Title
Supporting Ecological Research With a Flexible Satellite Sensornet Gateway

Authors
Silva, Fabio
Graham, Eric
Rundel, Phil
et al.

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Supporting Ecological Research With a Flexible Satellite Sensornet Gateway

Fabio Silva[1], Eric Graham[3], Philip Rundel[2], Annette DeSchon[1], Wei Ye[1], Spundun Bhatt[1], and Yuri Pradkin[1]
[1]USC Information Sciences Institute, [2]UCLA Ecology and Evolutionary Biology, [3]UCLA Center for Embedded Networked Sensing

Introduction: Supporting distributed sap flow monitoring at Stunt Ranch

Motivation

- **Enable wide adoption of sensor network technology by scientific community**
- **Develop a turnkey solution for easy data collection at remote locations for ecological research**

System Design Goals

- **Robust for unattended operation**
- **Ease of use by non-technology experts**
- **Extensible, allowing multiple areas around the site**
- **Flexible architecture to support different sensors**

Ecological Application

Long-term investigation of the influence of the 2006-2007 southern California drought conditions on the water relations of shrub and tree species that differ in their depth of rooting

- Rainfall over this past hydrologic year has been less than 25% of normal, making it the driest year on record
- Collect environmental measurements for the site: Temperature, relative humidity, wind speed, rainfall, soil moisture, and solar radiation
- Collect sap flow measurements from various species

Problem Description: Application requirements entail distributed communications approach

Deployment Challenges

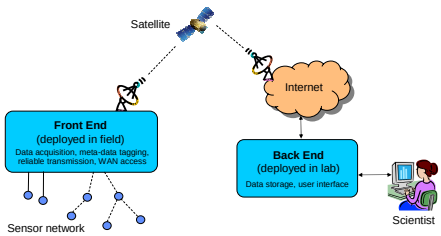
- **Remote location**
  - Minimal site infrastructure
- **Allow multiple researchers to collaborate**
  - Share common infrastructure
    - Communication link
    - Site data acquisition and storage device
    - Basic site climate measurements
  - Monitor different species of trees and shrubs
    - Increases geographic and topographic range

Engineering Requirements

- **Support heterogeneous set of sensors**
  - Different manufacturers and electrical interfaces
- **Near real-time access to data**
  - Need reliable data transfer over unreliable communication links
  - Scientist may adjust parameters (e.g. sampling rate) in response to external or measured factors
  - Allow prompt diagnosis of component failures
    - Minimize potential gaps in the data

Proposed Solution: Sensor Processing and Acquisition Network (SPAN)

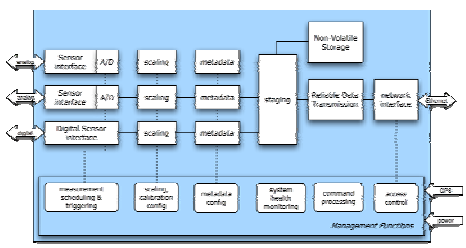
SPAN Architecture and Protocols

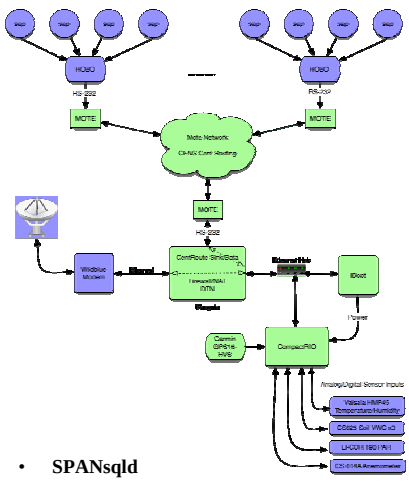


- **SPAN Architecture**
  - Front end components (deployed in the field) are connected to back end (lab) via satellite link
  - Data acquisition platform
    - Technology has matured enough for scientists to deploy flexible sensor network systems. More than a data logger, this robust, user configurable, core technology component allows flexible field deployments with support for analog, digital, serial, and networked sensors.
  - Local wireless enables geographic extensibility
- **SPAN Protocols**
  - Data
    - Based on the NEES protocol, extended to support richer API
    - Metadata insertion for traceability
    - Stores data locally if not connected to back end
    - Data is transferred reliably
  - Command
    - Unified API to control different sensors
    - Obtain metadata for each channel (sensor make, model, etc)
    - Enable or disable channels
    - Configure channel method and sampling frequency
  - Status
    - Users can query platform for status
    - System can send notifications when certain conditions are detected

Deployment at Stunt Ranch

- **SAP sensors**
  - Constant-heating sap flow sensors to continuously monitor the flow of water through the xylem of replicated stems of different plant species to compare their access to soil moisture with plant water stress
- **HOBO data logger**
  - Collects data from sap sensors, performs A/D conversions
- **Motes**
  - Obtain measurements from the HOBO data loggers
  - Uses CENS Cent route for transmitting measurements to gateway
- **Mote network gateway (Stargate)**
  - Network server code which transmits sensor data to CompactRIO
- **CompactRIO**
  - Leveraged on code developed for the NEON Project
    - First version deployed at James Reserve in February 2007
  - Features added since first deployment
    - Operational reliability improved via new data queuing and memory management approach
    - Framework to support integration of diverse set of sensors
    - Client network code which retrieves data from mote network
    - Improved support for GPS
    - Enhanced reliability including inactivity-timeouts on network connections
- **Router (Stargate)**
  - Scripts initialize router and firewall software





- **SPANsqld**
  - Contacts CompactRIO and collects data and status
  - Stores measurements in local MySQL database
- **User interfaces**
  - MyPHPadmin allows easy data query and visualization
  - Nagios is used to monitor system health and notify users
  - Sensorbase interface for data sharing and use by scientists
- **Sample data from bench system**

Timestamp	From Channel	On Platform	Numerical Data	String Data
2007-09-07 21:31:14.0	HMP45T	cns-webbie	24.5140361785889	2.45140366442E+1
2007-09-07 21:30:44.0	HMP45T	cns-webbie	21.8951678276062	2.18951679942E+1
2007-09-07 21:30:14.0	HMP45T	cns-webbie	20.3228592872	2.03228585553E+1
2007-09-07 21:29:44.0	HMP45T	cns-webbie	20.3406476974487	2.03406470952E+1
2007-09-07 21:29:13.0	HMP45T	cns-webbie	20.3462481498718	2.03462471912E+1
2007-09-07 21:28:43.0	HMP45T	cns-webbie	20.3597521781921	2.03597533062E+1
2007-09-07 21:28:13.0	HMP45T	cns-webbie	20.3422951698303	2.03422941822E+1
2007-09-07 21:27:42.0	HMP45T	cns-webbie	20.4009294509888	2.04009304062E+1
2007-09-07 21:27:12.0	HMP45T	cns-webbie	20.2981519699097	2.02981522452E+1
2007-09-07 21:26:42.0	HMP45T	cns-webbie	20.3080344200134	2.03080347682E+1
2007-09-07 21:26:12.0	HMP45T	cns-webbie	20.3790484802246	2.03790477702E+1
2007-09-07 21:25:41.0	HMP45T	cns-webbie	20.3996133804321	2.03996128162E+1