Water in the Cloud:
A new system for field water monitoring with Cloud data access

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Abstract. Agricultural field water monitoring for irrigation management is still problematic despite the advent of automatic data collecting systems for electromagnetic (EM) soil water sensors. Annual fees for data access can be large, equipment can be expensive, data may not be easily available, and data may not reflect meaningful soil water content values that can be the basis for irrigation decisions. A new system based on open source software and the Arduino hardware platform for datalogging, telemetry and transmission of data to the Internet Cloud has been coupled with accurate, low power EM soil water sensors based on TDR technology to form a complete system for accurate, low cost field soil water content monitoring with Cloud data access. The new wireless sensor network (WSN) system consists of two devices, a wireless node and a wireless gateway, that are installed in weather-proof enclosures in the field. The node collects data from soil water sensors and transmits it wirelessly using the LoRa protocol to the gateway. The gateway collects data from multiple nodes and then retransmits it to a URL on the Internet using a cellular modem. The ARS Irrigation Scheduling Supervisory Control and Data Acquisition (ISSCADA) system for center pivot variable rate irrigation control was updated to receive soil water data wirelessly and to display it in a graphical user interface. The ISSCADA system also can use the soil water data to inform decisions that are automatically presented daily to the irrigator as a prescription map that can be accepted and downloaded to a center pivot control panel with a mouse click. Both the WSN and ISSCADA systems are scheduled for release as commercial products in 2019.

Keywords: Internet of things, wireless sensor network, Internet Cloud, node, gateway, datalogger

INTRODUCTION

The irrigation scheduling supervisory control and data acquisition (ISSCADA) system patented by USDA ARS (Evett et al., 2014) employs wireless sensor networks (WSN) to gather data on crop canopy temperature using infrared thermometers (IRT) mounted on a moving center pivot lateral and in the field, soil water sensors at select locations in the field, and weather instruments (relative humidity, air temperature, wind speed and solar irradiance). It calculates the crop water stress index (CWSI) on a 1-min or 5-min interval using the weather and canopy temperature data. The CWSI data for daylight hours between approximately 2 h after sunrise to 2 h before sunset are integrated into a single integrated crop water stress index (iCWSI) for each measurement zone in the field. Maps of canopy temperature and iCWSI are made available for visual inspection, and algorithms are applied to the iCWSI data combined with the soil water data to determine where in the field to irrigate and how much. With a mouse click, the irrigation manager may upload the resulting prescription map to the center pivot control panel to direct irrigation.

An effective and relatively inexpensive IRT wireless sensor network was conceived and tested by O'Shaughnessy et al. (2013) and later commercialized through a cooperative research and development agreement (CRADA) (model SAP-IP-IRT, Dynamax, Inc., Houston, TX). And, accurate, low-power and relatively low cost soil water content sensors based on time domain reflectometry (TDR) were developed and commercialized through another CRADA (model TDR-315L and TDR-310S, Acclima, Inc., Meridian, ID), becoming an ASABE 50 Award winner. However, the soil water sensor data were telemetered using rather expensive wireless dataloggers, making the soil water WSN costly and thus effectively limiting the number of field locations that could be monitored.

In 2017, Schomberg et al. (2017) demonstrated a low-cost wireless node and gateway system based on the Arduino platform. The node functioned as a datalogger capable of acquiring data from sensors that employed the SDI-12 wired communications protocol, then storing the data in an on-board flash drive. The data were periodically transmitted to the gateway using the LoRa long-range, low power radio protocol. A gateway could accept data from multiple nodes. In field situations a single gateway at the edge of a field would acquire data from multiple nodes with each node capable of handling eight sensors. Data were downloaded from the gateway to a mobile phone, tablet or other Bluetooth capable device using Bluetooth wireless communications. This system was successfully deployed in 57 fields in four Southeastern seaboard states (Fig. 1). The system's low cost and effectiveness appeared ideal for use with the ISSCADA system. Schomberg developed a CRADA to transfer the technology to a commercial manufacturer, while simultaneously providing for gateway communications to the Internet Cloud using a cellular modem in place of the Bluetooth radio.

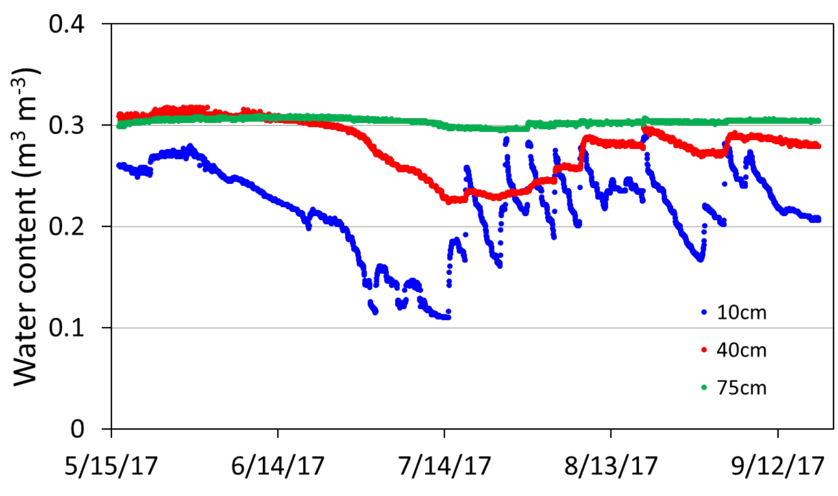

Figure 1. Example soil volumetric water content data from 2017 field experiment with no cover crop (Schomberg et al.). Sensors were placed at 10-, 40- and 75-cm depths.

METHODS and MATERIALS

The main hardware components of the experimental Arduino-based node and gateway system cost approximately $190.00 for the gateway and $65.00 for a node (Table 1) (Thompson et al., 2018).

Table 1. Main hardware components.

Part	Description	Manufacturer
MoteinoMEGA with LoRa transceiver (915 MHz)	Microcontroller	LowPowerLab (Canton, MI)
microSD Transflash Breakout	microSD slot	SparkFun Electronics (Niwot, CO)
PCF8523 Real-Time Clock (RTC) Breakout Board	Clock (node)	Adafruit Industries (New York, NY)
DS3231 Precision RTC Breakout Board	Clock (gateway)	Adafruit Industries (New York, NY)
FONA 3G Cellular + GPS Breakout	Cellular module	Adafruit Industries (New York, NY)

The 2018 version of the Arduino-based node and gateway are illustrated in Figure 2. The cellular modem transmits data to an FTP site using an Internet-of-Things (IOT) platform from MathWorks, Inc. known as ThingSpeak (https://thingspeak.com/).

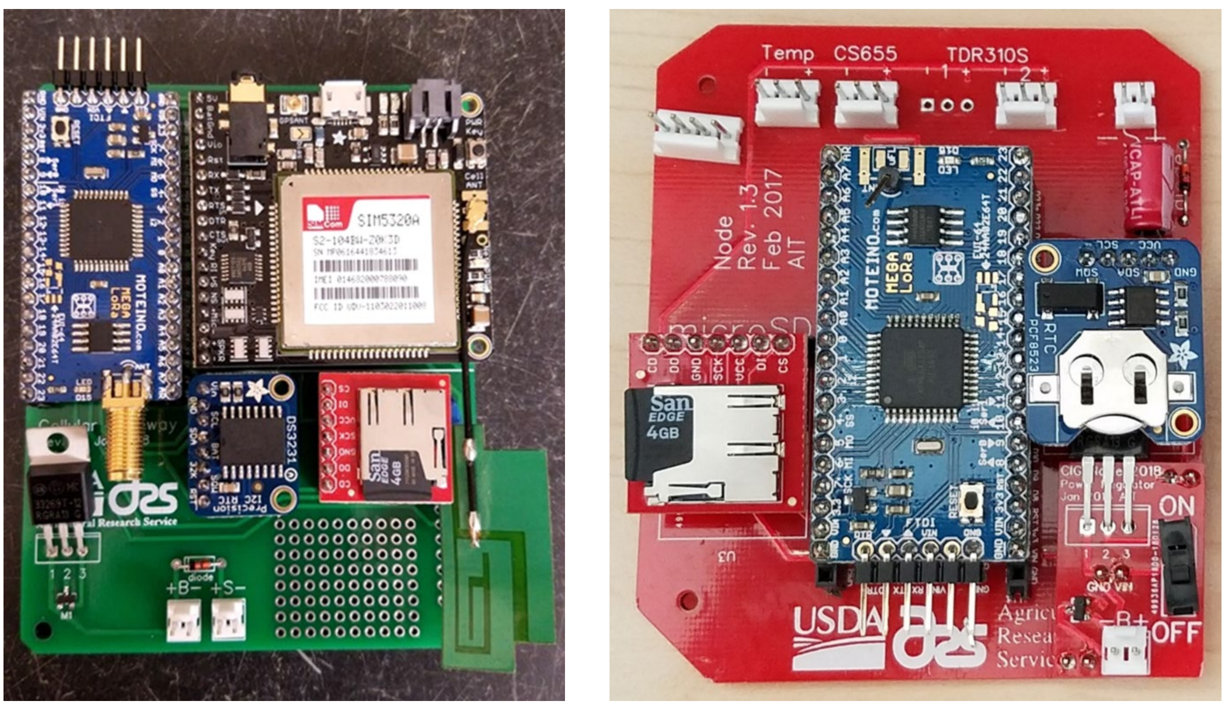

Figure 2. The Arduino-based gateway with cellular modem and LoRa transceiver (left) and node with LoRa transceiver (right). (Photos by A. Thompson)

Data can be pulled from the MathWorks URL and visualized. Results were not available at the time of writing.

RESULTS and FUTURE GOALS

The node and gateway system with cellular modem uplink to the Cloud was tested by Thompson et al. (2018), and was deployed in 2018 at four field locations in Uzbekistan (data not shown). A prototype commercial node has been developed (Fig. 3) as well as a prototype commercial gateway. The design includes a watertight plastic enclosure with integrated solar panel for a stand-alone product.

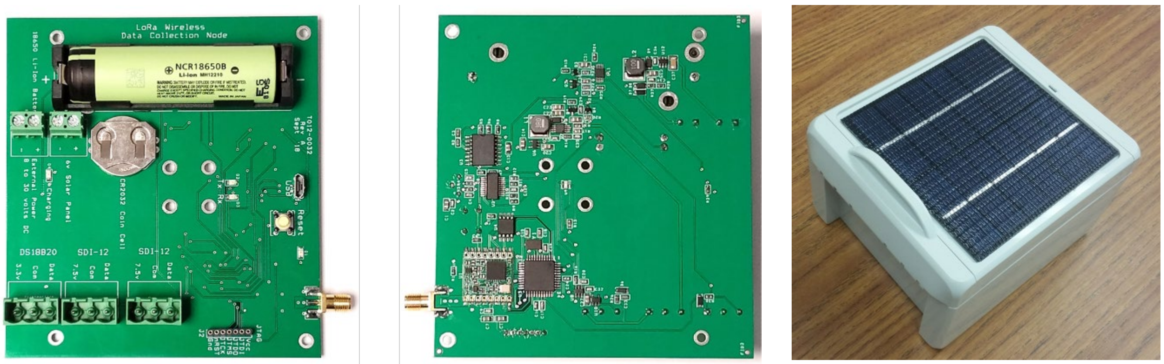

Figure 3. A prototype commercial node with lithium-ion battery showing front and back sides of the circuit board (left) and the enclosure with integrated solar panel (right). (Photos by A. Thompson)

The upcoming commercial products are intended for use with the model TDR-315, TDR-315L and model TDR-310S TrueTDR soil water sensors from Acclima, Inc. (Fig. 4). These sensors utilize TDR to capture a TDR waveform (Evett, 2003) and analyze it for pulse travel time, which is related nonlinearly to the soil apparent permittivity and practically linearly to the soil volumetric water content. As implemented in these sensors, the TDR method is not strongly influenced by soil temperature and bulk electrical conductivity (BEC) changes, including those related to water content (BEC increases with water content), temperature (BEC increases with temperature) and clay content and type (BEC increases with soil content of most clay types). Testing in clayey soil has verified the efficacy of the TDR method implemented in these sensors (Schwartz et al., 2016). Plans for field testing of the commercial node-gateway system include locations in several U.S. states and a watershed in Jordan where the cellular data uplink has potential to greatly reduce travel time and increase data availability to researchers and watershed managers.

Figure 4. Acclima model TDR-315L (top) and model TDR-310S (bottom) sensors for soil apparent permittivity, bulk electrical conductivity, temperature and volumetric water content.

The commercial node-gateway system will also be tested with the ARS ISSCADA system for center pivot irrigation decision support. The ISSCADA system utilizes a client-server software architecture (Andrade et al., 2016, 2017) that was modified to include a wireless soil water sensing network. The GIS-based graphical user interface displays icons showing the locations in the field of the soil water sensor nodes and the relative depletion levels at each location are indicated by icon color (Fig. 5). Clicking on a particular icon brings up a display of the soil water content for all sensors connected to the corresponding node (Fig. 6). This was used in 2017 experiments in an irrigation decision support algorithm that included the iCWSI and soil water content (O'Shaughnessy et al., 2018, this proceedings). In beta tests at a humid and two sub-humid locations and a semi-arid location, crop yields for cotton and corn managed with the modified ISSCADA system were similar to those obtained using local irrigation scheduling practices. Also, corn water use efficiencies were similar among irrigation management methods. The irrigation water use efficiency was greater for cotton produced with the ISSCADA system in a sub-humid climate.

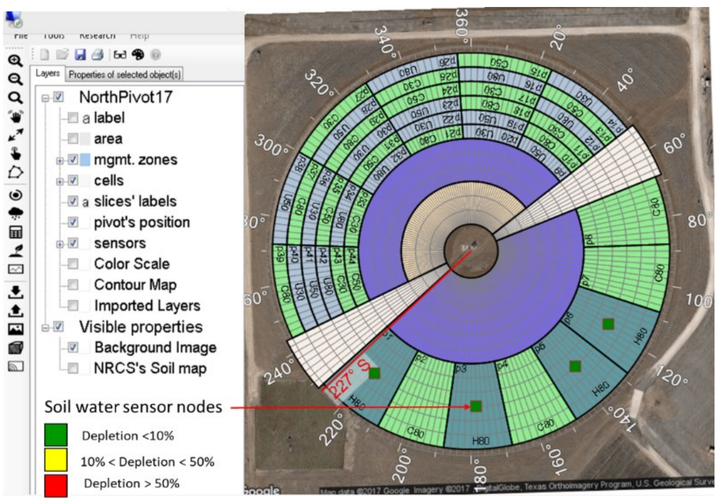

Figure 5. A screenshot of the ISSCADA software interface showing locations of soil water sensor nodes and the relative level of soil water depletion. Also shown are management zones for an experiment contrasting VRI zone control (upper left half of pivot) with sector control (lower right half of pivot).

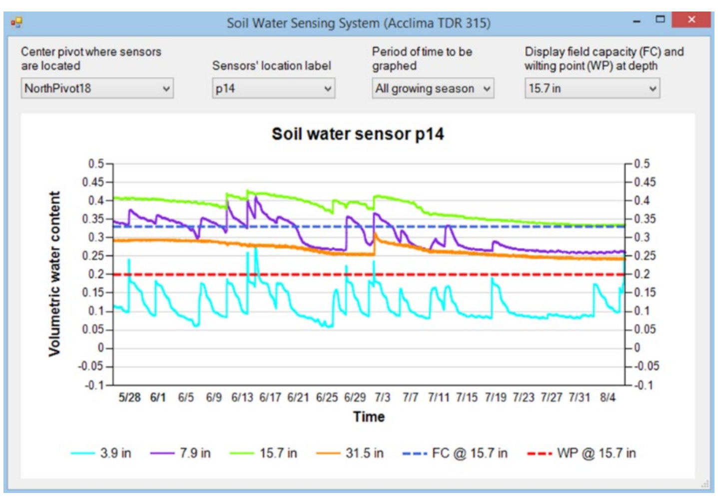

Figure 6. A screenshot of the ISSCADA software interface showing the time series of volumetric soil water content for each sensor at that node and the depth of the sensor.

SUMMARY

The Internet-of-Things (IoT) approach so sensor systems is already being applied in many industrial settings and increasingly for agricultural field operations (e.g., Kohanbash et al., 2013). The LoRa based node and gateway system for soil water sensor data acquisition and wireless telemetry described here provides an effective, low-cost, solar-powered solution for delivering data to the Internet Cloud at a URL that can be accessed by anyone with access rights. For irrigation decision support systems such as ISSCADA, this provides a data access solution that fits well with the underlying wireless in-field and multiple field communications concept that allows user interaction with a data-laden interface on a remote cellular telephone, tablet or other computer that communicates with a single or with multiple irrigation systems for both control and data acquisition.

REFERENCES

Andrade, M.A., O'Shaughnessy, S.A., and Evett, S.R. (2016). A GIS-based Decision Support Tool for Center Pivot Irrigation Systems. *In Proc. 2016 ASABE Annual International Meeting*, St. Joseph, MI.

Andrade, M.A., O'Shaughnessy, S.A., and Evett, S.R. (2017). ARSPivot- A sensor based decision support tool for the integrated irrigation management of VRI center pivot systems. In Proceedings of the 28th Annual Central Plains Irrigation Conference, Burlington, CO. February 21-22, 2017.

Evett, S.R. Soil Water Measurement by Time Domain Reflectometry. 2003. In B.A. Stewart and Terry A. Howell (editors). Encyclopedia of Water Science, Marcel Dekker, Inc. New York. Pp. 894-898.

Evett, S.R., S.A. O'Shaughnessy and R.T. Peters. 2014. Irrigation Scheduling and Supervisory Control Data Acquisition System for Moving and Static Irrigation Systems. United States Patent No.: US 8,924,031 B1. Issued December 30, 2014.

Kohanbash, D., G. Kantor, T. Martin and L. Crawford. 2013. Wireless sensor system design for monitoring and irrigation control: User-centric hardware and software development. HorrTechnology 23(6): 725-734.

O'Shaughnessy, S.A., S.R. Evett, P.D. Colaizzi and T.A. Howell. 2013. Wireless sensor network effectively controls center pivot irrigation of sorghum. *Appl. Engr. Agric.* 29 (6), 853-864. doi 10.13031/aea.29.9921

O'Shaughnessy, S.A., M.A. Andrade, K.C. Stone, E.D. Vories, R. Sui, and S.R. Evett. 2018. Adapting a VRI irrigation scheduling system for different climates and fields. Irrigation Association Technical Conference, Dec 7-10, 2018, Long Beach, CA.

Schomberg, H.S., A. Thompson, S.R. Evett and D.K. Fisher. 2017. Arduino based gateway-node system for soil water measurement in on-farm research. Presented at the 2017 ASA-CSSA-SSSA Meeting – Managing Global Resources for a Secure Future. Oct. 22-25, 2017, Tampa, FL. https://scisoc.confex.com/crops/2017am/recordingredirect.cgi/id/31692

Schwartz, R.C., S.R. Evett, S. Anderson and D. Anderson. 2016. Evaluation of a direct-coupled TDR for determination of soil water content and bulk electrical conductivity. Vadose Zone J. 15(1)2016. doi: 10.2136/vzj2015.08.0115.

Thompson, A., H. Schomberg, S. Mirsky, C. Reberg-Horton, B. Davis and S. Evett. 2018. On-farm gateway-node system for monitoring soil water content and soil temperature. Poster presented at 2018 ASA-CSSA-CSA Meeting - Enhancing Productivity in a Changing Climate, Nov. 4-7, 2018, Baltimore, MD.