Title

SYS7: CENS Systems-Infrastructure Overview

Authors

Richard Guy
Mohammad Rahimi
Karen Weeks
et al.

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Center for Embedded Networked Sensing

Systems Infrastructure Overview

Richard Guy, Mohammad Rahimi, Karen Weeks, Vineet Agarwal, Naim Busek, Lewis Girod, Ben Greenstein, Sam Irvine, Rahul Kapur, Martin Lukac, Andrew Parker, Nithya Ramanathan, Tom Schoellhammer, Thanos Stathopoulos, Jeff Tseng, Hanbiao Wang, Deborah Estrin

CENS Systems Lab - http://lecs.cs.ucla.edu

Introduction: Sensor network applications development/deployment is complex

Effective ENS requires end-to-end systems

- **Sensor, sensor host, gateway, database, user interface**
  - some COTS, some research, some reusable, some missing
- **Development requirements different from deployment needs**
- **More complex than domain scientist is prepared to construct**

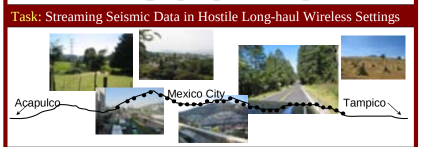
Need to explore what's needed, what's not

- **What software is common to all/most/some/few domains?**
- **What is reusable from previous distributed systems work?**
- **What is unique to embedded networked sensing?**
  - What deployment management tools are required?

Accomplishments: Significant development/deployment in three domains + core foundation

Seismic

Task: Streaming Seismic Data in Hostile Long-haul Wireless Settings



Problem Description: End-to-end protocols are unsuitable for partially operable network

- **String of 50 hard-to-access sensor stations**
- **Long-haul (5-15km) 802.11b links**
  - Weather; forest; RF noise
- **Limited power at each station**
  - 10 days' worth of battery (+ solar)
- **Limited per-station storage capacity**
  - 40 station-days available

Solution: Hop-by-hop transport with end-to-end acks

- **Capture/package raw sensor data, 3MB/hour**
  - Push chunks opportunistically towards gateway
  - Drive-by collection at some sub-strings
  - Standalone urban nodes with direct Internet link
- **End-to-end checksum for integrity**
- **End-to-end storage reclamation acks**
- **Bulk data conversion at UCLA archive**
  - To industry standard MiniSEED data format

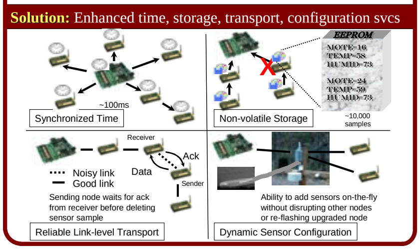
Micro-Climate

Task: Deploy several micro-climate/habitat embedded sensor networks

Problem Description: Prototype deployments showed need for enhanced disconnected behavior & flexible sensor configuration

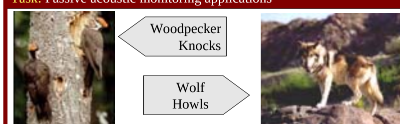
- **Poor/no wireless connectivity is common, not rare**
  - Can exist for extended periods (hours, days)
- **Need sensor nodes to store many data samples**
  - But have limited RAM; no useful concept of time
- **Initial data results can motivate rearrangement of sensors, or additional sensors**
  - Including new prototype sensors from sensor groups

Solution: Enhanced time, storage, transport, configuration svcs



Acoustic

Task: Passive acoustic monitoring applications



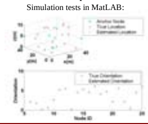
Problem Description: Self-localization, self-calibration needed for collaborative acoustic monitoring

- **Precise synchronization across sampled channels**
  - Required for accurate direction of arrival (DOA)
- **Acoustic localization system**
  - Based on time of flight (TOF) of acoustic signals
- **3-D localization/orientation of microphone arrays**
  - Required for 3-D target localization via bearing-crossing
  - Hard to obtain/maintain in field; bumping implies re-localization

Solution: Acoustic ENSBox: portable acoustic monitoring box

- **Main Objectives**
  - Synchronized acoustic sampling
  - 12-24 Hour lifetime on batteries
  - Water-resistant enclosure
- **Hardware Features**
  - Stargate CPU
  - 4 Channel VXP440 sampling card (16 bit/48K)
  - Internal LI+ battery pack
  - Audio mic preamps (TI OPA726) and speaker amplifier (COTS speaker)
  - RTI 1207A condenser mic capsule
- **Acoustic performance**
  - Speaker/Mic/Sampling system response
  - Preamp and microphone module are selected to have a very flat frequency response

- **Acoustic Ranging Component**
  - In-lab tests with 4 nodes
  - In line of sight (LOS) conditions, achieves accuracy to a centimeter
  - Multipath and obstructions can introduce larger errors which can be persistent aspects of the environment
- **Localization Component**
  - Simulation tests in MatLAB:



Emstar

The Need: A software framework for design, development, deployment, and operation of heterogeneous ESNs

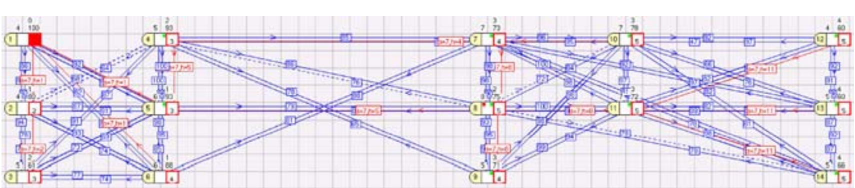
- **Sensor network software tends to be monolithic**
  - Need more component re-usability, without inflexible layered stack
- **Sensor network systems tend to be language-specific**
  - Difficult to leverage components from other ENS software systems
  - Integration of binary images not generally supported
- **Sensor networks are notoriously invisible**
  - Very difficult to 'see' inside an operational in-situ ESN

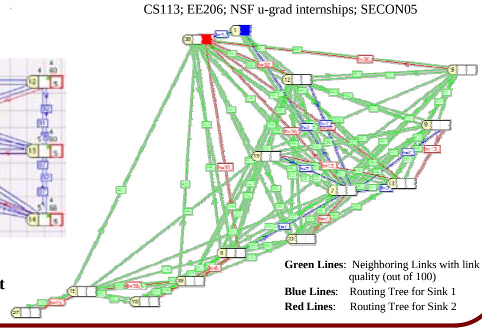
The Solution: The Emstar family of extensible/reusable tools, services, and libraries

- **Tools (simulation, emulation, visibility)**
  - EmSim/EmCee, EmRun, EmView/EmProxy
- **Services (network, time, IPC,**
  - Link/neighborhood estimation; time synchronization; routing; IPC device abstractions; HostMote/MoteNIC
- **Libraries**
  - General purpose utility routines; domain-specific routines

Status: Emstar is maturing from a single-lab tool, to a widely-adopted development environment.

- **Used by >100 active users (support list e-mail)**
  - 21 universities, 11 companies, 11 countries, 5 continents
  - > 1,000 downloads April 1-June 15, 2005
- **Major effort to improve documentation**
  - Better how-to documents, tutorials, class materials
- **Workshops at UCLA, ESN conferences**
  - CS113; EE206; NSF u-grad internships; SECON05





Visualization tools examples

Can easily collect node-by-node data of various metrics

Can easily display in 2-D graphical form the ESN layout/metrics

Above: display of Boelter Hall ceiling testbed

Right: James Reserve systems research transect

Green Lines: Neighboring Links with link quality (out of 100)

Blue Lines: Routing Tree for Sink 1

Red Lines: Routing Tree for Sink 2