BEARS | Berkeley Education Alliance for Research in Singapore

SinBerBEST | Singapore-Berkeley Building Efficiency and Sustainability in the Tropics

Scaling Smart Spaces: Concept and Exploration

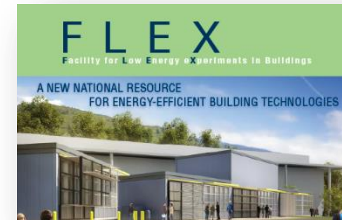
SinBerBest AGM 2013

NANYANG TECHNOLOGICAL UNIVERSITY

NUS National University of Singapore

Motivation

- Building energy monitoring/optimization is active area of research
  - Dynamic building-occupant interaction
  - New materials/systems verification testing



- It is promising to link multiple physical smart spaces in real-time.
  - Acquire and apply the knowledge to design, monitor, and manage smart spaces .
  - Improve building design, environmental modeling, energy resource optimization, and building control.

Main Objectives

- To Interconnect geographically distributed smart spaces (smart homes and offices, buildings, etc.) in real time.
- To implement data exchange and information delivery in smart spaces embedded with heterogeneous Wireless Sensor Networks (WSNs).
- To analyse the collected data and optimize the sensor network deployments in smart spaces via context-aware modelling and computing.

The Problem

- Difficult to maintain same density of sensor deployment
- Scaling cannot be done strictly using geo-spatial expansion
- Heterogeneous environment with different sensor node platforms deployed across different smart spaces.
- Data management and analytics for large-scale WSNs
- Flexibility required to test different BAS profiles

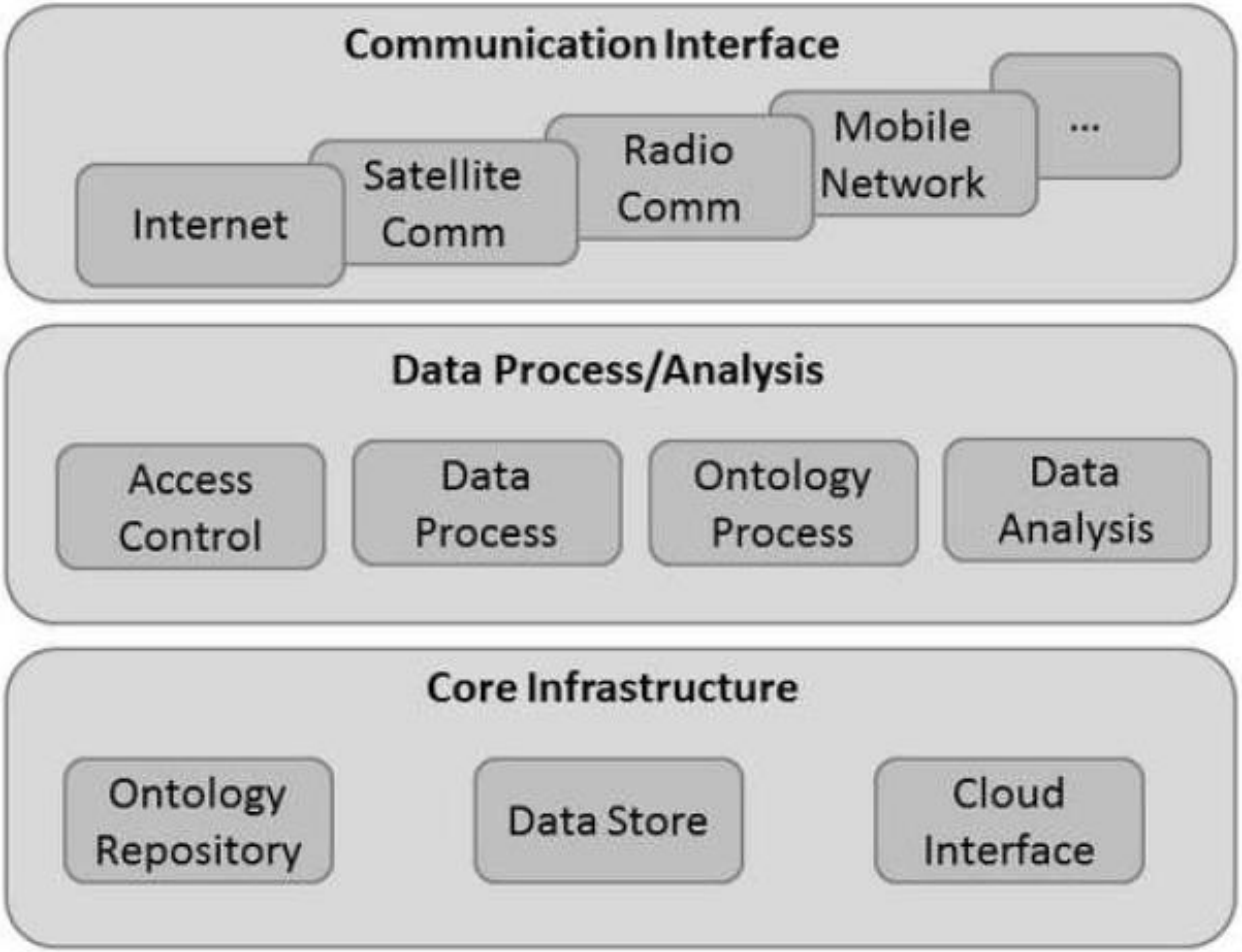
Our Solution - Ecosense

Wireless Sensor Networks + **Pervasive Middleware Technologies** + **High Performance Computing** = **Cyberinfrastructure for Smart Buildings**

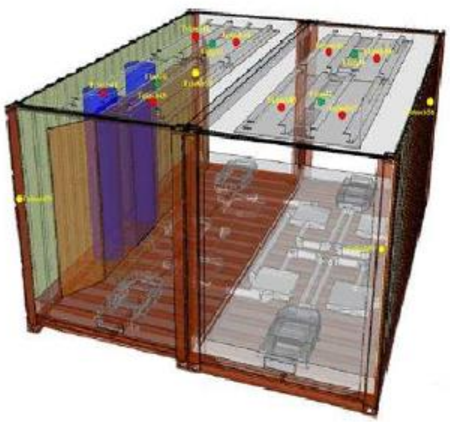
EcoSense: Cyberinfrastructure to Support Smart Spaces

- Wireless sensor networks provide the means to monitor the physical world in an unobtrusive manner.
- Pervasive middleware technologies provide mechanisms for interpreting spatial variability thus enabling classification
- High performance computing technologies such as grid and cloud computing provide the infrastructure for data management, processing and analysis.

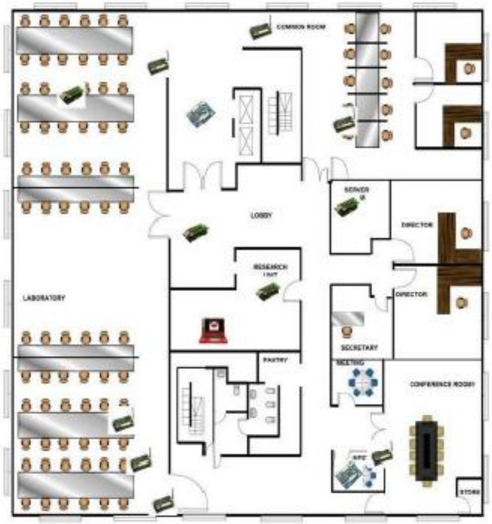
Ecosense Architecture



Testbedding



BubbleZERO Testbed



Intellisys Testbed

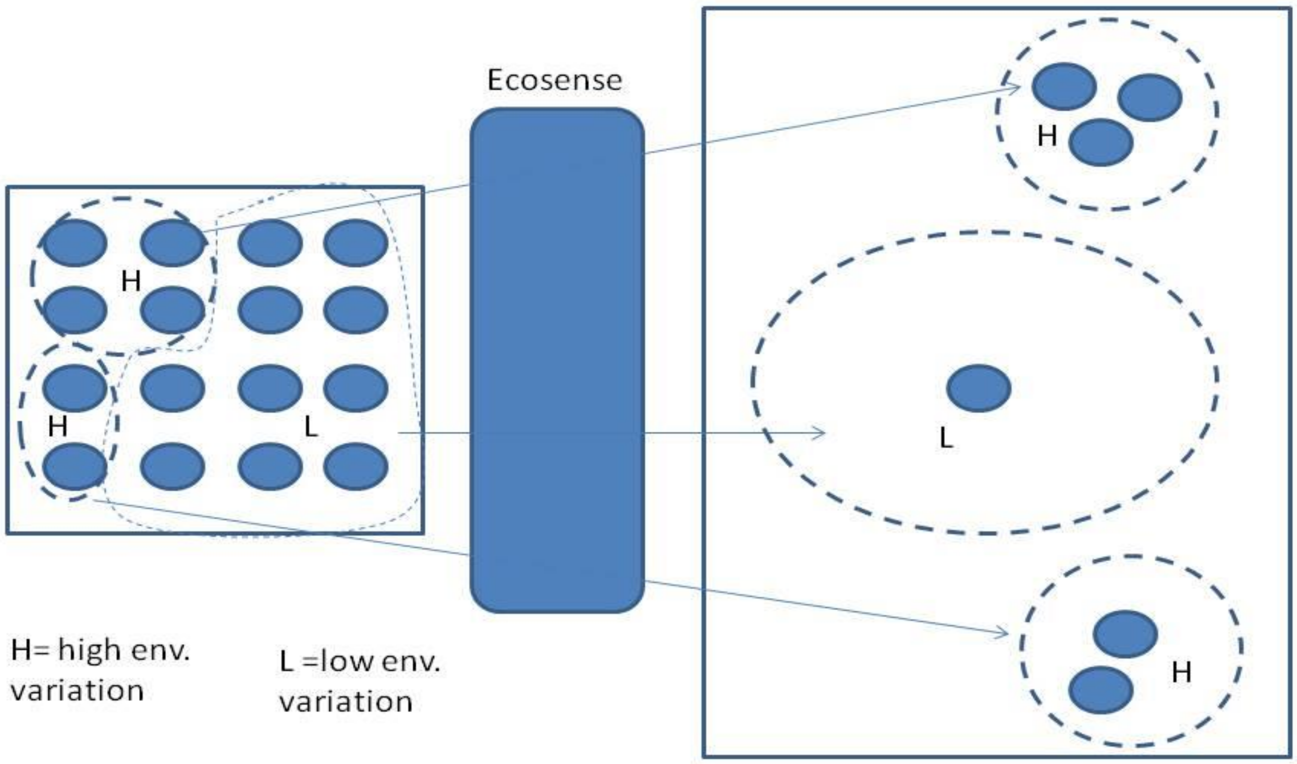
- Heterogeneous sensor networks
  - Micaz with Tiny OS
  - TelosB with Contiki OS
  - iMotes
  - IRIS

Context Modeling

- Based on the observations from an intensively instrumented smart space, to model and identify the areas with different environmental variability, which are referred to as *context zones*.

- Two dimensions in identifying environmental variability:
  - *Temporal variability*: the changing of the monitored characteristics over time (e.g. different temperatures at a specific location over time).
  - *Spatial variability*: the difference of the monitored characteristics over space (e.g. different temperatures in different locations at the same time).

Linking



Context Zones

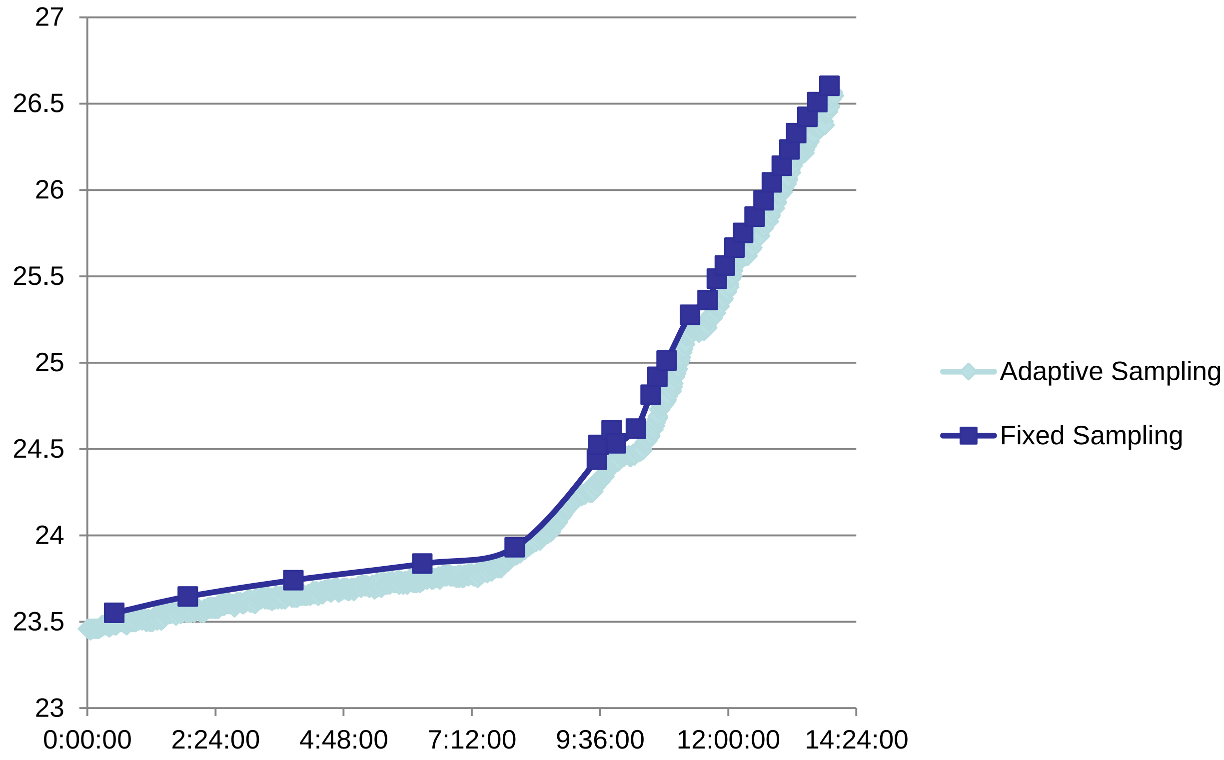
- Based on temperature variability, identified locations requiring greater sensor density and vice versa

- Able to reduce sensors deployed

Smart Space	*Node*	*Near airbox/vent*
BubbleZero	1-1	No
BubbleZero	2-1	Yes
BubbleZero	3-1	Yes
BubbleZero	4-1	No
BubbleZero	1-2	No
BubbleZero	2-2	Yes
BubbleZero	3-2	Yes
BubbleZero	4-2	No
Intellisys	1-1	No
Intellisys	1-2	No
Intellisys	1-3	No
Intellisys	2-1	Yes
Intellisys	2-2	Yes
Intellisys	2-3	Yes

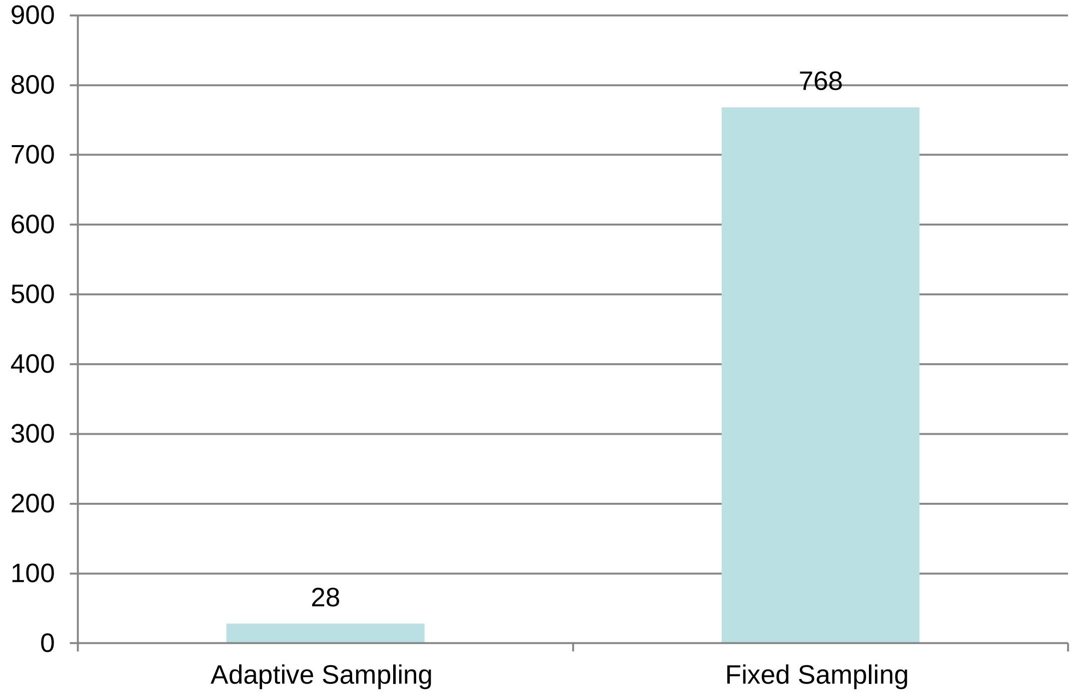
Sampling Rate Optimization

- Adjust sampling rate based on temporal variation
- Significant power reduction



Transmission

- The data tranmissed by adaptive sampling is only 0.36% of fixed sampling.



Future Work

- Implement real-time VO-to-VO control schemes to optimize energy efficiency.

- Design cyber-physical actuation systems to enable real-time operation of smart spaces.

- Facilitate the development, simulation, and validation of new building technologies through the FLEX [1] testbeds to be built by BCA.