SenseWeb: Wikipedia of Sensors

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Microsoft Research

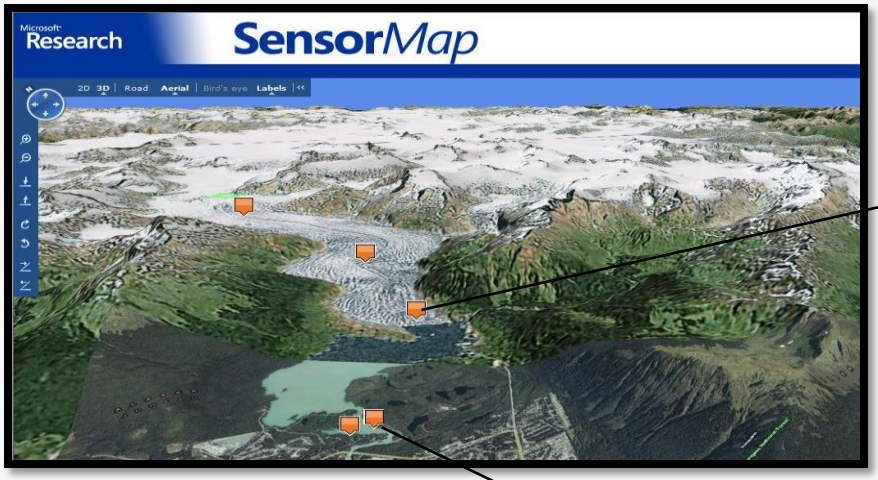
Instrumentation Is Hard

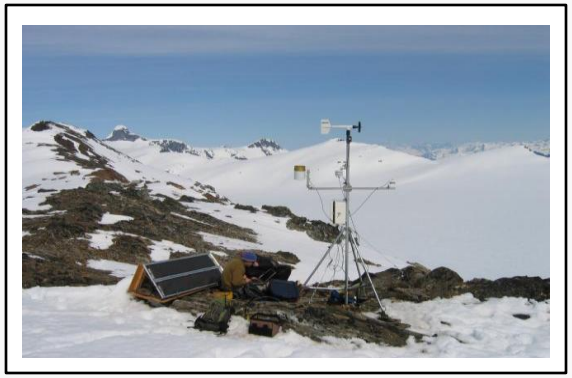
1. Share *data*
   - Swivel, Sloan sky survey, Fluxdata.org, BWC Data Server
2. Deploy macro-scopes
   - Addresses few domains

3. Share all ***instrumentation***: SenseWeb

SenseWeb Example

Scientists in Alaska (NASA, NOAA, UAS)





SenseWeb Example

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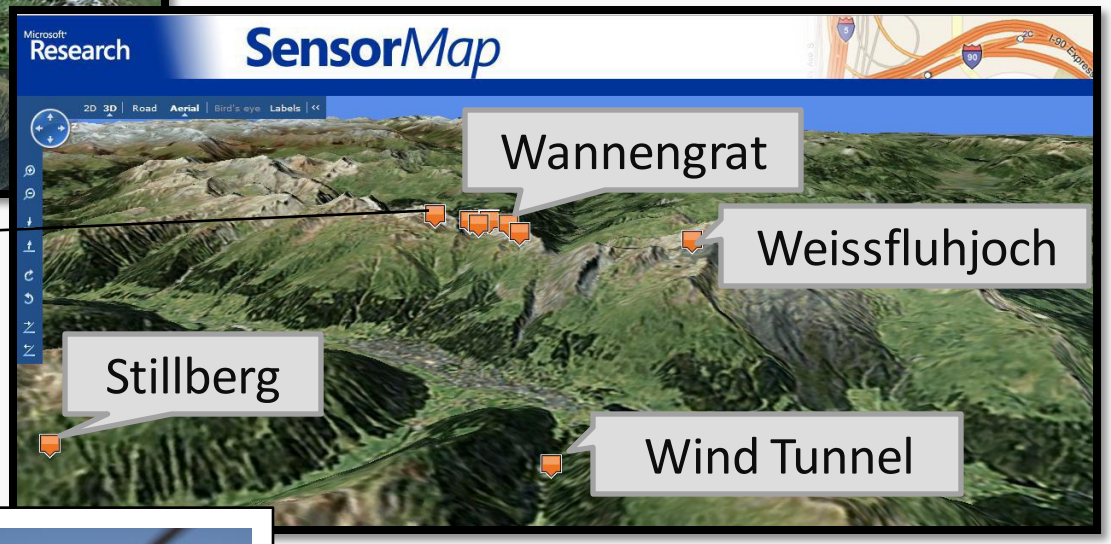

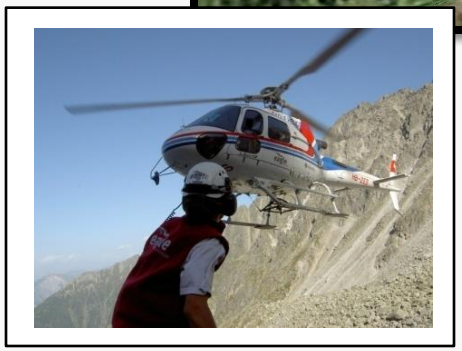

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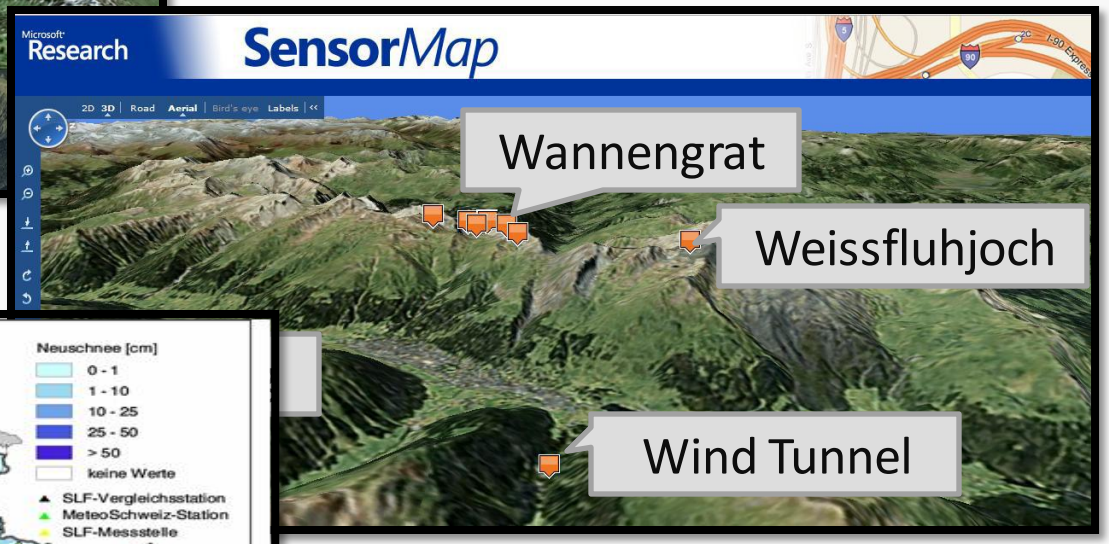
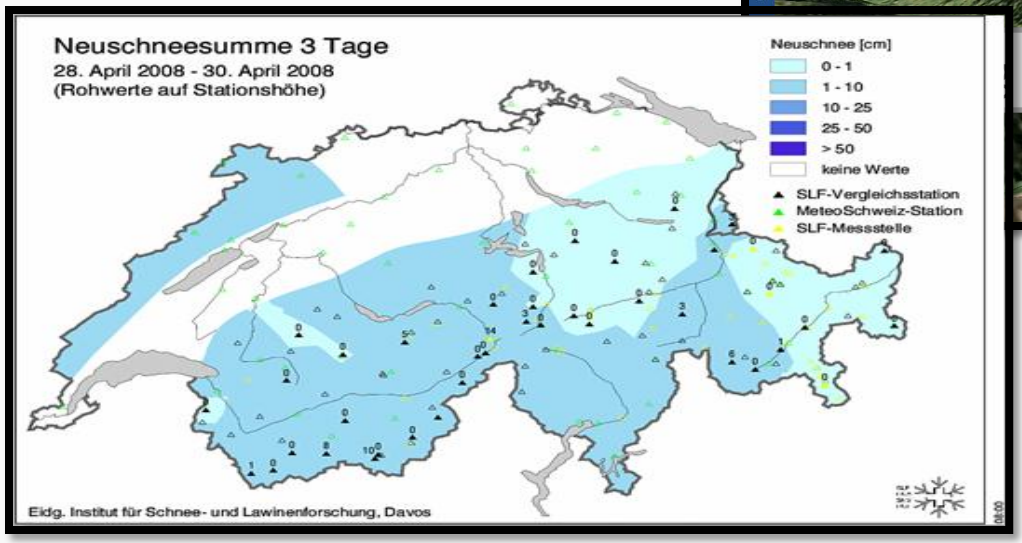
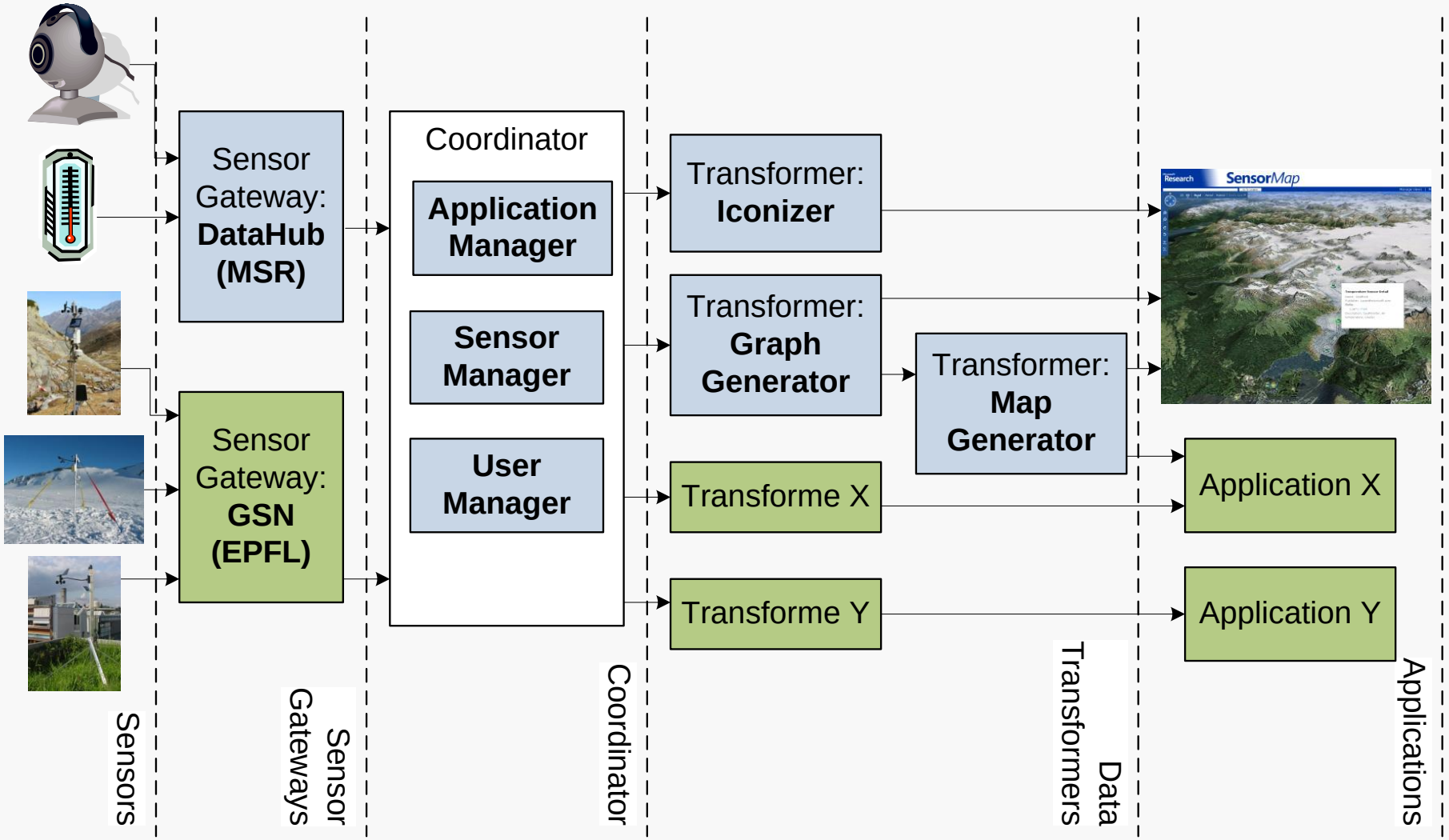


Swiss Snow and Avalanche Info (SLF)



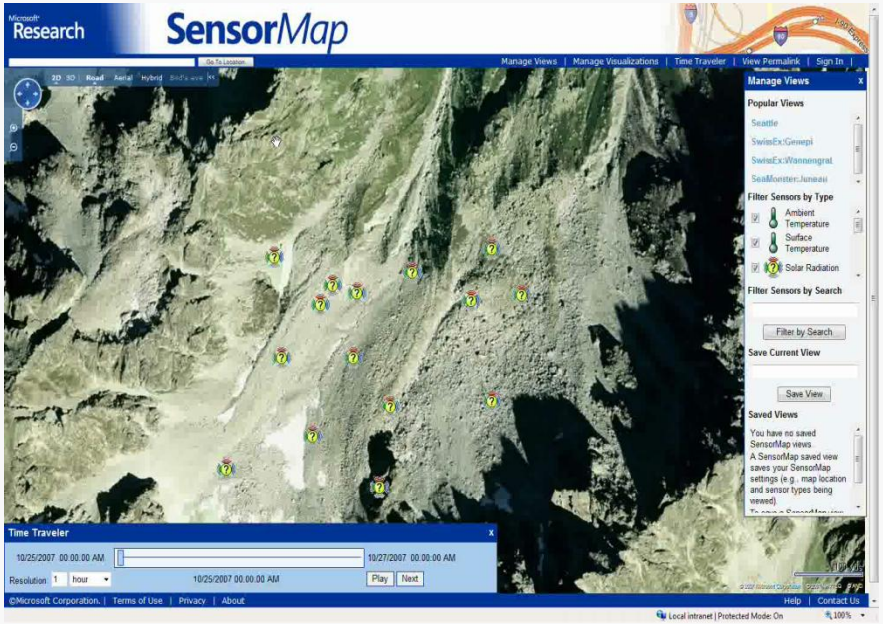
System Design

SenseWeb: System Design



SenseWeb: Front-end

- In situ data analysis
- Discover correlations, dependencies, and distributions
  - Comparison chart, Contour maps, temporal exploration



http://atom.research.microsoft.com/sensormap/

Design Challenges

Heterogeneity

- Capability: bandwidth, power, computation
- Willingness to share
- Measurement accuracy

Scalability

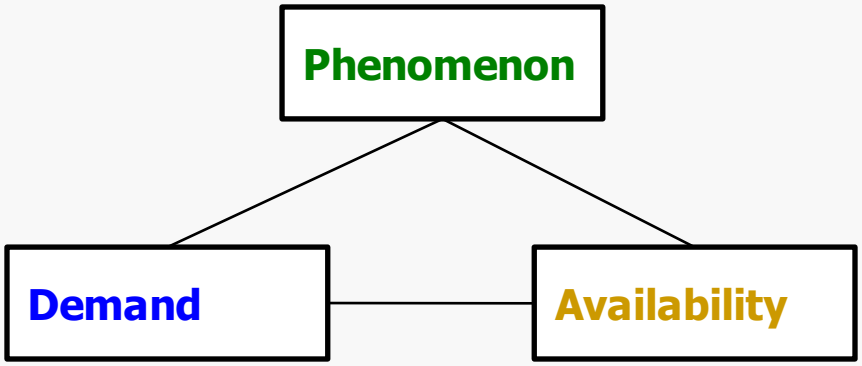
- Streaming all raw data from all sensors to all applications not feasible

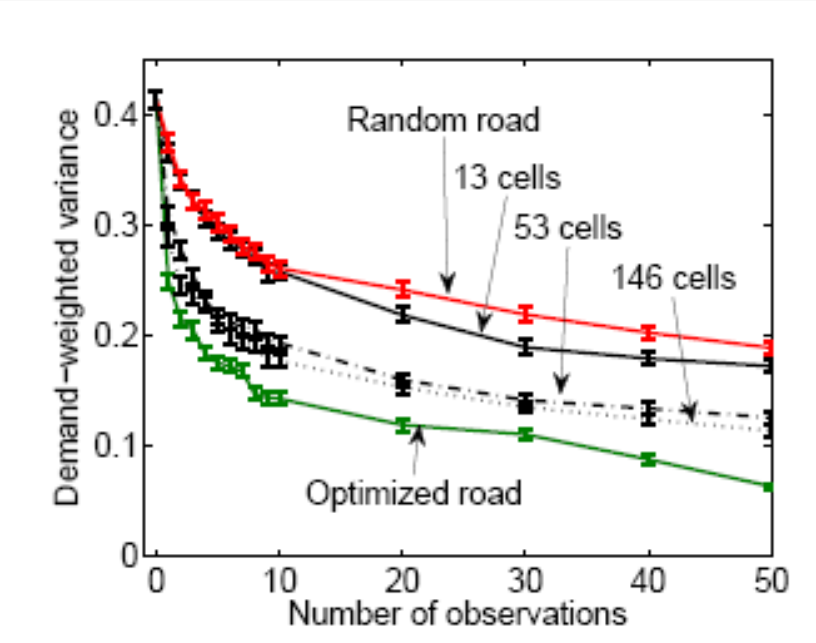
Security and Privacy

Data Verifiability, Trust

Minimize Sensor Probes

- Consider value of probing sensors
  - **Information value** (collapse uncertainty)
  - **Demand** (usage: "utilitarian" impact)
- Sensor availability
  - **Predict** based on history
- Preferences
  - **Abide by preferences** (Eg. Privacy)

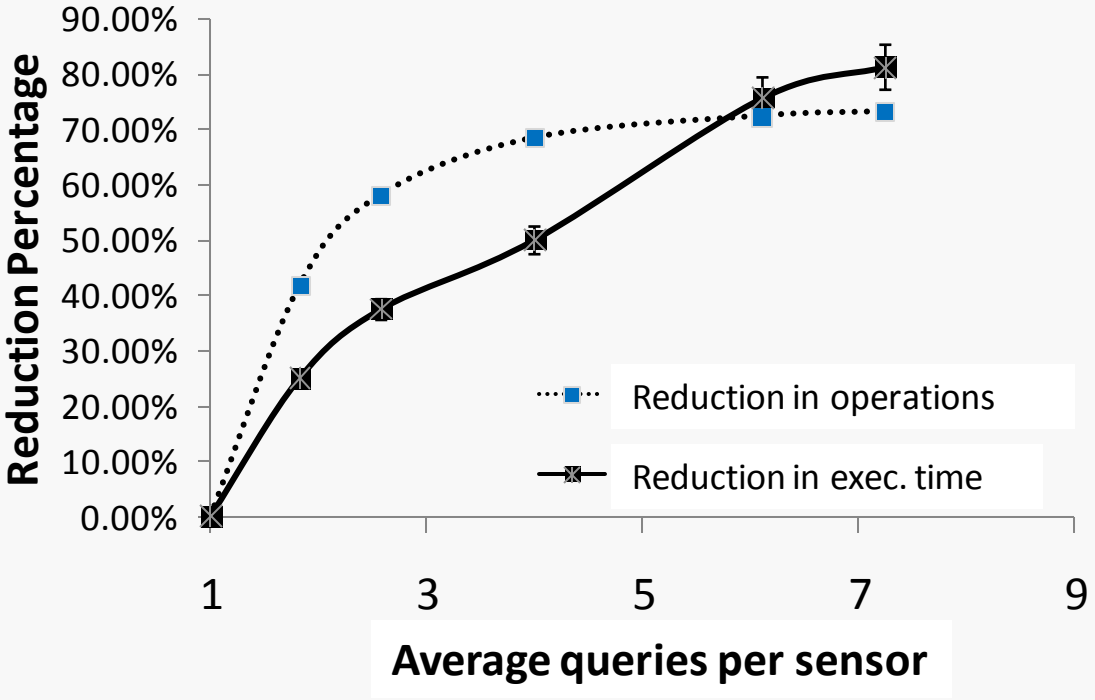




Details: Krause et al, "Towards Community Sensing," IPSN 2008.

Streaming Multiple Sensors to Multiple Applications

- Detect overlap
  - In sensors used
  - In computation performed on streams
    - Including intermediate steps



Details:

1. Ahmad et al, "COLR-Tree: Communication-Efficient Spatio-Temporal Indexing for a Sensor Data Web Portal", *ICDE 2008* [BEST RESEARCH PAPER]

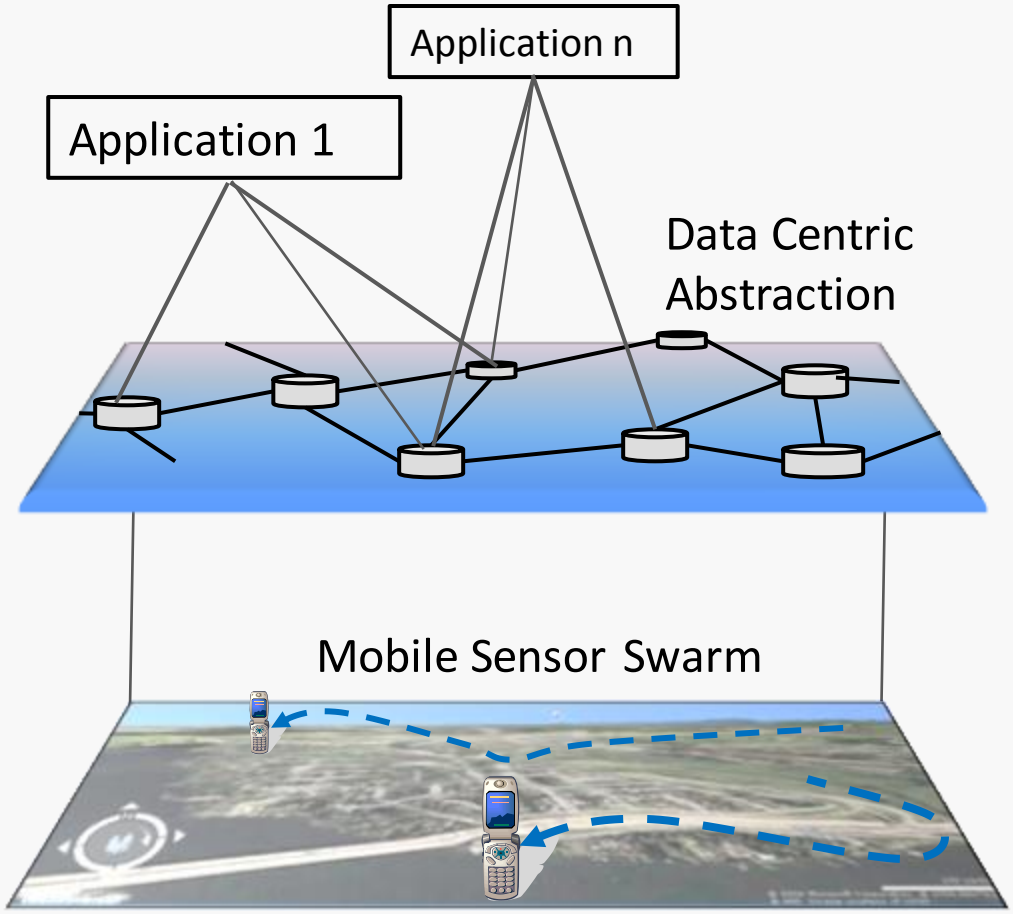
2. Tavakoli et al, "Online Sensing Task Optimization in Shared Sensing Infrastructures," submitted.

Mobile Contributors in SenseWeb

+ More coverage

- Hard for application to track relevant devices

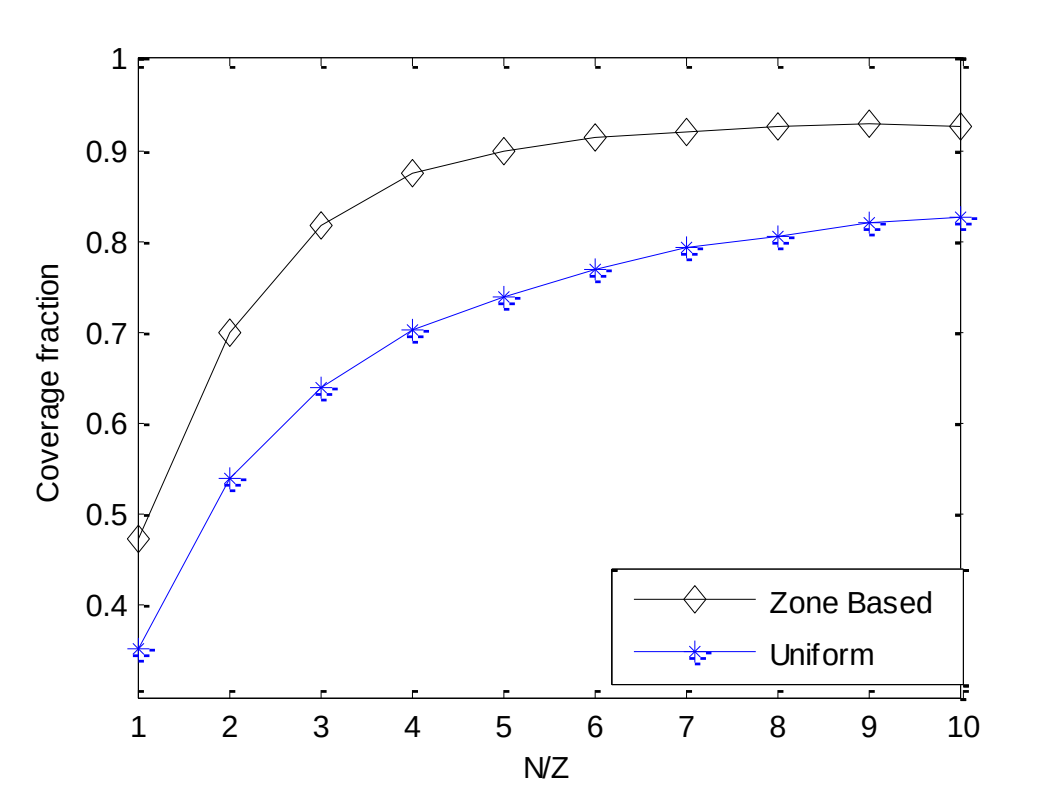
- **Solution:** data centric abstraction
  - Location based indexing
    - using GPS, cell-tower triangulation, content based location



Using Data Centric Abstraction

Tests run on real world dataset (Bellevue street traffic).

N/Z: number of sensors per zone
Note: For similar coverage, the number of sensors needed is much less with data centric abstraction



Details:

1. Kansal et al, "Location and Mobility in a Sensor Network of Mobile Phones," NOSSDAV 2007.
2. Kansal et al, "Building a Sensor Network of Mobile Phones," IPSN (Demo) 2007.

Other Technical Challenges

- Enhance visualization performance in SensorMap
  - Details: ACM GIS 2008
- Tasking sensors efficiently
  - Share probing load by sensor quality, resource availability, and application tolerance (in submission)
- Preserve query response accuracy
  - Ensure gateway has included all sensors available in its calculation

SenseWeb: Collaborative R&D

Collaborative Engagements

- 11 universities funded through Microsoft External Research Request for Proposals
- Additional universities and scientific/government agencies involved through SenseWeb usage

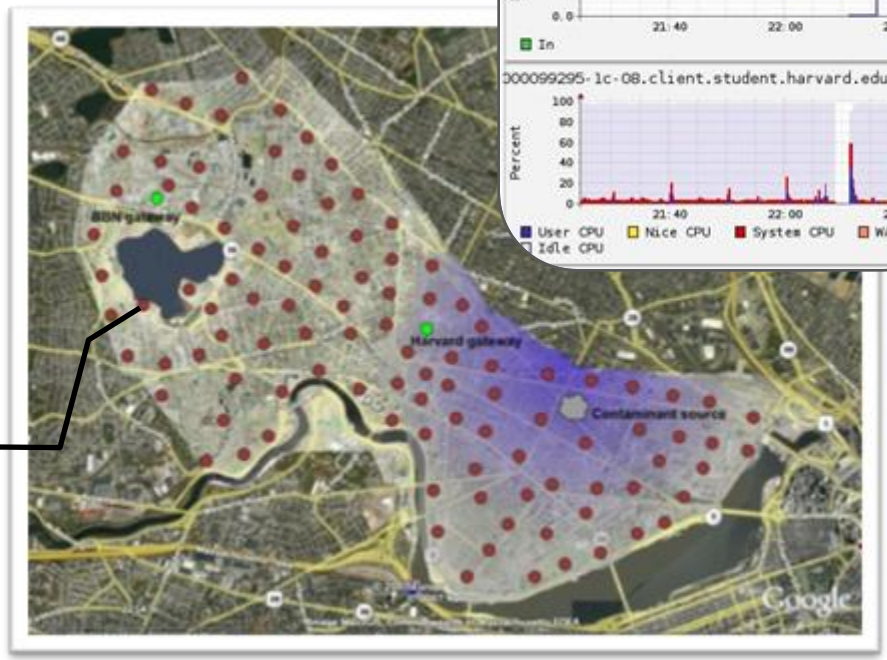
Nanyang Technological University: NWS

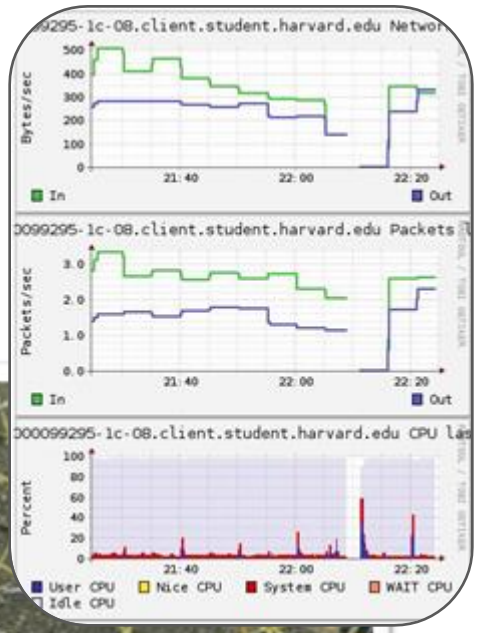
NANYANG TECHNOLOGICAL UNIVERSITY

- National Weather Study: mini weather stations in schools throughout Singapore

Harvard: CitySense

- Large scale urban monitoring
- Network health sensing
- Urban environment sensing

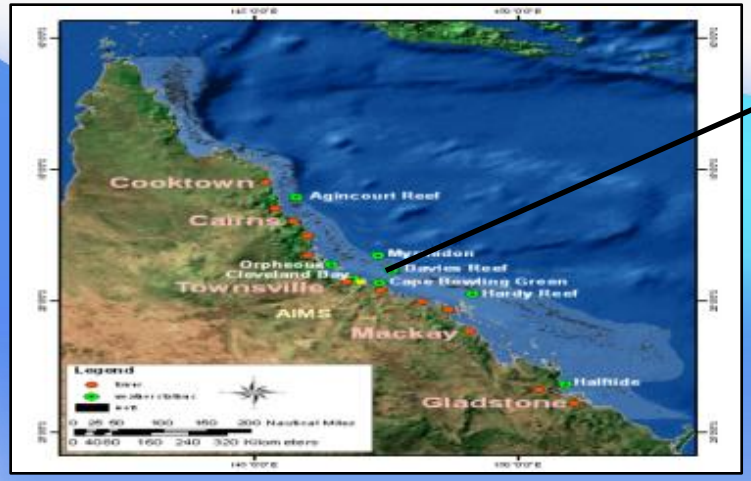


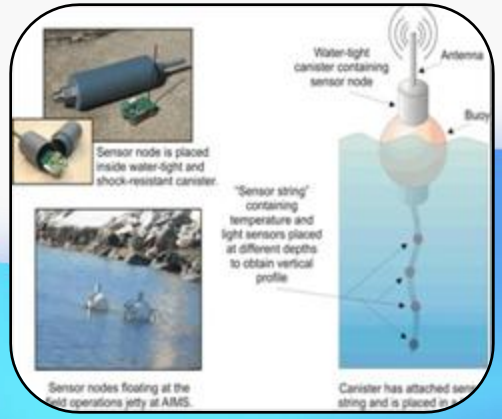


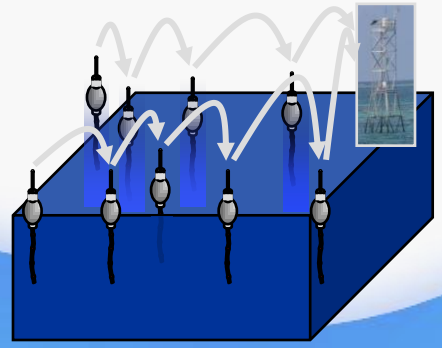
U. Melbourne: Great Barrier Reef

THE UNIVERSITY OF MELBOURNE

- coral reef ecosystems: early indicators of climate change and human influence







Feng Chia U/Tsing Hua U: Debris Flow

Debris flow sensing

- 921 earthquake in 1999 caused land collapse
- Crevices formed in rocks and soil: typhoons and surface runoff causes debris flows
- Debris flows cause severe damage to the land, property, and life.

Debris Flow sensor

Geophone

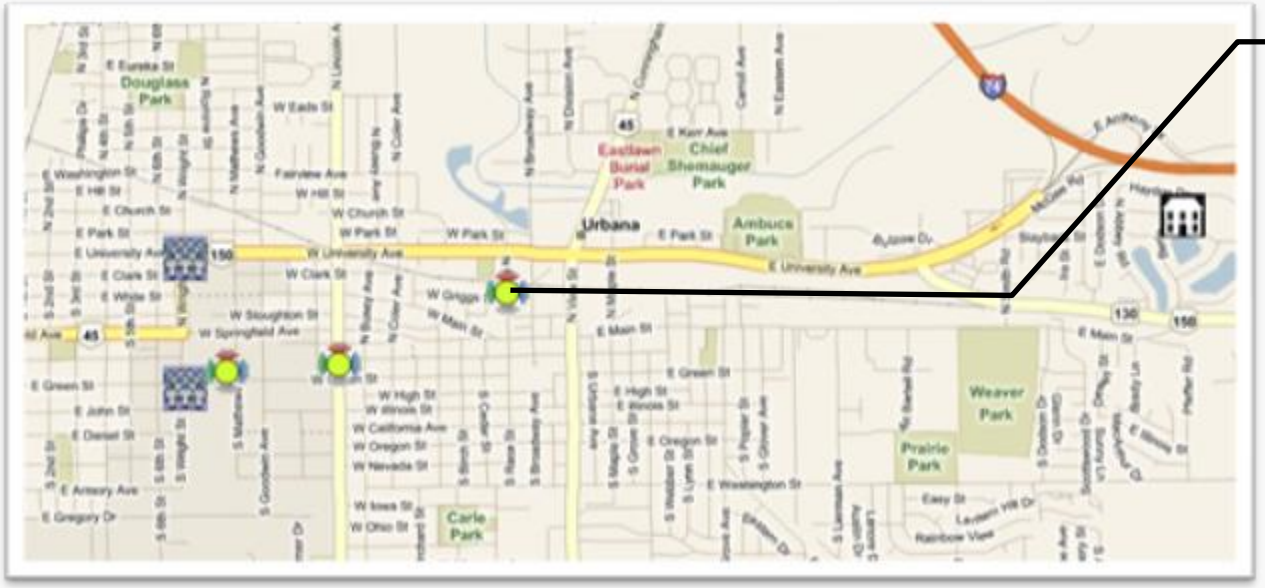
Pore pressure Gauze

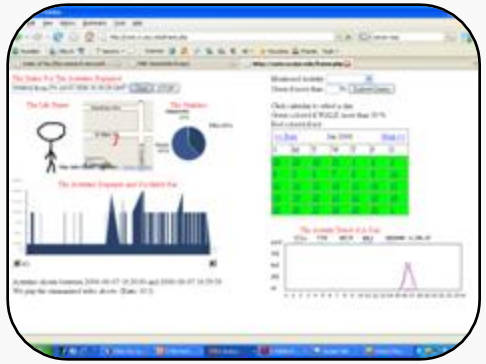
Ohio State U: Kansei

- Sense mobility in urban campus-area habitats
- Sense health/availability of equipment in a test bed

UIUC: ActionWeb

- Monitor mobile activities
- First person activities (Eg. Patient lifestyle change)





U Virginia: MetroNet

- Sensors at storefront windows in Charlottesville
- Count people passing store/enter store
  - Analyze effects of advertising, window displays, weather, events on pedestrian business

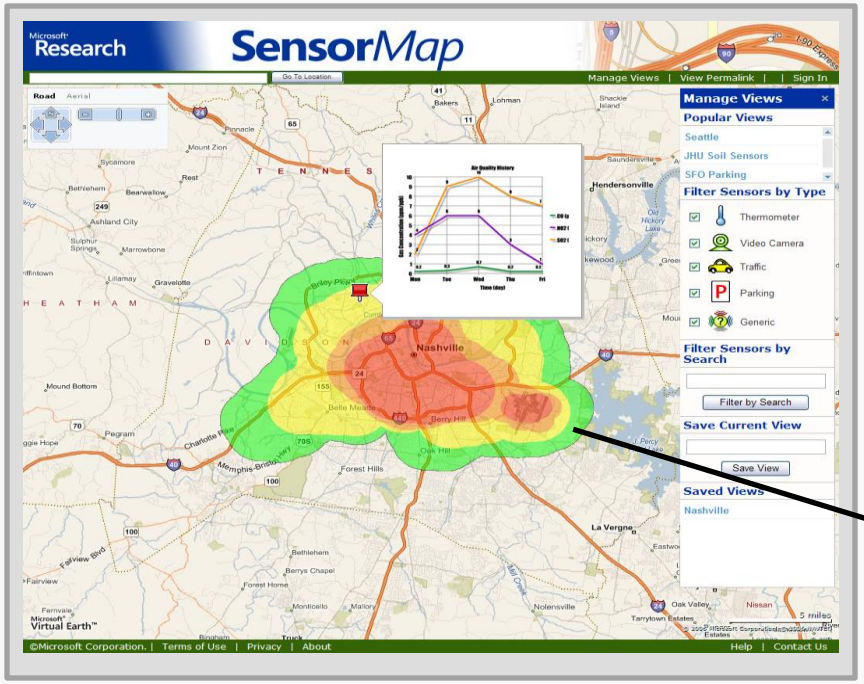
U Washington: Indoor Events

UNIVERSITY OF WASHINGTON

- Define sophisticated high-level events over the low-level sensor data
- Gracefully handle input data errors
- Uses RFID sensors

Vanderbilt: Air Quality

- Urban air pollution monitored using car mounted mobile sensors



SenseWeb Collaboration Experience

Advantages to Users		Advantage to Researchers
• Re-use spatio-temporal visualization and analysis tools • Data sharing	Application Layer	• Understand app needs: data analysis, visualization • Prototype applications: environmental, urban, scientific
• Get mapping UI, VE imagery, terrain data • Get indexing, database features	System and Tools	• New types of sensors: vector sensors • New capabilities: mobility, semantic web, wiki access
• Get more similar and related sensors • Ease of management of sensors	Sensor Deployment	• Work without own deployment • Get access to variety of hardware

Tools for Sensor Sharing

http://research.microsoft.com/nec/senseweb

- Internet gateway for sensors
  - Open web service API
    - Supports several sensor types via semantic hierarchy
- Tools available for download
  - Tutorials available online

Action Items

- Seed Applications
  - Immediate use to prompt rapid deployment
- Community involvement
  - Tools and platforms to ease sharing

PEOPLE/PRIVATE

Flooded road image from cell-phones

GOVT.

Govt. deployed stream sensors

SCIENTISTS

Scientist deployed soil moisture sensor

Thank You

Applications of Shared SN's

Community Fitness and Recreation

- Runners: Where are sidewalks broken? Construction finished on 24th St?
- Mountain Bikers: Average biker heart rate at Adams Pass on trail 320? [SlamXR]
- Surfer: What is the wave level and wind speed at Venice Beach now?

Real Time Information

- Public initiated instant news coverage

Science

- Continent scale phenomenon study using sensors deployed by multiple labs

Business

- What are people doing tonight? Restaurant waiting times in midtown?
- Mall visitor activity and parking usage across franchise outlets worldwide

Example: Rainstorm Management

Govt. deployed stream Sensors
(Eg. USGS)

Geo-stamped flooded road image from cellphones
(Eg. SensorPlanet)

Scientist deployed soil moisture sensor network
(Eg. LifeUnderYourFeet)

Data from home weather stations
(Eg. Wunderground)

Road flooding aware cab dispatch

City road route management and repairs

Tourist day planner

Landscape maintenance scheduling and inventory

Mountain bike router

SENSOR CONTRIBUTORS

SENSING APPLICATIONS

SensorMap Usage

Experiment Planning

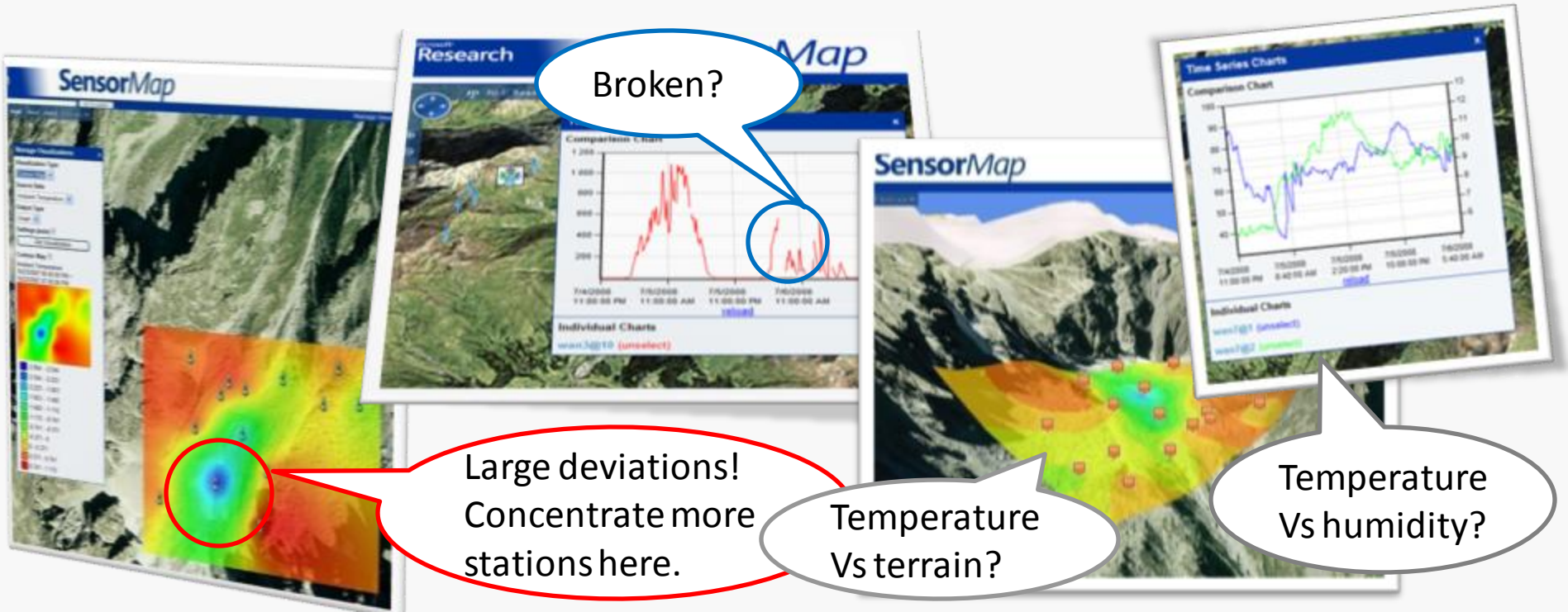
To view sensor layout and visualize measurements in real-time to decide the placement of sensors

Deployment Monitoring

To inspect real-time output of sensors, and to discover and fix broken sensors

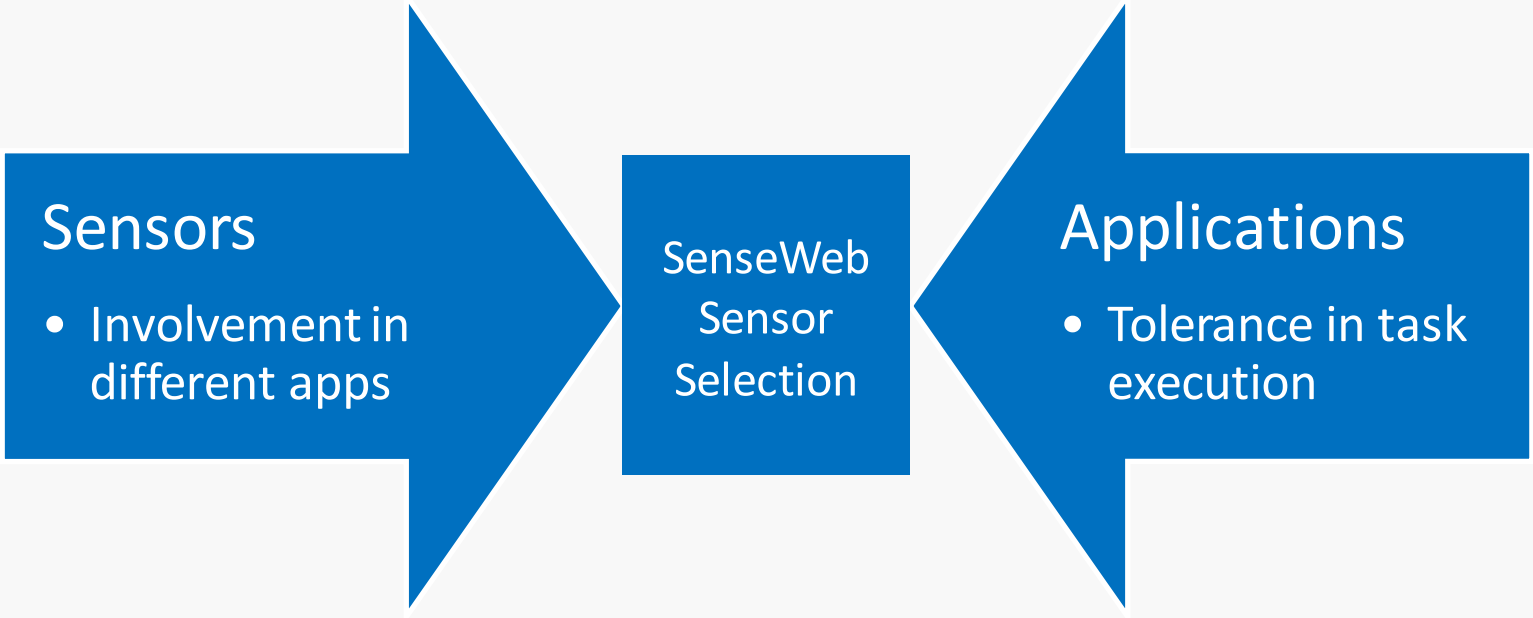
Data Analysis

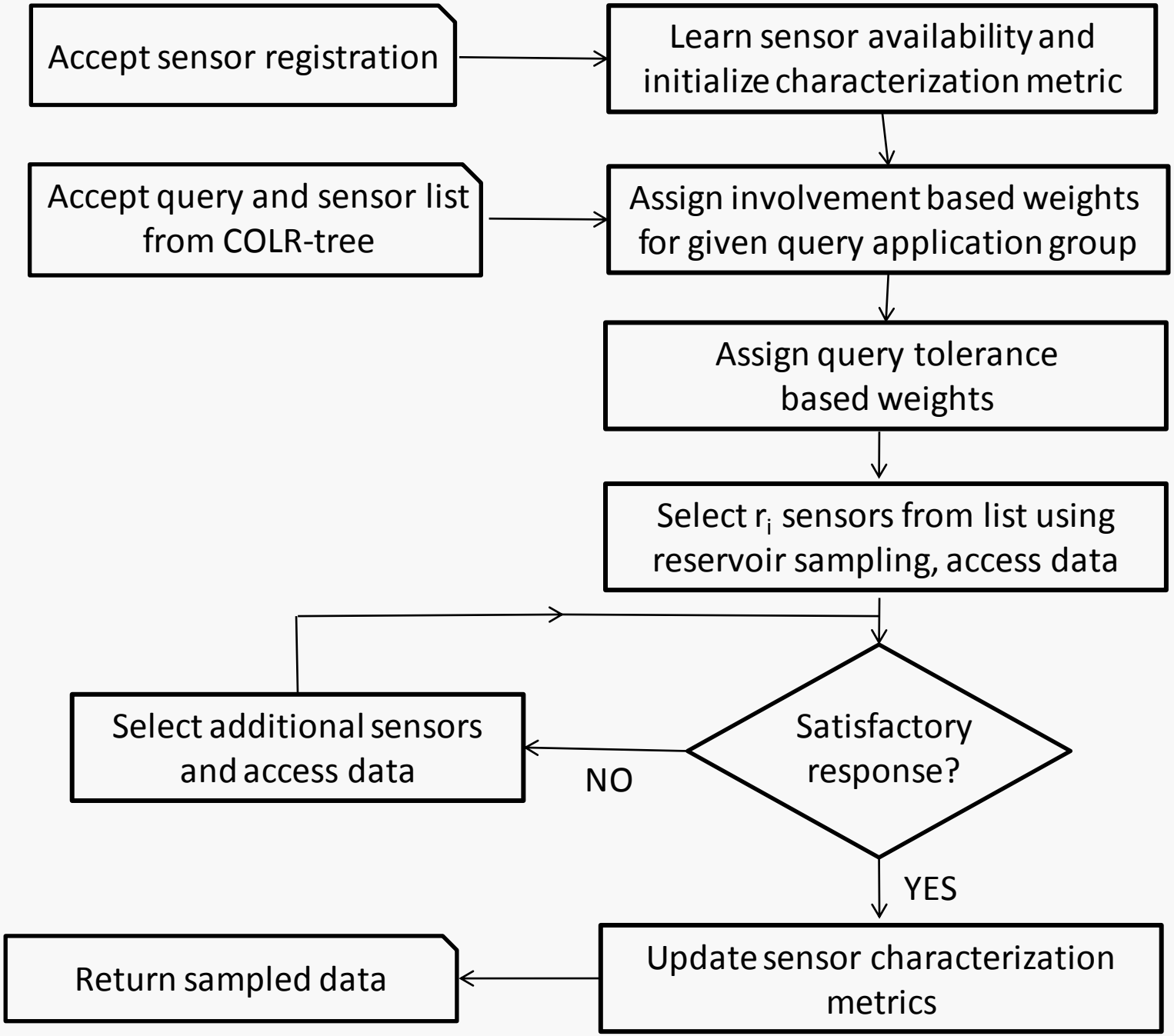
To visualize dependencies among different measurements and correlations with topological terrains

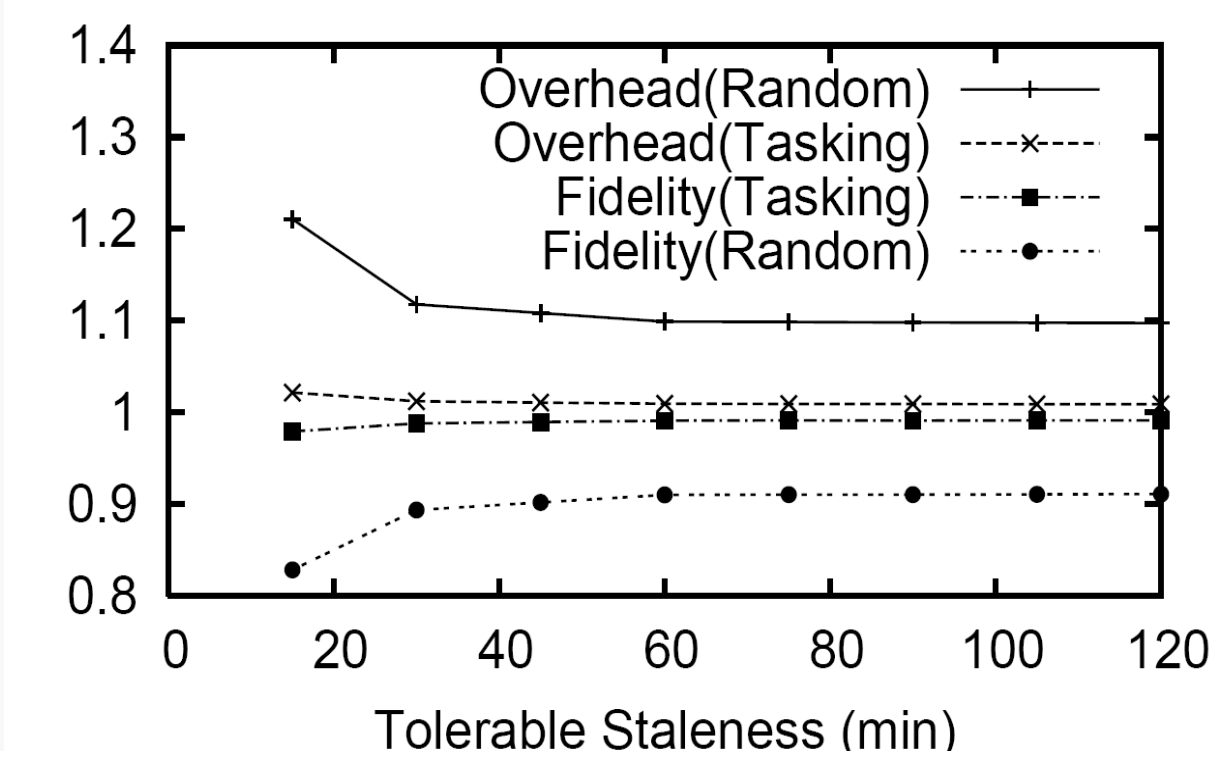


Tasking Heterogeneous Sensors

- Select uniformly rather than overloading the best sensors
- Leverage lower capability sensors when usable for a query
- Learn and adapt to sensor characteristics: availability, bandwidth
- Weighted reservoir sampling
  - Weighted random selection, with desired number of sensors




Accept sensor registration
Learn sensor availability and initialize characterization metric
Accept query and sensor list from COLR-tree
Assign involvement based weights for given query application group
Assign query tolerance based weights
Select r_i sensors from list using reservoir sampling, access data
Satisfactory response?
NO
Select additional sensors and access data
YES
Update sensor characterization metrics
Return sampled data

Tasking Algorithm Performance

- Test on USGS stream water sensors
  - Random selection vs. Weighted reservoir sampling