Toward embedded sensor networks in north temperate lakes

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Single, expensive buoy
Several, intermediate cost buoys
Hundreds of cheap, special-purpose, networked sensors
The LTER Network

- AND = Andrews Experimental Forest
- ARC = Arctic Tundra
- BES = Baltimore Ecosystem Study
- BNZ = Bonanza Creek
- CAP = Central Arizona Phoenix
- CDR = Cedar Creek Reserve
- CWT = Coweeta Hydrologic Lab
- FCE = Florida Coastal/Everglades
- GCE = Georgia Coastal Ecosystems
- HBR = Hubbard Brook
- HFR = Harvard Forest
- JRN = Jornada Basin
- KBS = Kellogg Biological Station
- KNZ = Konza Prairie Reserve
- LUQ = Luquillo Experimental Forest
- MCM = McMurdo Dry Valleys
- NET = Network Office
- NTL = North Temperate Lakes
- NWT = Niwot Ridge
- PAL = Palmer Station
- PIE = Plum Island Estuary
- SBC = Santa Barbara Coastal
- SEV = Sevilleta
- SGS = Shortgrass Steppe
- VCR = Virginia Coast Reserve
People in the Field
Current networking

- T1 connection
- Cat5 LAN w/servers, bunch of workstations
- 802.11b wireless network
  - cloud around lab
  - research use
- 900 MHz serial
Our uses of wireless networking

- Typical LAN communication
- Fish crews and PDAs
  - identification
  - data entry, QA/QC, upload
- Remote buoys
  - Permanent deployments
  - Roving deployments
- Embedded sensor networks
Ethernet spread spectrum communication

Serial spread spectrum communication

Meteorology and temperature profile buoy

Serial spread spectrum communication

Lake metabolism buoy

Serial spread spectrum communication

Ethernet spread spectrum communication

Vertical profiling buoy
3) Large profiling buoy
Portable Lake Metabolism Buoys
Oracle

Text file on Trout Fileserver

Sparkling Lake Raft
Date: 92 of 2002
Time: 1600

Air Temp: 0 °C
Surf Temp: 0

Depth
Temperature (Celcius)
5 10 15 20

Text file on Trout Fileserver
Sensors

Control/logging

Communication

Data processing

Archive/analysis
Immediate needs

Better infrastructure to leverage human effort
  Field crews
  Less time from field to DB
  Fewer errors

Better power management
  Demands of power-hungry sensors
  Higher sampling frequencies
  Less maintenance/loss of data
Trends in ecosystem research demand…

1. Technology co-evolves with ecosystem questions

2. We expand from our experience in…
   1. humans scales – days, weeks, months, long-term, and few lakes
   2. fair weather
   3. modeling other scales to identified key research

3. And move toward…
   1. scaling to regions
   2. short temporal
   3. multiple dimensions
   4. any weather conditions
Our state of the art: Embedded wireless sensing systems

1. Inexpensive sensors coupled with microcontrollers (e.g., XBow chips)
2. Network topology changes, including higher node densities, and reliable communication
3. Applications of artificial intelligence (AI)
4. Evolving ecosystems questions
Hydrodynamic processes, as driven by weather
Storms => mixing => lake metabolism
develop an intelligent environmental sensing network capable of detecting episodic environmental events and their consequences to lake dynamics
Figure 4. Protocol stacks and key strategies for energy conservation addressed in this proposal.

- Sleep-wake cycles based on task
- Data compression

- Multiple routes/Multiple descriptions
- Network flow formulation
- Routing with many sleeping nodes

- Power control
- Forward error correction
- Radio range management
Figure 7. The command and control system (CCS) orchestrates data acquisition, intelligent agents, and data QA/QC. The CCS is a distributed collection of middleware that hooks-up with web services. The system includes:

- **User Interface**
  - "live" data and sensor status
  - dynamic db query

- **Intelligent Agent**
  - detect events
  - adjust sampling protocols
  - perform data QA/QC

- **Oracle Database**

- **Retriever Controller**
  - send/receive data stream
  - upload to database

The CCS communicates with buoy data and sampling protocols through web services.
Where to from here?

Better power sources
More radio range or higher node densities
Communication among sensors
Scalable systems
People