Scaling Smart Spaces : Concept and Exploration

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Motivation

- ❑ Recent advances in embedded devices and communication networks enable the creation of ambient intelligent environments, also known as *smart spaces*.
- ❑ 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 analyze the collected data and optimize the sensor network deployments in smart spaces via context-aware modeling and computing.

The Problem

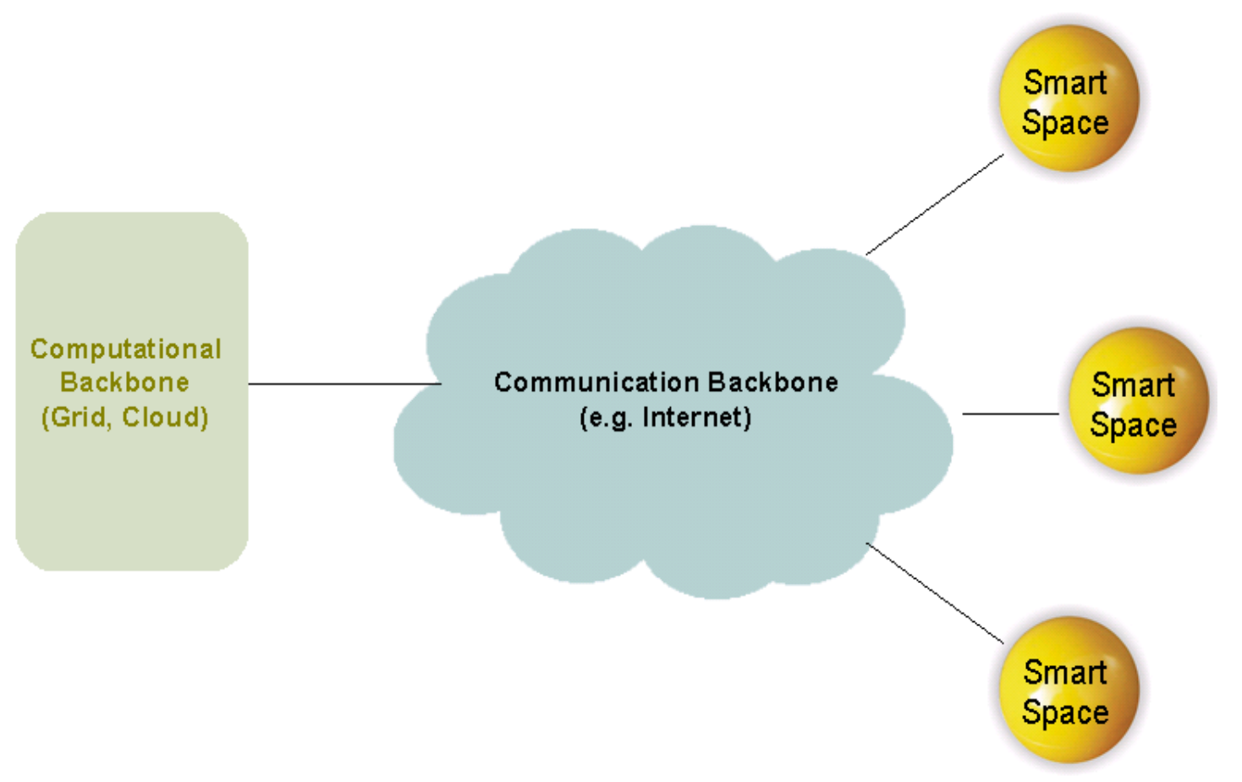
- ❑ Incorporating semantic knowledge into resource-constrained WSNs.
- ❑ Heterogeneous environment with different sensor node platforms deployed across different smart spaces.
- ❑ Exploring environmental characteristics across different smart spaces based on context modeling.
- ❑ Optimization of large-scale WSN deployment.
- ❑ Data management and analytics for large-scale WSNs.

Our Solution - EcoSense

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

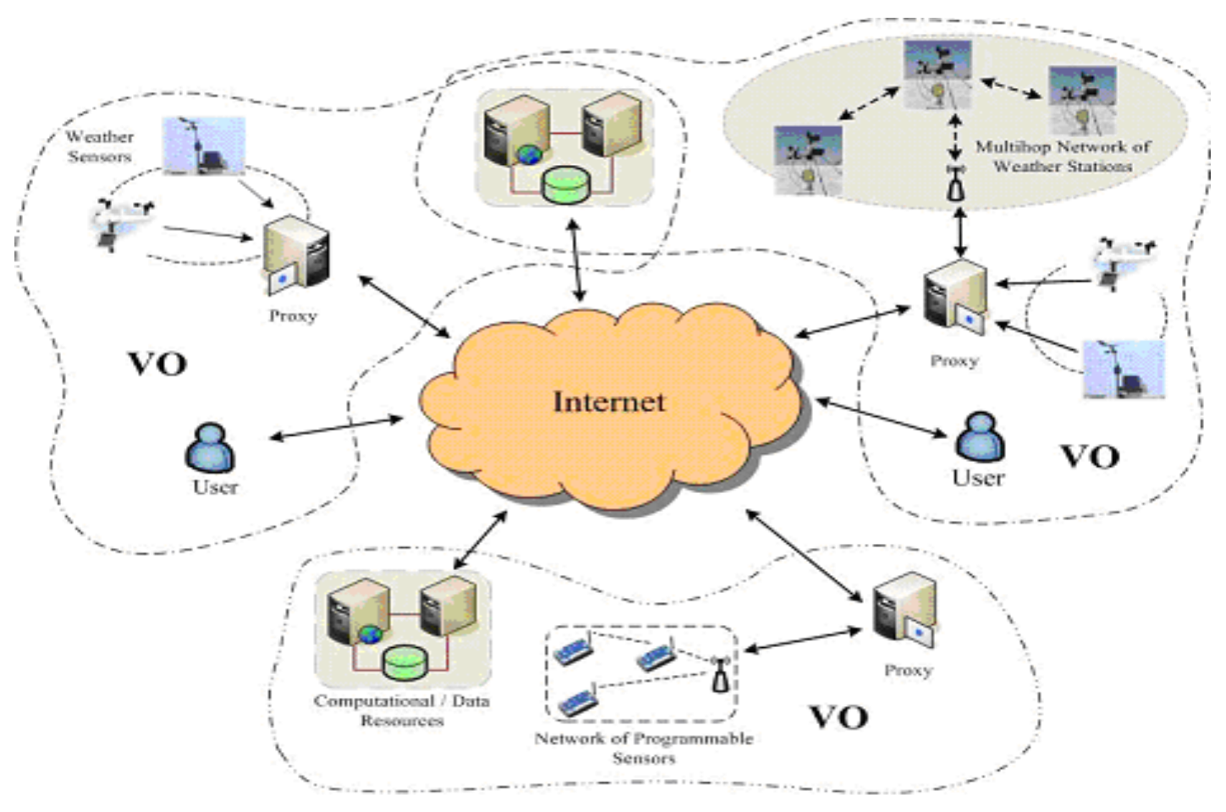
- ❑ EcoSense: cyberinfrastructure to support smart spaces.
- ❑ Wireless sensor networks provide the means to monitor the physical world in an unobtrusive manner.
- ❑ Pervasive middleware technologies provide mechanisms for interpreting who is consuming what resource.
- ❑ High performance computing technologies such as grid and cloud computing provide the infrastructure for data management, processing and analysis.

EcoSense Framework Design



- ❑ Employ the *sensor grid design* philosophy to interconnect geographically distributed smart spaces.
- ❑ Make use of *sensor network virtualization* to enable the interoperability of heterogeneous sensor networks.

Sensor Grid Architecture

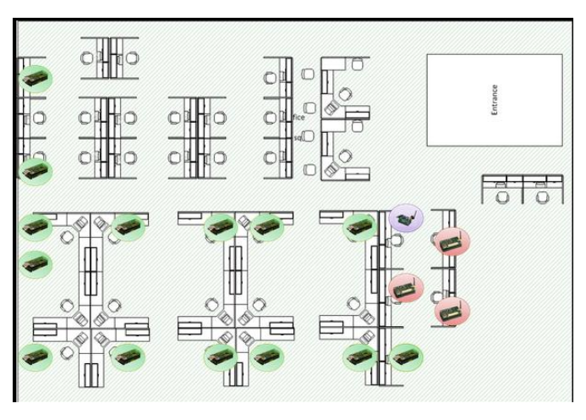


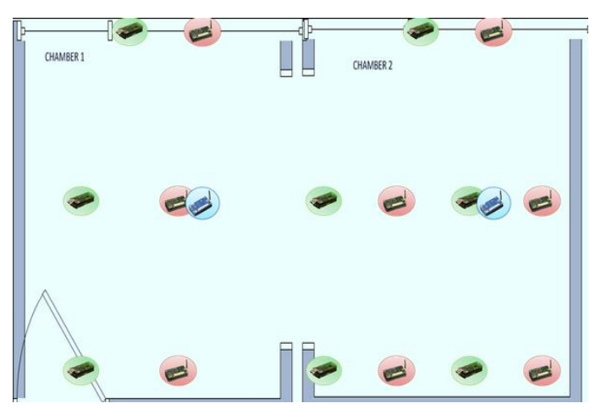
- ❑ Data and resource sharing across Virtual Organizations (VO).
- ❑ VO-level semantic ontology for context interpretation.
- ❑ Service-oriented middleware for real-time data management and analytics.

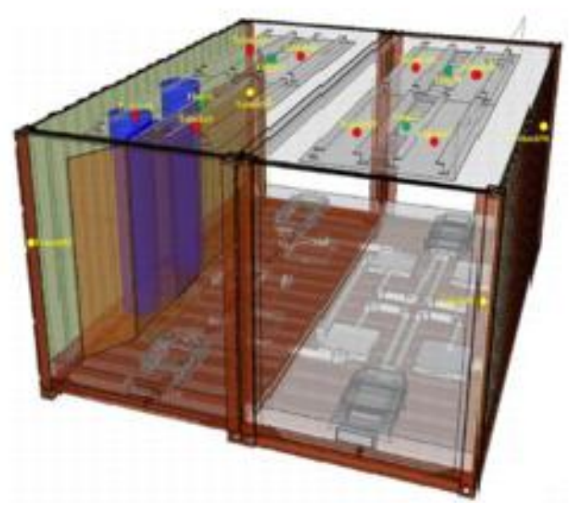
Scaling Scenario

- ❑ Transit from small-scale testbeds to real-world buildings by enabling testing and measurement of energy use and building environment data.
- ❑ Measure data from a small but intensively instrumented smart space to derive scaling information for larger associated smart spaces.
- ❑ Techniques
  - Context Modeling
  - Linking

Testbeds







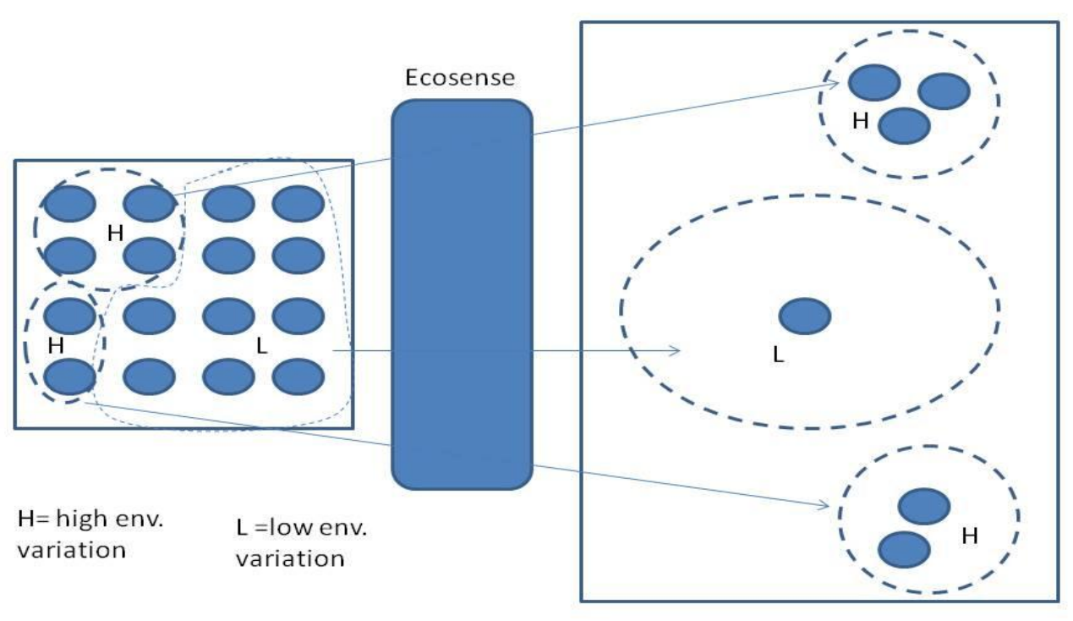
- ❑ SinBerBEST
  - **B**uilding **E**fficiency and **S**ustainability in the **T**ropics.
  - To improve building energy efficiency, while maintaining comfort, safety, security, and productivity in tropical buildings.
- ❑ BCA
  - **B**uiling and **C**onstruction **A**uthority.
  - To provide quality training, learning and research programmes for the development of an excellent built environment.
- ❑ BubbleZERO
  - **S**ingapore-**E**TH **C**entre (SEC) for Environmental Sustainability.
  - To prototype and test low-energy building technologies.

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 areas*.
- ❑ 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

- ❑ Transfer the modeling from one smart space to another by linking the identified context areas.



Expected Outcomes

- ❑ Minimize the number of sensor nodes to be deployed
  - By linking the context areas with respect to spatial variability.
  - For example, fewer sensors are needed in the areas with low spatial variability.
- ❑ Minimize the sampling and data transmission frequency of sensor nodes
  - By linking the context areas with respect to temporal variability.
  - For example, it is natural to have lower sampling frequency and longer transmission interval of sensor nodes in the areas with low temporal variability.

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.

[1] FLEX, "Facility for Low Energy eXperiments in Buildings," http://utbf.lbl.gov, 2012.