EVALUATION OF UBIQUITIOUS USE OF WIRELESS SENSOR NETWORK TECHNOLOGY IN DATA ACQUISITION AND TELEMETRY APPLICATIONS

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ABSTRACT

Industrial wireless sensor networks can be designed to meet the strict requirements of specific distributed applications. Emerging standards have enabled the development of low-cost, low-power sensor nodes that are quickly becoming a commodity, enabling the realization of efficient and reliable data acquisition and telemetry in many systems. Moreover, new and exciting possibilities arise from the distributed computing power of the sensor nodes, the ability to monitor and aggregate data across large arrays of sensors, and the ability to model dynamic and rugged environments that were previously beyond the reach of traditional data acquisition and telemetry systems.

KEY WORDS

Sensor Networks, Wireless, Telemetry, Data Acquisition, iNET

WIRELESS SENSOR NETWORK RESEARCH IN SPECIFIC APPLICATIONS

Wireless Sensor Networks (WSNs) are composed of micro electro-mechanical systems that communicate wirelessly with each other over short distances. A large number of these systems are combined in a field to allow the coordinated transmission of data collected using on-board sensors. These networks are characterized by their low power operation in providing data acquisition in response to user queries or pre-defined events. Transmissions are typically broadcast in nature, yielding low-overhead operation due to their low cost and small size. As a result, many considerations for application-specific design are addressed due to the large number, high density, mobility, low power operation, limited memory, computational power, and wireless communication of the networks of sensor nodes [Akyildiz].

Research in the last several years has shown that WSN technology can be applied to a variety of applications. Southwest Research Institute (SwRI®) has capabilities to combine active radio frequency (RF) techniques with traditional network probing for network mapping and geolocation. SwRI has also demonstrated the capability to employ standard WSN techniques for remote data acquisition using custom hardware in ruggedized applications for environmental monitoring and underwater mapping.

SwRI has researched the use of WSNs in the assessment of natural hazards such as volcanism, earthquakes, and mass landslides (Figure 1 and Figure 2). These scenarios call upon geoscientists to rapidly deploy instruments to characterize these earth processes, often with little lead-time and in dangerous working conditions. SwRI has shown that WSN technology has the potential to redefine the approach to characterization of earth processes by developing a WSN with a radar-like differential range measurement system. The system uses estimated ranges between radios operating as cooperative radar targets to generate a map of the surrounding terrain. With features such as inexpensive and expendable sensors deployed in large numbers, the ability to deploy sensors in a range of modes including aerial scattering from aircraft, three dimensional positioning of sensors, and remote reconfigurability, SwRI has found that WSNs show excellent potential for applications of earth process characterization and hazard mitigation.

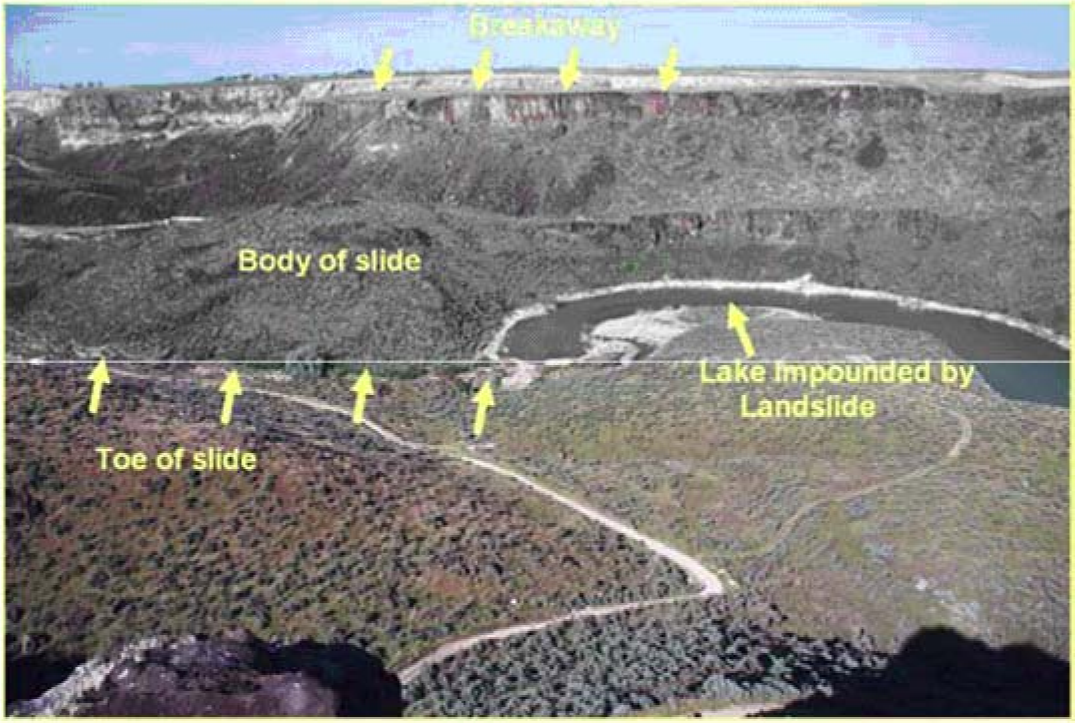

Figure 1. Landslide Assessment using WSN in Salmon Falls, Idaho

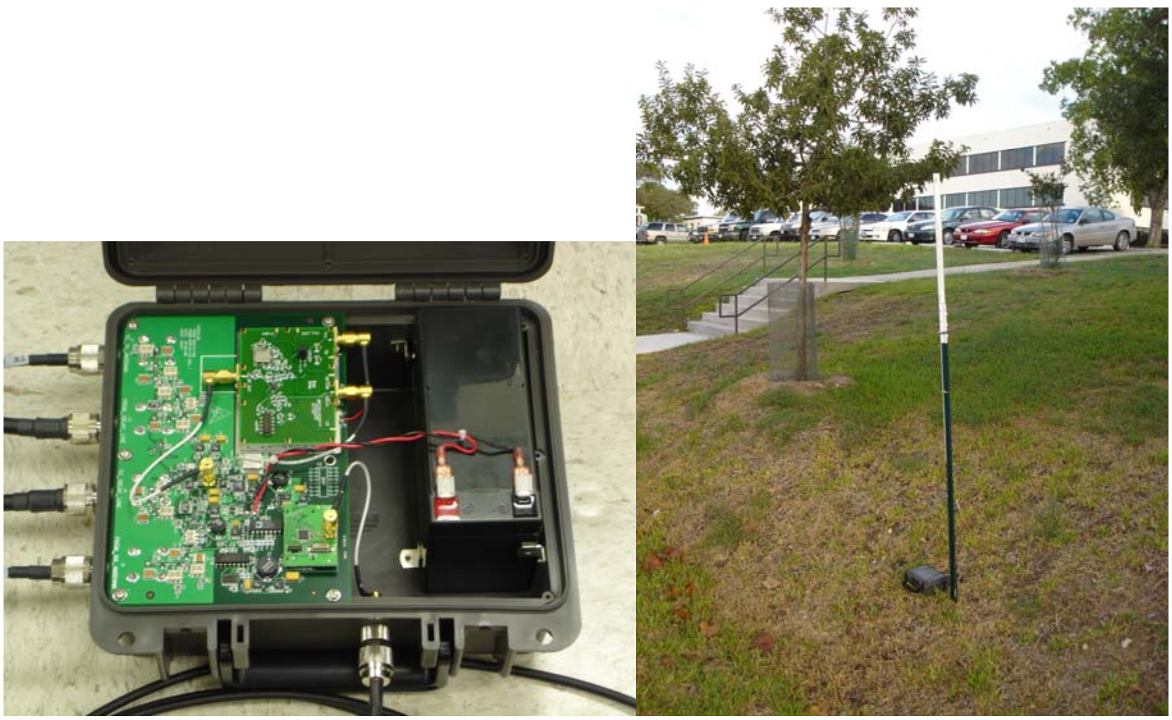

Figure 2. WSN for Continuous Wave Phase Measurement for High-Precision Distance Measurement

A research effort was recently undertaken by SwRI to develop and demonstrate an inexpensive, neutrally buoyant sensor node technology for measuring velocity, pathway traveled, and conduit size observed by sensors that float with water conveyed via a karst conduit (Figure 3). A WSN is formed between mobile sensor nodes emplaced in conduits and stationary sink nodes located at sinkholes and wells along the conduit. The sensors are instrumented to record velocity and path, with ultra-sound sensors to measure conduit dimensions, and with transponders that emit a signal when they exit the spring. The sensors also employ mapping and data cataloguing techniques that allow them to store large amounts of data in small amounts of memory from relatively few readings extending the travel time capabilities of the sensors. This proposed method for the mapping, characterization, and analysis of karst aquifers illustrates the ability to design WSNs to specific applications that would otherwise be costly and extremely dangerous when using traditional methods.

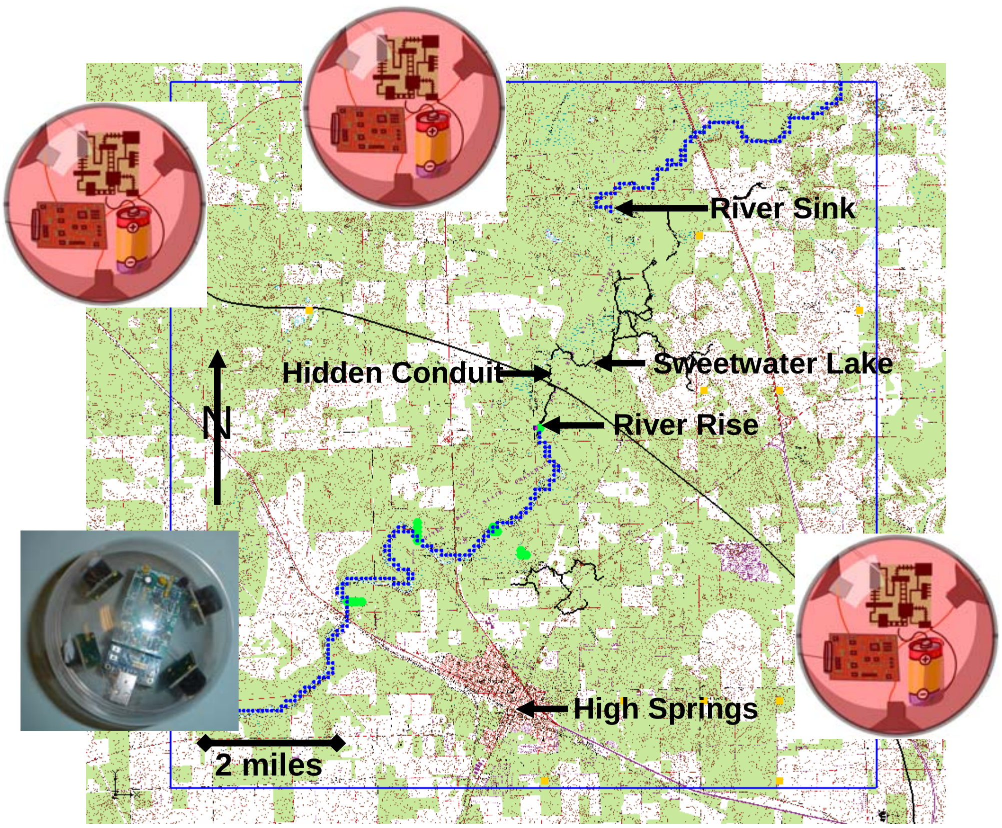

Figure 3. Karst Aquifer Mapping with Underwater Sensor Nodes

In a Defense Advanced Research Projects Agency (DARPA)-funded research effort, SwRI developed a prototype system to demonstrate the feasibility of utilizing unmanned aerial vehicles (UAVs) in a cooperative manner to increase accuracy in the location of targets of interest (Figure 4). Drawing on expertise in WSNs, cooperative systems, path planning, and time difference of arrival (TDOA) algorithms, SwRI utilized RF modeling of the area of interest in order to deduce handheld communication device emitter locations. The model was initially seeded with a three-dimensional model of the anticipated network and RF environment. Subsequently, battery-powered helicopter units were tasked to verify and refine the understanding concerning the RF propagation and the precise emitter locations. Related methods could be used to traverse WSNs based on other standard protocols.

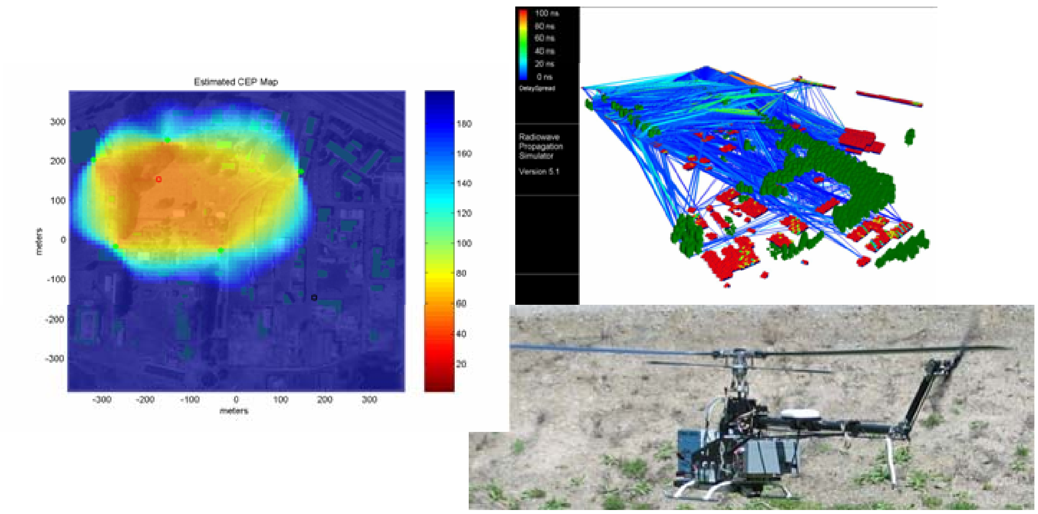

Figure 4. UAV Location of Targets of Interest

UTILIZING WIRELESS SENSOR TECHNOLOGY IN NETWORKED DATA ACQUISITION AND TELEMETRY

SwRI has demonstrated the capability to create a network-enhanced data acquisition and telemetry system for the testing and evaluation of airborne vehicles (Figure 5). Through this project, a vehicle network was designed and employed to collect data from various data acquisition units (DAUs) and telemeter a subset of the data to a ground network. The system also provided recording and dynamic data selection capabilities. An analogous data acquisition and telemetry architecture is being developed in the emerging iNET (integrated Network-Enhanced Telemetry) efforts.

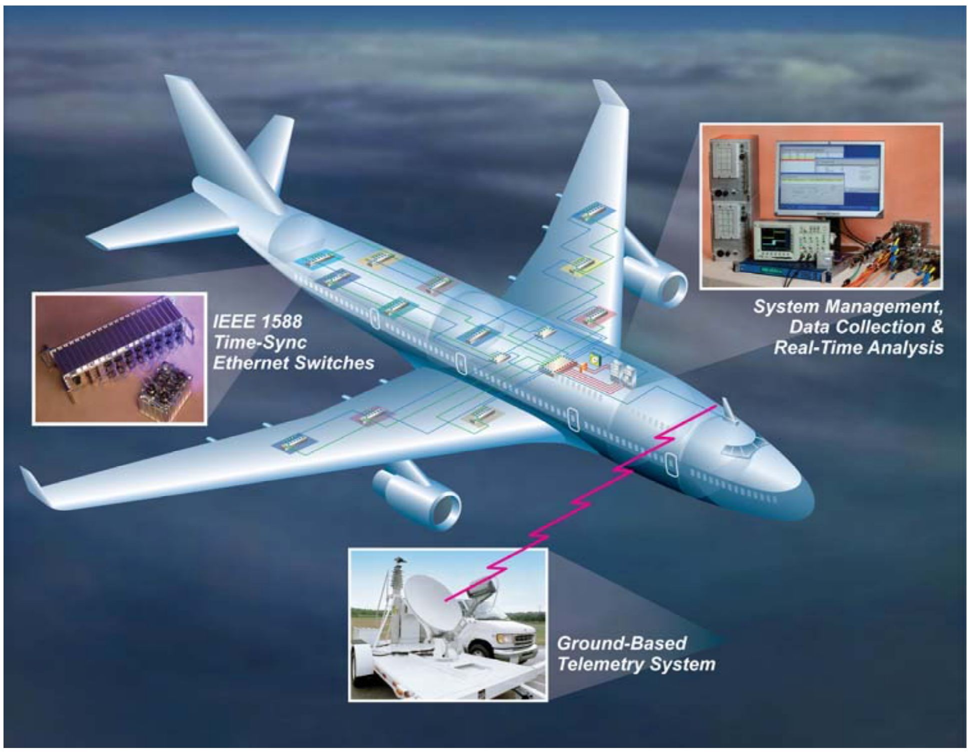

Figure 5. Network-Enhanced Data Acquisition and Telemetry System

This system is easily extensible to include data acquisition via WSNs in hazardous and inaccessible locations of the vehicle and its surrounding environment. This is realized with additional DAU hardware serving as a gateway to sensor networks in the system. Data is sent through the network using the customary method of the DAU selecting a subset of the data for encapsulation and transmission on the airborne network using standard data protocols and formats. Moreover, additional data processing, selection, and aggregation is possible within the WSN before reaching the DAU.

Robust protocols and accessible hardware are available for utilization in WSNs to support such data acquisition and telemetry systems. The most predominant standard for the use of smart sensors to interface a network system is the Institute of Electrical and Electronics Engineers (IEEE) 1451 standard. IEEE 1451 defines a family of Smart Transducer Interface (STI) standards that permit systems to automatically identify sensors and obtain their calibration and operating parameters. The proliferation of IEEE 1451 allows the connection of plug-and-play sensor devices to a network-enhanced data acquisition and telemetry system. With some additional effort, application-specific WSNs can be designed to interface these systems using currently available technology such as Crossbow's wireless sensor node hardware platforms (www.xbow.com).

With the commoditization of WSN hardware, new applications can be realized in data acquisition and telemetry systems. Protocols are currently implemented in available wireless sensor hardware to allow the addition of low-cost, low-power, reliable data acquisition networks to current data acquisition and telemetry systems. Distributed data acquisition on test vehicles can be designed with the ability to monitor and aggregate data across large arrays of sensors. This allows the ability to monitor harsh environments previously inaccessible by traditional data acquisition and telemetry systems.

Whereas previous systems required countless cables for bus transmission, network communication, and power, fields of sensors can now be deployed over the entire body of test vehicles without the addition of cable weight. The ad-hoc routing from the sensors to the data sink also eliminates the need for additional communication switches in the network. Additionally, failure of a single sensor node is not mission-critical, as neighboring nodes in the dense fields of sensors can collect data in the area and effectively route around malfunctioning nodes. Finally, data acquisition sensors can be planned for long-term deployment on in-service systems. Power-efficient wireless sensor networks can be designed with inductive coupling to draw power wirelessly from the vehicle system or with energy sources that last the lifetime of the test vehicle.

CONCLUSION

In conclusion, we see that the current state of the art of WSNs provides a hint to future data acquisition and telemetry applications that lie ahead. We have shown that current wireless sensor network technology can be tailored to a variety of applications including the telemetry of fields of data from inaccessible environments for widespread assessment of natural hazards, the use of computing power on waterproof sensor nodes to dynamically model and remotely report data about karst aquifers, and even the RF modeling and telemetry of large environments by unmanned aerial vehicles to locate targets of interest. These applications are just a cross-section of the capabilities offered by wireless sensor networking. When considering the use of wireless sensor technologies in the emerging wave of network-enhanced data acquisition and telemetry systems, we can realize a new suite of applications allowing the remote monitoring of fields of interest on test articles. The strict requirements of these applications can be met using low-cost, low-power, computationally powerful sensor nodes for the collection and aggregation of data across large arrays of sensors deployed in dynamic and rugged environments previously beyond our reach.

REFERENCES

Please see the following resources for further information on WSNs:

I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless Sensor Networks: A Survey", *Computer Networks (El-sevier)*, vol. 38, pp. 393-422, 2002.

Southwest Research Institute, Communications and Embedded Systems Website, http://commsystems.swri.org/

Crossbow Technology, Inc. Website, http://www.xbow.com/

National Institute of Standards and Technology, IEEE 1451 Website, http://ieee1451.nist.gov/