WIRELESS SENSOR NETWORK FOR MEASUREMENT OF SOIL WATER POTENTIAL

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Abstract: In this paper is proposed solution of a problem of soil water potential monitoring and irrigation scheduling using wireless sensor network (WSN). It discuses an optimal measurement method and separately describes hardware and software realization of the nodes forming the data collection mechanism with desktop visualization.

Keywords: WSN, soil water potential, data collection, ZigBit

1 INTRODUCTION

In recent years the significance of water protection and conservation is steadily increasing. Knowledge about soil water content is a key component in the process of evapotranspiration and water monitoring research. It is also a good indicator for irrigation systems and a good predictor for climate changes. The system capable to doing this consist of one or more end stations spread out over an area. Each end station has a soil water potential sensor and regularly sends data to a base station, which stores data and eventually controls irrigation.

2 MEASUREMENT METHOD

There are two main parameters, which describe physical state of water in soil: the volumetric water content and the soil water potential. The first one denotes how much water is present in the soil and the second one tells how much water is available for plants [1]. This value is more useful for agricultural purposes.

The water potential can be measured by several methods. Well tested and commercially available products are tensometers, heat dissipation probes, gypsum or granular matrix blocks and dielectric sensors. The chosen method must has a low power consumption, an accuracy at least 10 % and it should be durable. To fulfill these requirements a heat dissipation and tensometers can be excluded due to their high power consumption and bad durability. Fair solutions are dielectric water potential sensor MPS-1 and granular matrix sensor Watermark. Both methods use a porous material, which is inserted into the soil as a sensitive probe. When the equilibrium under the law of thermodynamics is reached, the water potential of the soil is same as the water potential of the porous block. MPS-1 measures dielectric permittivity of the ceramics and Watermark measures the resistance of a fine sand aggregate mixed with gypsum crystals held inside a permeable membrane. To prevent polarization in resistivity measurement, a small AC voltage with a frequency of 1 to 10 kHz is used.

An advantage of the Watermark sensor is in its lower range from -2 to -200 kPa (more wet soil), lower price and better accuracy while MPS-1 is more durable and has 20% accuracy of the sensor reading in the range -10 to -500 kPa.

2.1 CONVERSION OF ELECTRIC RESISTIVITY INTO WATER POTENTIAL VALUES

Since the watermark sensor has a different characteristic in different ranges [2], calibration curve can be unified and approximated by 5^{th} degree polynomial with temperature compensation,

$$SWP = f(R)^{(A+B.T)}, \tag{1}$$

where R denotes resistance, T is temperature, f(R) is 5th degree polynomial and A, B are temperature compensation parameters determined by the method of least mean squares.

3 WIRELESS SENSOR NETWORK

A typical WSN node consists of a microprocessor, a transceiver, sensors and a power source. Design is usually focused on a low power consumption, a long range, an autonomy and a reliability. The hardware concept for both stations is shown in Figure 1 and 2.

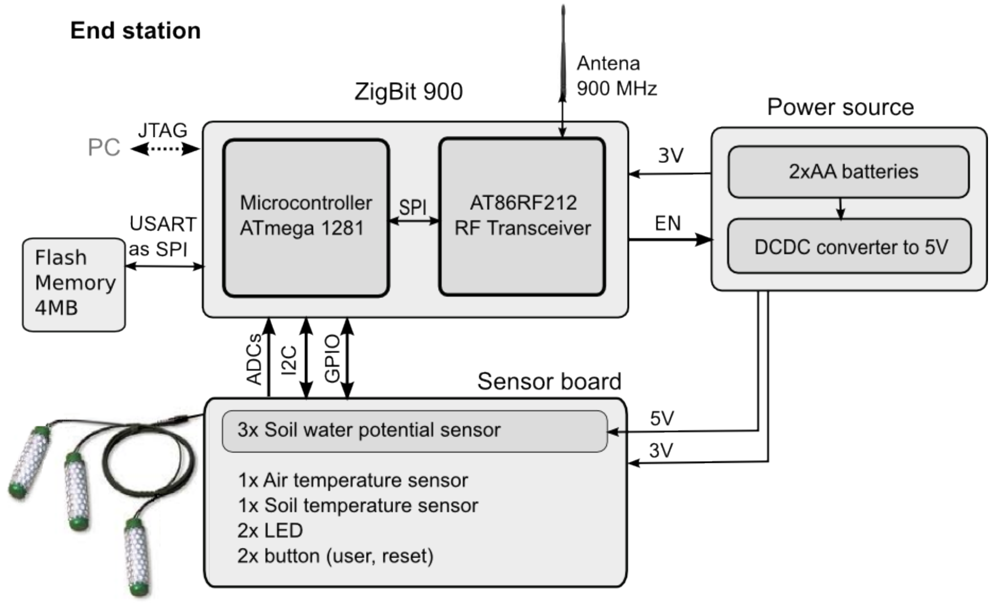

Figure 1: Block diagram of end station

The end station contains a set of sensors and a flash memory allowing over-the-air firmware upgrade. The power state of the sensors is controlled by the enable input of the DC-DC converter. The voltage value of water potential sensor output is measured by ADCs of the ZigBit module. To compensate temperature dependence of the soil water potential, the sensor set is supplemented by a soil temperature sensor working on I2C.

The end station regularly with a configurable period measures water potential and temperature of the soil. After that, data are immediately sent to the base station and a sleep mode is called what ensures energy savings. Since a sampling period will be around 15 min and active mode takes only couple of milliseconds, the end station is able to work more than a year on a two AA batteries. This time depends on the number of sensors because in a primary stage the each end station will have three water potential sensors to handle inconsistent values. If any remote configuration wants to be made, coordinator must wait until the end device wakes up and then sends an indication message about changes, e.g. a new sampling frequency, to the end device.

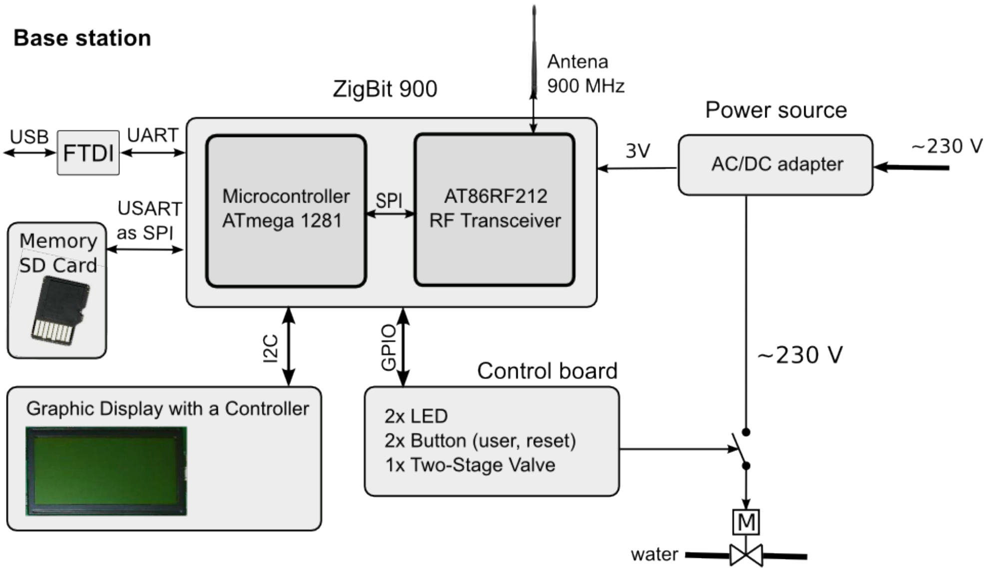

Figure 2: Block diagram of the base station

The WSN is built on an embedded software stack BitCloud, which implements base core of the Zigbee PRO standard. The transceiver range built in ZigBit900 is limited within 6 km from the base station under optimal conditions in plain land.

Between other special features of this system belong an firmware upgrade over the air, an user button, which triggers the data sending and a two-stage valve controller for the irrigation scheduling. To improve flexibility and workability without a computer, a graphic display and SD memory card are implemented. After pressing the user button 1 on the base station, the actual values and settings are shown on the display. The user button 2 is used to plot the latest history. The data transfer and the configuration can be done in both ways, through the SD memory card or directly through the USB port and FTDI converter.

The whole application is supported by java program, which visualizes data and performs new settings of the remote end nodes. There are two patterns on the display, the soil water potential and the amount of water used for watering.

4 CONCLUSION

The established wireless sensor network fulfill requirements of a long lifetime, a portability and a remote configuration. It is flexible and can be easily reconfigured from data collection to irrigation control with an watering optimization algorithm. To facilitate user operation, the graphic display and SD memory card are implemented. The limitation of this sensor network is a permanent power source of the base station and lower sensor accuracy.

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