Design Space and Applications of Sensor Networks

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What is a Sensor Network?

- De-facto definition by early US-based research projects (Smart Dust, NEST, ...)
  - Deployment: random
  - Mobility: static nodes
  - Size/resources/cost: tiny/constrained/cheap
  - Heterogeneity: identical nodes
  - Infrastructure: none, ad hoc
  - Connectivity: connected network
  - Coverage: dense
  - Size: thousands of nodes
  - Lifetime: years

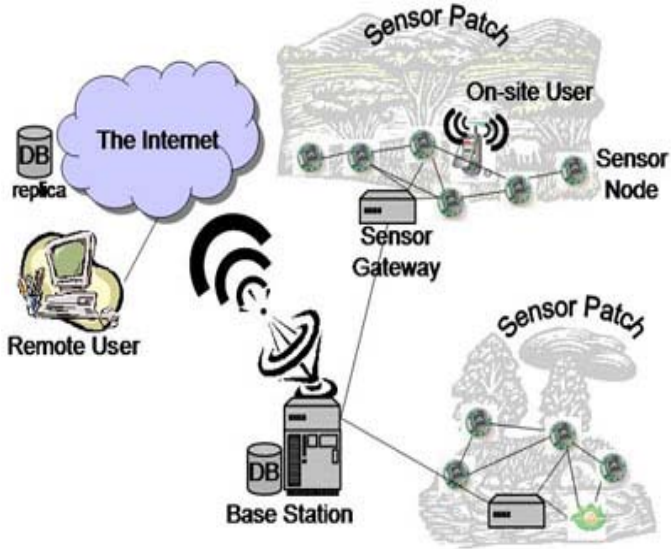
… and Reality?

- Is this definition matched by concrete existing applications?
- Why is this important?
  - Identify opportunities for future research
  - Generic hardware and software for a wide range of applications
  - Collaborative research
  - Background: ESF workshop in April 2004
- This talk
  - Examines concrete applications
  - Explores the design space of sensor networks
  - Discuss implications

Applications

Bird Observation

- Nesting behavior of birds
  - Occupancy of nesting burrows
  - Nodes in nesting burrows and on the ground
- Features
  - Deployment: manual
  - Heterogeneity: wheather, burrow, gateways
  - Topology: star of clusters



[www.greatduckisland.net]

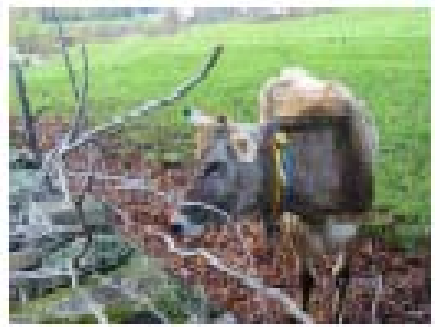
ZebraNet

- Bahaviour of wild animals
  - Activity patterns, grouping behavior
  - Nodes worn by animals
  - Mobile base station
- Features
  - Mobility: mobile
  - Connectivity: sporadic
  - Infrastructure: GPS, mobile base station

[www.princeton.edu/~mrm/zebranet.html]

Cattle Herding

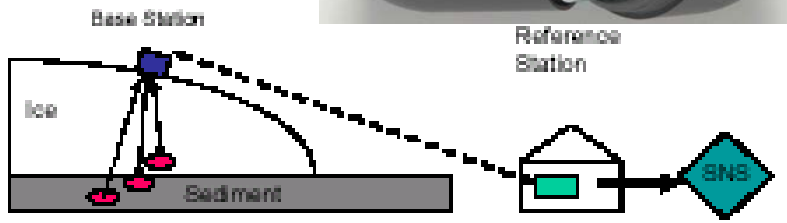
- Virtual fence lines
  - Improved usage of feedlots
  - Reduced overhead (physical fences)
  - Sensor nodes attached to cows, can provide acoustic stimulus
- Features
  - Mobility: mobile
  - Connectivity: intermittent



[WAMES 2004]

Glacier Monitoring

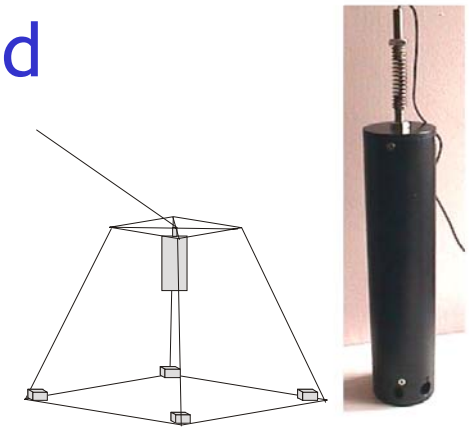
- Monitor sub-glacier environments
  - Displacements, intra-glacier dynamics
  - Nodes deployed in drill holes
  - Base station on top of glacier
- Features
  - Node size: brick
  - Infrastructure: diff GPS, GSM
  - Topology: star
  - Network size: tens



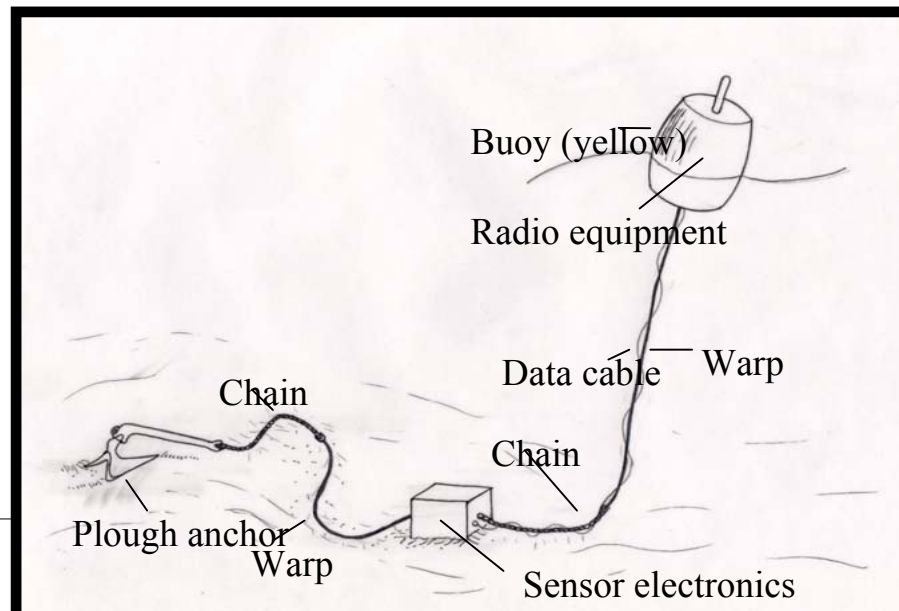
[envisense.org/glacsweb]

Bathymetry

- Impact of a wind farm on environment
  - Structure of ocean ground (sand banks, tidal activity)
  - Sensor nodes on ocean ground connected to buoy



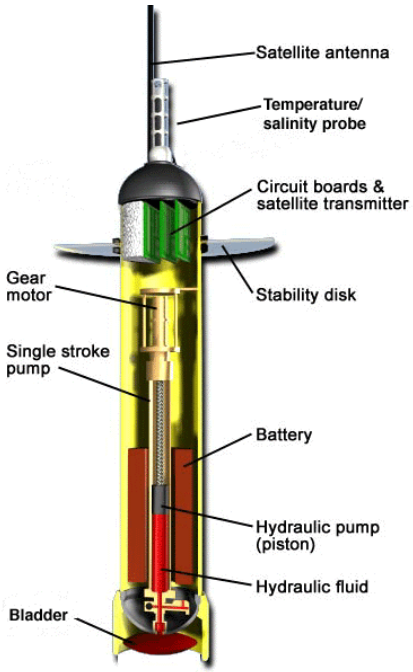
- Features
  - Node size: bricks
  - Infrastructure: GPS

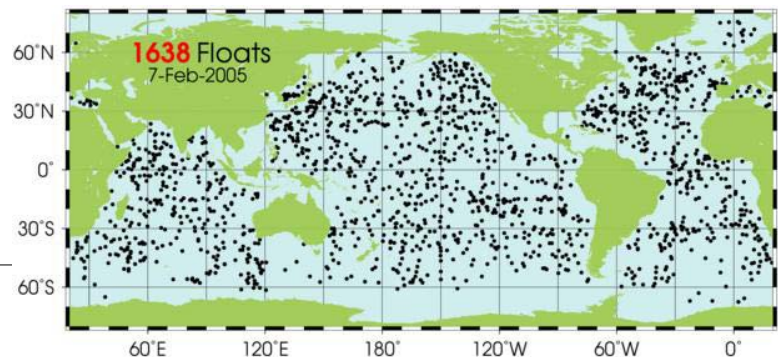


[envisense.org/secoas.htm]

Ocean Monitoring

- State of the upper ocean
  - Temperature, salinity, current profile
  - 1500 free-drifting sensors
  - Cycle to 2000 m depth every 10 days
  - Satellite communication
- Features
  - Node cost: 15000 USD
  - Node size: brick
  - Mobility: mobile
  - Connectivity: sporadic
  - Infrastructure: satellite
  - Topology: star
  - Depolyment: iterative

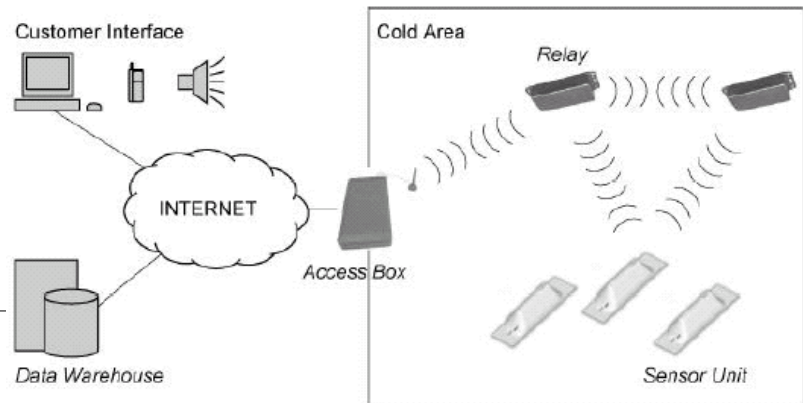




[www.argo.ucsd.edu]

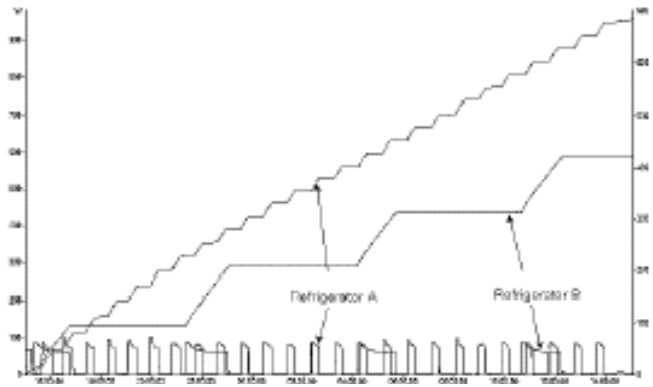
Cold Chain Mgmt.

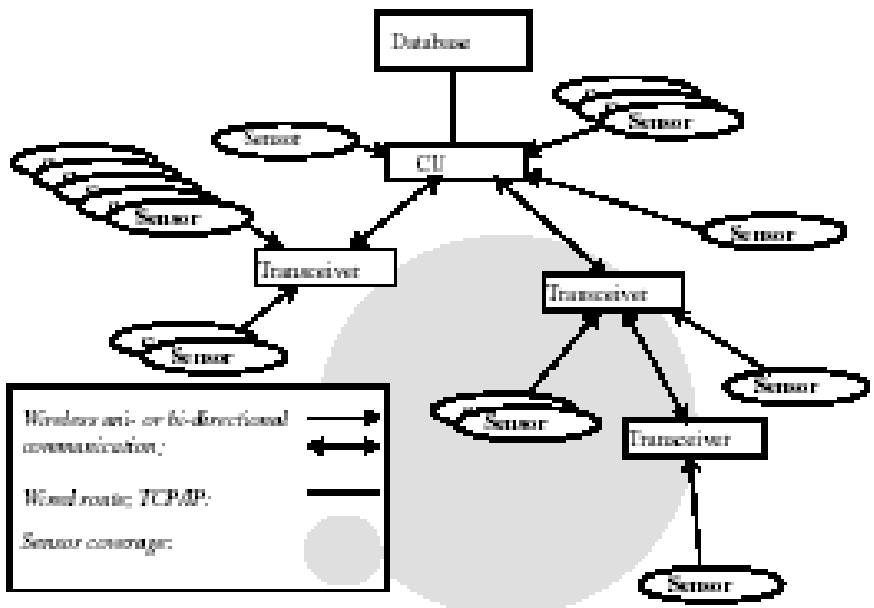
- Temperature compliance of cold chains
  - Temperature of goods from production, via distribution centers, stores, to consumer
  - Sensors transported with goods
  - Relay units (interconnect sensors)
  - Access box (gateway to Internet)
  - Central ware house
- Features
  - Mobility: mobile
  - Connectivity: intermittent
  - Heterogeneity: sensors, relays, access boxes



Power Monitoring

- Monitor power consumption in office buildings
  - Sensor nodes attached to outlets
  - Transceivers, central unit
- Features
  - Powered from power grid
  - Heterogeneity

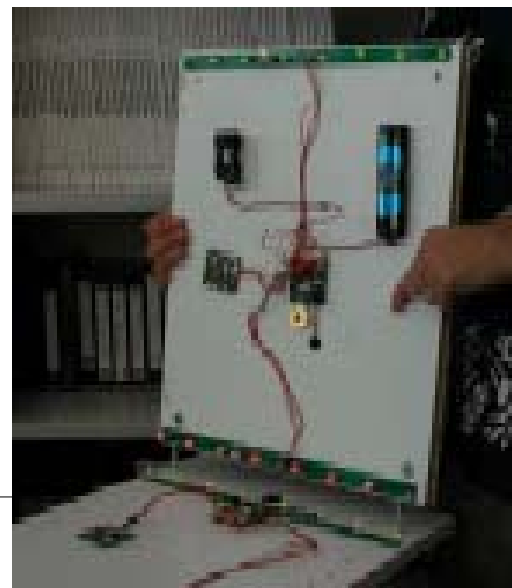




[EWSN 2004]

Parts Assembly

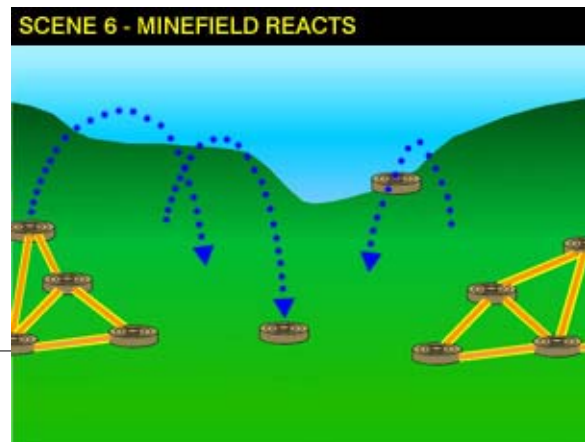
- Assist users in assembly of composite objects
  - E.g., do-it-yourself furniture
  - Sensors integrated into parts and tools
  - Optical feedback
- Features
  - Heterogeneity: tools, different sensors
  - Lifetime: hours
  - Network size: tens
  - Topology: single hop



[www.vision.ethz.ch/projects/furniture]

Self-Healing Mine Field

- Anti-tank landmines automatically ensure coverage
  - Hop into breach line using rocket thrusters
  - Avoid use of anti-person landmindes
- Features
  - Mobility: active mobility
  - Node size: brick



[www.darpa.mil/ato/programs/SHM]

Design Space

Design Space I

- Deployment
  - Manual vs. Random
  - One-time vs. Iterative
- Mobility
  - Immobile vs. Partly vs. All
  - Occasional vs. Continuous
  - Active vs. Passive
- Cost, size, resources, energy
  - Brick, matchbox, grain, dust
- Heterogeneity
  - Homogeneous vs. Heterogeneous

Design Space II

- Infrastructure
  - Infrastructure vs. Ad hoc
- Network topology
  - Single-hop vs. Star vs. Tree vs. Graph
- Connectivity
  - Connected vs. Intermittent vs. Sporadic
- Coverage
  - Sparse vs. Dense vs. Redundant

Design Space III

- Network size
  - Tens to thousands
- Lifetime
  - Hours to years
- Other QoS requirements
  - Real-time constraints
  - Robustness
  - Tamper resistance
  - Unobtrusiveness
  - Stealth

Implications

Implications - Hardware

- Cover design space with hardware platforms
  - Are custom designs avoidable?
  - Modular approaches?
  - What is a sufficient set of platforms?
- Selection/composition of a suitable platform
  - Based on application requirements
  - Can this be automated?

Implications - Software

- Consistent programming across the design space
  - Suitable programming models and middleware abstractions?
  - Overhead of such abstractions?
  - What about cross-layer optimizations?
- A service-centric approach?
  - Service interfaces would include methods to specify appl. requirements
  - Automatic selection of appropriate service implementations

Further Implications

- Certain regions in the design space not covered by existing solutions
  - Opportunities for future research
- WSN is a multi-disciplinary research area
  - Cooperation of users, appl. domain experts, hardware designers, software developers
  - An explicit design space may help to coordinate research cooperation

Summary

- „Traditional definition“ of WSN not matched by many concrete applications
- Motivation for an explicit design space
- Implications on
  - Hardware platforms
  - Software techniques
  - Collaborative research
- Details
  - K. Römer, F. Mattern: „The Design Space of Wireless Sensor Networks“, IEEE Wireless Communications, Vol. 11 No. 6, Dec. 2004
  - ESF Workshop: www.vs.inf.ethz.ch/events/esf-wsn04

Ads

- Fachgespräch Sensornetze
  - ETH Zurich, March 23/24
  - www.fachgespraech-sensornetze.de
- Summer School on Sensor Networks and Smart Objects
  - Schloss Dagstuhl, Aug 28 – Sept 3
  - www.vs.inf.ethz.ch/events/dag2005