Adaptive Home/Building Energy Management System Using Heterogeneous Sensor/Actuator Networks

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Energy consumption in Japan

- Can be divided into 3 sectors
- Have been increasing over the past half century
  - Mainly due to increasing population and economic development
  - Although development of new low-consumption appliances contribute in no small part to reducing the emission of greenhouse gases, remember the recent rapid growth in comfort services is resulting in high power consumption.

[Graph showing energy consumption trends from 1965 to 2005, divided into industrial, commercial and residential, and transport sectors.]
EMS (Energy Management System)

- Although there has been research, integrating a new device and developing an appropriate system are not easy.
  - Difficult to satisfy those who have different lifestyles
- Key feature of next generation EMS is **Adaptability**
  - If several multi-vendor sensors/actuators in heterogeneous networks are able to communicate, information could be extensively used by various devices.
Adaptive HEMS/BEMS (A-HEMS/BEMS)

- Controlling energy consumption by convergence of heterogeneous networks
  - PLC, Wi-Fi, Echonet, DLNA, cellular, sensor networks, …

- Although several standards model devices from various perspectives by focusing on different aspects, we used the PUCC specifications.
  - An advantage in discovering services/devices through a structured P2P network
  - If the sensor gateway of another domain network acts as the P2P node, the PUCC P2P network allows nodes to access the connected network adaptively.
Mutual complementary overlay sensor network

- Home network needs to maintain a communication infrastructure
  - The best way to construct a new home network is to use existing cables or wireless.
  - However, the PLC signals are attenuated by different phases and the wireless communication quality is degraded by obstacles, transmission distance, and noise.

- To solve these problems, we have proposed a mutual complementary overlay sensor network improves the arrival rate by using two different types of media.
  - Many combinations, but we developed one using PLC/ZigBee as prototype.
Prototype hardware platform

- Various evaluation boards and several enhancement modules to deploy mutual complementary overlay sensor network for A-HEMS/BEMS
  - Temperature, illuminance, and motion
- Enhancement modules that can be connected through enhancement board
  - Humidity sensor, infrared remote control module, smart meter, smart switch
  - Enable conventional appliances without telecommunication capabilities to connect
  - Allows users to construct a control environment easily, cheaply, and without the need for information appliances
Although the PUCC P2P nodes are the sensor gateway and the mobile phone, we can freely configure the cooperative behavior of sensors and actuators from a mobile phone.

- Easy to integrate other new vendor devices after deployment and to develop an appropriate system for those who have different lifestyles.
Example of user interface

Cellular phone
Start screen
- Generate GUI based on metadata gateways have

Event definition
- Select the sensors the user wants to set an event
- Parse a event condition sent from the client, and determine whether the event occurs.
- Use event-tree
- The event occurs
- Determine whether the event occurs based on the event-tree generated by this module.

Action settings
- Select the event you defined
- Send subscribe message

Sensor gateway
Event parsing module
- Parse a event condition sent from the client, and determine whether the event occurs.

Gateway
- Device metadata
- Service metadata
Visualization of temperature transition

From 20 to 21 o’clock

From 21 to 22 o’clock

From 22 to 23 o’clock

From 23 to 24 o’clock
Installation level of Adaptive HEMS/BEMS

- **Level 1:** illuminance, temperature, humidity, motion
  - Visualize the transition of unaware information, such as environmental data, presence or absence

- **Level 2:** + smart power meter
  - Make out the effect of energy-saving actions by revealing the correlation between life pattern and energy consumption

- **Level 3:** + smart power switch
  - Execute basic environmental control for energy saving, such as turning off standby power of legacy appliances

- **Level 4:** + infrared remote control
  - Include multi-vendor devices as controlled objects

- **Level 5:** + healthcare sensor (body temperature, heartbeat, weight)
  - Execute personal environmental control based on the different comfort level and condition

- **Level 6:** + weather sensor, micro-grid (solar, heat, gas, fuel cell)
  - Environmental control has to be consciously aware of the balance between nature and artificial control by taking advantage of using information on heterogeneous networks.