A Wireless Sensor Network for the Nursery and Greenhouse Industry

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Index Words: real-time, cost-effective, environmental, data, irrigation, environmental, management,

Significance to the Industry: We have successfully developed a wireless sensor network comprised of third generation wireless nodes developed by Carnegie Mellon Robotics Institute that integrate a variety of sensors which can measure substrate water, temperature, electrical conductivity, daily photosynthetic radiation and leaf wetness (Ech20 series; Decagon Devices, Pullman WA) in real-time. Control of irrigation solenoids is also possible using these rugged low-power sensor nodes, based on the measurement of real-time substrate moisture data. With this system, growers can deploy sensors within their growing operation to provide three of the most important environmental data streams for monitoring plant growth and productivity. A web-based graphical reporting system has the capability of monitoring real-time data from their production areas, from anywhere in the world with an internet connection. Growers should reap an immediate financial payback through improved plant growth, more efficient water and fertilizer applications, together with a reduction in disease problems related to over-watering.

Nature of Work: A number of researchers have published information on the potential of sensors that have the ability to directly sense the water status of soils in the field (4, 5). Relatively sophisticated systems are being used at similar scales in vineyards (4), forestry nurseries (3) and golf courses (1) for similar purposes and while the sensors perform well, these systems are extremely expensive, and have limitations for many fruit and field growers including power and communications in remote areas. Higher-tech greenhouse irrigation systems (5, 10) have been in use for some years now, but most of these systems do not provide a control system to manage irrigation scheduling. Affordable systems that can transmit data for long distances from low-power nodes are essential – since real-time information will greatly improve the quality of the management decisions made using that data.
In previous research, Murray (6) and others (2,7) found that multiple time-domain reflectometry (TDR) sensors must be used in organic substrates, to provide an accurate and repeatable measure of water content (2, 6, 7). Various container sizes will probably require specific sensor lengths and/or configurations. In addition, Murray (6) provided practical information on placement of sensors with overhead (sprinkler) and drip irrigation systems, together with the minimum number of probes that should be used in varying situations. A TDR network was deployed for three years to monitor and control irrigation scheduling in a container-nursery environment (8). This research network significantly reduced water consumption by 50% over cyclic timed overhead irrigation, and significantly reduced nitrogen and phosphorus leaching from container nursery production systems (8, 9).

The Carnegie Mellon University (CMU) sensor network (11) is composed of battery-powered sensor nodes, each consisting of a rugged waterproof box that measures approximately 3" x 5" x 7" (Fig. 1). Each node contains a microprocessor, a radio for wireless communication, and an interface board that provides for multiple sensor interfaces. When the nodes are deployed in the field, they use built-in radios to automatically find one another and form a wireless network. This network can then be used to relay real-time data from sensors attached to the nodes to a central computer. The network achieves a six to 12-month battery life through a synchronized, low-duty-cycle, geographical forwarding routing scheme.

The CMU sensor network has three unique features that distinguish it from other wireless data collection systems: (1) the communications are multi-hop; (2) the network is self-configuring, and (3) the nodes can be used to actuate a solenoid valve, which will allow for automated monitoring and control, should the grower wish to utilize this control capability. The first feature allows transmission of data over distance longer than the range of a single radio i.e., if a node is not within range of the central computer, it automatically finds another node to act as a relay (Fig 1). The second feature means that the network is easy to install and that it can be reconfigured by simply moving the nodes around. It also means that the system is can withstand single-point failures – i.e., if a node should fail, the network automatically finds an alternate path for the data transmission. The third feature makes it possible to go beyond sensing and use the nodes to monitor and control devices automatically or from remote locations.

We have developed a short list of what we consider are essential features for any technology system which uses sensors for environmental monitoring and control. The sensors must be mobile for efficient movement to critical areas. Data from sensors should be transmitted wirelessly over large distances with little to no interference and with minimal power requirements. That data should be automatically logged and made available in an interpretable form for the user. Additionally, the data should also be easily integrated into the irrigation system for automatic control. Finally, the sensor/node system should be scaleable to
increase the size or usefulness in the nursery. Additionally the system should be inexpensive (less than $5,000 for a starter network), and user-friendly (plug and play operation) to install and operate.

By hybridizing the CMU system with Decagon and other low-cost commercial sensors, we have taken advantage of the prior research and development that Carnegie-Mellon University has put into developing the wireless network. These nodes have a unique capability to dynamically route any data gathered by the sensors, to the base node. In addition, the nodes are waterproof, lightweight and durable (Fig. 2), and can be quickly moved with the sensors to another location. Most importantly, we have configured the nodes to accept a variety of analog and digital sensors, with the ability to "push" a signal to actuate solenoids for irrigation management and other environmental control functions for ‘plant-driven’ environmental control. The grower can of course fully intervene and control the system at any times in ‘manual’ (monitoring) mode.

The WebSensor software (Fig. 3) is very easy to use, customizable (i.e. can accommodate specific calibration curves for various substrates), and integrates with a web-version that allows for data sharing over the internet. For these reasons, we feel that this hybrid system addresses all the major grower priorities and it will allow us to move forward with implementation of a ‘plant-driven’ irrigation management system into the industry within a short time. However, before that can happen, we have considerable optimization work to do by deploying into real production systems, to ensure that it does in fact perform adequately in a range of commercial operational environments.

Literature Cited:


**Fig. 1. Schematic of the Operational Sensor Network**
Fig 2. An operational second-generation wireless node with various $\text{Ech}_2\text{O}$ and analog sensors.

Fig 3. Computer screen capture of WebSensor graphic user interface and reporting system.