Expanding the Usefulness of Existing Data-Collection Infrastructure with Wireless Sensor Networks

USGS science for a changing world

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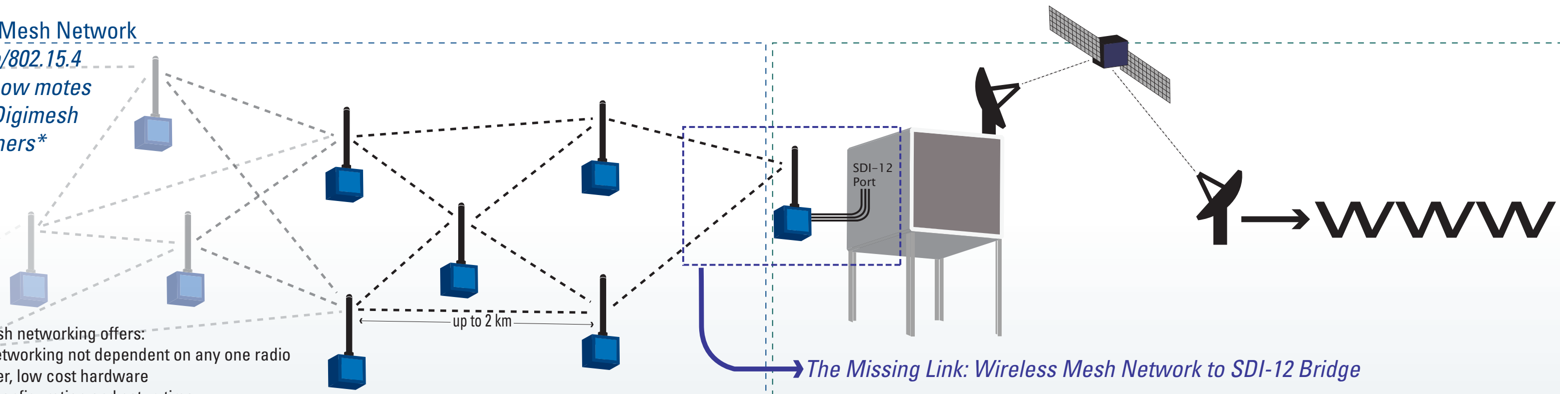
The concept: Combine the advantages of wireless mesh networking with the universal SDI-12 standard

Wireless Mesh Network

- *-ZigBee/802.15.4*
- *-Crossbow motes*
- *-XBee Digimesh*
- *-and others**

Existing Data Collection Infrastructure:

- *-USGS stream gaging network*
- *-Earthscope seismic network*
- *-NEON Nat'l Ecological Obs. Net.*
- *-and others*



Wireless mesh networking offers:
- -Robust networking not dependent on any one radio
- -Low power, low cost hardware
- -Minimal configuration and setup time

Existing infrastructure offers:
- -Field personnel for sensor installation and maintenance
- -Data telemetry
- -Online data portals

Wireless Mesh Networking

Wireless mesh networking (WMN) describes low-power radios arranged so that every radio operates as a repeater, allowing networks to be deployed over a large spatial area with minimal hardware. They can be self-configuring, where the best radio links ("routes") are discovered automatically; self-healing, where routes are automatically changed if a radio is lost; and sleeping, offering periods of very low power consumption for minutes or hours at a time.

WMN is reaching a "tipping point" of advanced, low-cost hardware. Wide-spread adoption by the earth science community, however, is hindered by complex programming requirements.

The project presented here aims to make the advantages of WMN available to a broad audience through the current standard for datalogger-sensor communication, SDI-12.

SDI-12

SDI-12 (Serial Data Interface - 1200 baud) is a protocol designed to allow multiple sensors on a single bus. Therefore, a WMN would be deployable at a station already measuring SDI-12 sensors. The protocol operates by sending command packets, based on ASCII characters, addressed to a specific sensor. The sensor in turn responds with the measured parameter(s).

Nearly every datalogger sold for earth science use in the past 15 years has an SDI-12 port. The USGS alone operates more than 7000 SDI-12 dataloggers. The protocol is well-understood by field technicians.

The SDI-12 protocol allows up to 62 sensors on a single bus, each with multiple parameters. Each wireless radio is considered a sensor, and each sensor at the radio (soil moisture probe, rain gage, etc.) is considered a parameter.

The Implementation

Currently, off-the-shelf Digi XBee 900 Mhz 50 mW radios are used. These low-power, spread-spectrum radios provide 2 km line-of-sight range with 6" whip antennas and 8 km range with small Yagi antennas. They can be set to sleep in a very low power mode for up to 4 hours. While sleeping, the radios are unresponsive and consume just 60 µA. At the end of the sleep cycle, each radio wakes simultaneously, ready to measure attached sensors.*

At a 15 minute sleep/30 second wake cycle, the radios can sample 2 soil moisture probes using the integrated analog-to-digital converter for an indefinite time if powered by a 6 cm-square solar panel, or up to 2 months if powered solely by 2 AA batteries. Alternatively, the hardware is capable of measuring any sensor with voltage output.

A base station/bridge unit is under development by USGS to coordinate the wireless network, collect data, and format it appropriately for the SDI-12 standard. Custom firmware, written in C, is being written to run on an Atmel AVR microcontroller. The bridge unit connects directly to an existing datalogger and translates between SDI-12 and the WMN protocol, allowing sensors at each wireless radio to be measured independently.*

Once completed, the firmware, hardware schematics, and circuit board designs will be publically available from the author. The target cost of the hardware is $80 for the wireless nodes and $120 for the bridge unit. Also, the project seeks to make available an open-source library of SDI-12 microcontroller software code for other projects.

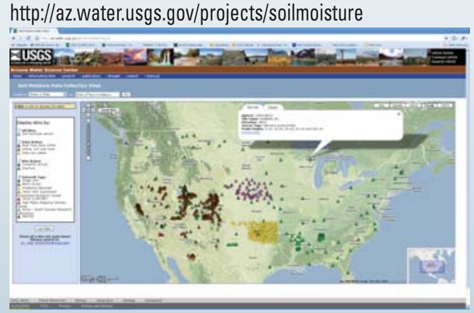
USGS is currently seeking cooperators for further development and field testing.

*Mention of a particular brand name or trademark does not imply endorsement by the U.S. Government.

The goal: a nationwide soil moisture monitoring network

Compared to rainfall and stream gaging networks, the soil moisture component of the water cycle is poorly sampled:

http://az.water.usgs.gov/projects/soilmoisture



An enhanced soil moisture monitoring network would benefit runoff and flood forecasting, provide calibration and validation data for climate models, and enable more accurate drought monitoring.

While existing data collection infrastructure offers clear benefits for the deployment of soil moisture sensors, often stations are not ideally located for soil moisture measurement. For example, USGS gaging stations have real-time satellite telemetry providing data immediately to a web-accessible portal. They are typically located, however, on near-stream bank deposits, whereas upland soil moisture measurements would be more representative of the region. Therefore a wireless solution is desirable so that sensors can be located where they are needed.

Although commercial hardware is available to deploy wireless sensors at dataloggers, none combine the characteristics of mesh routing, low-power radios, and low cost that this project seeks to develop. The hardware is specifically designed to be depolyable by field personnel without programming.

Wireless mesh networks are well-suited for measurement of soil moisture, which is a spatially variable phenomena that varies slowly over time. Measurements are necessary over a large area, requiring many sensors, but can be made periodically rather than continuously, a characteristic conducive to low-power, sleeping networks.

The initial phase of the project aims to deploy 5 wireless soil moisture stations per SDI-12 datalogger, each with two probes, at 15 cm and 30 cm depths. Fifteen-minute samples will be stored in the WMN bridge unit. When a "measure" command is received on the SDI-12 bus from the host datalogger, the WMN bridge unit provides the average of the 15 minute readings collected over the past four hours. Both the 15 minute measurement interval and the four hour averaging period are configurable through SDI-12 commands issued by the datalogger.

Hardware under development at USGS. Unit on left is hard-wired to an SDI-12 capable datalogger and coordinates communication with remote wireless nodes, shown on right.