Smart Home and Smart Community Simulator

Japan Advanced Institute of Science and Technology (JAIST)
National Institute of Information and Communications Technology (NICT)

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"Smart" Systems

- Mixture of traditional embedded systems (ET) and enterprise information (IT) systems
- Interaction with real-world entities
  - Sensors and Actuators
  - CPS (Cyber Physical Systems)
- Networking of all entities
  - M2M (Machine to Machine), IoT (Internet of Things), IoE (Internet of Everything)
  - SoS (System of Systems)
- Intelligence
  - cloud computing
  - Big-Data
Five Elements for Smart Systems

- **Connect**
  - connecting various kinds of sensors and actuators [M2M communication, connectivity]

- **Sense**
  - data acquisition, read the situation [sensing, context extraction]

- **Make a decision**
  - based on the knowledge decide what to do [control logics, algorithms]

- **Actuate**
  - 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)
    - Low-speed old technologies (kbps) [<500kHz band]
    - High-speed (100Mbps~1Gbps) [2~200MHz band]
    - Low-speed and low-power [<500kHz band]
  - Coaxial Cable Communication
    - High-speed (100Mbps~1Gbps)
  - Phone Line Communication
    - High-speed (<500Mbps)
  - Wireless Communication
    - Wi-Fi : high-speed and popular
    - Bluetooth : tough and secure
    - ZigBee, Z-Wave, Wi-SUN : long battery life and huge number of nodes
    - LPWA (LoRa, SigFox, Ingenu, Flexnet, NB-IoT, etc) : long distance long battery life
### “Connect” technology for HEMS - TTC TR-1043

<table>
<thead>
<tr>
<th>5-7</th>
<th>ECHONET Lite</th>
<th>ECHONET Lite over Layer2 frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>UDP / TCP</td>
<td></td>
</tr>
</tbody>
</table>

| 3   | IPv4        | IPv6                          |
|     | 6LoWPAN     |                               |

<table>
<thead>
<tr>
<th>2</th>
<th>IEEE802.3 family</th>
<th>G.9961</th>
<th>G.9972</th>
<th>IEEE1901</th>
<th>ITU-T G.9903</th>
<th>IEEE802.11 family</th>
<th>IEEE802.15.1 family</th>
<th>IEEE802.15.4 family</th>
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</thead>
<tbody>
<tr>
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<td></td>
<td>PAN profile</td>
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<table>
<thead>
<tr>
<th>1</th>
<th>IEEE802.3 family</th>
<th>G.9960</th>
<th>G.9963</th>
<th>G.9964</th>
<th>G.9972</th>
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<td>PAN profile</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Phy. Media</th>
<th>UTP / Optical Fiber</th>
<th>Power Line</th>
<th>Radio Wave (2.4/5G)</th>
<th>Radio Wave (2.4G)</th>
<th>Radio Wave (2.4G/920M) (※)</th>
</tr>
</thead>
</table>

| Ethernet | ITU-T G.hn | IEEE1901 JJ-300.20 | JJ-300.21 HD-PLC | ITU-T G.hnem JJ-300.11 G3-PLC | Wi-Fi | Bluetooth | IEEE802.15.4/4e/4g JJ.300-10 Wi-SUN ZigBee IP, 920IP |

※Only ZigBee IP supports 2.4G
## “Sense” and “Actuate”

### Sensing and actuating devices in ECHONET standard

<table>
<thead>
<tr>
<th>Class Group</th>
<th>Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor-related Device Class Group</td>
<td>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, luminance 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</td>
</tr>
<tr>
<td>Air Conditioner-related Device Class Group</td>
<td>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)</td>
</tr>
<tr>
<td>Housing/Facilities-related Device Class Group</td>
<td>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</td>
</tr>
<tr>
<td>Cooking/Household-related Device Class Group</td>
<td>electric hot water pot (electric thermos), refrigerator, combination microwave oven (electronic oven), cooking heater, rice cooker, washing machine, washer and dryer</td>
</tr>
<tr>
<td>Health-related Device Class Group</td>
<td>weighing machine</td>
</tr>
<tr>
<td>Management/Operation-related Device Class Group</td>
<td>no objects defined now</td>
</tr>
<tr>
<td>Audiovisual-related Device Class Group</td>
<td>display, television</td>
</tr>
</tbody>
</table>
“Make a Decision“ & “Learn”
Next Generation Home Networks (2007)

- Cloud computing for home appliances

Service Providers

Various Industries like retail, repair, logistics, etc.

Internet

NGN

Home Gateways

Domain Controllers

ISPs

Portals / Platforms

Wide Area Networks

In-House Network

Non-Intelligent Devices

Proprietary Protocol Devices

Various Industries like retail, repair, logistics, etc.
Smart home / community Testbed

- A testbed (workbench) designed for development of next generation smart home
- Consists of real part (experimental houses) and virtual part (simulators)

**Experimental Houses**
- Testbed for Ambient Network System 2 (TANS2)
- Experimental house, iHouse

**Simulators**
- Protocol-based HN Emulator
  - StarBED with SpringOS, RUNE, QOMET
  - Popular home network middleware
- Environment simulator
  - Numerical simulation of physical data in the house environment
CHADANS = Cloud-computing empowered Home-network Architecture testbed for Ambient Network Systems

StarBED

Various Industries like retail, repair, logistics, etc.

Service Providers

Portals/Platforms

Widearea Networks

In-House network

Non-Intelligent Devices

Proprietary Protocol Devices

CHADANS = Cloud-computing empowered Home-network Architecture testbed for Ambient Network Systems

JAIST Super Computers

Protocol-based HN Emulator

Environment Simulator

Various Industries like retail, repair, logistics, etc.
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

<table>
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<tr>
<th>TANS2</th>
<th>iHouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC*, energy management</td>
<td>All services</td>
</tr>
<tr>
<td>Full-automatic experiment</td>
<td>Automatic experiment for non-interactive services</td>
</tr>
<tr>
<td>Scenario based automatic configuration</td>
<td>Automatic configuration for basic part of equipments</td>
</tr>
<tr>
<td>Temperature, humidity, luminance</td>
<td>Real user experience for all services</td>
</tr>
</tbody>
</table>

* HVAC = Heating, Ventilation and Air-Conditioning
TANS2: Testbed for Ambient Network System 2
iHouse: ishikawa, internetted, inspiring, intelligent House

- Advanced Experimental and Provisioning Facility of Home Network Systems
- Based on “Standard House Design” by Architectural Institute of Japan
iHouse Floor Plan

1st Floor
- Entrance Hall
- Washroom
- Bathroom
- Dining Room & Living Room
- Japanese Style Room

2nd Floor
- Spare Room
- Master Room
- Bed Room 1
- Bed Room 2
Outlets and Windows

Normal Outlet

Experiment Outlet

Power over Ethernet (PoE)

ECHONET Circuit Part for Driving Motor
Sensors

- Motion Sensor
- Temperature & Brightness Sensor
- Door Open/Close Detection Sensor
Weather Sensors

- Aerovane (Wind Speed & Direction)
- Luminometer
- Sunshine Recorder
- Thermometer & Hygrometer
- Rain & Snow Gauge
Curtain

Curtain Automatic Motor

Communication Module

Driving Motor Module
Air-conditioner

WiFi or Bluetooth Communication Adapter
Light (DC Powered LED)
iHouse Features

- Connecting sensors, housing equipment, home appliances and electronic devices using ECHONET
  - Resulting more than 300 objects
  - ECHONET Lite v1.1 and ECHONET v3.6 is switchable
- All kinds of applications are supported and provides many different APIs
  - ECHONET
  - UPnP (via the ECHONET-UPnP gateway)
  - Simplified language called HGML (Home Gateway Markup Language)
  - "Kaden API" APIs from Ministry of Economy, Trade and Industry (METI)
- Cloud-based services without local servers
  - Network connection and OSGi-based home gateways
iHouse Wiring

- Experiment outlets that are connected to separate breakers are provided for measuring and experimental equipment
- 24/48V DC power supply to all the LED lights and PoE sockets
  - In-house DC power supply as long as AC 100V power line
  - Also 400V DC power supply that is installed for the solar panel
- Power grid connection via the neighboring facility, Ishikawa Create Laboratory
  - Distribution line emulator
  - Solar panel
  - Li-Ion battery
  - Fuel cell
  - Engine co-generation
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

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<th>Protocol-based HN Emulator</th>
<th>Environmental Simulator</th>
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<tr>
<td>Emulation of all network part of the HN system using StarBED technologies</td>
<td>Numerical simulation for physical environment in the house</td>
</tr>
<tr>
<td>Simulation with macro-model of components based on the statistical model from measured data</td>
<td>Measured data as boundary condition</td>
</tr>
<tr>
<td>Connection to StarBED</td>
<td>Connection to super computers in JAIST</td>
</tr>
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</table>
StarBED
StarBED

- The world largest network simulator
- http://starbed.nict.go.jp
Protocol-based HN Simulator

- Intel Architecture 32 (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

- Physical field simulation based on CFD etc.
- Home appliance and protocols
- Power consumption of all kinds of home devices
- Human activity based on statistical data and mental models

Physical Environment Simulator
Home Network Simulator
Electric Power Simulator
Human Simulator
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 (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 (STC)
  - Cluster of thousands of nodes

- Connection to super computers in JAIST
  - Massively parallel processors: Cray, NEC, SGI, etc
エコキャンパス計画を進める日本大学文理学部周辺地域を対象として、地域モデルを想定。
地域モデルは、中学・高校と周辺住宅地区で電力エネルギーネットワークを構築するコミュニティを想定（①～④）し、コミュニティ内では各施設に設置したHEMS・センサー・GWを通じて、エネルギー消費を最小にするエネルギーマネジメント技術の導入について計画する。
また、コミュニティデータ収集対象として、今回対象の学校のほか、大学および周囲の小学校を想定（③～⑧）している。
Design of Power distribution line
Community Simulator
ITU-T FG-Smart deliverables
- Use Cases for Smart Grid
- Requirements of communication for Smart Grid
- Smart Grid Architecture
- Smart Grid Overview
- Terminology

Figure 2. Conceptual Reference Diagram for Smart Grid
Relationship of SmartGrid Standards

**Smart Grid Domain Model**

- IEC62325
  - Energy Market
- IEC61970-CIM
  - EMS Operation
  - Power Systems
- IEC61968-DCIM
  - DMS Operation
  - Asset Management
  - Consumer Meter
  - Load Control

**OpenADR (Automated Demand Response)**
- OASIS

**EI (Energy Information standards)**
- EIS Alliance

**FSGIM (Facility Smart Grid Information Model)**
- ASHRAE SPC201

**ZigBee SEP2 (Smart Energy Profile)**

**EUI (Energy Usage Information model)**
- ESPI (Energy Service Provider Interface)
- NAESB

**Smart Grid Common Base Model**

**CIM Core, Domain package**

**Information Technology**

- **UML**
  - Use case, Class diagram
  - Sequence, State Transition
- **XML**
  - RDF Schema
  - XML Schema

**詳細は電気学会技術報告、「スマートグリッドにおける需要家施設のサービスインフラ」(2015.02発行)を参照**
**Inter/intra-regional collaboration**

<table>
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<th>Types</th>
<th>Organizations</th>
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<tbody>
<tr>
<td>Participation</td>
<td>APT/ASTAP</td>
</tr>
<tr>
<td>Core member</td>
<td>CJK(ARIB, CCSA, TTA, TTC), GSC, 3GPP/3GPP2, oneM2M</td>
</tr>
<tr>
<td>MoU/LoI</td>
<td>ITU, ETSI, IEEE, GISFI, TSDSI, MSTFBI, NBTC, ZigBee Alliance, Wi-SUN Alliance, HD-PLC, GSMA, etc</td>
</tr>
</tbody>
</table>
Activities of Next generation HN system WG

Next generation HN system WG

The areas of standardization expertise of this working group are home network systems including architecture, user support and service platform, all of which are studied by WP1 of ITU-T SG15.

Apr.2004 Established

After the successful end of DHF (Digital Home network Forum), TTC launched the Next Generation HN System WG which inherits the achievements of DHF.

Upstream activities of Next generation HN system WG are:

- ITU-T J.190r1 (Architecture of MediaHomeNet)
- ITU-T H.622 (A generic home network architecture with support for multimedia services)
- ITU-T G.9903 (Narrowband orthogonal frequency division multiplexing power line communication transceivers for G3-PLC networks)
- ITU-T G.9970 (Generic home network transport architecture)
- ITU-T G.9971 (Requirements of transport functions in IP home networks)
- ITU-T G.9973 (Protocol for identifying home network topology)
- TR-1043 (Implementation guidelines of Home network communication interface)
- TR-1053 (Customer support functions for home network service platform)

ITU-T Y.2070 (Requirements and architecture of home energy}
Concluding Remarks

- IoT Systems like smart home and smart community consists of real devices and cyber components which includes cloud services in the network.
- To develop the smart community system, smart home and services for them, testbed that covers both real and cyber part of the system is required.
- We have developed such an environment with real experimental houses (TANS2 and iHouse) and simulators (Protocol-based HN simulator and environmental simulator).
- We are now developing the community simulator based on real model city and “virtual pilot program” will be realized.
SpringOS

Environmental description (topology part)

```plaintext
nodeset client class c num 1
nodeset server class s num 1
netset ethnet class e num 4

attach server.netif["lan0"] ethnet[0]
attach server.netif["lan1"] ethnet[1]
attach server.netif["lan2"] ethnet[2]
attach server.netif["lan3"] ethnet[3]

attach client.netif["lan0"] ethnet[0]
attach client.netif["lan1"] ethnet[1]
attach client.netif["lan2"] ethnet[2]
attach client.netif["lan3"] ethnet[3]
```

Execution description

Described as a remote procedure execution and synchronization condition
RUNE

- RUNE Manager on each host OS provides the function of Conduit communication
- A space is allocated to each summation entity and communication between space is provided by Conduit