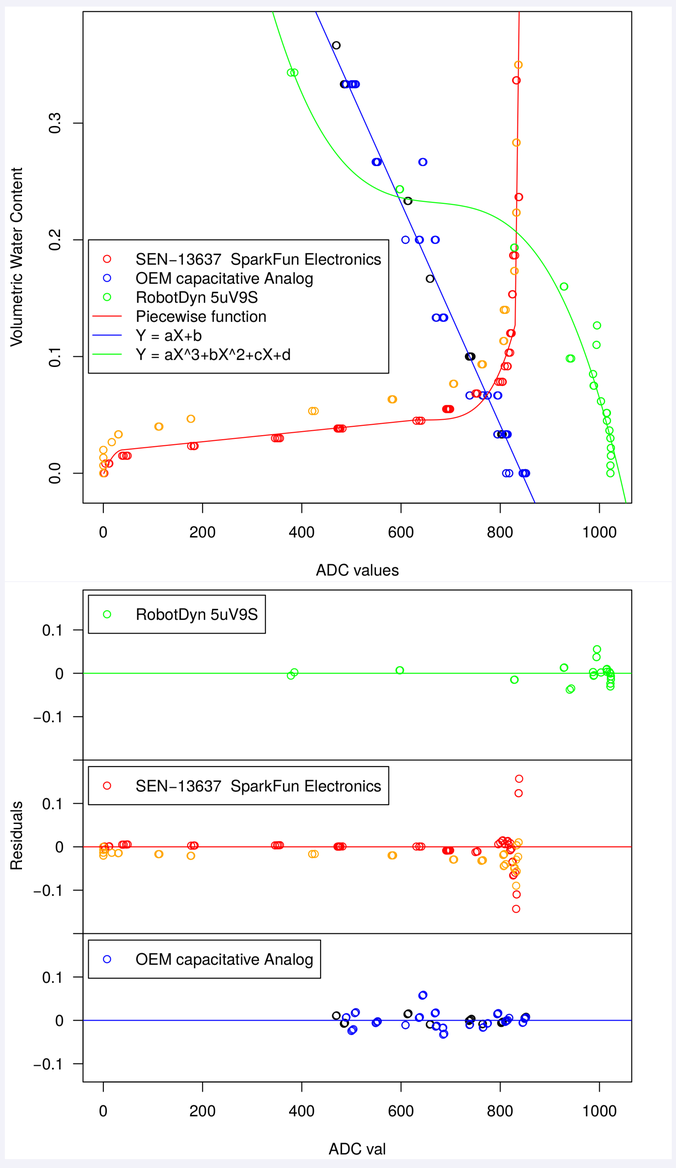
The core of a node is the controller. The selected controller is the Moteino board, which is an Arduino clone that includes an analog-digital converter (ADC).

Sensors selection.

Moteino interacts with analog sensors by using the ADC and digital sensors connected over an I^2C BUS.

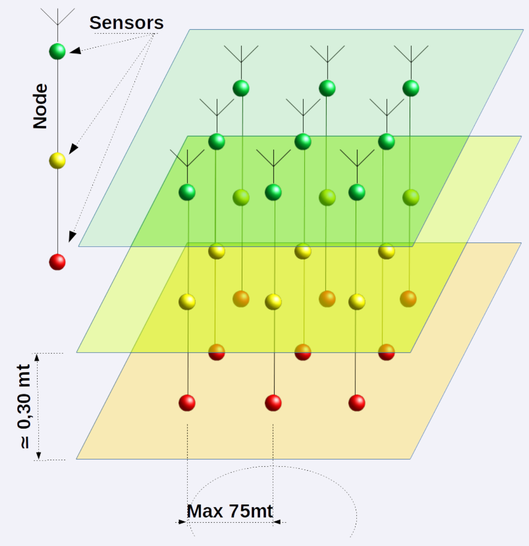
Low-cost moisture sensors do not have meaningful specification and characteristics and usually are designed to provide only a qualitative measurement.

The calibration of sensor has been carried out in laboratory by means of a set of measurement of soil moisture, under controlled setup.



The upper plot shows the trends of different sensors: resistive and capacitative. The second plot shows the residuals against the observed ADC values.

Network - Design



3D model of the ground, with sensors at precise depth on the location of the nodes providing knowledge of different layers.

The network implements a hierarchical routing protocol capable of detecting new nodes and choosing the most energy efficient path.

The efficiency of a path is evaluated according to battery level and power trasmmission.

The topological information (distances between nodes) is deducted by the signal strength, furnished by the Moteino library.

The main-node is capable of sending the data to a web server. The server will expose the data and will provide some diagnostics for the network. Adding a battery monitor to the nodes improves the network design allowing a more accurate choice of the routing paths.

The used radio library grants the ability to send a single radio message or a broadcasted message. By combining two kind of messages at a software level, we implemented a network protocol. The narcoleptic library allows to save power during the standby time of the node.

Software implementation.

The language used to write the software in the controller is a C++ subset. The software implementation is responsible for regulating the synchronization of the radio communication and sampling. The software is also responsible for distributing the writing of the Flash and EEPROM memory attempting to increase the life expectancy.

The program uses EEPROM to store the addresses related to the data written on Flash memory. This choice is motivated to spread the writing over the entire flash memory and eventually roll over.

The narcoleptic library allows selecting the microcontroller functionality to be disabled during the sleeping periods. Reducing functionality at the minimum allows the microcontroller to run at low energy since radio transceiver is disabled, a synchronization mechanism is needed for enabling the transceiver when radio messages are expected.

$$Add = E_0 * 10^3 + \sum_{n=1}^{40} \quad (1)$$

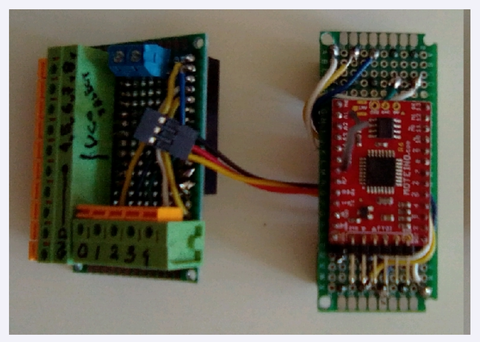
$$E_n \qquad 0 >= E_{0-40} <= 250 \quad (2)$$

(1)The address (Add) is calculated using a weighted summation of 40 bytes.
(2) The nth byte (E_n) assumes values on the 0 to 250 range.

Conclusion

The designed node can host analog or digital sensors, allowing the implementation of a heterogeneous network.

The low cost is achieved not only by adopting the open hardware Arduino clone as a node, but by using low-cost sensor after a proper test. The current node design costs around 100 USD, including the sensors.



The node is built using a prototyping board and allows the replacement of the Moteino and the plugging of the sensor.

Forthcoming Research

- Appling or adapting the same solution in another scenario.
- The power consumption can be optimized extending the battery life.
- The main-node can be equipped with a solar-panel for backing-up the battery in case of failure.

Affiliations

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References

[1] C. Nyle, R. Weil, The Naure an property of Soils 14th edition, Pearson International Edition, Ltd ISBN: 978-0-13-513387-3, pp. 1-3, (2008).
[2] P Goyal, U Singh, "Hierarchical based Routing Protocol in WSN" International Journal of Computer Applications (NGTBES-2016)

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