Automatic Monitoring and Controlling of Irrigation System Using Wireless Sensor Networks and GSM

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Abstract—An automated irrigation system was developed to optimize water use for agricultural crops. The system has a distributed wireless network of soil-moisture and temperature sensors placed in the root zone of the plants. In addition, a gateway unit handles sensor information, triggers actuators, and transmits data to a web application. An algorithm was developed with threshold values of temperature and soil moisture that was programmed into a microcontroller-based gateway to control water quantity. The system was powered by photovoltaic panels and had a duplex communication link based on a cellular-Internet interface that allowed for data inspection and irrigation scheduling to be programmed through a web page. The automated system was tested in a sage crop field for 136 days and water savings of up to 90% compared with traditional irrigation practices of the agricultural zone were achieved. Three replicas of the automated system have been used successfully in other places for 18 months. Because of its energy autonomy and low cost, the system has the potential to be useful in water limited geographically isolated areas.

Index Terms—Automation, cellular networks, Internet, irrigation, measurement, water resources, wireless sensor networks (WSNs).

I. INTRODUCTION

There are many systems to achieve water savings in various crops, from basic ones to more technologically advanced ones. For instance, in one system plant water status was monitored and irrigation scheduled based on canopy temperature distribution of the plant, which was acquired with thermal imaging .In addition, other systems have been developed to schedule irrigation of crops and optimize water use by means of a crop water stress index (CWSI) . This index was later calculated using measurements of infrared canopy temperatures, ambient air temperatures, and atmospheric vapor pressure deficit values to determine when to irrigate broccoli using drip irrigation. Irrigation systems can also be automated through information on volumetric water content of soil, using dielectric moisture sensors to control actuators and save water, instead of a predetermined irrigation schedule at a particular time of the day and with a specific duration. An irrigation controller is used to open a solenoid valve and apply watering to bedding plants (impatiens, petunia, salvia, and vinca) when the volumetric water content of the substrate drops below a set point.

An alternative parameter to determine crop irrigation needs is estimating plant evapotranspiration (ET). ET is affected by weather parameters, including solar radiation, temperature, relative humidity, wind speed, and crop factors, such as stage of growth, variety and plant density, management elements, soil properties, pest, and disease control . Systems based on ET have been developed that allow water savings of up to 42% on time-based irrigation schedule.

In this paper, the development of the deployment of an automated irrigation system based on microcontrollers and wireless communication at experimental scale within rural areas is presented. The aim of the implementation was to demonstrate that the automatic irrigation can be used to reduce water use. The implementation is a photovoltaic powered automated irrigation system that consists of a distributed wireless network of soil moisture and temperature sensors deployed in plant root zones. Each sensor node involved a soil-moisture probe, a temperature probe, a microcontroller for data acquisition, and a radio transceiver; the sensor measurements are transmitted to a microcontroller-based receiver. This gateway permits the automated activation of irrigation when the threshold values of soil moisture and temperature are reached. Communication between the sensor nodes and the data receiver is via the Zigbee protocol , under the IEEE 802.15.4WPAN. This receiver unit also has a duplex communication link based on a cellular-Internet interface, using general packet radio service (GPRS) protocol, which is a packet-oriented mobile data service used in 2G and 3G cellular global system for mobile communications (GSM). The Internet connection allows the data inspection in real time on a website, where the soil-moisture and temperature levels are graphically displayed through an application interface and stored in a database server. This access also enables direct programming of scheduled irrigation schemes and trigger values in the receiver according the crop growth and season management. Because of its energy autonomy and low cost, the system has potential use for organic crops, which are mainly located in geographically isolated areas where the energy grid is far away.

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II. DESIGN AND IMPLEMENTATION

The automated irrigation system hereby reported, consisted of two components (Fig. 1), wireless sensor units (WSUs) and a wireless information unit (WIU), linked by radio transceivers that allowed the transfer of soil moisture and temperature data, implementing a WSN that uses ZigBee technology. The WIU has also a GPRS module to transmit the data to a web server via the public mobile network. The information can be remotely monitored online through a graphical application through Internet access devices.

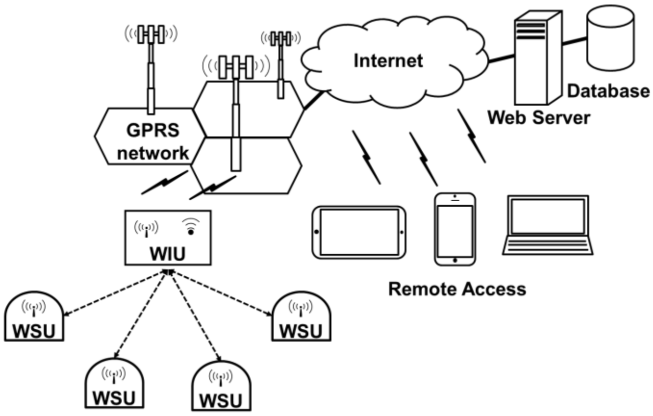

Figure 1: Configuration of the automated irrigation system

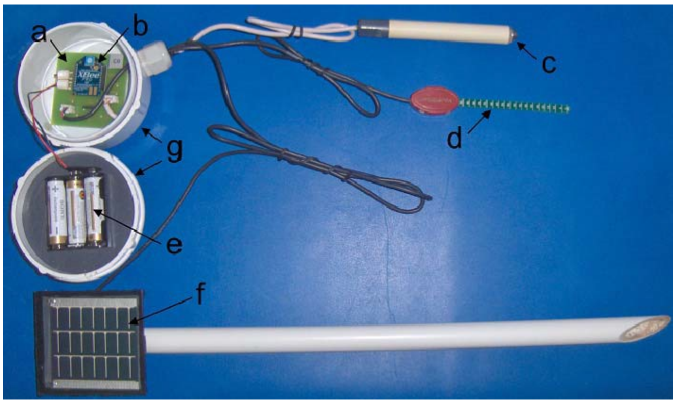

Fig. 2. WSU. (a) Electronic component PCB. (b) Radio modem ZigBee. (c) Temperature sensor. (d) Moisture sensor. (e) Rechargeable batteries. (f) Photovoltaic cell. (g) Polyvinyl chloride container

III. SYSTEM HARDWARE

1.Wireless Sensor Unit

A WSU is comprised of a RF transceiver, sensors, a microcontroller, and power sources. Several WSUs can be deployed in-field to configure a distributed sensor network for the automated irrigation system. The microcontroller, radio modem, rechargeable batteries, and electronic components were encapsulated in a waterproof Polyvinyl chloride (PVC) container. These components were selected to minimize the power consumption for the proposed application.

i. ARM 7:

The ARM7 family includes the ARM7TDMI, ARM7TDMI-S, ARM720T, and ARM7EJ-S processors. The ARM7TDMI core is the industry's most widely used 32-bit embedded RISC microprocessor solution. Optimized for cost and power-sensitive applications, the ARM7TDMI solution provides the low power consumption, small size, and high performance needed in portable, embedded applications. The ARM7TDMI core uses a three-stage pipeline to increase the flow of instructions to the processor. This allows multiple simultaneous operations to take place and continuous operation of the processing and memory systems. As the processor is having a high speed it is easy to make the communication between the RF module and the Image acquisition module.

ii. ZigBee Modules:

ZigBee (over IEEE 802.15.4) technology is based on short range WSN and it was selected for this battery-operated sensor network because of its low cost, low power consumption, and greater useful range in comparison with other wireless technologies like Bluetooth (over IEEE 802.15.1), UWB (over IEEE 802.15.3), and Wi-Fi (over IEEE 802.11) . The ZigBee devices operate in industrial, scientific, and medical 2.4-GHz radio band and allow the operation in a so-called mesh networking architecture, which can be differentiated into three categories:

1) coordinator;
2) router;
3) end device.

iii. Soil Sensor Array:

The sensor array consists of two soil sensors, including moisture and temperature that are inserted in the root zone of the plants. The VH400 probe was selected to estimate the soil moisture because of low power consumption (<7 mA) and low cost. The probe measures the dielectric constant of the soil using transmission line techniques at 80 MHz, which is insensitive to water salinity, and provides an output range between 0 and 3.0 V, which is proportional to the volumetric water content (VWC) according to a calibration curve provided by the manufacturer. The sensor was powered at 3.3 V and monitored by the microcontroller through an ADC port.

iv. Photovoltaic Cell:

To maintain the charge of the WSU batteries, a solar panel MPT4.8-75 was employed. Each solar panel delivers 50 mA at 4.8 V, which is sufficient energy to maintain the voltage of the three rechargeable batteries. A MSS1P2U Schottky diode

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(Vishay, Shelton, CT) is used to prevent the solar module and to drain the battery when is in the dark. The solar panel is encapsulated in a 3-mm clear polyester film with dimensions of 94 mm × 75 mm. This flexible panel was mounted on a PVC prismatic base (100 mm × 80 mm × 3.17 mm) that is fastened in the upper part of a PVC pole allowing for the correct alignment of the photovoltaic panel to the sun. The stick is 50 cm of length and 12.5 mm of diameter; the lower end of the pole had a tip end to be buried.

2. Wireless Information Unit

The soil moisture and temperature data from each WSU are received, identified, recorded, and analyzed in the WIU. The WIU consists of a master microcontroller ARM 9an X-Bee radio modem, a GPRS module MTSMC-G2-SP (Multi-Tech Systems, Mounds View, MN), an RS-232 interface MAX3235E (Maxim Integrated, San Jose, CA), two electronic relays, two 12 V dc 1100 GPH Live well pumps (Rule-Industries, Gloucester, MA) for driving the water of the tanks, and a deep cycle 12 V at 100-Ah rechargeable battery L-24M/DC-140 (LTH, Mexico), which is recharged by a solar panel KC130TM of 12 V at 130 W (Kyocera, Scottsdale, AZ) through a PWM charge controller SCI-120 (Syscom, Mexico). All the WIU electronic components were encapsulated in a waterproof PVC box as shown in Figs. 5 and 6. The WIU can be located up to 1500-m line-of-sight from the WSUs placed in the field.

i. Master Microcontroller(ARM 9)

The functionality of the WIU is based on the microcontroller, which is programmed to perform diverse tasks .
The first task of the program is to download from a web server the date and time through the GPRS module. The WIU is ready to transmit via XBee the date and time for each WSU once powered. Then, the microcontroller receives the information package transmitted by each WSU that conform the WSN.

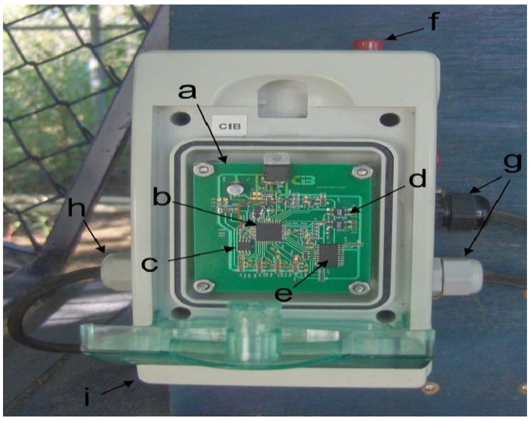

Figure 3. WIU. (a) Electronic component PCB. (b) Master microcontroller.(c) Solid state memory. (d) Optical isolators. (e) RS-232 interface. (f) Push button. (g) Output cables to pumps. (h) Supply cable from charge controller.

ii. GPRS Module:

The MTSMC-G2-SP is a cellular modem embedded in a 64-pins universal socket that offers standardsbased quad-band GSM/GPRS Class 10 performance. This GPRS modem includes an embedded transmission control protocol/Internet protocol stack to bring Internet connectivity, a UFL antenna connector and subscriber identity module (SIM) socket. The module is capable of transfer speeds up to 115.2 K b/s and can be interfaced directly to a UART or microcontroller using AT commands. It also includes an onboard LED to display network status.
The GPRS was powered to 5 V regulated by UA7805 (Texas Instruments, Dallas, TX) and operated at 9600 Bd through a serial port of the master microcontroller and connected to a PCB antenna. The power consumption is 0.56 W at 5 V.

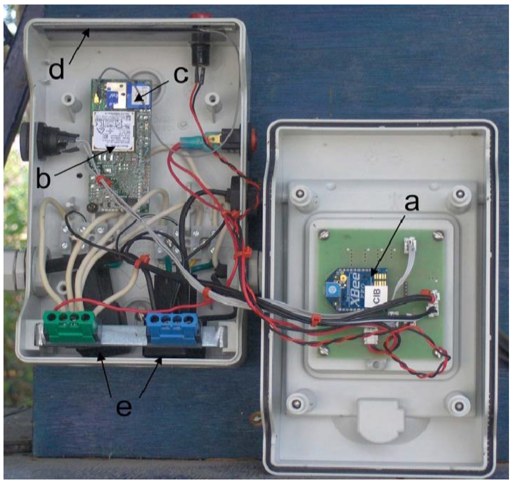

Fig. 6. Inside view of the WIU. (a) Radio modem ZigBee. (b) GPRS module. (c) SIM card. (d) GPRS PCB antenna. (e) Pumps relays.

iii. Watering Module:

The irrigation is performed by controlling the two pumps through 40-A electromagnetic relays connected with the microcontroller via two optical isolators CPC1004N (Clare, Beverly. MA). The pumps have a power consumption of 48 W each and were fed by a 5000-l water tank.

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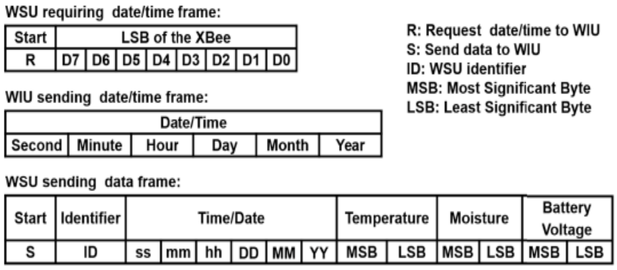

Fig 7.Communication frames between a WSU and the WIU.

IV. IRRIGATION SYSTEM OPERATION

Automated irrigation triggered by soil moisture for four days are shown in Fig7; when the soil moisture value fell below the threshold level of 5.0% VWC, the irrigation system was activated for 35 min according to IA-3, whereas the soil temperature remained below the threshold level.

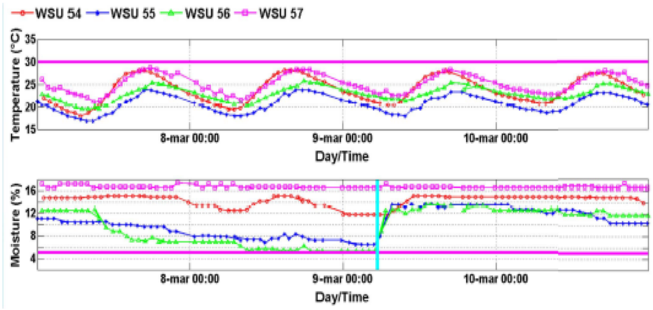

Figure 7: Automated irrigation (vertical bars) triggered by the soil moisture threshold ≤ 5% VWC.

Figure 8: Automated irrigation systems for the experimental production stage

V. DESIGN FLOW

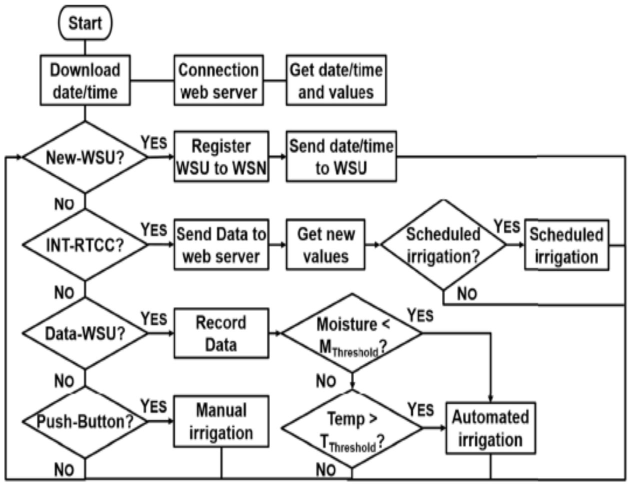

Fig. 9. Algorithm of the master microcontroller in the WIU for the automated irrigation system.

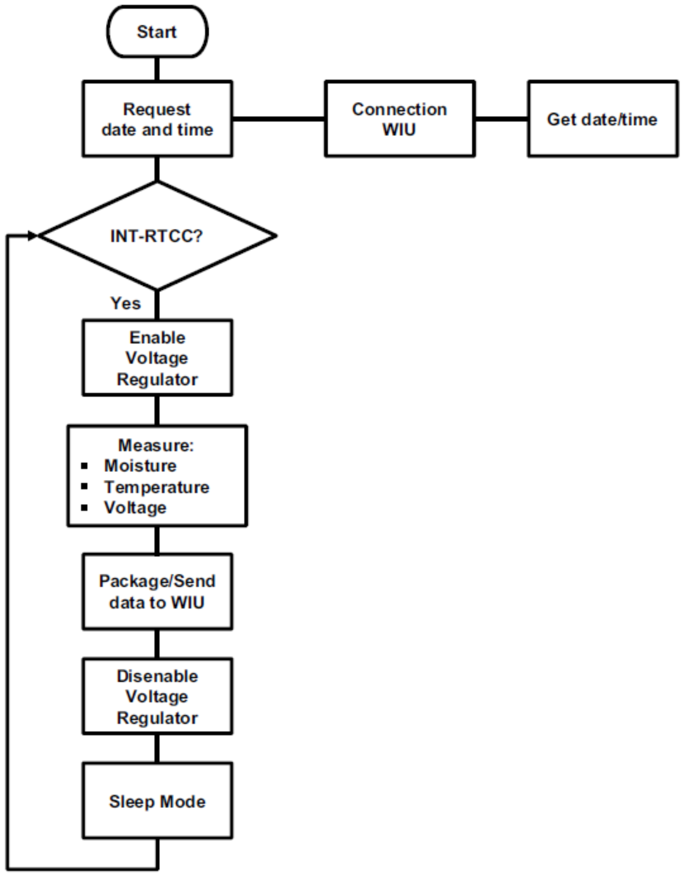

Fig. 10. Algorithm of wireless sensor unit (WSU) for monitoring the soilmoisture and temperature.

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VI. CONCLUSION

The automated irrigation system implemented was found to be feasible and cost effective for optimizing water resources for agricultural production. This irrigation system allows cultivation in places with water scarcity thereby improving sustainability.

The automated irrigation system developed proves that the use of water can be diminished for a given amount of fresh biomass production. The use of solar power in this irrigation system is pertinent and significantly important for organic crops and other agricultural products that are geographically isolated, where the investment in electric power supply would be expensive. The irrigation system can be adjusted to a variety of specific crop needs and requires minimum maintenance. The modular configuration of the automated irrigation system allows it to be scaled up for larger greenhouses or open fields. In addition, other applications such as temperature monitoring in compost production can be easily implemented. The Internet controlled duplex communication system provides a powerful decision making device concept for adaptation to several cultivation scenarios. Furthermore, the Internet link allows the supervision through mobile telecommunication devices, such as a smartphone.

Besides the monetary savings in water use, the importance of the preservation of this natural resource justify the use of this kind of irrigation systems.

VII. REFERENCES

[1] W. A. Jury and H. J. Vaux, "The emerging global water crisis: Managing scarcity and conflict between water users," Adv. Agronomy, vol. 95, pp. 1–76, Sep. 2007.

[2] X. Wang, W. Yang, A. Wheaton, N. Cooley, and B. Moran, "Efficient registration of optical and IR images for automatic plant water stress assessment," Comput. Electron. Agricult., vol. 74, no. 2, pp. 230–237, Nov. 2010.

[3] G. Yuan, Y. Luo, X. Sun, and D. Tang, "Evaluation of a crop water stress index for detecting water stress in winter wheat in the North China Plain," Agricult. Water Manag., vol. 64, no. 1, pp. 29–40, Jan. 2004.

[4] S. B. Idso, R. D. Jackson, P. J. Pinter, Jr., R. J. Reginato, and J. L. Hatfield, "Normalizing the stress-degree-day parameter for environmental variability," Agricult. Meteorol., vol. 24, pp. 45–55, Jan. 1981.

[5] Y. Erdem, L. Arin, T. Erdem, S. Polat, M. Deveci, H. Okursoy, and H. T. Gültas, "Crop water stress index for assessing irrigation scheduling of drip irrigated broccoli (Brassica oleracea L. var. italica)," Agricult. Water Manag., vol. 98, no. 1, pp. 148–156, Dec. 2010.

[6] K. S. Nemali and M. W. Van Iersel, "An automated system for controlling drought stress and irrigation in potted plants," Sci. Horticult., vol. 110, no. 3, pp. 292–297, Nov. 2006.

[7] S. A. O'Shaughnessy and S. R. Evett, "Canopy temperature based system effectively schedules and controls center pivot irrigation of cotton," Agricult. Water Manag., vol. 97, no. 9, pp. 1310–1316, Apr. 2010.

[8] R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements—FAO Irrigation and Drainage Paper 56. Rome, Italy: FAO, 1998.

[9] S. L. Davis and M. D. Dukes, "Irrigation scheduling performance by evapotranspiration-based controllers," Agricult. Water Manag., vol. 98, no. 1, pp. 19–28, Dec. 2010.

[10] K. W. Migliaccio, B. Schaffer, J. H. Crane, and F. S. Davies, "Plant response to evapotranspiration and soil water sensor irrigation scheduling methods for papaya production in south Florida," Agricult. Water Manag., vol. 97, no. 10, pp. 1452–1460, Oct. 2010.

[11] J. M. Blonquist, Jr., S. B. Jones, and D. A. Robinson, "Precise irrigation scheduling for turfgrass using a subsurface electromagnetic soil moisture sensor," Agricult. Water Manag., vol. 84, nos. 1–2, pp. 153–165,Jul. 2006.

[12] J. S. Lee, Y. W. Su, and C. C. Shen, "A comparative study of wireless protocols: Bluetooth, UWB, ZigBee, and Wi-Fi," in *Proc. IEEE 33rd Annu. Conf. IECON*, Nov. 2007, pp. 46–51.

[13] M. R. Frankowiak, R. I. Grosvenor, and P. W. Prickett, A review of the evolution of microcontroller-based machine and process monitoring," *Int. J. Mach. Tool Manuf.*, vol. 45, nos. 4–5, pp. 573–582, Apr. 2005

[14] W. Guo, W. M. Healy, and Z. MengChu, "Impacts of 2.4-GHz ISM band interference on IEEE 802.15.4 wireless sensor network reliability in buildings," *IEEE Trans. Instrum. Meas.*, vol. 61, no. 9, pp. 2533–2544, Sep. 2012.

[15] N. Baker, "ZigBee and Bluetooth strengths and weaknesses for industrial applications," *Comput. Control Eng. J.*, vol. 16, no. 2, pp. 20–25, Apr./May 2005.

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