

INTEGRATING A MESH NETWORK INTO THE REAL-TIME SMART SENSOR ARRAY FOR SCHEDULING IRRIGATION

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In 2004 we first developed a real-time smart sensor array for measuring soil moisture and temperature. Further testing in 2005 and 2006 showed the system to be effective at providing real-time monitoring of soil moisture conditions. The sensor readings were used to schedule irrigation in several fields. Additionally, by observing sensor readings after irrigating, the sensor array provided a means of determining the effectiveness of an irrigation event in bringing soil moisture values to desired levels.

The goal of our study was to adapt and evaluate an alternative wireless system for use with the sensor array. For this project, we selected to evaluate mesh networking as the alternative. This wireless system creates a wireless mesh network between the nodes. We used Mica2 motes which use transceivers operating at a radio frequency of 916 Mega hertz (Mhz) to provide the wireless component. The motes are manufactured and sold by Crossbow® Technology Inc. Because the mote's radio circuitry includes a transceiver, the motes are capable of both transmitting and receiving wirelessly. This capability is used by the onboard operating system to allow the motes to act as repeaters – receiving and passing along transmissions from other motes. The transmission pathways, established mote-to-mote, create a mesh network. If a pathway between motes becomes obstructed, the operating system will re-route the data through other motes. The wirelessly transmitted data from all motes in a network eventually reach a gateway where the data can then be uploaded to a data logger. The mote-to-mote communications and re-routing capabilities aid in overcoming obstructions and give the overall network great range.

During 2007, we substituted motes for the RFID tags in our smart sensor nodes and installed the system in the NESPAL field for a season-long evaluation. Wireless mesh networks, formed by Mica2 motes, showed promise as an alternative to RFID tags for accessing soil moisture information from remote locations in an agricultural field. The motes were able to re-route signals when the pathway between two motes failed.

Initially, the mesh network worked as expected, with each node reporting the soil moisture values. However, as the plant canopies grew taller, the motes' transmission range decreased. This was most likely caused by a portion of the signal bouncing off the foliage and arriving at the receiving mote out-of-phase with the main component of the radio energy. This out-of-phase portion acts to attenuate the main rf beam. As the crop grew taller, the motes' transmitting and receiving ranges, which have a line-of-site distance up to 400 feet over level, non-cropped ground, were reduced to a range of less than 120 feet.

One attempt to increase the motes' transmit range was to construct higher gain, collinear antennas. These are constructed by soldering together multiple 3.25 inch antenna sections. As the number of sections is increased, gain, and ultimately range, increases. Initial tests of 4-section collinear antennas on non-cropped ground showed an increase of range of as much as 30%. However, when the collinear antennas were placed in the crop foliage, their range was no better than the original antennas.

To overcome this issue, the original antennas were inserted into the top of an 8 foot, 0.25 inch diameter hollow, flexible, fiberglass rod. The antenna was connected to the mote via an electrical cable that ran through the fiberglass rod. This placed the antenna above the plant canopy. The rods were mounted to the PVC enclosure protecting the electronics with a spring used for conventional CB antennas (Figure 1). The flexible rods and spring allowed field equipment, such as sprayers, to bend the rods and pass over the sensors without damaging them throughout the growing season. This solved the range issue but did make the node



Figure 1. To overcome the range issue, the original mote antennas were enclosed in an 8 foot, 0.25 inch diameter hollow, flexible, fiberglass rod. The rods were mounted to a PVC pipe used as a supporting stake with a spring used for conventional CB antennas. The pipe also supported the PVC enclosure housing the node circuitry including the Mica2 motes.

slightly more cumbersome to transport during installation. An unexpected benefit of this extended antenna was that it made the location of the sensor nodes easily visible and ensured that they would not be accidentally damaged during normal field operations.

A more serious problem may be that three of the 12 motes failed during the growing season. We were not able to determine the specific reason for the mote failures. After extensive discussions with the manufacturer, we concluded that the design of the motes may not have been robust enough to survive a full season in the field under the high heat, high humidity conditions we have in southern Georgia.

We have recommended design modifications to the manufacturer which are now being implemented. A new design will be available for the 2008 growing season which should ensure that the motes will have a long, multi-season, life. The positive outcome of these failures was that we were able to document that the mesh network reestablished itself and the motes were able to re-route signals when the pathway between two motes failed.

Conclusions

Wireless mesh networks, formed by Mica2 motes, showed promise as an alternative to RFID tags for accessing soil moisture information from remote locations in an agricultural field. The motes were able to re-route signals when the pathway between two motes failed. However, to become a practical alternative, a method must be found to allow the transmit/receive range of the motes to be maintained as the crop matures. Possible solutions include trying different antenna configurations to increase gain or to simply place the motes in a tighter mesh by decreasing the distance between motes.

We have held discussions with two different companies interested in commercializing the mesh network approach. The first is a small start-up agricultural electronics company based in Miller Co., Georgia. The second is a larger, well established agricultural electronics company based in Nebraska who has strong ties to national pivot manufacturers. There are no firm agreements at this time however we are optimistic that with the involvement of the Agricultural Innovation Center, progress will be made soon.