Smart House Testbed for both Physical and Cyber Entities

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Outline

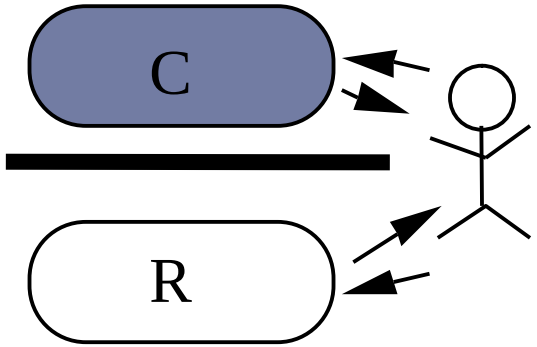
- Smart house as a typical ubiquitous computing system
- 5 functional components of ubiquitous computing systems
- Importance of the "Cloud Computing" part of the smart house
- Requirements of the testbed for smart house development
- Our testbed based on StarBED and iHouse, and some simulation examples

Ubiquitous / Ambient computing

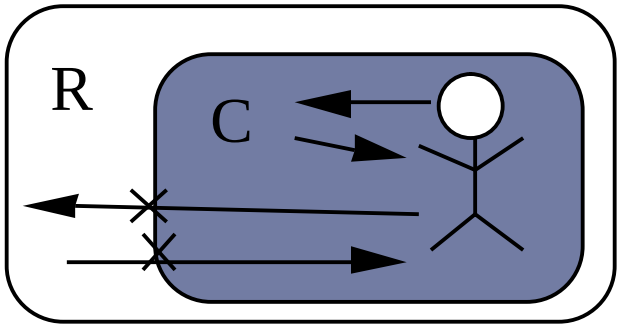
- Involves real-world elements:
  - sensors
    - temperature, humidity, wind velocity, illumination, ...
    - noise, motion, button, touch-panel, ...
  - actuators
    - heater, cooler, ventilator, light, lock, buzzer, ...
    - video display, speaker, ...
  - users
    - behavior
    - preferences
  - context
    - high-level context

Mixture of Real(Physical) and Cyber(Computer) entities

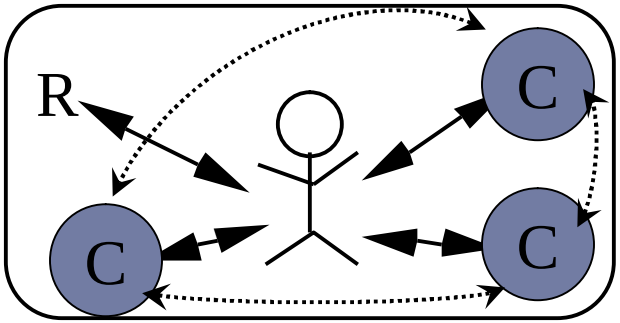
- Human- computer interaction



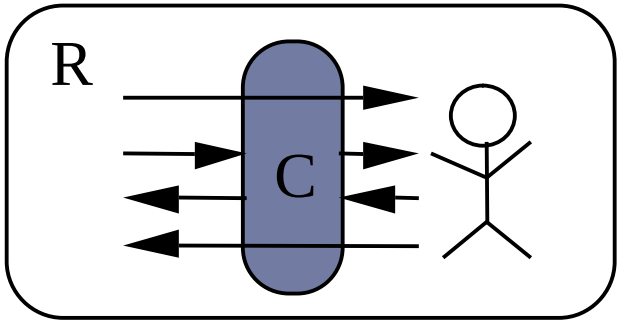
(a) GUI



(b) Virtual Reality



(c) Ubiquitous (Ambient) computing



(d) Augmented (Mixed) Reality

C: Cyber
R: Real

Five functional elements for ubiqutous computing systems

- connect
  - connecting various kinds of sensors and actuators [M2M communication, connectivity]
- feel
  - data acquisition, read the situation [sensing, context extraction]
- make a decision
  - based on the knowledge decide what to do [control logics, algorithms]
- take an action
  - take a physical action using actuators [actuation]
- learn
  - remember the situation and results of actions [database]

"Connect" -with no new wire-

- Long history and variety of technology options
- Examples:
  - Power Line Communication(PLC)
    - Lo-Speed (kbps) old technologies (<500kHz band)
    - Hi-Speed (100M-1Gbps) (2M-200MHz band)
    - Lo-Speed and Lo-Power (<500kHz band)
  - Co-Ax Cable Communication
    - Hi-Speed (100M-1Gbps)
  - Phone Line Communication
    - Hi-Speed (<500Mbps)
  - Wireless Communication
    - Wi-Fi : high speed and popular
    - Bluetooth : tough and secure
    - ZigBee, Z-Wave : long battery life and huge number of nodes

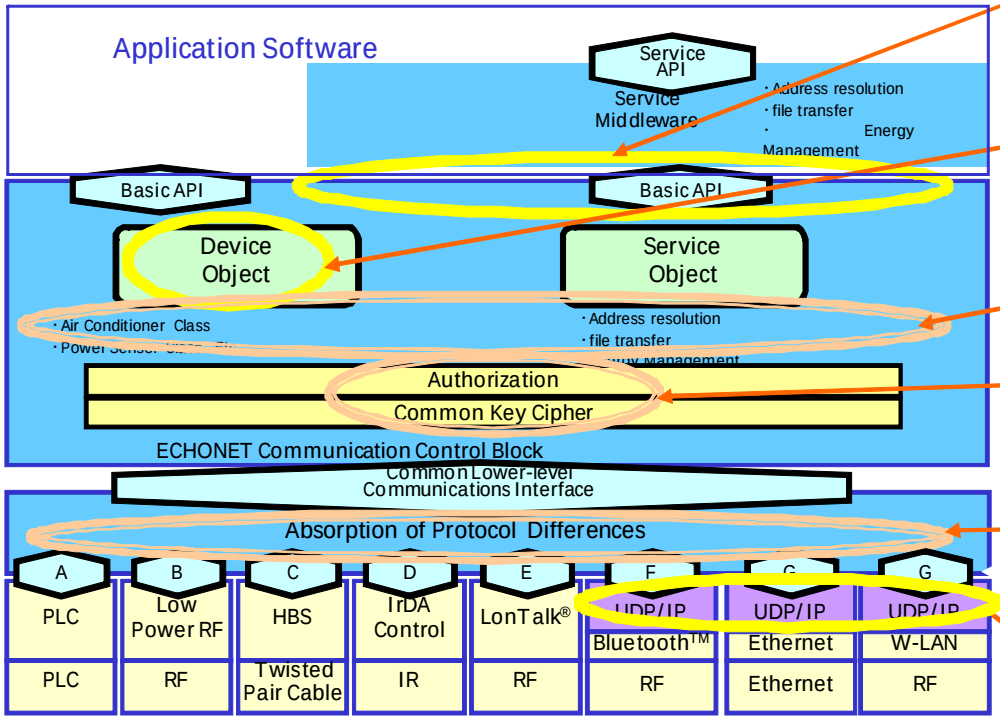
"feel" and "take an action"

- Sensor and Actuator objects in ECHONET standard

class group	devices
Sensor-related Device Class Group	gas leak sensor, crime prevention sensor,emergency button, first-aid sensor, earthquake sensor, electric leak sensor, human detection sensor, visitor sensor, call sensor, condensation sensor, air pollution sensor, oxygen sensor, illuminance sensor, sound sensor, mailing sensor, weight sensor, temperature sensor, humidity sensor, rain sensor, water level sensor, bath water level sensor, bath heating status sensor, water leak sensor, water overflow sensor, fire sensor, cigarette smoke sensor, CO2 sensor, gas sensor, VOC sensor, differential pressure sensor, air speed sensor, odor sensor, flame sensor, electric energy sensor, current value sensor, water flow rate sensor, micromotion sensor, passage sensor, bed presence sensor, open/close sensor, activity amount sensor, human body location sensor, snow sensor
Air Conditioner-related Device Class Group	home air conditioner, air conditioner ventilation fan, air cleaner, humidifier, electric heater, Fan heater, package-type commercial air conditioner (indoor unit), package-type commercial air conditioner (outdoor unit)
Housing/Facilities-related Device Class Group	electrically operated shade, electric shutter, electric storm window, sprinkler (for garden), off peak electric water heater, electric toilet seat (warm-water washing toilet seat, heating toilet seat, etc.), electric lock, instantaneous water heater, bathroom heater and dryer, household solar power generation, cold or hot water heat source equipment, floor heater, watt-hour meter, gas meter, LP gas meter, general lighting, buzzer
Cooking/Household-related Device Class Group	electric hot water pot (electric thermos), refrigerator, combination microwave oven (electronic oven), cooking heater, rice cooker, washing machine, washer and dryer
Health-related Device Class Group	weighing machine
Management/Operation-related Device Class Group	no objects defined now
Audiovisual-related Device Class Group	display, television

ECHONET as an international standards

- ECHONET Consortium since 1997
  - 6 Promoter members: Toshiba, Panasonic, Hitachi, Mitsubishi, Sharp and TEPCO



[IEC 62480] Multimedia Home Network - Network interface for network adapter

[IEC 62394] Service Diagnostic Interface for ECHONET

[ISO/IEC 14543-4-1] Communication Layers Part 1 (Upper Layer)

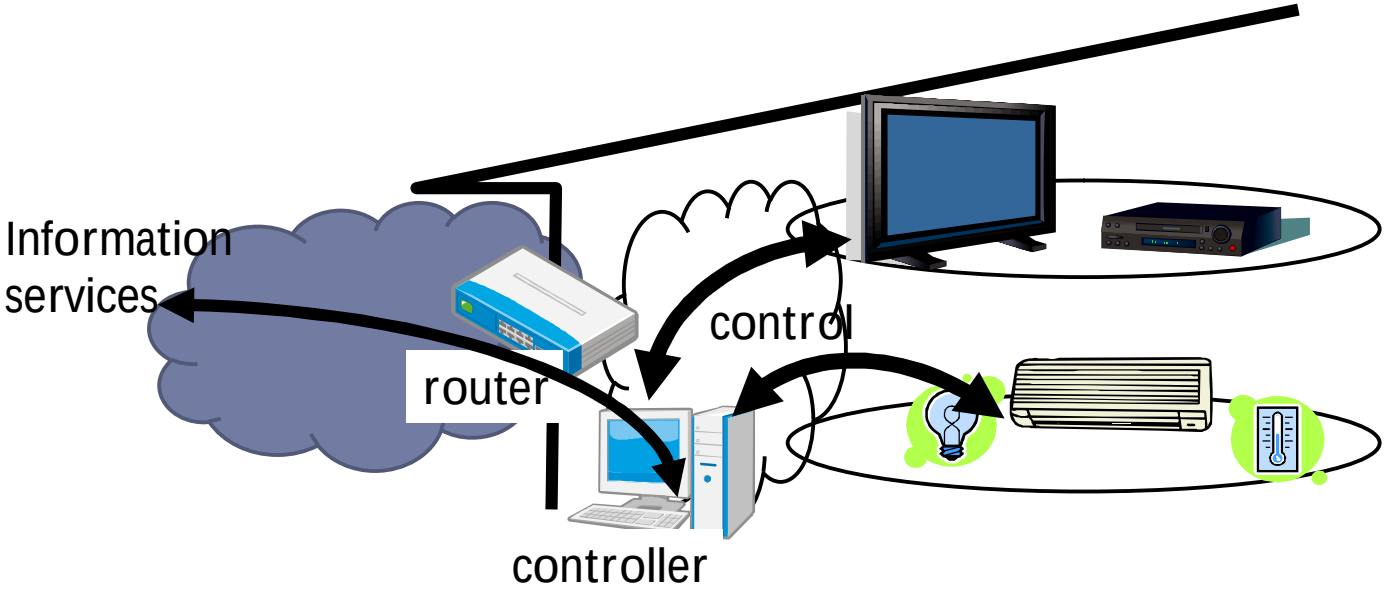
[ISO/IEC 24676] Secure Communication Middleware Protocol

[ISO/IEC 14543-4-2] Communication Layers Part 2 (Lower Layer)

[IEC 62457] Home Network Communication Protocol over IP for Multimedia Household Appliances

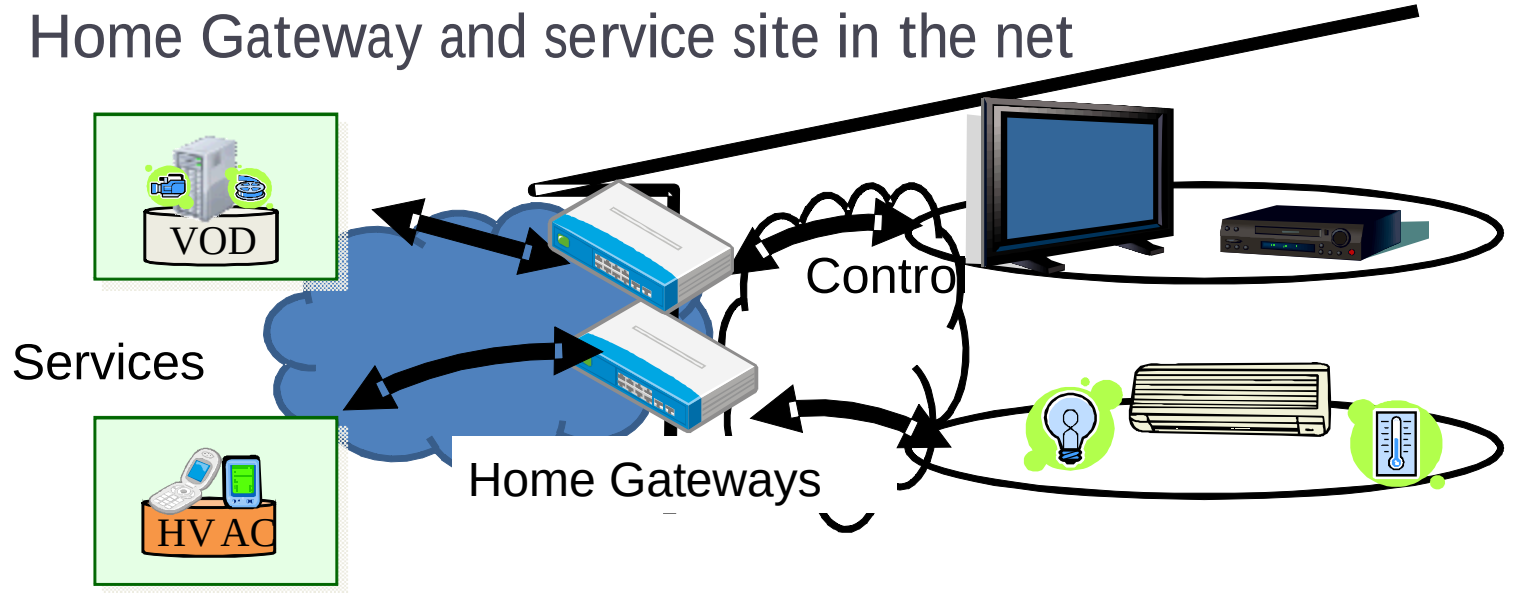
"make a decision" Stand-alone controller

- "Smart" control mechanism is required to extract the context from the sensor data and make a decision
- Some information like weather forecasting requires network connection to services
- Controller must be "Smart"...



"make a decision" Application Service Provider for home

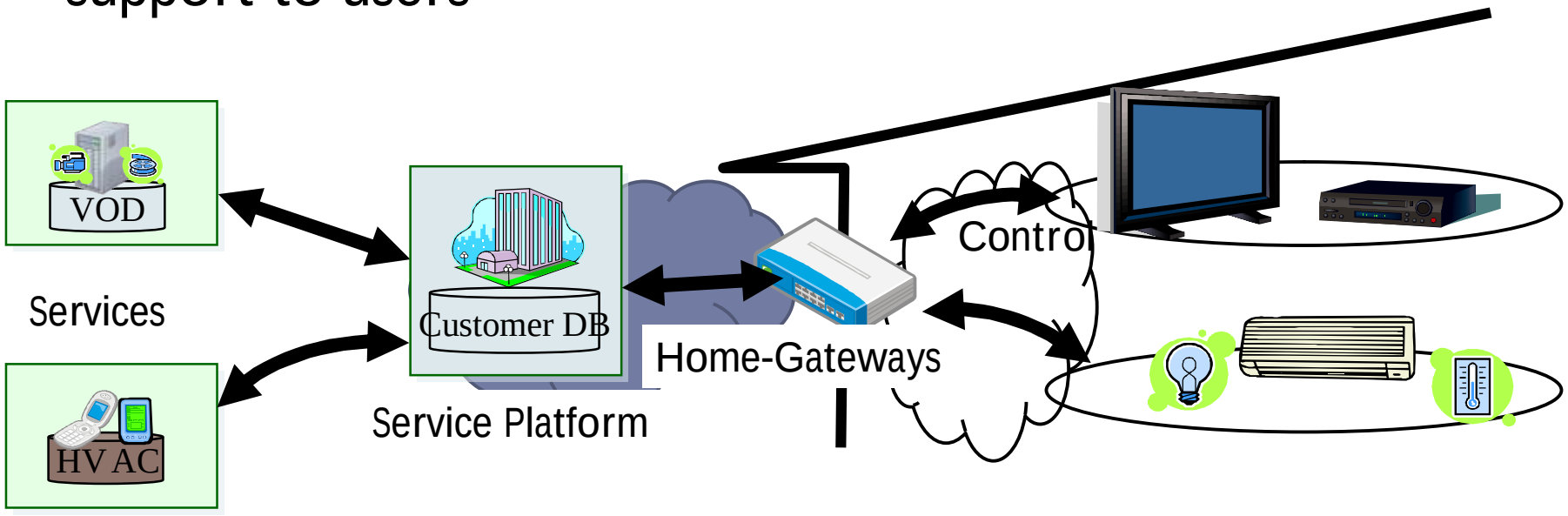
- Smart controller needs smart administrator
  - Software updates, security issues, drivers for devices, etc.
- Farm out!!
  - Home Gateway and service site in the net



- Each service requires its own home-gateway, and multi-vendor solution is not easy

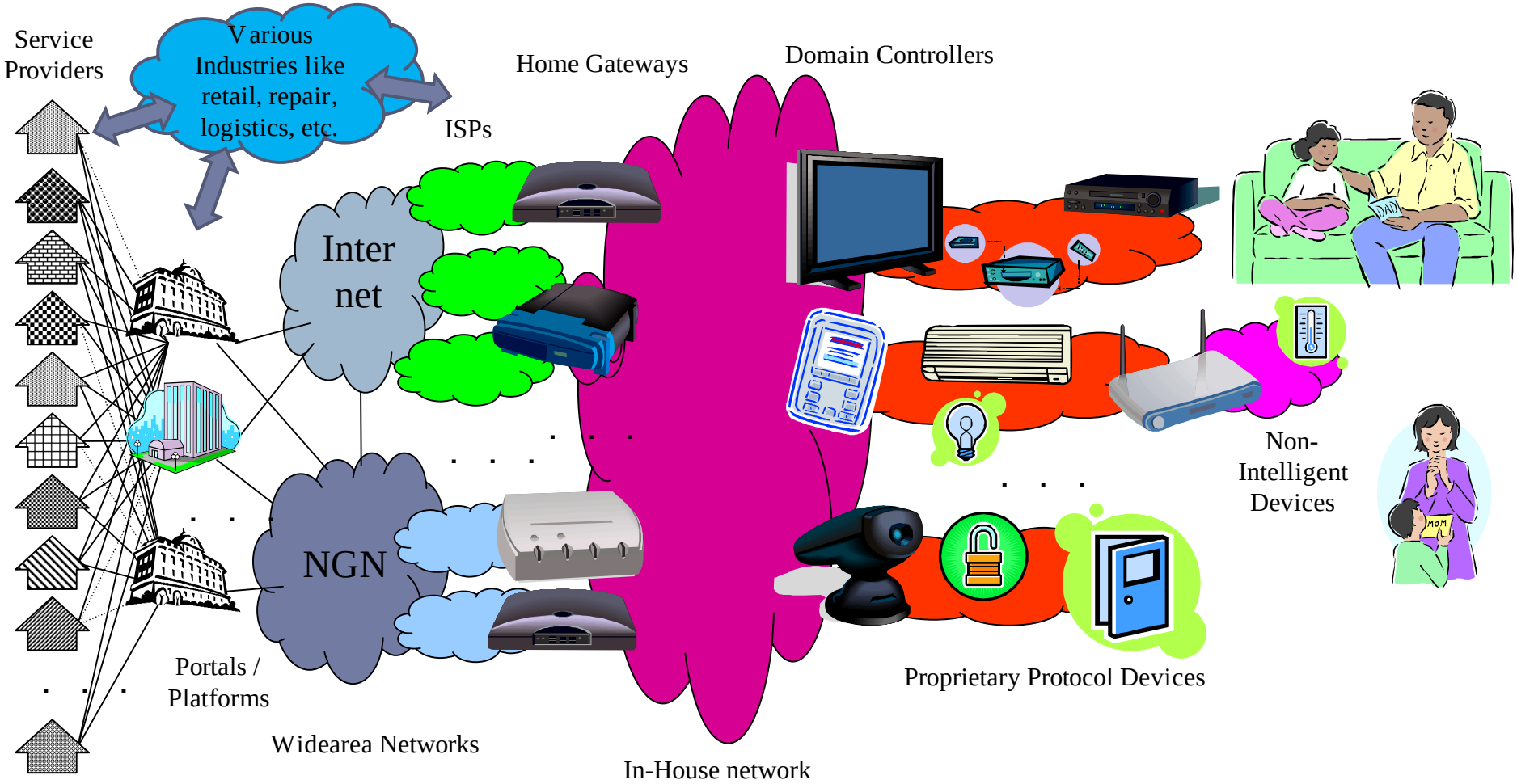
"make a decision" and "learning" Service Platform

- Service platform business between homes and services
- Gives API to service providers and one stop customer support to users



- This enables "leaning" of the user reactions and their preferences (collective intelligence of home network)

Next generation smart home network = Cloud computing for home appliances



Smart House testbed

- A testbed (workbench) designed for development of next-generation Home Network systems including Smart Houses for Smart Grid
- Consists of experimental houses and simulators

A. Experimental houses

A.1 TANS2

A.2 iHouse

B. Simulators

B.1 Protocol-based HN Emulator

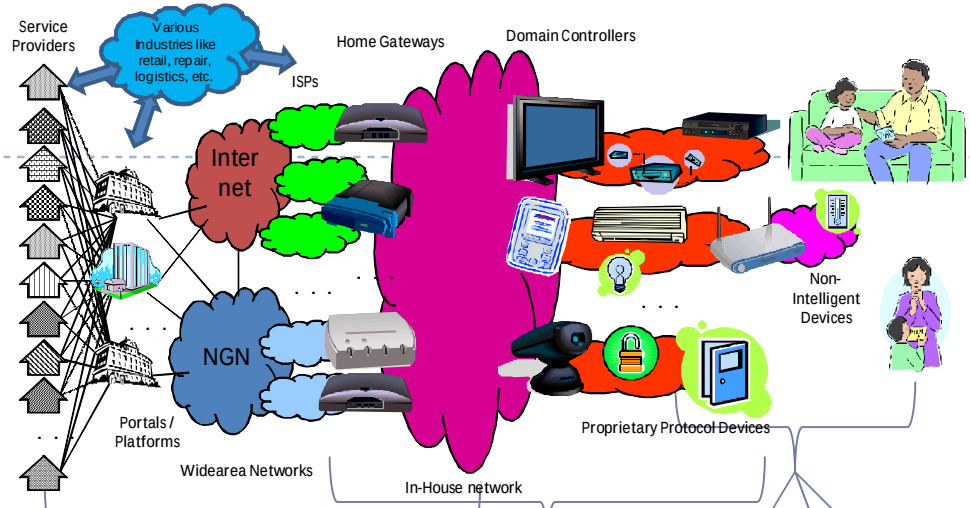
- StarBED with SpringOS, Rune, QOMET
- Popular home network middleware

B.2 Environment simulator

- Numerical simulation of physical data in the house environment

CHADANS

(Cloud-computing empowered Home-network Architecture testbeD for Ambient Network Systems)



StarBED
(NICT HRC)

Protocol-based HN Emulator

iHouse

SuperComputers
(JAIST ISC)

Environment Simulator

TANS2

Requirements for experimental houses

1. Coverage of service types
2. Repetitive experiments with parameters
3. Automatic configuration for various kinds of experiments
4. Organoleptic evaluation by users

	A.1 TANS2	A.2 iHouse
1	HVCA, Energy management	All services
2	Full-automatic experiment	Automatic experiment for non-interactive services
3	Scenario based automatic configuration	Automatic configuration for basic part of equipments
4	temperature and humidity, luminance	Real user experience for all services

iHouse: {Ishikawa, Internetted, Inspireing, Intelligent} House

- Advanced Experimental and Provisioning Facility of Home Network Systems (ホームネットワーク高度実証実験施設)
- Based on "Standard House Design" by Architectural Institute of Japan

outlets and windows

sensors

TANS2: Testbed for Ambient Network System 2

Requirements for simulators

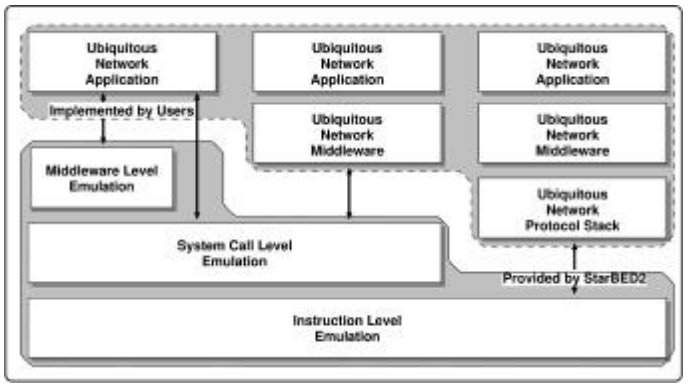
1. All components from services on the net to physical environment in the house
2. Utilization of measured experimental data
3. Scalability for million+ users

	B.1 Protocl-based HN Emulator	B.2 Environmental Simulator
1	Emulation of all network part of the HN system using StarBED technologies	Numerical simulation for physical environment in the house
2	Simulation with macro-model of components based on the statistical model from measured data	Measured data as boundary condition
3	Connection to StarBED	Connection to super computers in JAIST

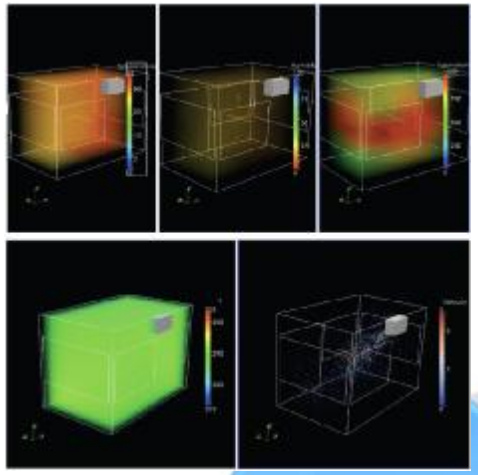
StarBED

Protocol based home network simulator

- Intel IA-32 processor based cluster
- Combination of real device, simulation and emulation
- Emulation approach
  - Execution of the real object code of the target system
  - Real-time execution
  - Interaction with real devices and users
- Multi-level emulation
  - Binary-level (processor emulation)
  - System call, library (OS emulation)
  - API (middleware emulation)
  - Behavior (device/system emulation, statistical model)



Environmental Simulator



Home Network Simulator

Home appliance and protocols

Physical Environment Simulator

Physical field simulation based on CFD etc.

Electric Power Simulator

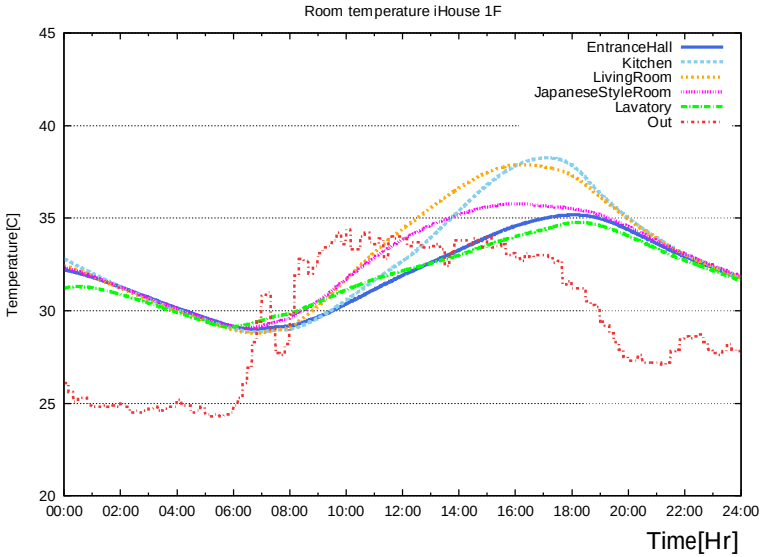
Power consumption of all kinds of home devices

Human Simulator

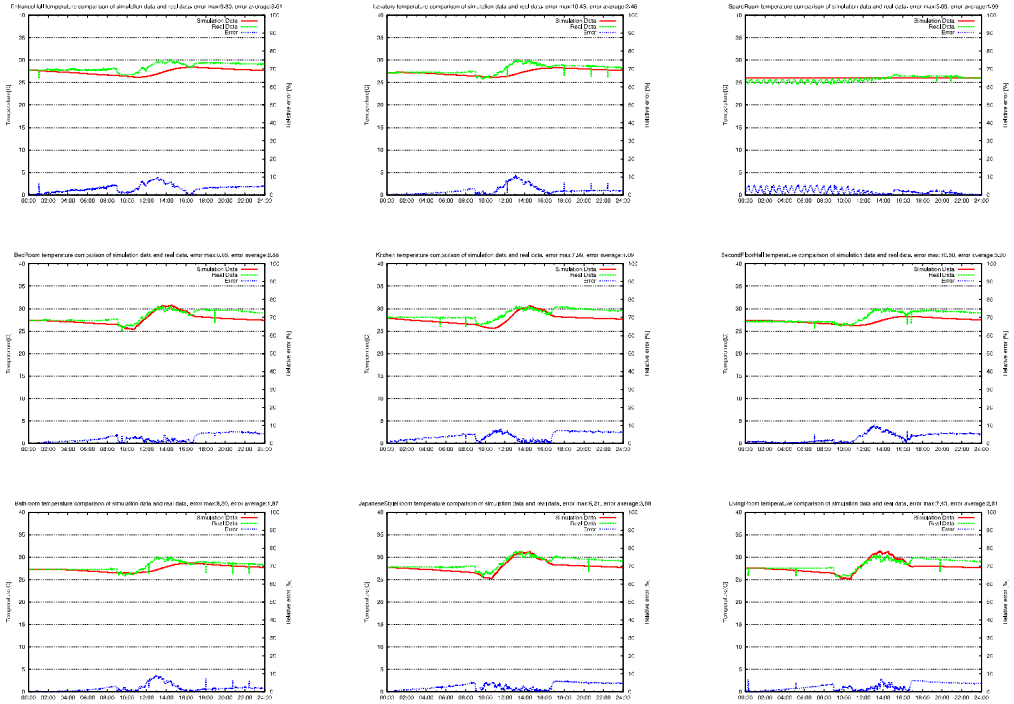
Human activity based on statistical data and mental models

Simulated iHouse

- Thermal conduction and Computational Fluid Dynamics (CFD) based modeling of iHouse



Simulated temperatures of rooms in iHouse



Difference between simulated and observed temperatures in each room

Scalability up to millions of houses

- Multi-level emulation of "Rune" (Real-time Ubiquitous Network Emulation environment)
  - Variable grain of the emulation for required reality and/or real-time processing
  - Home appliance, house, community, town, city, etc.
- Auto-configuration by "SpringOS"
  - K-Language is provided to describe the simulator configuration
- Connection to StarBED
  - NICT Hokuriku StarBED Technical Center
  - Cluster of thousands of nodes
- Connection to super computers in JAIST
  - Massively parallel processors: Cray, NEC, SGI, etc.

Conclusions

- Ubiquitous computing systems like smart house consists of real devices and cyber components which includes cloud services in the net
- To develop the smart grid system, smart house and services for them, testbed which covers both real and cyber part of the system is required
- We have developed such an environment with real experimental houses (iHouse and TANS2) and simulators (Protocol based simulator and Environmental simulator)
- We are now constructing town-level simulation based on real model city and "virtual pilot program" would be ralized