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
- 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.

Testbeds
- SinBerBEST
  - Building Efficiency and Sustainability in the Tropics.
  - To improve building energy efficiency, while maintaining comfort, safety, security, and productivity in tropical buildings.
- BCA
  - Building and Construction Authority.
  - To provide quality training, learning and research programmes for the development of an excellent built environment.
- BubbleZERO
  - Singapore ETH Centre (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).

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.

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

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.

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