# Smart Home and Smart Community Simulator

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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 (Sysem of Systems)
- Intelligence
  - cloud computing
  - Big-Data

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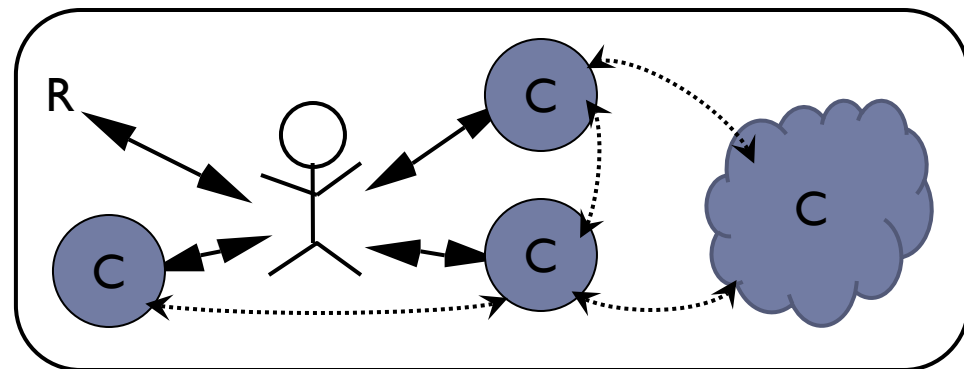
Five Elements for Smart Systems

▸ 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

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"Connect" technology for HEMS - TTC TR-1043

	Ethernet	ITU-T G.hn	IEEE1901 / HD-PLC	ITU-T G.hnem / G3-PLC	Wi-Fi	Bluetooth	IEEE802.15.4/4e/4g / Wi-SUN / ZigBee IP, 920IP	
5–7	ECHONET Lite							ECHONET Lite over Layer2 frame
4	UDP / TCP							
3	IPv4 IPv6			IPv6 6LoWPAN	IPv4 IPv6		IPv6 6LoWPAN	
2	IEEE802.3 family	G.9961 G.9972	IEEE1901	ITU-T G.9903	IEEE802.11 family	IEEE802.15.1 family PAN profile	IEEE802.15.4 IEEE802.15.4e	
1	IEEE802.3 family	G.9960 G.9963 G.9964 G.9972	IEEE1901	ITU-T G.9903	IEEE802.11 family	IEEE802.15.1 family	IEEE802.15.4 IEEE802.15.4g	
Phy. Media	UTP / Optical Fiber	Power Line			Radio Wave (2.4/5G)	Radio Wave (2.4G)	Radio Wave (2.4G/920M)(※)	

Bottom labels:

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**

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※Only ZigBee IP supports 2.4G

"Sense" and "Actuate"

▶ Sensing and actuating devices in ECHONET standard

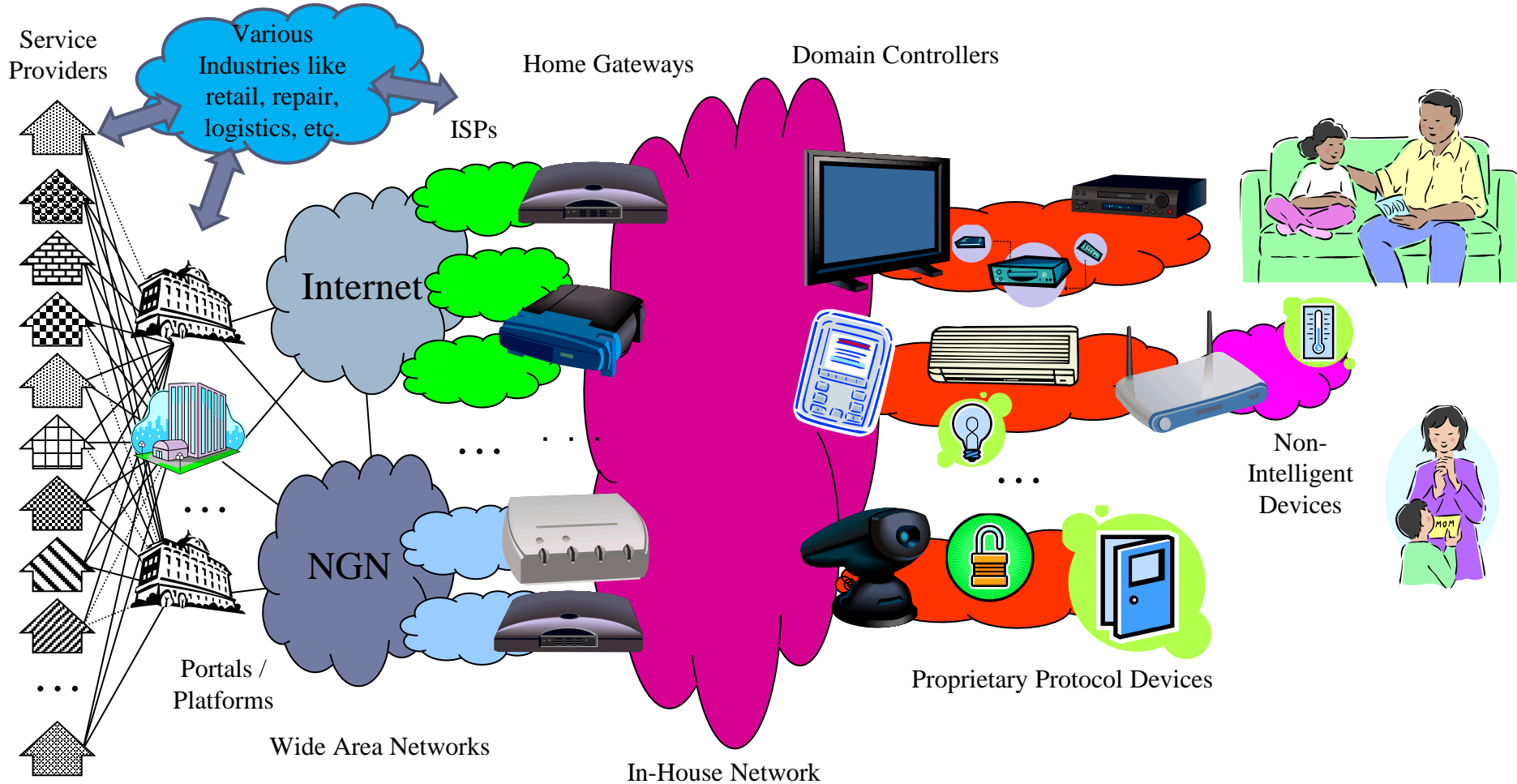| Class Group	Devices
Sensor-related Device Class Group	gas leak sensor, crime prevention sensor, emergency button, first-aid sensor, earthquake sensor, electric leak sensor, human detection sensor, visitor sensor, call sensor, condensation sensor, air pollution sensor, oxygen sensor, luminance sensor, 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
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

"Make a Decision" & "Learn"

情報収集

ルータ

制御

コントローラ

スタンドアロン型HN

VOD

サービス

HVAC

制御

ホームゲートウエイ

ASP型HN

VOD

サービス

顧客情報

HVAC

サービス
プラットフォーム

ホームゲートウエイ

制御

プラットフォーム型HN

Next Generation Home Networks (2007)

▶ Cloud computing for home appliances

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)
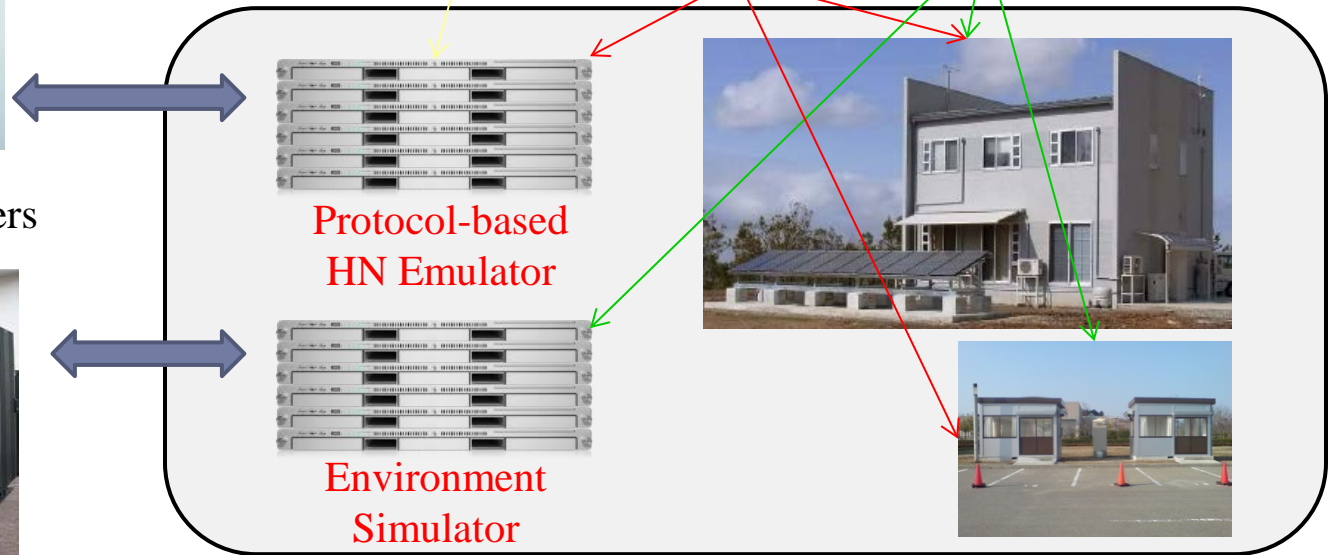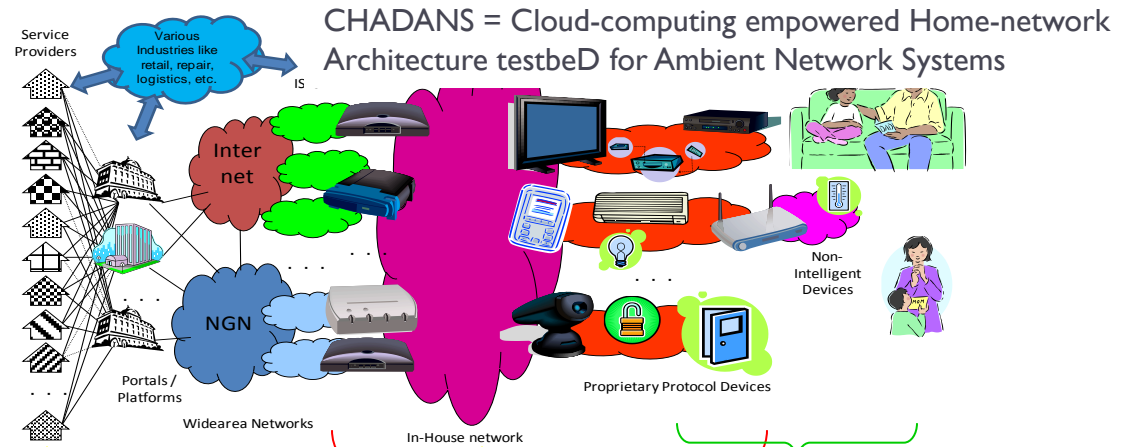
☐ Experimental house, iHouse

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
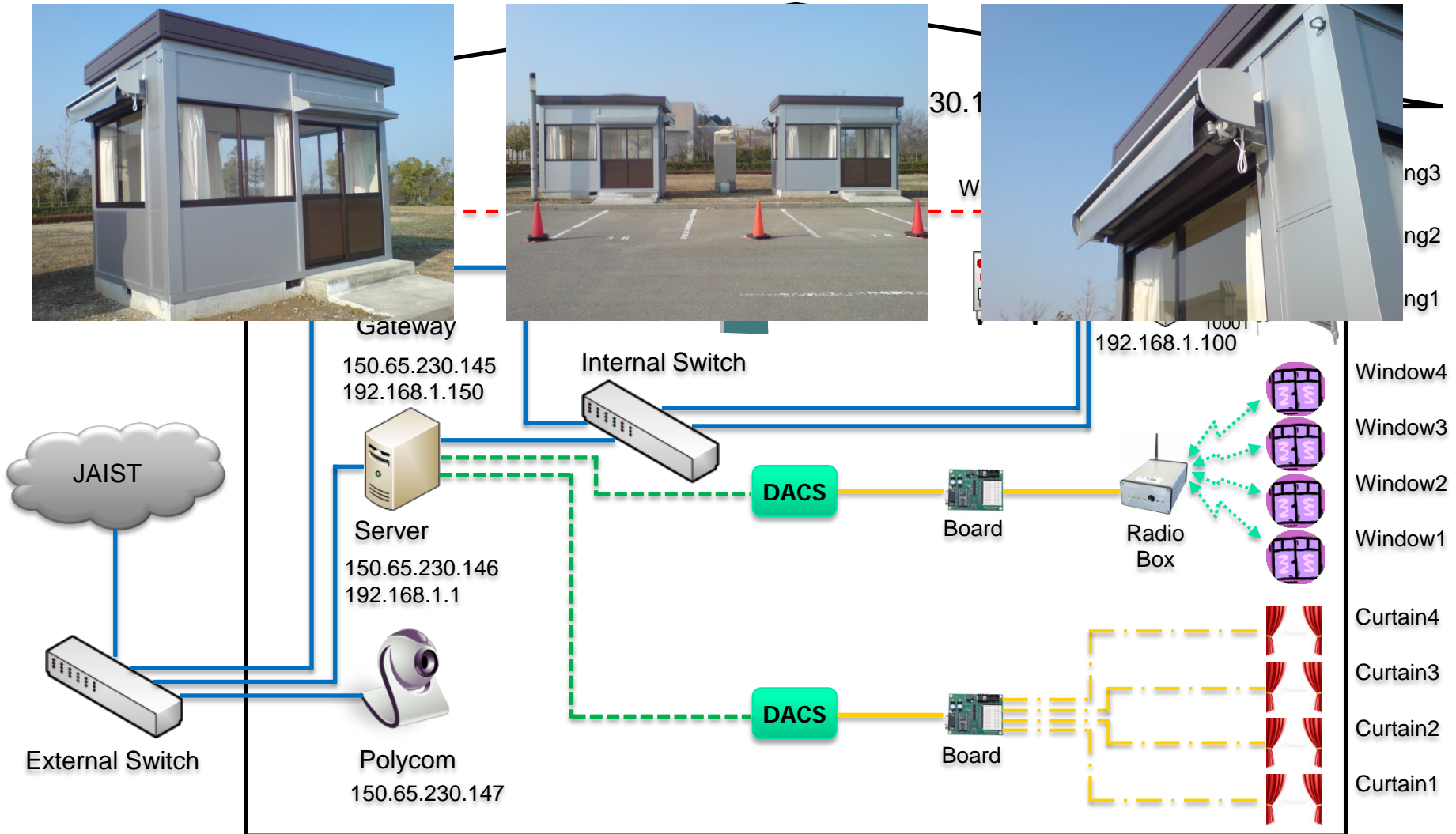
CHADANS

StarBED

JAIST Super Computers

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

Service Providers

Various Industries like retail, repair, logistics, etc.

IS

Inter net

NGN

Portals / Platforms

Widearea Networks

In-House network

Non-Intelligent Devices

Proprietary Protocol Devices

Protocol-based HN Emulator

Environment Simulator

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

TANS2	iHouse
HVAC*, energy management	All services
Full-automatic experiment	Automatic experiment for non-interactive services
Scenario based automatic configuration	Automatic configuration for basic part of equipments
Temperature, humidity, luminance	Real user experience for all services

* HVAC = Heating, Ventilation and Air-Conditioning

TANS2: Testbed for Ambient Network System 2

30.1

W

ng3

ng2

ng1

192.168.1.100

Gateway

150.65.230.145
192.168.1.150

Internal Switch

JAIST

Server

150.65.230.146
192.168.1.1

External Switch

Polycom

150.65.230.147

DACS

Board

Radio Box

Window4

Window3

Window2

Window1

DACS

Board

Curtain4

Curtain3

Curtain2

Curtain1

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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

- Kitchen
- Entrance Hall
- Washroom
- Bathroom
- Dining Room & Living Room
- Japanese Style Room

2nd Floor

- Spare Room
- Bed Room 2
- Master Room
- Bed Room 1

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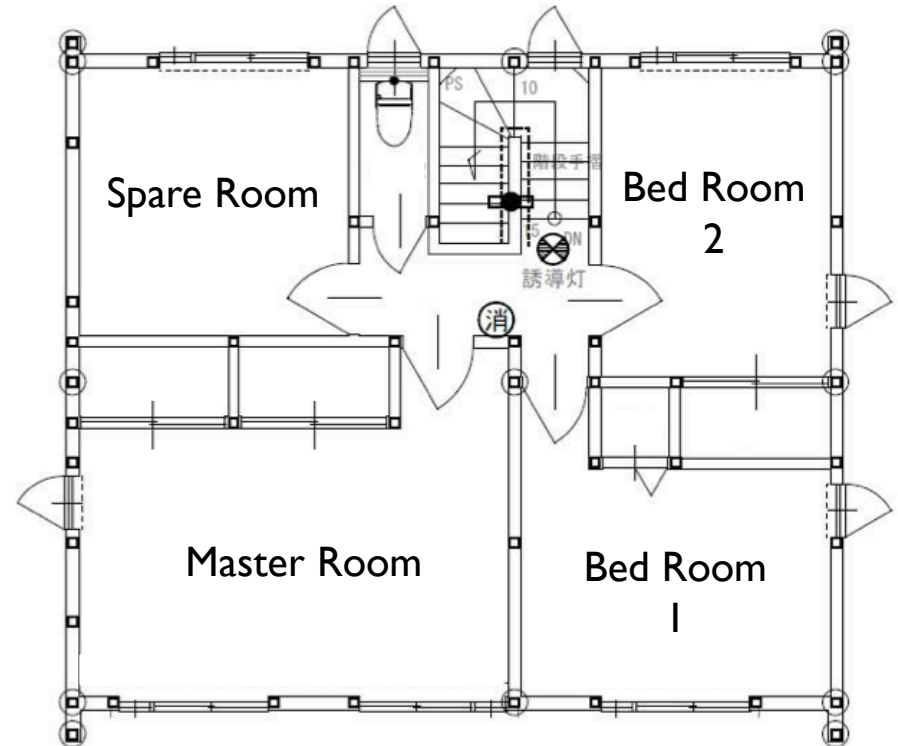
Outlets and Windows

Power over Ethernet (PoE)

Normal Outlet

Experiment Outlet

ECHONET Circuit Part for Driving Motor

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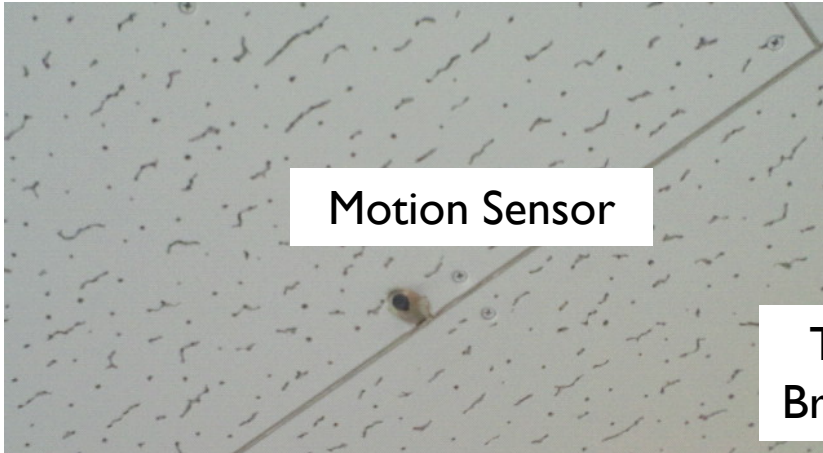
Motion Sensor
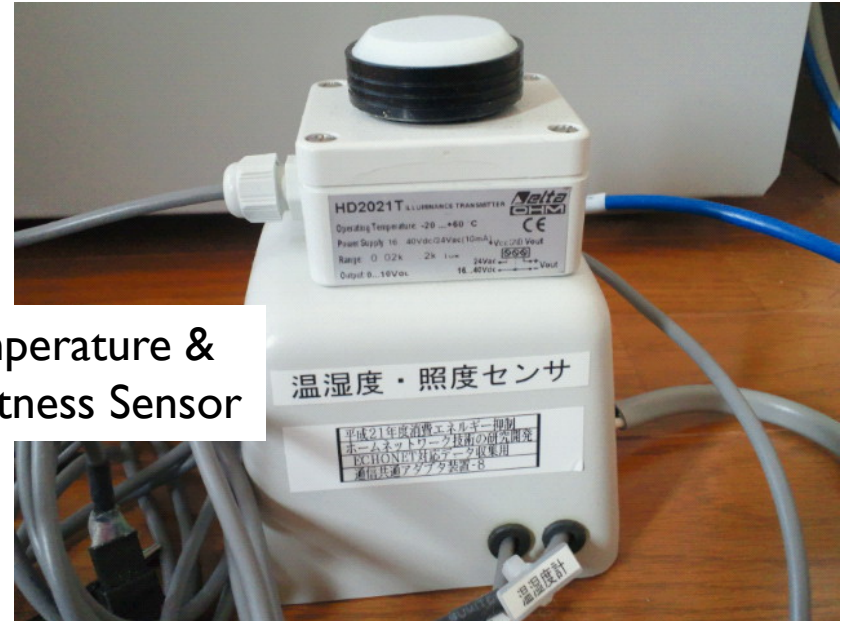
Temperature & Brightness Sensor
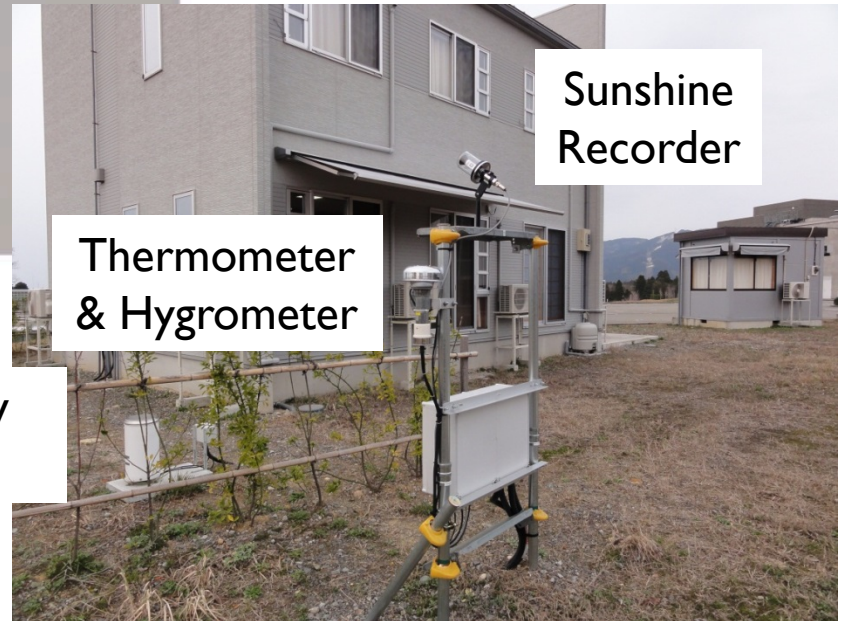
Door Open/Close Detection Sensor

温湿度・照度センサ

Weather Sensors
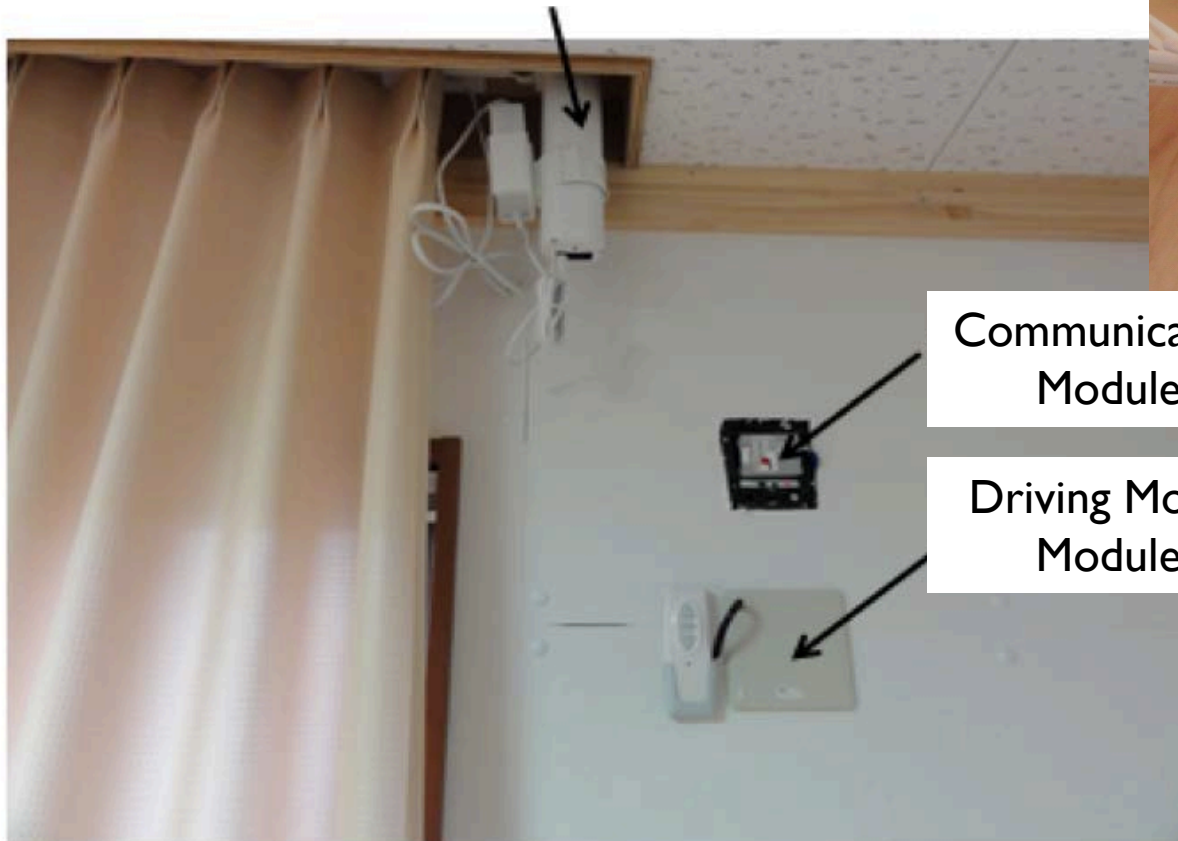

Aerovane (Wind Speed & Direction)

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

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

StarBED

StarBED

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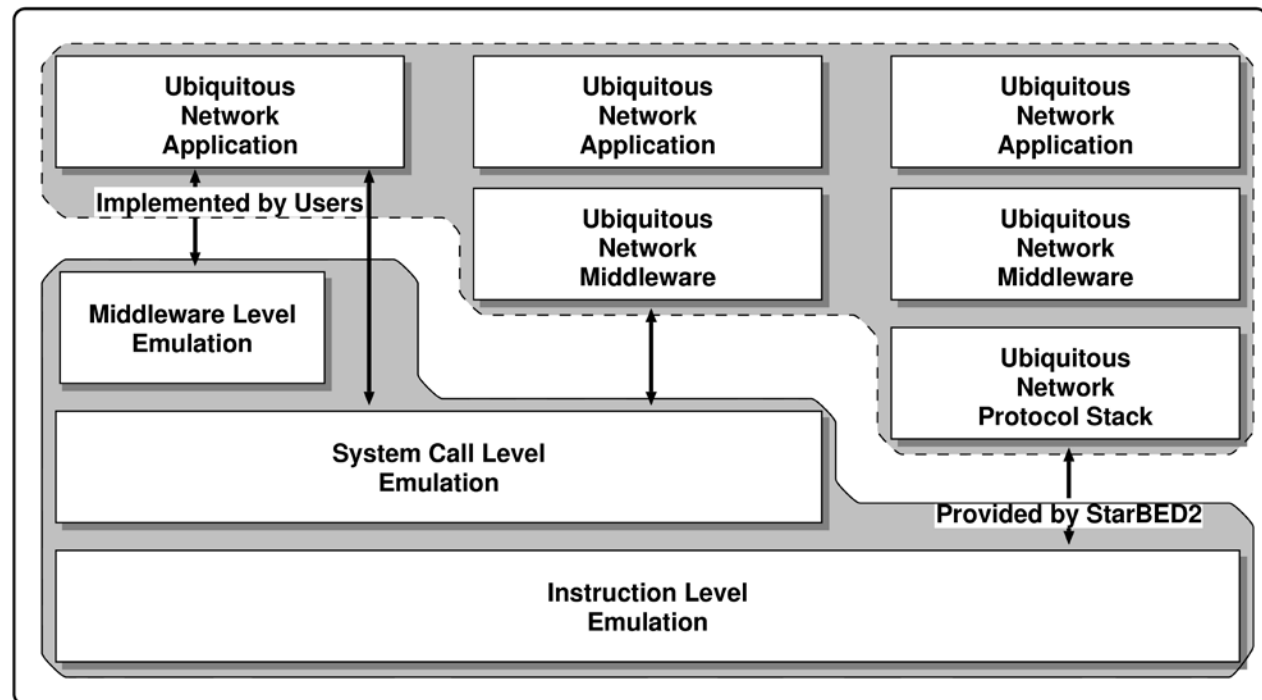- http://starbed.nict.go.jp
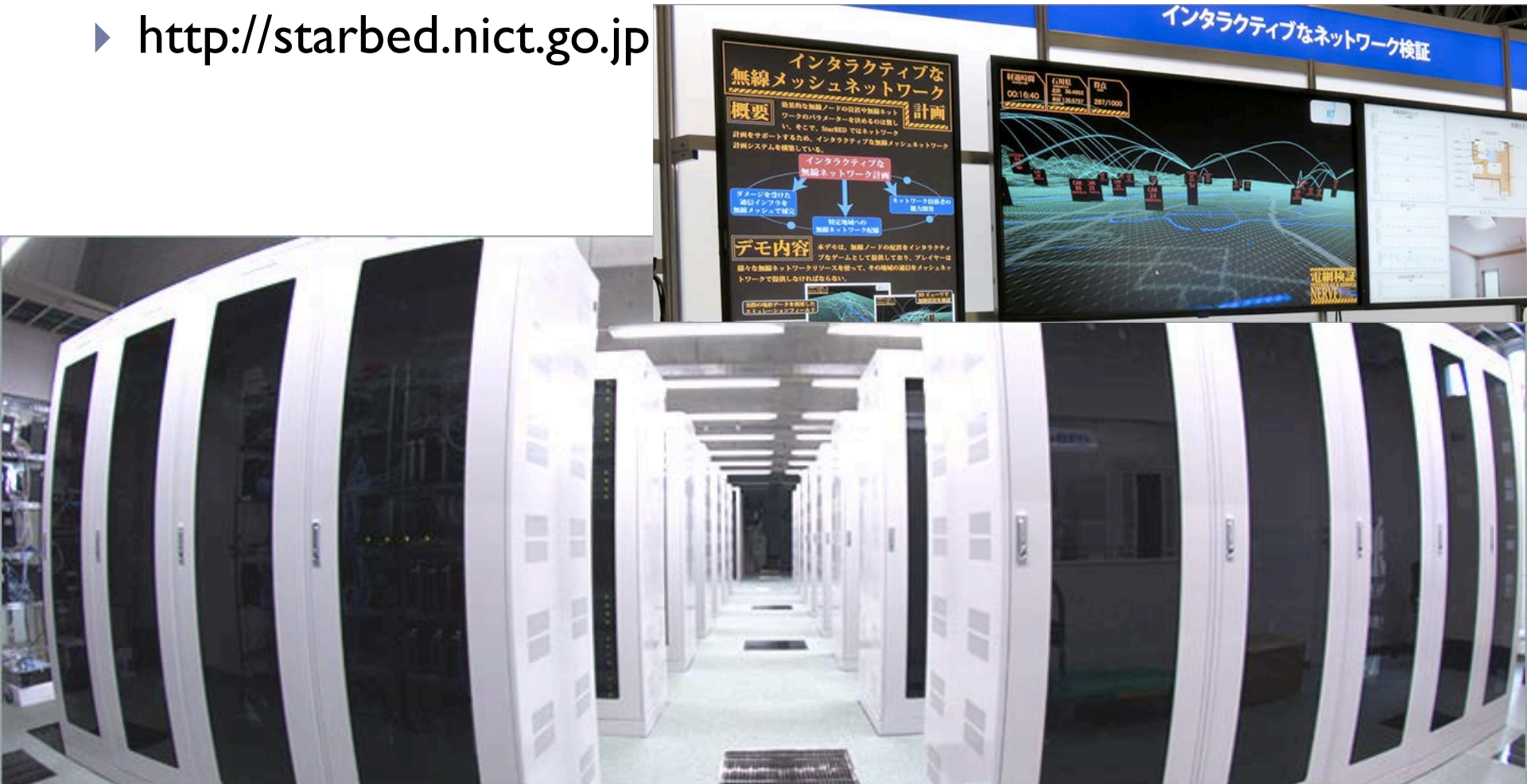
Protocol-based HN Simulator

▸ Intel Architecture 32 (IA-32) processor based cluster

▸ Combination of real device, simulation and emulation

▸ Emulation approach
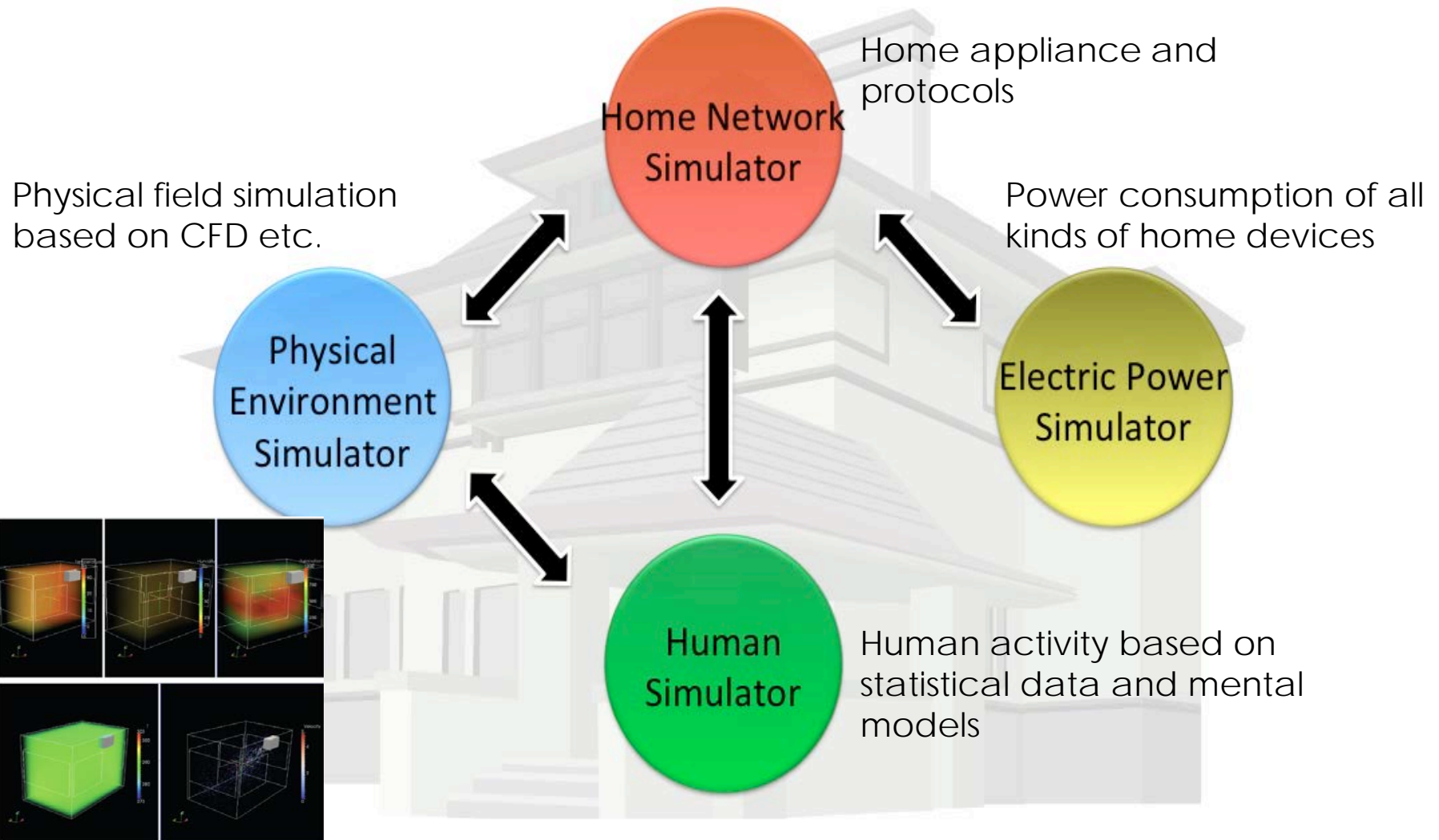 ▸ Execution of the real object code of the target system
  ▸ Real-time execution
  ▸ Interaction with real devices and users

▸ Multi-level emulation
  ▸ Binary-level (processor emulation)
  ▸ System call, library (OS emulation)
  ▸ API (middleware emulation)
 ▸ Behavior (device/system emulation, statistical model)

Environmental Simulator

Home appliance and protocols

Physical field simulation based on CFD etc.

Power consumption of all kinds of home devices

Home Network Simulator

Physical Environment Simulator

Electric Power Simulator

Human Simulator

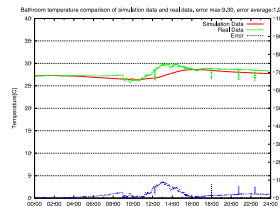Human activity based on statistical data and mental models

Simulated iHouse

▸ **Thermal conduction and Computational Fluid Dynamics (CFD) based modeling of iHouse**
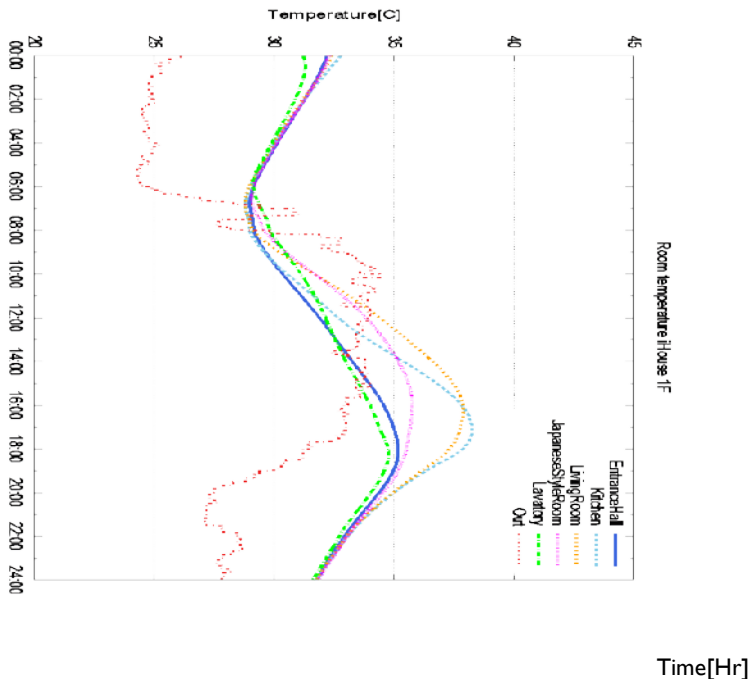
Simulated temperatures of rooms in iHouse

Difference between simulated and observed temperatures in each room

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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

Community model

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。

街 区	住 宅	学校	地域モデル	データ収集
①桜上水新築集合住宅街区	集合870戸	－	○	
②既設住宅街区	戸建40戸　集合90戸	－	○	
③日本大学櫻丘高校	－	延床　20,000㎡	○	○
④区立緑ヶ丘中学校	－	延床　8,000㎡	○	○
⑤日本大学文理学部	－	延床　85,000㎡		○
⑥区立松沢中学校	－	延床　7,400㎡		○
⑦区立松沢小学校	－	延床　9,600㎡		○
⑧区立赤堤小学校		延床　8,200㎡		○

①桜上水新築集合住宅街区
・総戸数870戸（中高層集合住宅6棟）
・平成27年に竣工予定の再開発住宅
・地域モデル計画
　（図は公表資料を基に作成）

地域モデル

⑥区立松沢中学校
・延床面積7,400㎡
・データ収集対象

⑦区立松沢小学校
・延床面積9,600㎡
・データ収集対象

データ取集対象

②既設住宅街区
・総戸数140戸（戸建40戸、低層集合住宅8棟90戸）
・地域モデル

⑤日本大学　文理学部
・平成27年に大規模建替工事予定
・建替に際し、エコキャンパス計画推進
・データ収集対象

⑧区立赤堤小学校
・延床面積8,200㎡
・データ収集対象

④区立緑ヶ丘中学校
・延床面積8,000㎡
・地域モデル/データ収集対象

③日本大学櫻丘高等学校
・延床面積20,000㎡
・地域モデル/データ収集対象

Design of Power distribution line

集合住宅ルート

変電所ルート

戸建住宅ルート

Community Simulator

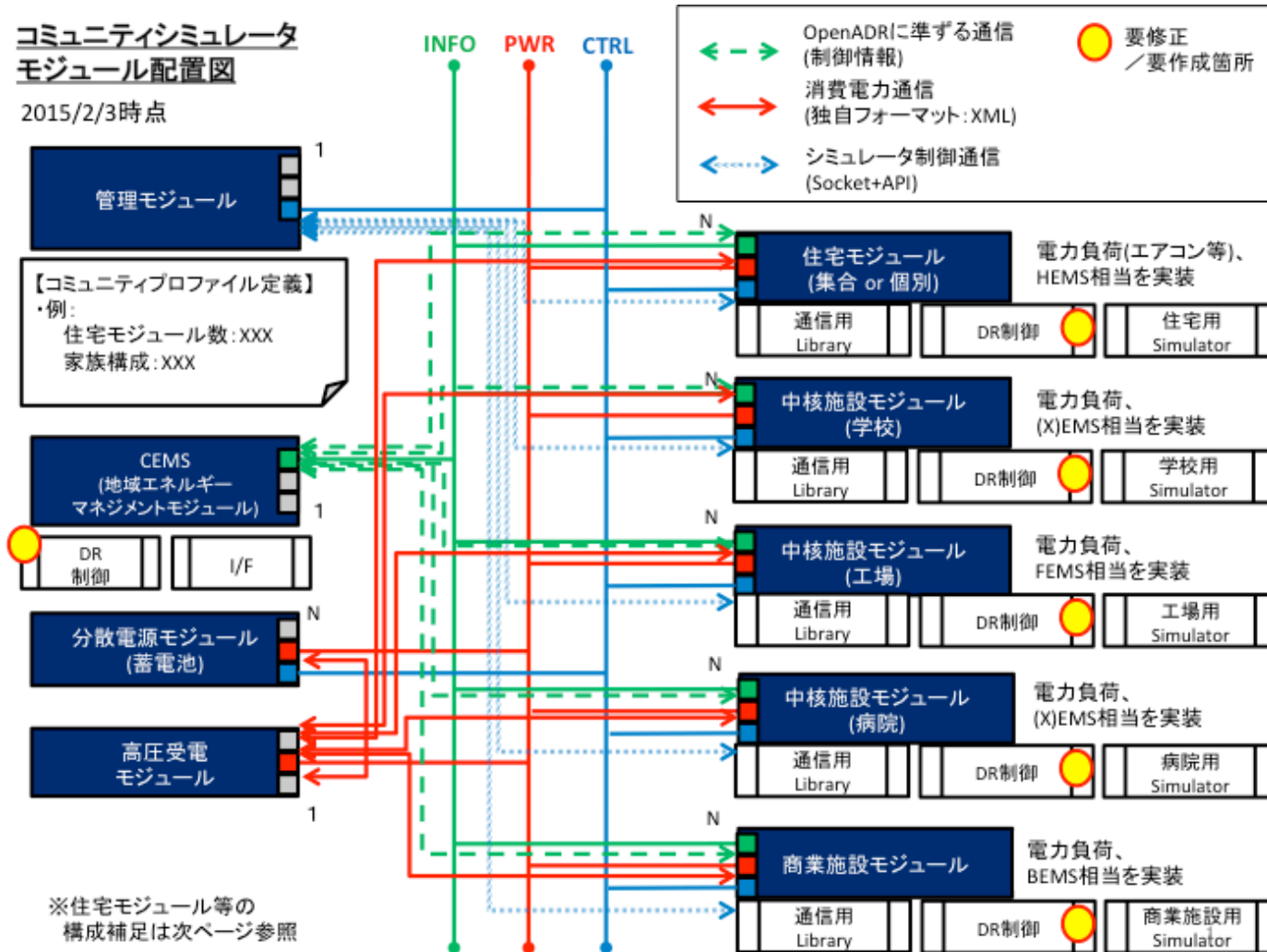# Conceptual Reference Diagram for Smart Grid
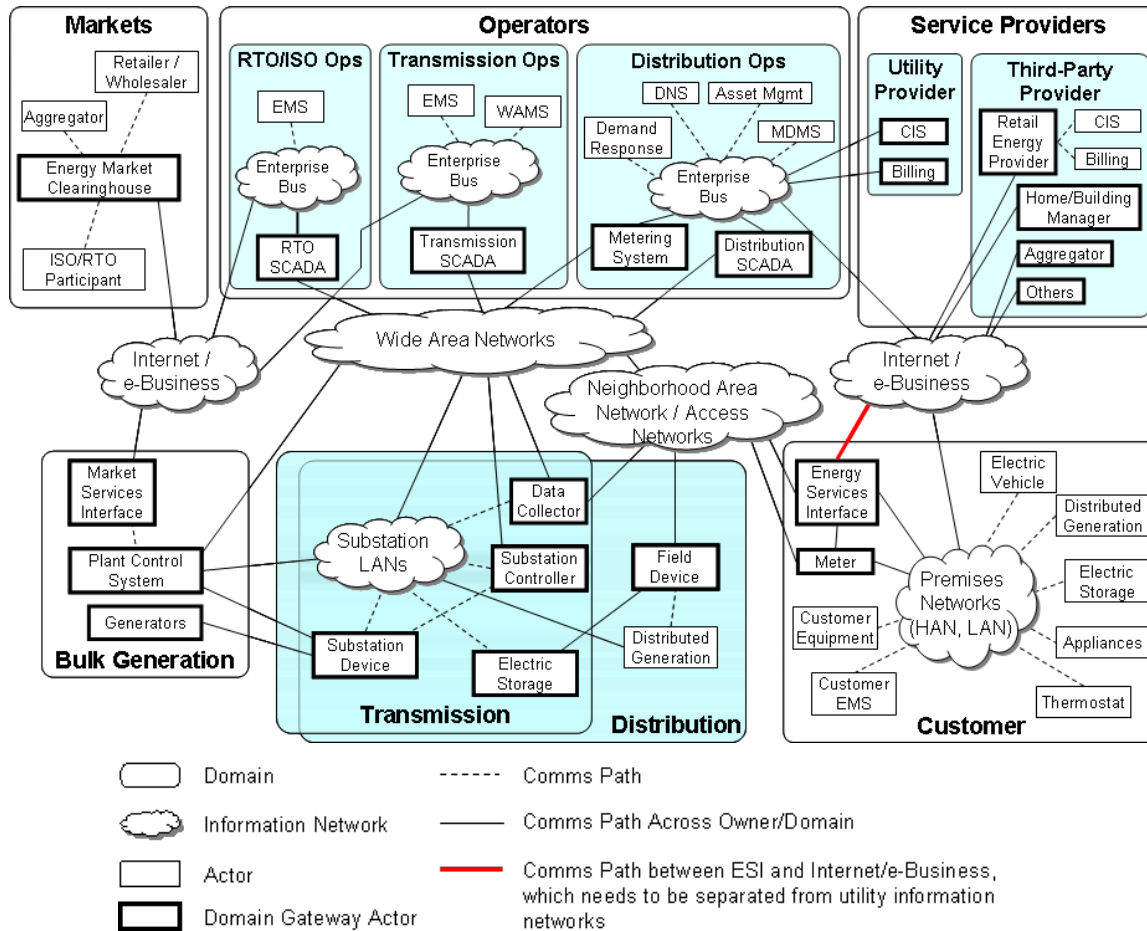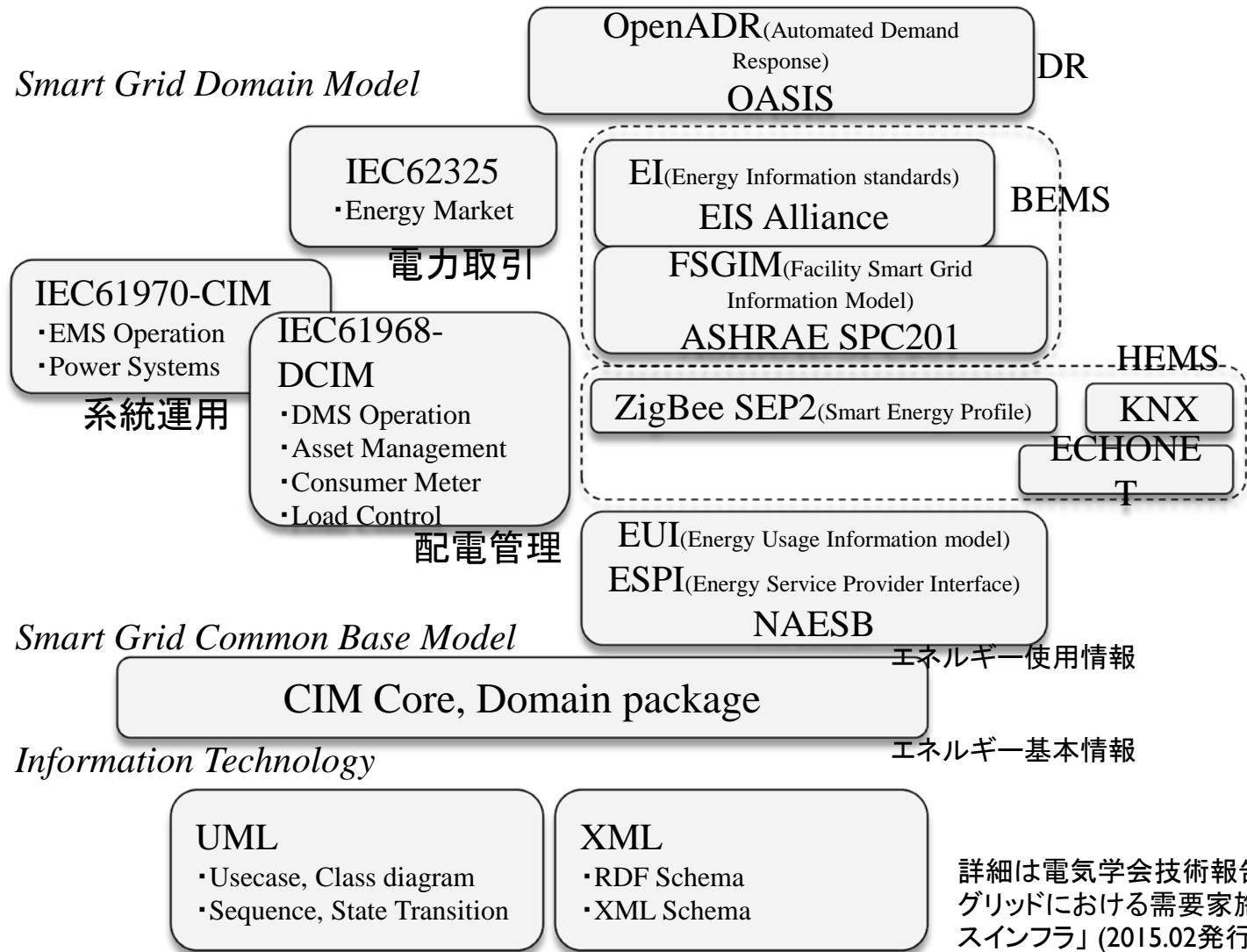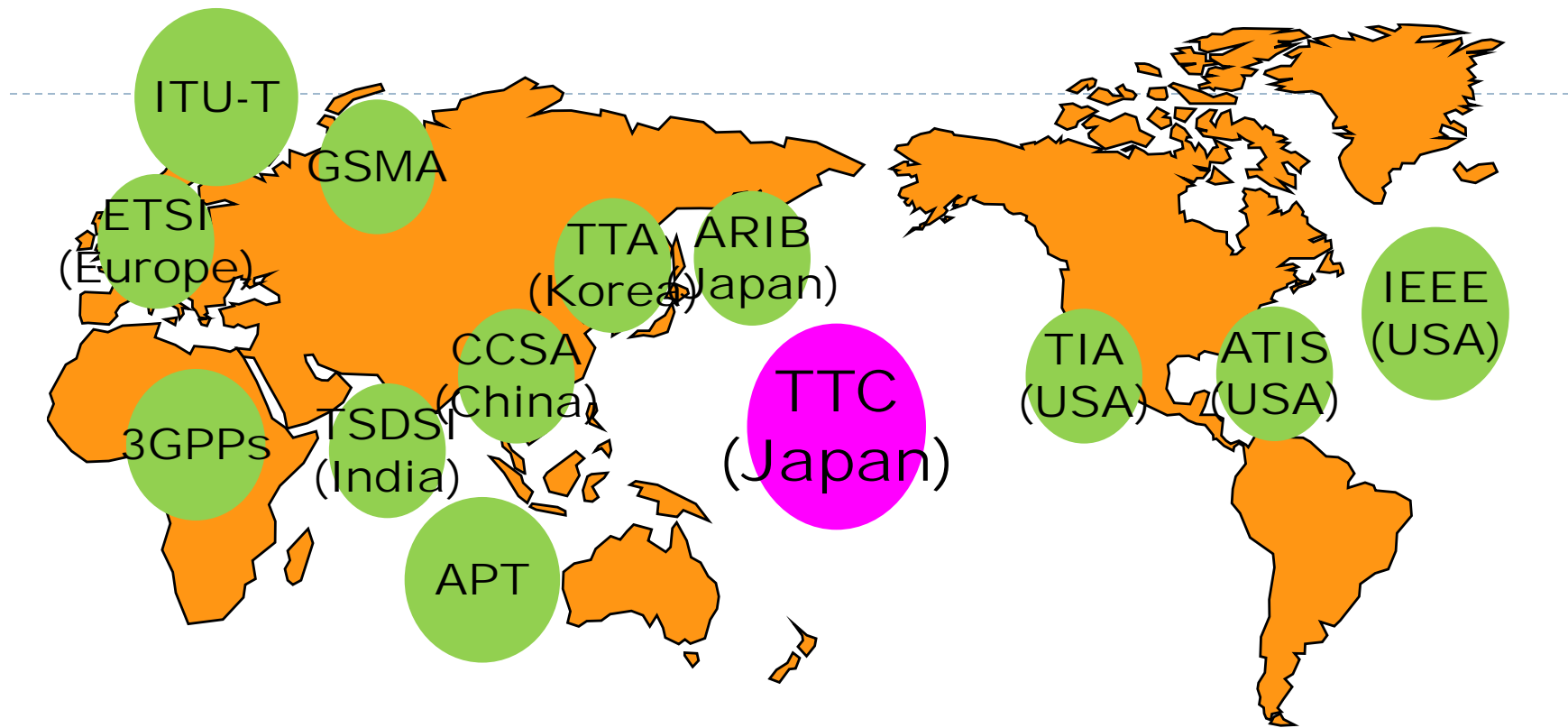
▸ From "Smart Grid overview" ITU-T FG-Smart deliverable

Figure 2. Conceptual Reference Diagram for Smart Grid

ITU-T FG-Smart deliverables
• Use Cases for Smart Grid
• Requirements of communication for Smart Grid
• Smart Grid Architecture
• Smart Grid Overview
• Terminology

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Relationship of SmartGrid Standards

Smart Grid Domain Model

OpenADR(Automated Demand Response)
OASIS

DR

IEC62325
・Energy Market

電力取引

EI(Energy Information standards)
EIS Alliance

FSGIM(Facility Smart Grid Information Model)
ASHRAE SPC201

BEMS

IEC61970-CIM
・EMS Operation
・Power Systems

系統運用

IEC61968-DCIM
・DMS Operation
・Asset Management
・Consumer Meter
・Load Control

配電管理

ZigBee SEP2(Smart Energy Profile)

KNX

ECHONET

HEMS

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

Smart Grid Common Base Model

CIM Core, Domain package

エネルギー使用情報

エネルギー基本情報

Information Technology

UML
・Usecase, 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

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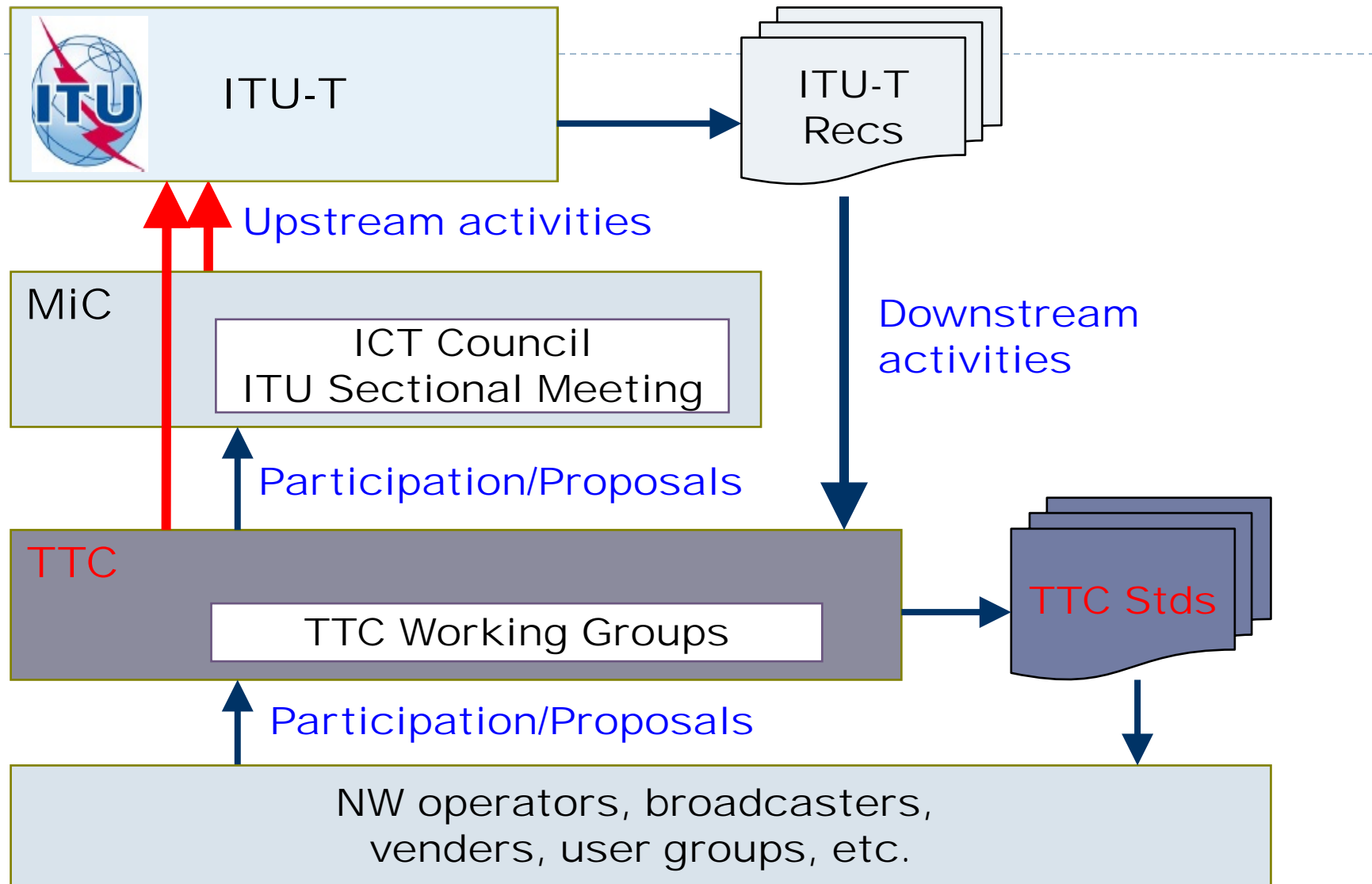
Activities of Next generation HN system WG

- ❑ **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

# Backup Slides

SpringOS

Environmental description (topology part)

```
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]
```
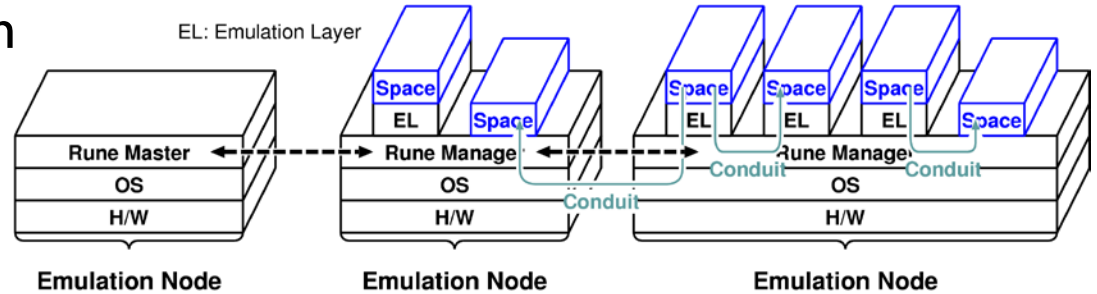
Execution description

Described as a remote procedure execution and synchronization condition

configuration phase

execution phase

40
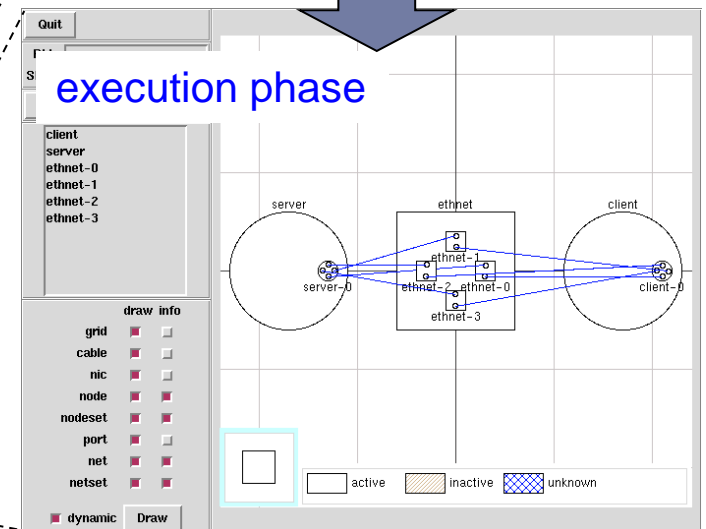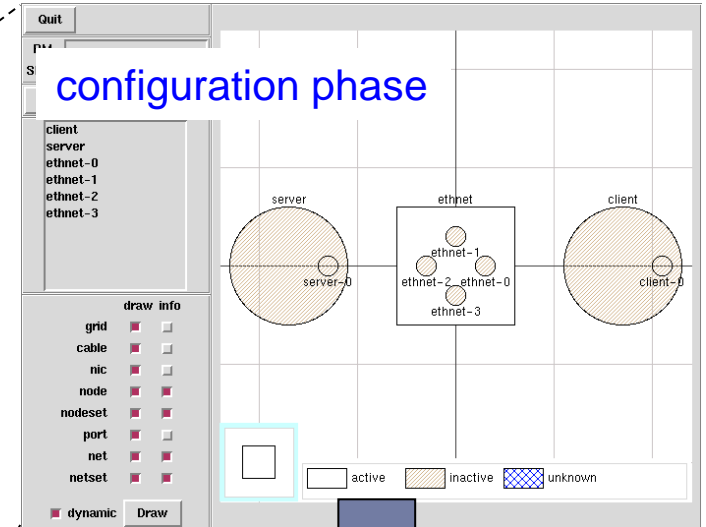
RUNE

▸ 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