Challenges facing in-situ sensing

Lessons learned from NEON

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The NSF National Ecological Observatory Network (NEON) is a major infrastructure program seeking to deploy dozens of soil, water, and air sensor arrays across the United States, all feeding a portal providing continuously updated data products to ecologists via the Internet. We have been working with the NEON program to design their in-situ network from data acquisition up to the WAN connectivity point. Our ESTO project, Satellite Sensornet Gateway (SSG), is motivated by the system challenges we see on NEON. Our goal is to make a networked in-situ sensor data-acquisition system for individual scientists that is just as capable as that developed for NEON.

While is in the design stage, we have observed what is hard in building large-scale sensor networks. We summarize several key challenges in the following bullets:

- **Integrating diverse sensors.** The selection of sensors should be driven by science requirements, rather than ease of integration. In-situ arrays, then, may include very sensors which have very diverse integration characteristics. Within one NEON array we are seeing dozen's of instruments possessing analog resistance or voltage interfaces in addition to digital interfaces accessed using a variety of proprietary protocols. This has motivated us to look at data acquisition platforms which have configurable, flexible, modular interfaces.

- **Configuration management.** Long-running sensor arrays will need ample field support (we expect weekly tending in many cases). The sensor instruments are associated with a host of metadata including calibration tables, firmware versions, and serial numbers which will vary from one unit to the next. Accurately tracking configuration changes such as instrument replacements or recalibration events is important in maintaining quality control in the resulting data products. This has motivated us to investigate technologies which allow embedding of the instrument identity (e.g., model and serial number) in the meta-data stream for archiving.

- **Ease of sensor integration.** Another aspect of long-lived, diverse sensor populations is that new instruments will be added later in the system lifetime. The initial engineering effort to construct and deploy a national-scale sensor array must also leave behind a system which permits new instruments to be integrated into the data-acquisition system long after the original designers are gone. This has motivated us to look at software environments which have re-usable components.

- **WAN access.** Early analysis indicates that some NEON sites will generate over 1 Mbps of constant stream data, and may generate ten-times as much with the addition of imaging instruments. Other sites, e.g., some temporary deployments, will require much less bandwidth. Just as important is the data flow in the reverse path needed for system commanding. Delivering bandwidth at all, and broadband in particular, to remote locations is expected to be both costly and challenging. This has motivated us to permit integration with a variety of WAN technologies – including wireline, GPRS, microwave, and satellite.

- **Metadata.** NEON has metadata requirements motivated by the science applications (e.g., measurement time, instrument location, sensor calibration table) and engineering requirements (e.g., data-acquisition system software revision number and available memory). A preliminary examination of metadata schema for NEON indicates that no one schema will directly satisfy all the projects needs. In fact, just understanding the metadata needs has turned out to be a challenge. This has motivated us, on the SSG project, to permit metadata changes after deployment.

There are a host of other interesting design issues to be addressed – security (including access control), robust data transfer protocols, flexible commanding protocols, wireless propagation in areas of heavy foliage – all of which need to be addressed for a successful design.

Our approach on the Satellite Sensornet Gateway project is to apply lessons learned from the NEON project to create a system which can be configured and deployed by a researcher with minimal programming or networking expertise. We are designing and building such a system under the guidance of an advisory board of earth scientists to ensure the system capabilities will be useful to a broad range of investigations.