ITU Workshop on the "Internet of Things - Trend and Challenges in Standardization"

(Geneva, Switzerland, 18 February 2014)

IoT, Ubiquitous Computing, and Open Data for Smart Environments

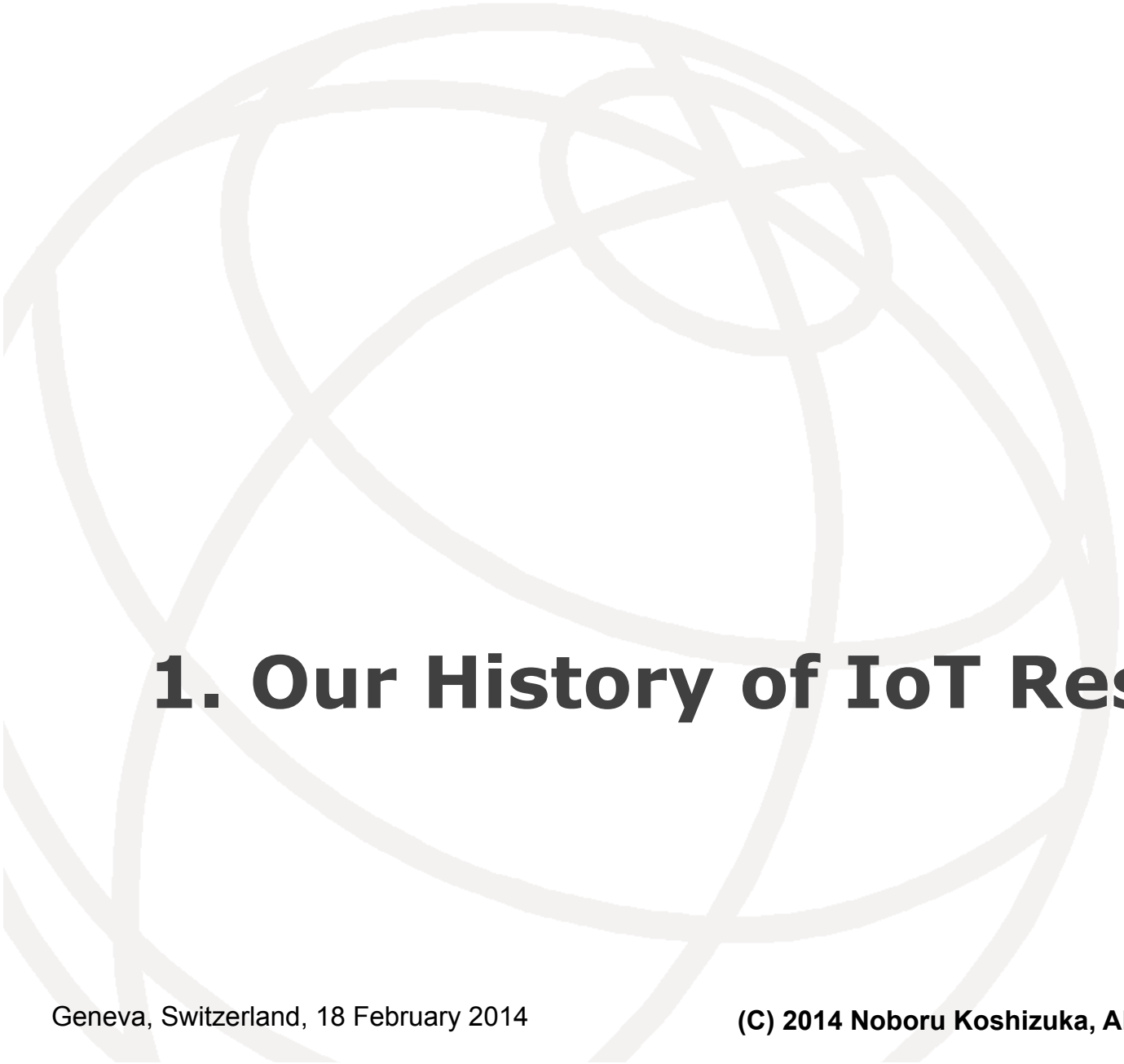
Noboru Koshizuka

Professor, The University of Tokyo

koshizuka@sakamura-lab.org

My Profile

- Name
  - Noboru Koshizuka（越塚　登）
- Titles
  - Professor, Interfaculty Initiatives in Information Studies, The University of Tokyo
  - Vice Director, YRP Ubiquitous Networking Lab.
  - Board member, Ubiquitous ID Center/T-Engine Forum
- Missions
  - R&D and education of computer science in university
    - Especially, ubiquitous computing, RFID, smart cards, embedded systems, operating systems, human-machine interfaces, computer networks, and so on…
  - Editor of the international standards of Networked Service Protocols Triggered by RFIDs in ITU-T SG16.
    - ITU-T Rec. F.771, H.621, H. 642.1, H.642.3
    - Liaison Officer between ISO/IEC JTC1 SC31 and ITU-T SG16



1. Our History of IoT Research

History of IoT
TRON Project since 1984

- TRON Project since 1984
  - I have Joined since 1988

- Ultimate goal is to realize IoT /Ubiquitous Computing
  - “Highly Functionally Distributed System”
  - “MTRON” (Macro TRON)
  - “Computer Everywhere Environment”

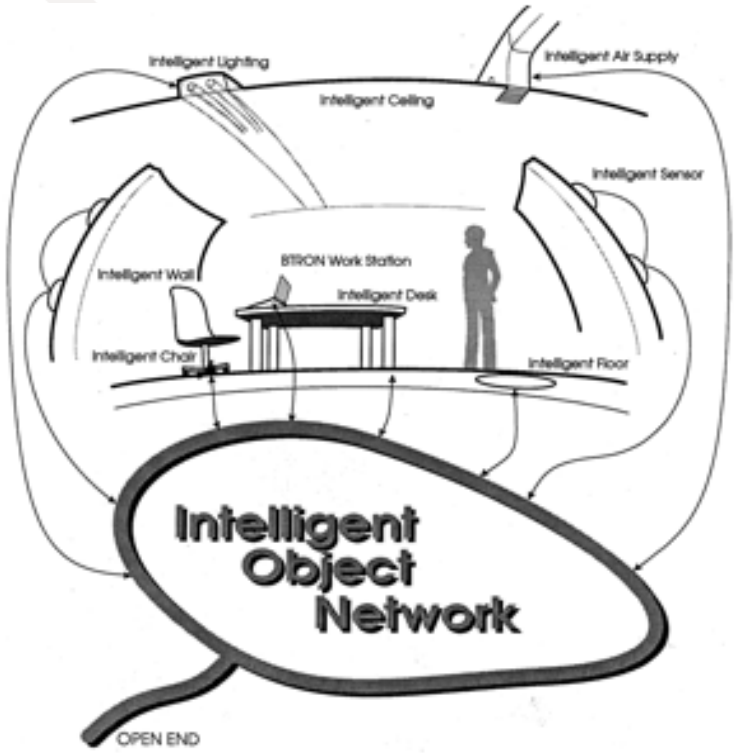


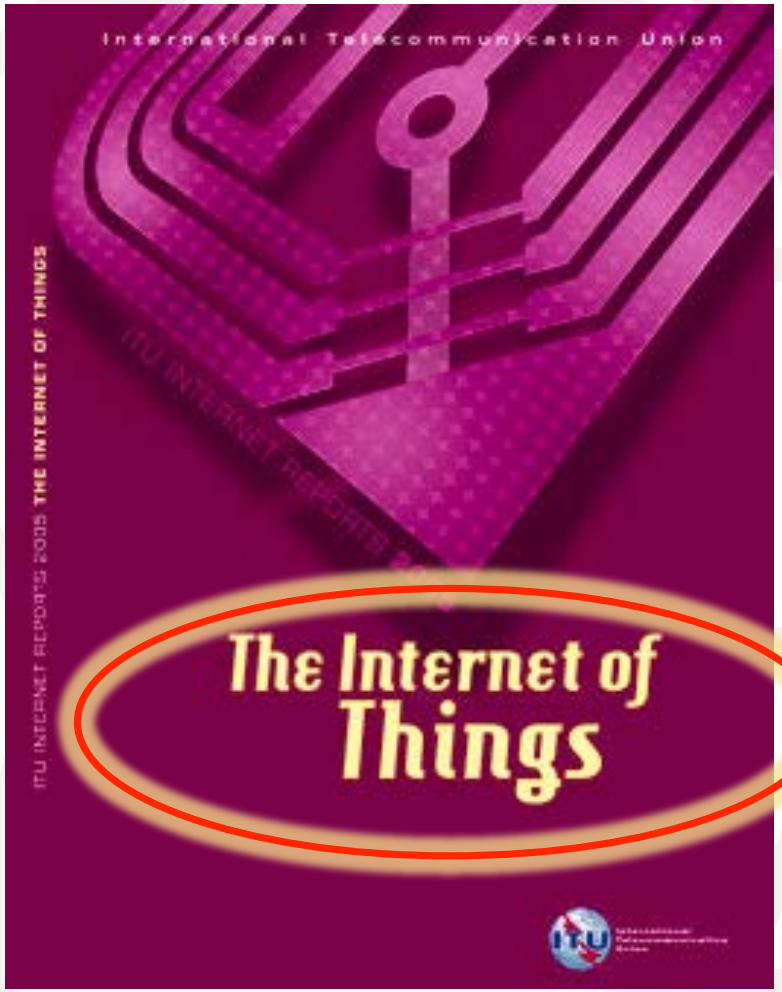
Figure 1. Highly Functionally Distributed System Environment

Dr. Ken Sakamura: “TRON Project 1987”

History of IoT
TRON Smart House (1989)

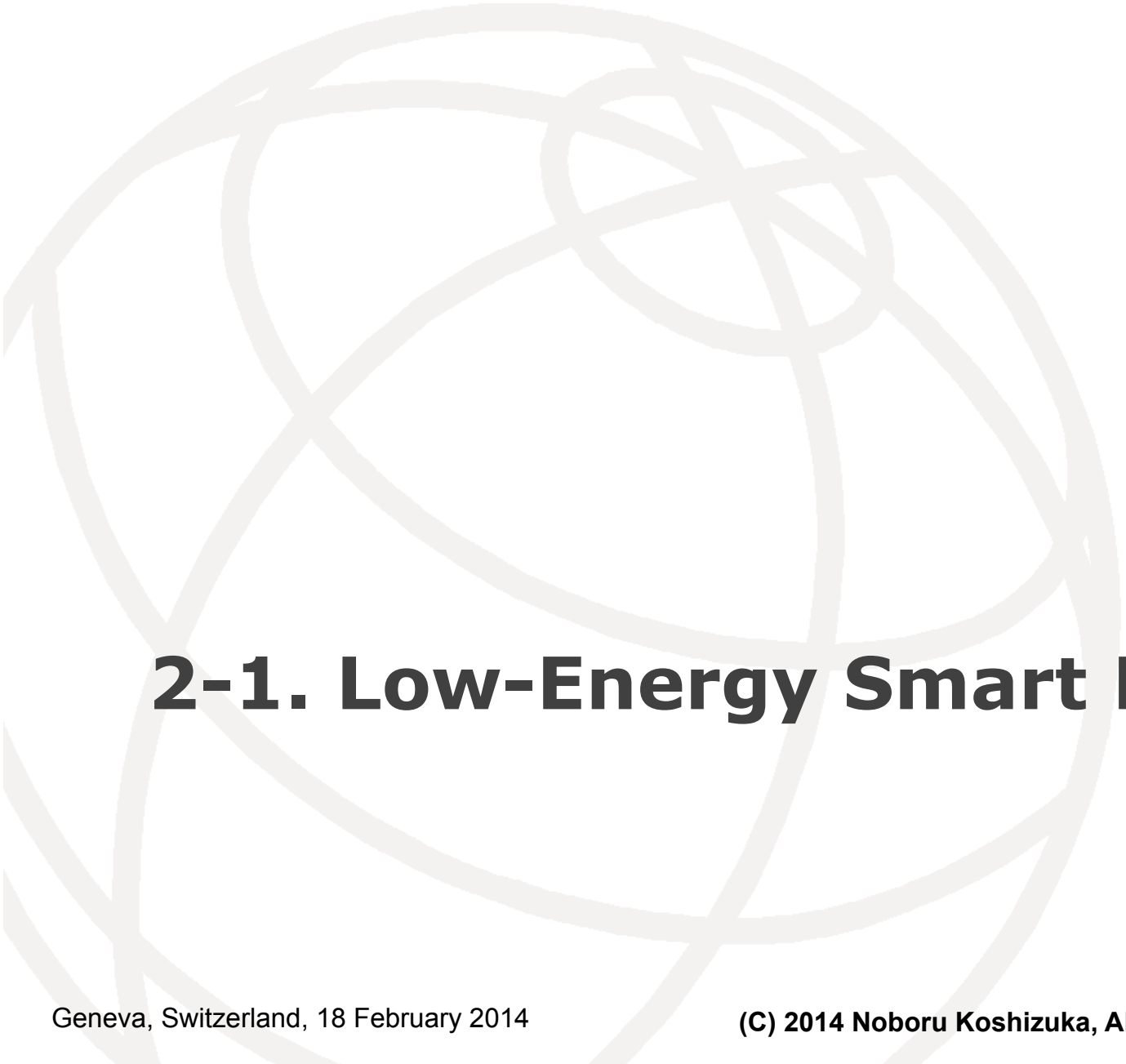
- More than 1,000 computers, sensors, and actuators are embedded in a house of width of 333m2

ITU Internet Reports 2005
"The Internet of Things"



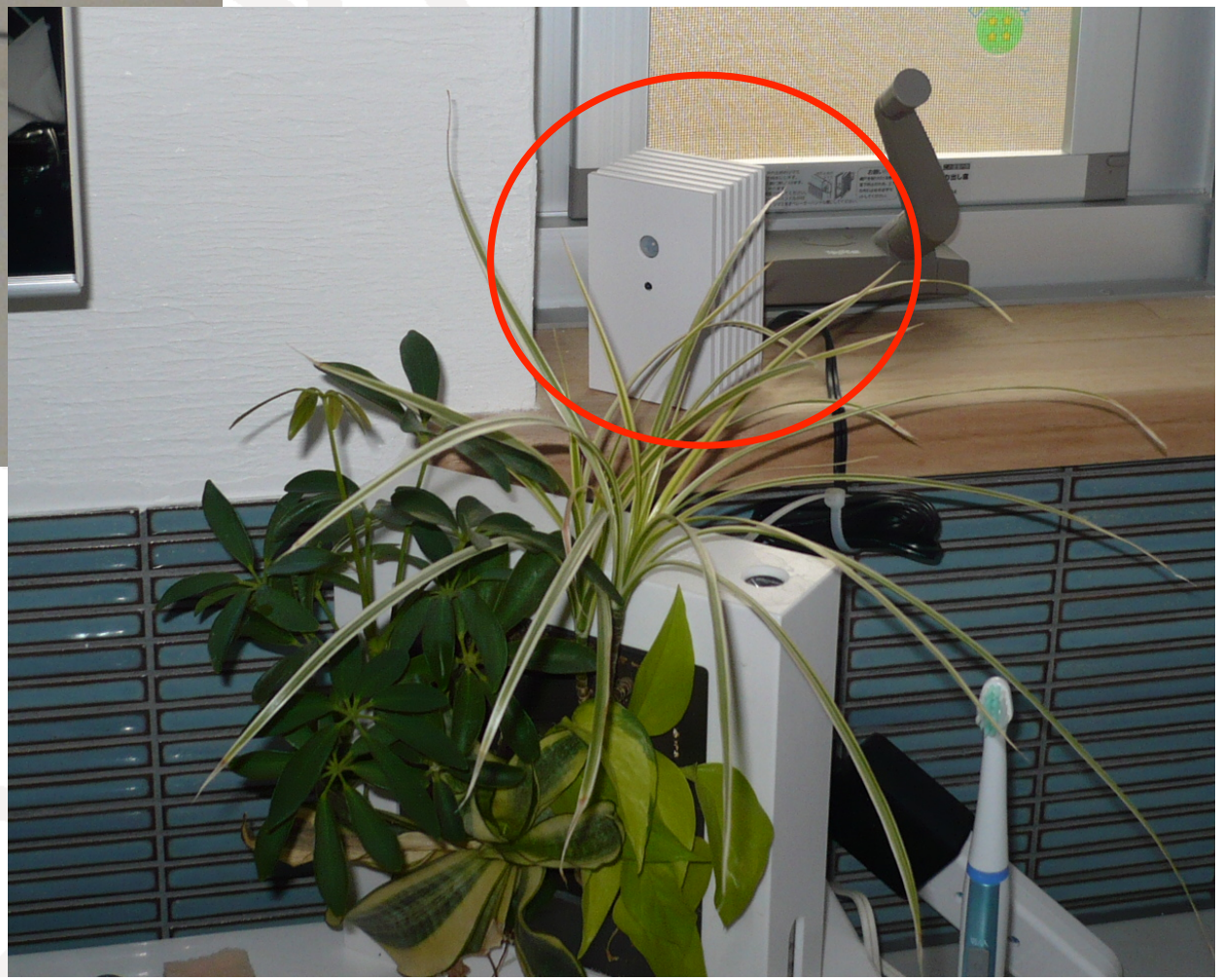
- ..."*Japan's Ubiquitous ID Centre*, for instance, has implemented a 128-bit addressing system for tagging individual objects. By some calculations, the ***ucode*** system would allow for a theoretical 340'000'000'000'000'000'000'000'000'000'000'000'000'000 codes to be assigned. This will permit a trillion tags to be assigned every day for a trillion years, and still have some left over." .....

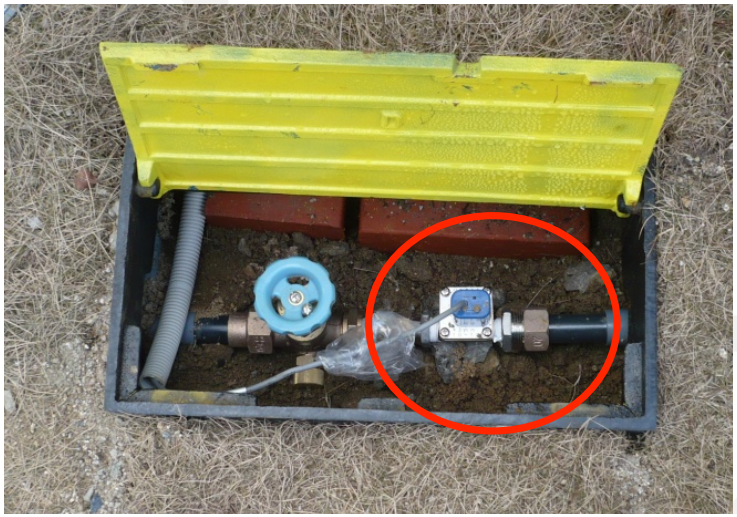
2. Iot Services and Applications of YRP UNL/Univ. Tokyo



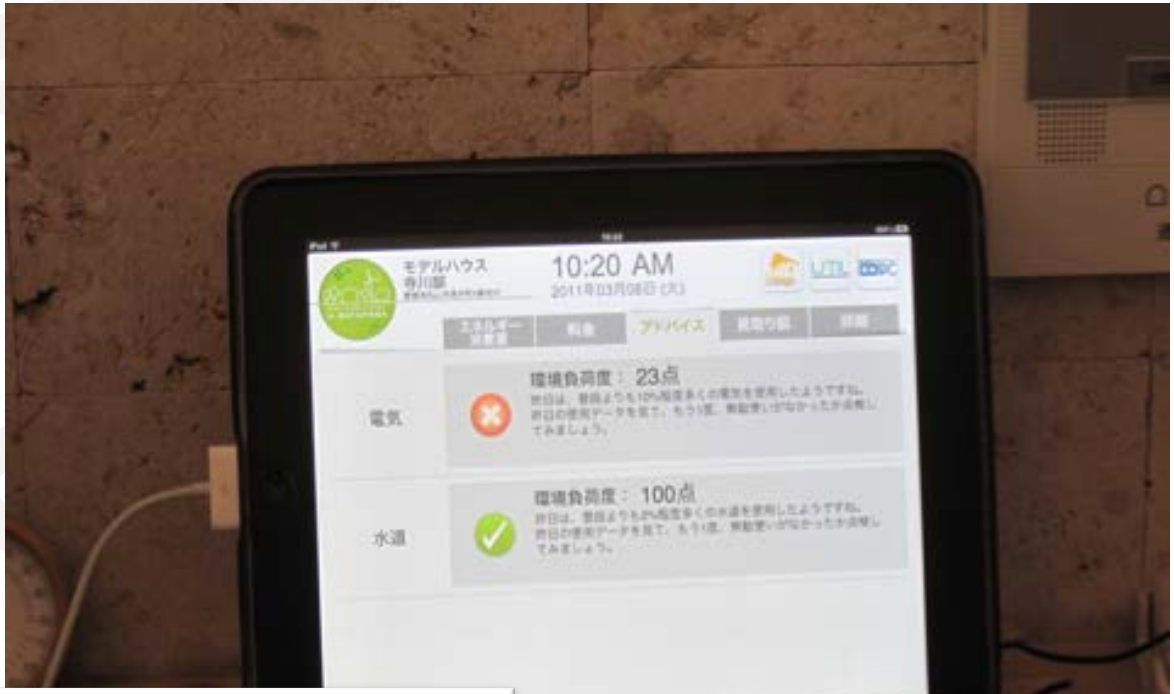
2-1. Low-Energy Smart House

Low-Energy Smart House





Monitoring via Pad Computers



Daily, Monthly, Yearly Graph Views

Power Consumption in 3D Layout View

2-2. Smart Emergency Medical Services:
Smart Hospitals and Smart Ambulance

Smart Emergency Medical Services (Smart Hospital)

Bed Sensors

sharing the information of current status of hospital rooms among medical staffs in the hospital and rescue team members automatically

Monitoring Current Status of Emergency Hospitals

Smart Emergency Medical Services (Smart Ambulance)

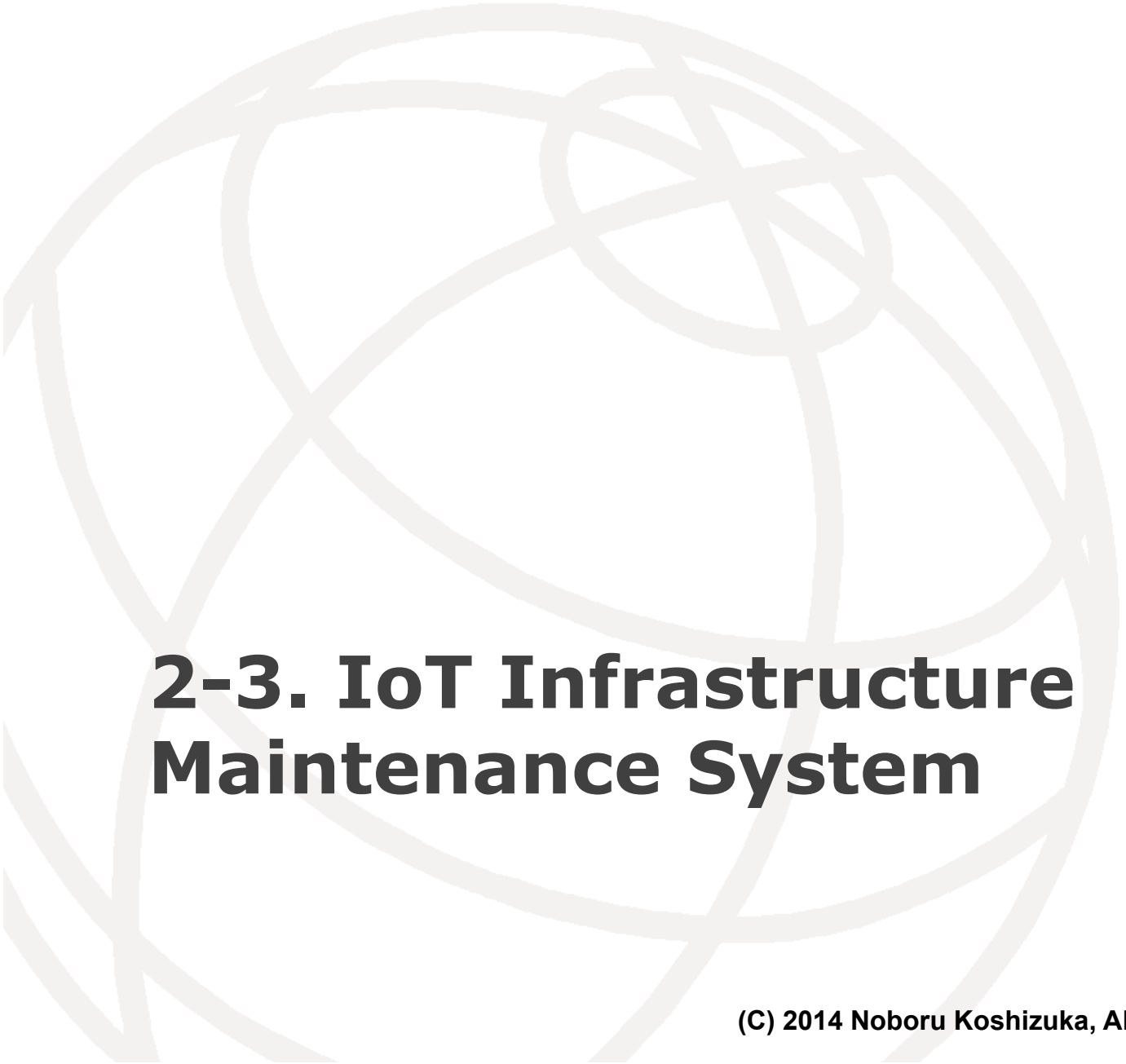
Remotely Controllable Camera

Transferring patient's information

Doctors in Hospital can see patients' images in real-time

Smart Ambulance

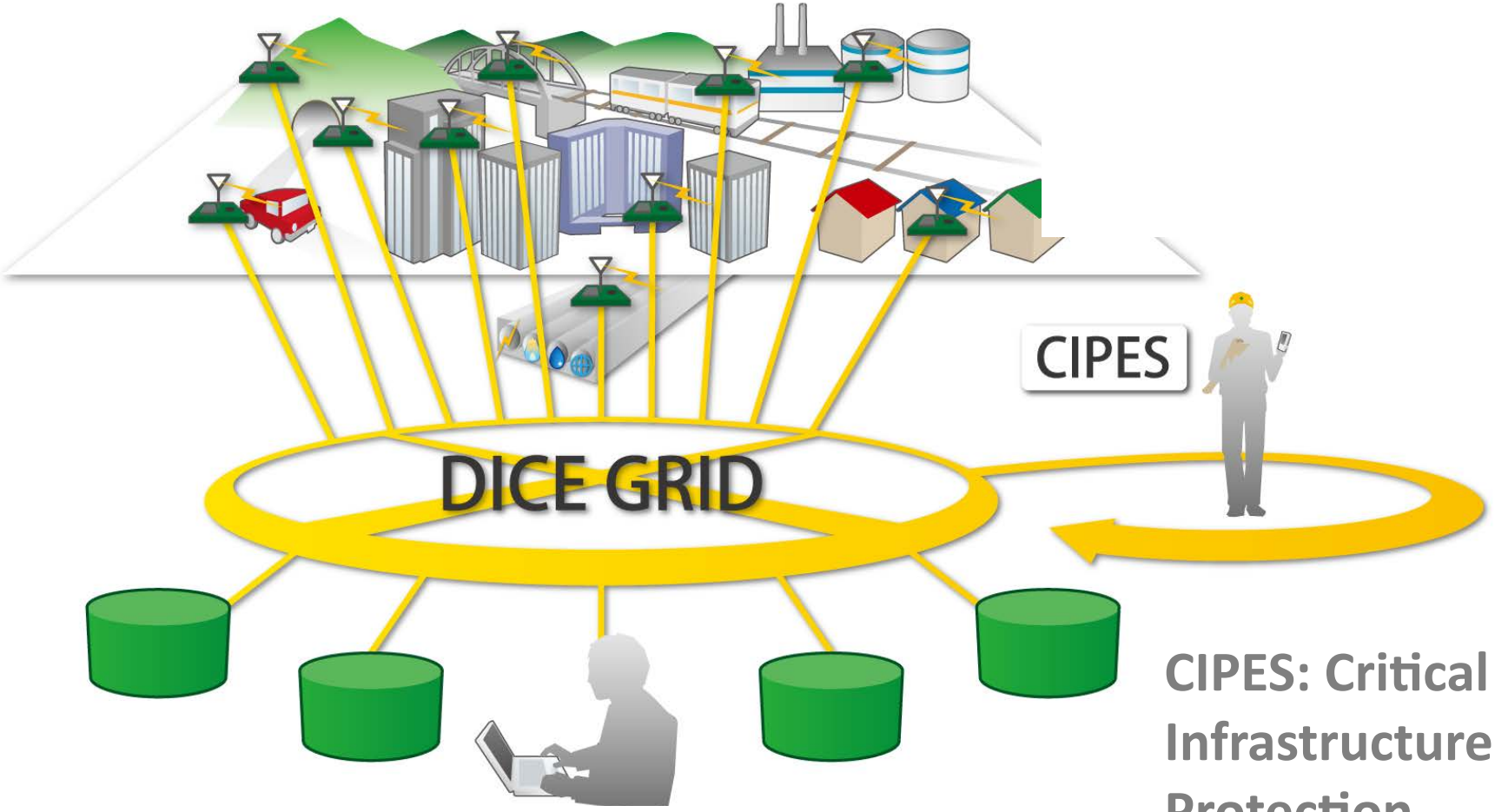
Monitoring Current Position of Ambulances Carrying Patients in Hospital (Doctors can know arrival time precisely)



2-3. IoT Infrastructure Maintenance System

IoT Infrastructure Maintenance System

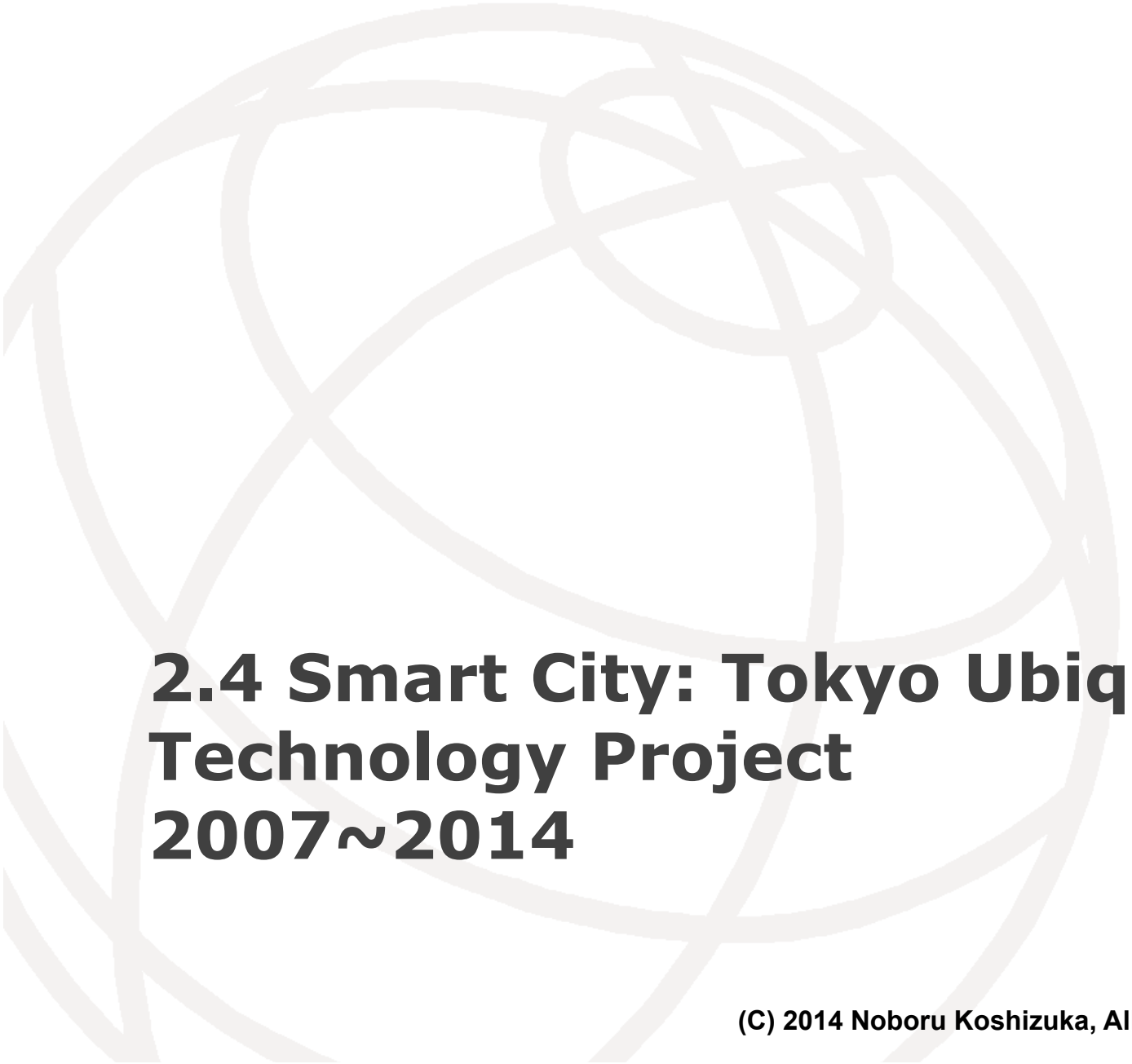
Many sensors and meters are facilitated



Collecting information automatically using IoT Technologies

CIPES: Critical Infrastructure Protection Expert System

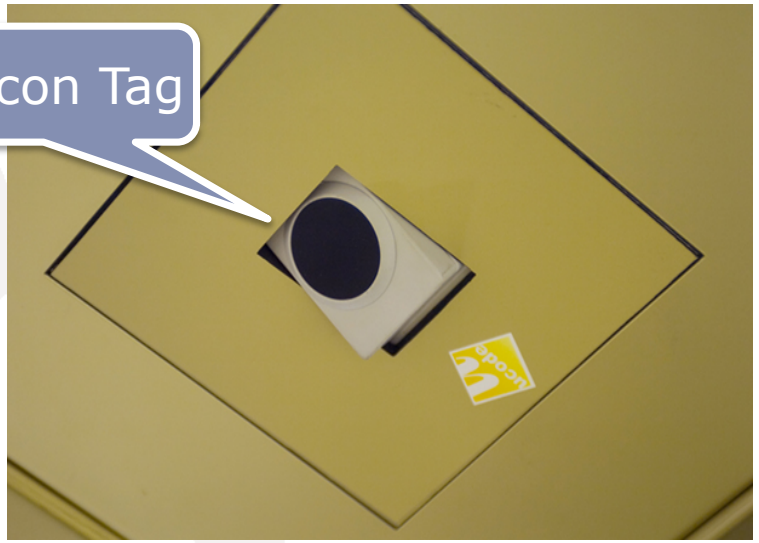

A Highway Structure Maintenance Management System
Designed by Ken Sakamura



2.4 Smart City: Tokyo Ubiquitous Technology Project 2007~2014

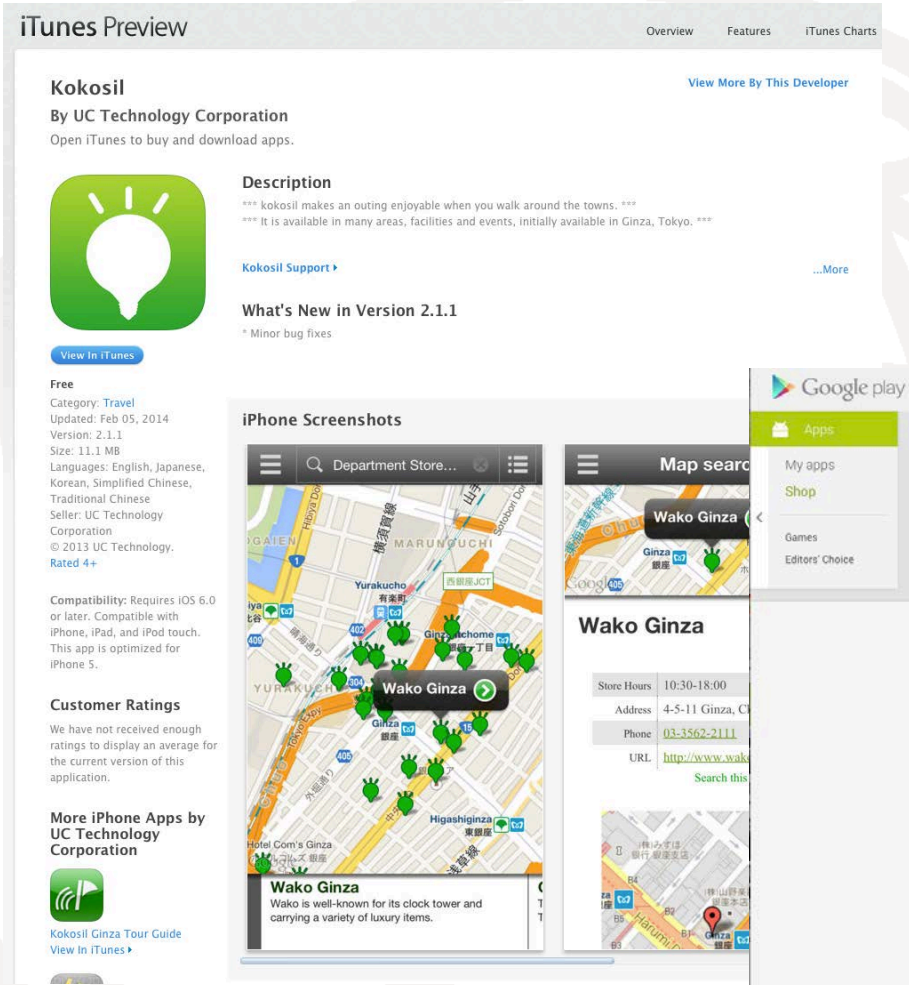
Location-aware information services

Thousands of ucode tags in the Ginza area in Tokyo

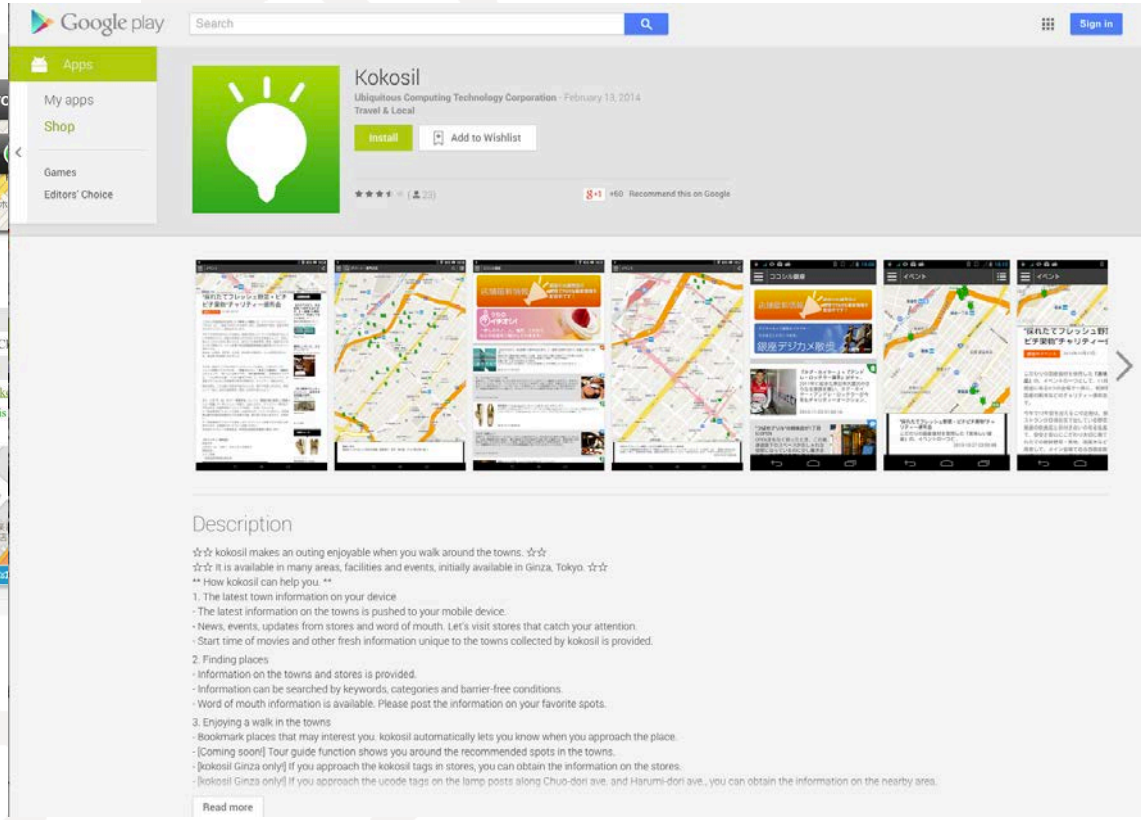


U-City: Location-aware information services

“kokosil” for iOS App. and Android App.



kokosil iTune Store

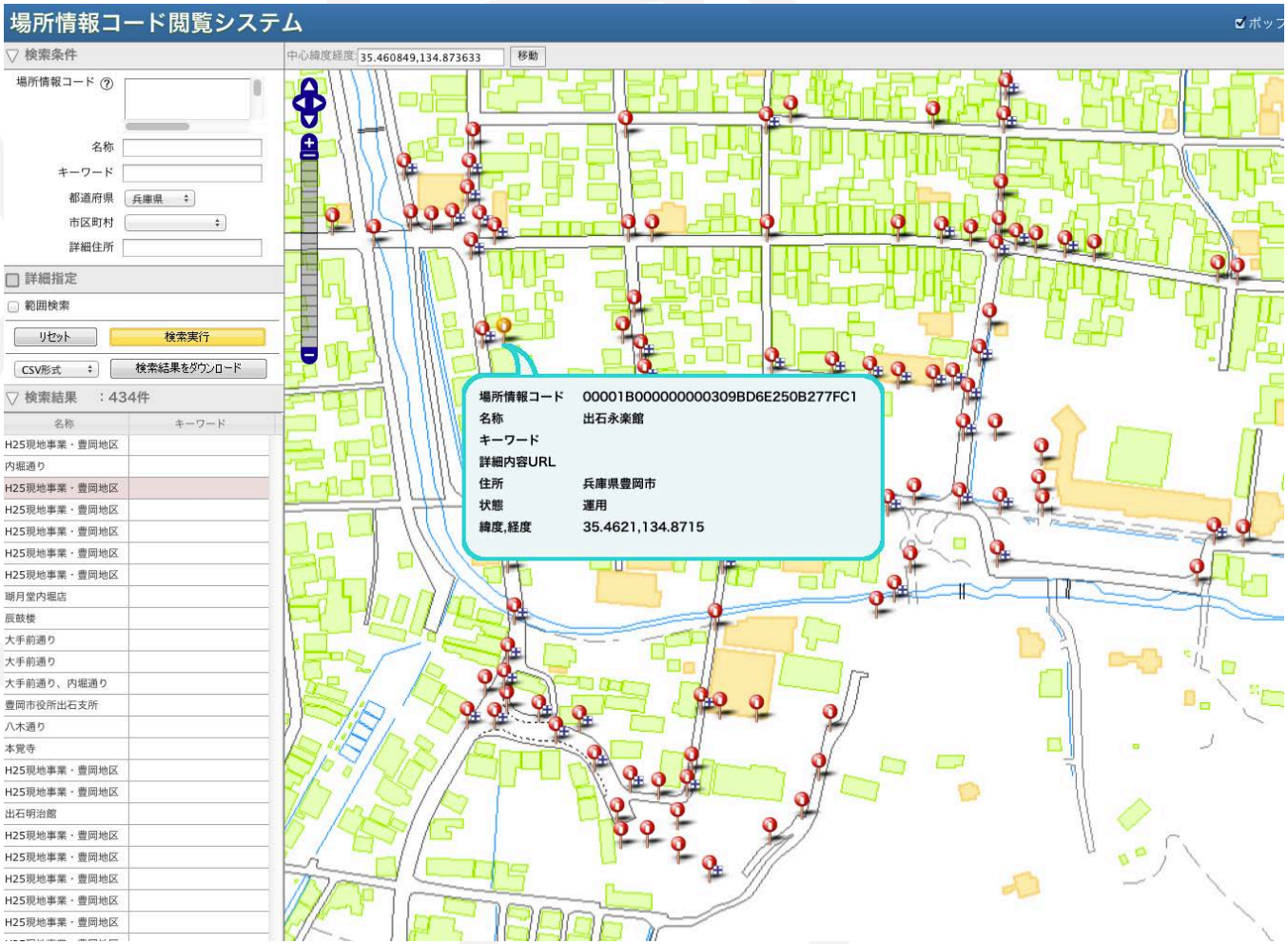


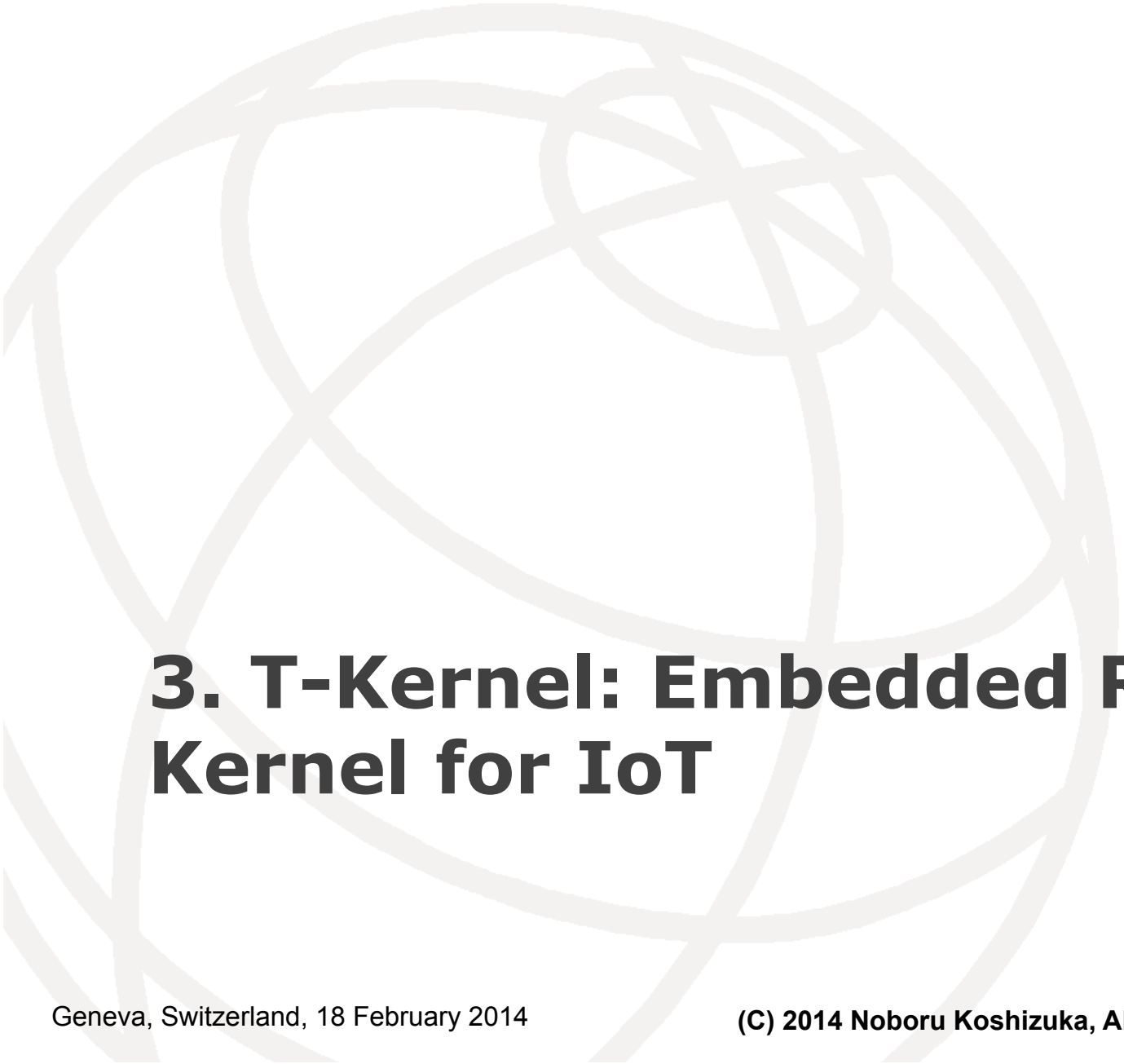
kokosil google play

2-5. National Standard Geo-code Infrastructure Started

National Standard Geo-code on the basis of ucode

Japanese government issues and manages the national geo-code based on ucode

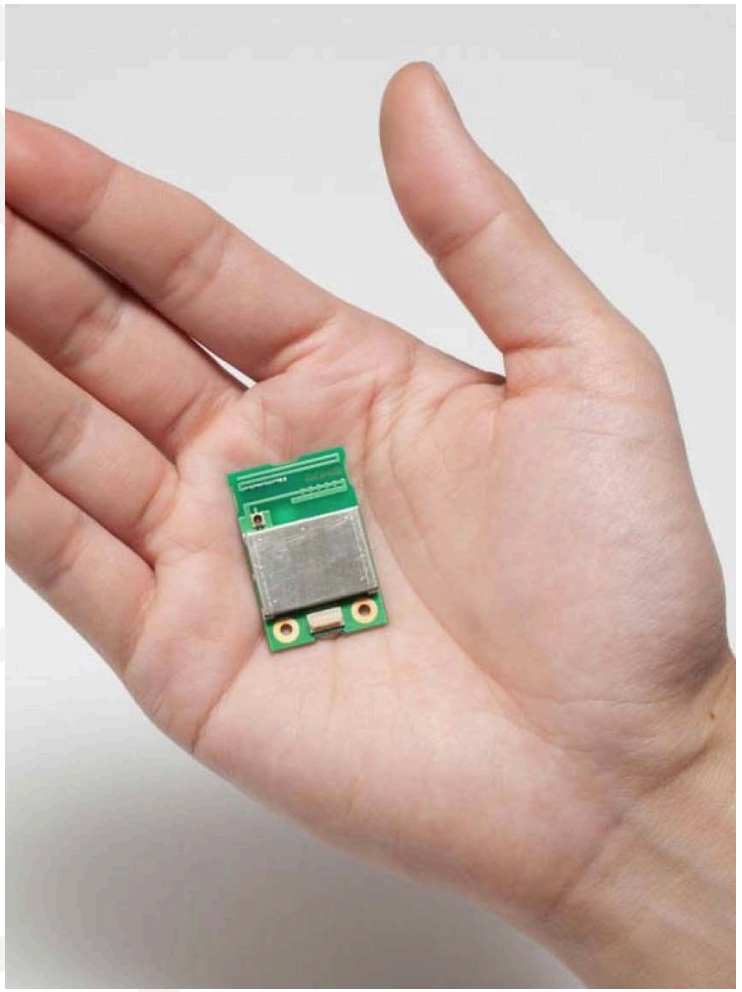




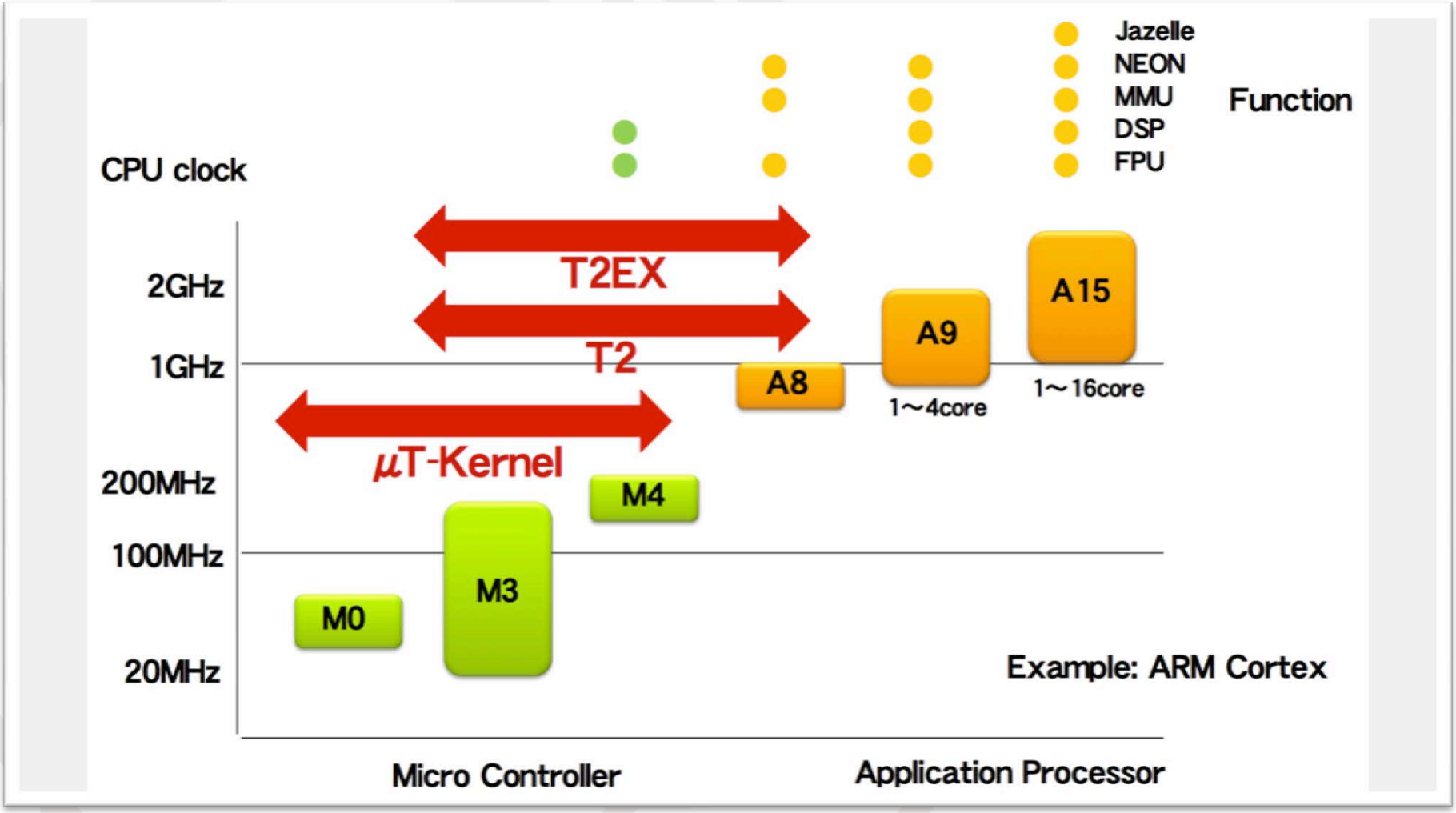
3. T-Kernel: Embedded Ral-time Kernel for IoT

µT-Kernel: RTOS for IoT (1)

- The latest version of T-Kernel for small-scale microcomputer
  - For 16-bit single-chip microcomputer and environments where the amount of ROM and RAM is limited
  - “µT-Kernel” designed to meet the demands to use small-scale MCU
- Keep balance of two conflicting demands
  - “strict specification” for improving the development efficiency
  - acceptance of adaptation/ optimization for improving execution performance



CPU Target of T-Kernel



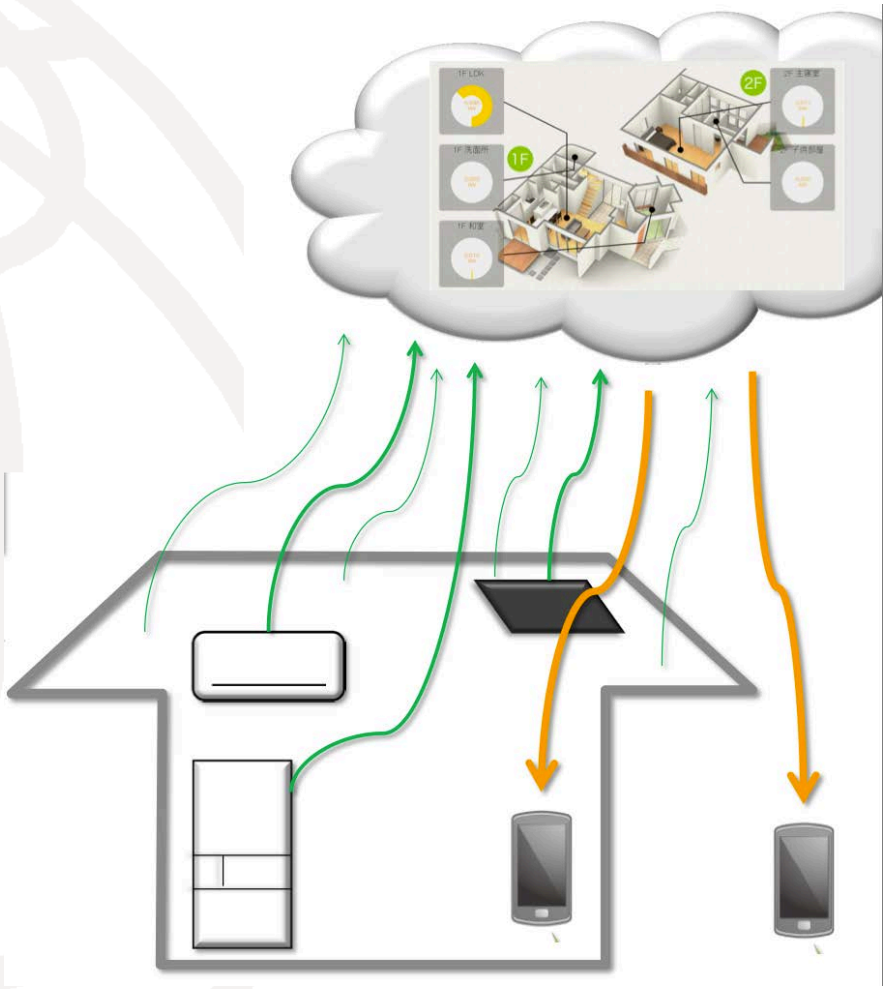
µT-Kernel: RTOS for IoT (2)

- Positioning of µT-Kernel
  - RTOS for M2M and the IoT nodes including small-scale Kaden (home electric and electronic appliances)
- Rich features for the IoT
  - Middleware for the IoT including network communication functions is required.
    - Middleware distribution is possible for improving the development efficiency.
  - Small memory footprint and low-power are essential.
    - Example: Sensor node to operate for 10 years with batteries only

Network for the IoT

- Far more objects will be connected to cloud from open network.
- Wireless network is appropriate in view of the wiring overhead and cost
- However, energy consumption for communication increases due to the increased number of nodes.

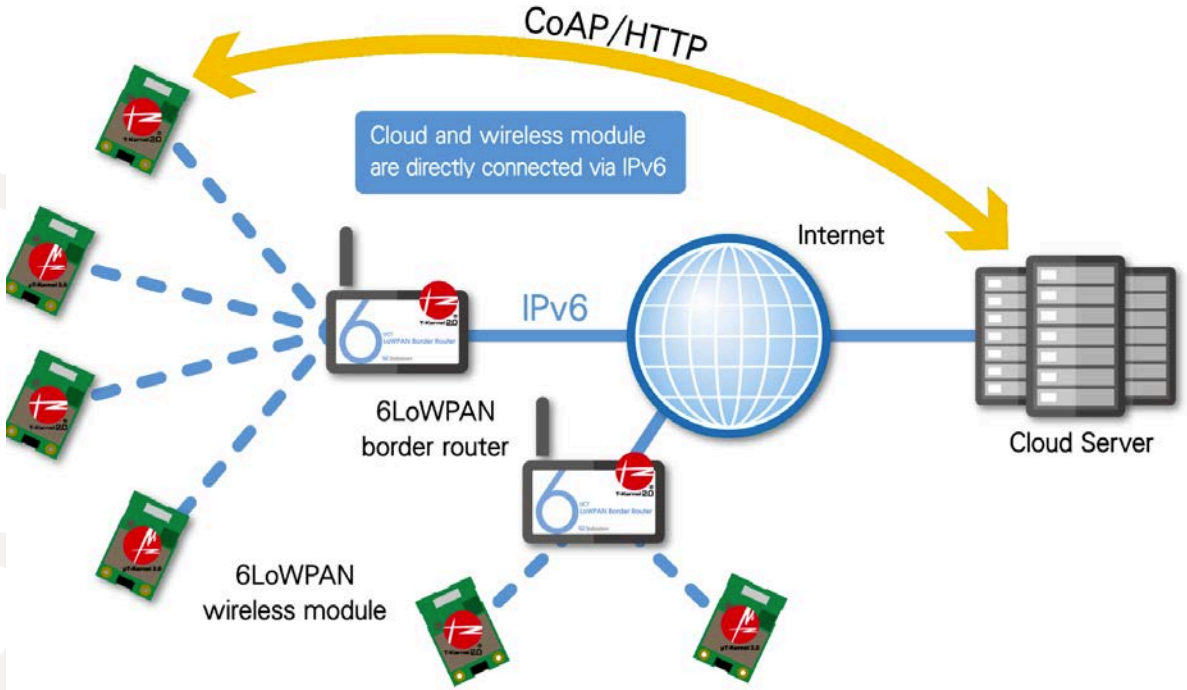
- Energy-efficient wireless communication is required
- Direct connection to cloud is desired.



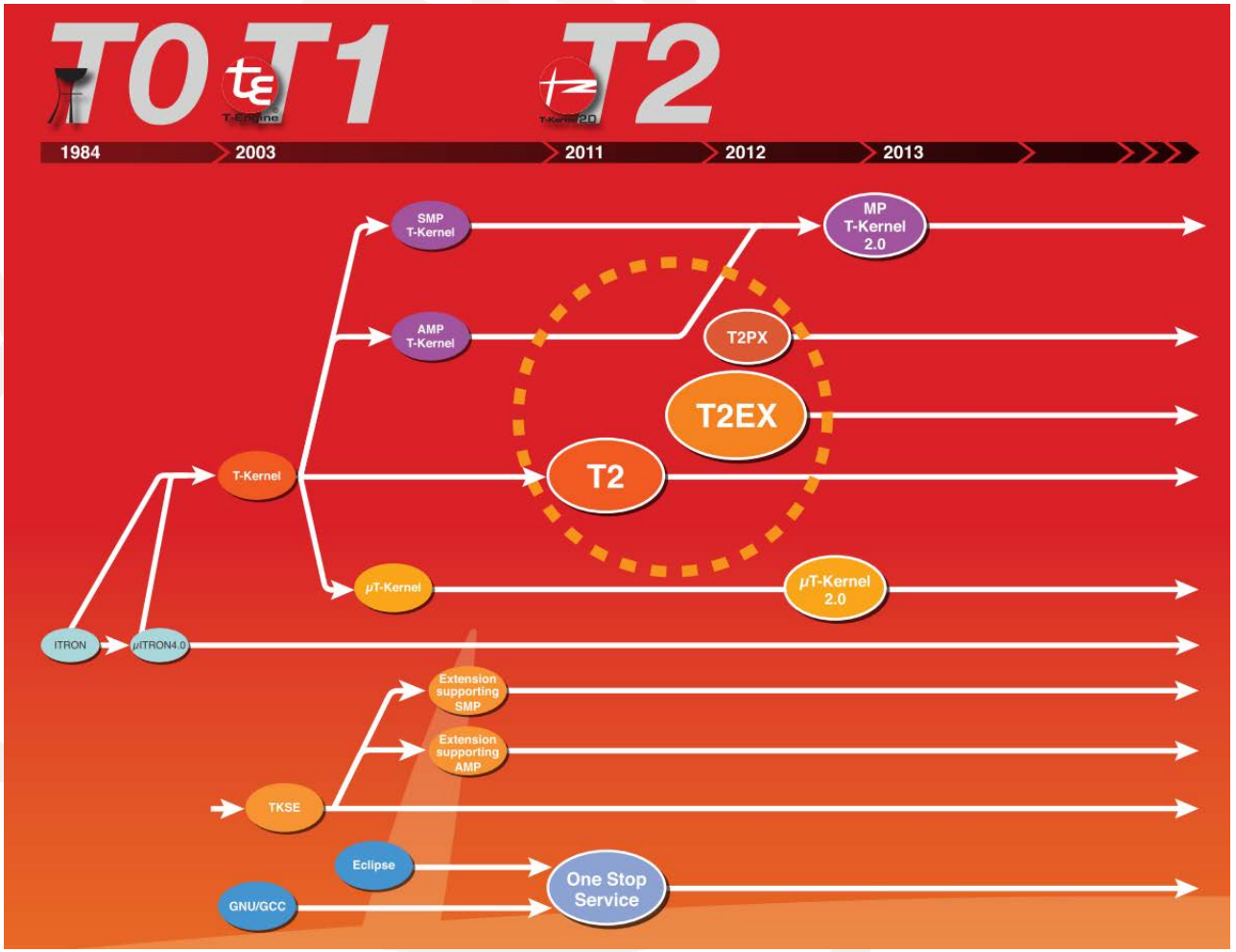
6LoWPAN Framework in µT-Kernel

- 6LoWPAN
  - “IPv6 over Low power Wireless Personal Area Networks” Protocol to realize IPv6-based communication on low- power wireless system
- Features
  - Direct low-power wireless connection to cloud is possible.
  - Web service on cloud and the IoT node can be directly connected by adopting 6LoWPAN Border Router for protocol conversion.

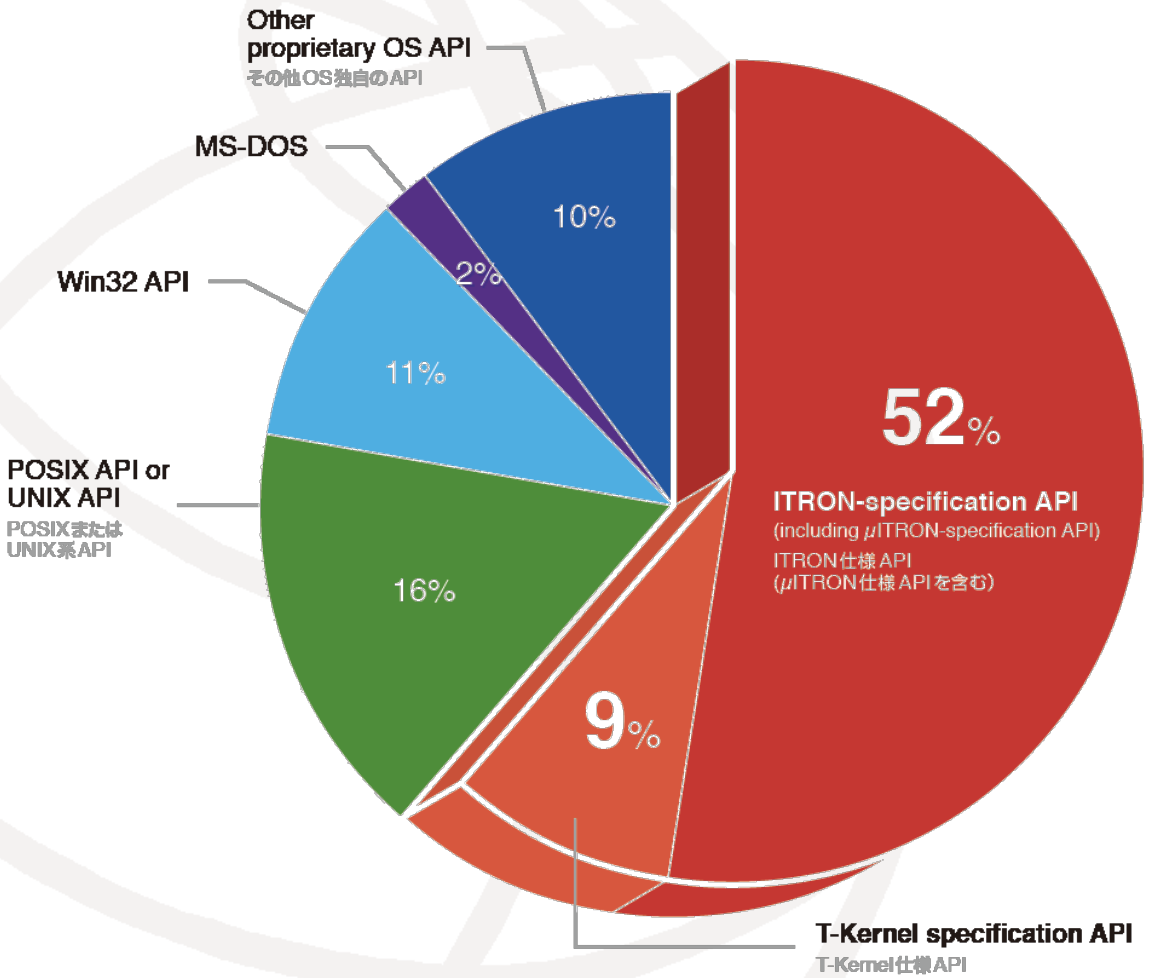
- Good fit for the IoT paradigm



Japan's De-facto Standard RTOS: ITRON/T-Kernel



ITRON, T-Kernel: Open Real-time Embedded OS



They have more than 50% market share in Japan.

List of companies and laboratory for collaboration

Member Organization List

(January 31, 2011: 295 members)

Executive Committee members 17

Aplix Corporation
DAI NIPPON PRINTING CO., LTD.
DENSO CORPORATION
eSOL Co., Ltd.
FUJITSU LIMITED
Fujitsu Semiconductor Limited
Hitachi, Ltd.
Hitachi ULSI Systems Co., Ltd.
NEC Corporation
Nihon Unisys, Ltd.
NTT DoCoMo, Inc.
Oki Electric Industry Co., Ltd.
Personal Media Corporation
Renesas Electronics Corporation
SATO CORPORATION
TOPPAN PRINTING CO., LTD.
Yokosuka Telecom Research Park, Inc.

A-members 19

Advanced Driver Information Technology GmbH (Germany)
AISIN AW CO., LTD.
Alpine Electronics, Inc.
CORE CORPORATION
GAIA System Solutions Inc.
Hitachi Information & Control Solutions, Ltd.
ITOCHU Corporation
Japan Traceability Association
Kyoto Micro Computer Co., Ltd.
Microsoft Corporation (USA)
NEC Soft, Ltd.
NIPPON TELEGRAPH AND TELEPHONE CORPORATION
PASCO CORPORATION
TOSHIBA CORPORATION
TOSTEM CORPORATION
Ubiquitous Computing Technology Corporation
UNION MACHINERY CO., LTD.
YAMAHA CORPORATION
YAZAKI CORPORATION

B-members 96

Advanced Polytechnic Center
A.I. CORPORATION
Altera Corporation (USA)
ARM Ltd.
Audio-Technica Corporation
AXELL CORPORATION
BIP SYSTEMS CORPORATION
China Household Electric Appliance Research Institute (China)
Chuo Engineering Co., Ltd.
Computex Co., Ltd.
CRESCO, LTD.
CSI Co., Ltd.
Custommedia Sdn. Bhd. (Malaysia)
Dalian uComSoft Co., Ltd. (China)
Dalian uLoong C&S Co., Ltd. (China)
DENSO CREATE INC.
E. D. Technology Corporation
EMPRESS SOFTWARE JAPAN INC.
Fuji Electric Holdings Co., Ltd.
Fuji Xerox Co., Ltd.
Fujitsu Computer Technologies Limited
Fujitsu Microelectronics Solutions Limited
Fujitsu Software Technologies Limited
GAIO TECHNOLOGY CO., LTD.
Genesys Corporation
Geographical Survey Institute
Grape Systems Inc.
HASHIBA GRAND CO., LTD.
Hitachi Advanced Digital, Inc.
Hitachi Solutions, Ltd.
iAnywhere Solutions K.K.
IAR Systems K.K.
Ibaraki Hitachi Information Service Co., Ltd.
Intel Microelectronics (M) Sdn. Bhd. (Malaysia)
ITTO SOFTWARE INC.
Japan Radio Co., Ltd.
JRC ENGINEERING CO., LTD.
JTEC Corporation
JANOMECREDIA Co., LTD.
JUSTSYSTEM Corporation
KINKEI SYSTEM CORPORATION
Koyo System Corporation
Kyoto Software Research, Inc.

T-Engine®

MATO Corporation
Matsutame Co., Ltd.
MIPS Technologies, Inc.
MITSUBISHI HEAVY INDUSTRIES, LTD.
MITSUI-SOKO CO., LTD.
MITSUI ZOSEN SYSTEMS RESEARCH INC.
Naito Densei Machida Mfg. Co., Ltd.
Nebit Co., Ltd.
NEC Aerospace Systems, LTD.
NEC Communication Systems, Ltd.
NEC Engineering, Ltd.
NEC TOSHIBA Space Systems, Ltd.
Nissin Systems Co., Ltd.
NTT COMWARE CORPORATION
OMRON Corporation
OMRON SOFTWARE Co., Ltd.
Open Kernel Labs, Inc. (Australia)
Peking Ubiquitous IC Tag Technology Co., Ltd. (China)
PIONEER CORPORATION
Planners Land Co., Ltd.
RICOH Company, Ltd.
RIGEL CO., LTD.
Ring coco co., ltd.
Robert Bosch Car Multimedia GmbH (Germany)
SANEI CO., LTD.
Saxa Inc.
Seiko Instruments Inc.
SEIKO Precision Inc.
Semiconductor Energy Laboratory Co., Ltd.
Semiconductor Technology Academic Research Center
Sennet, Inc.
SHARP CORPORATION
SHIMAFUJI ELECTRIC CO., LTD.
SILVER ELECTRONIC RESEARCH Co., Ltd.
SoftBrain Inc.
SoftSirius Co., Ltd.
Sony Corporation
Sophia Systems Co., Ltd.
TANBAC Co., Ltd.
TechMatrix Corporation
TEPCO UQUEST, LTD.
TOPCON CORPORATION
Toshiba Information Systems (Japan) Corporation
TOSHIBA MACHINE CO., LTD.
TOSHIBA TEC CORPORATION
TOSHIN ELECTRIC CO., LTD.
UNITEC CO., LTD.
Upwind Technology, Inc.
Viometrix Private Limited (Singapore)
Xilinx, Inc.
Yagi Antenna Inc.
Yokogawa Digital Computer Corporation
ZUKEN ELMIC, INC.

e-members 73

AJIS CO., LTD.
AOMORI PREFECTURAL GOVERNMENT
Brain Forum, Inc.
Boardwalk Inc.
CASTNET TOKYO Corporation
CENTER FOR BETTER LIVING
Central Research Institute of Electric Power Industry
ColorZip Inc.
CTI Engineering Co., Ltd.
Custommedia Sdn. Bhd. (Malaysia)
E&M, Inc.
Foundation Of River & Basin Integrated Communications
Fugaku Express Ltd.
Fuji Electric Retail Systems Co., Ltd.
Fuji Seal, INC.
Geospatial Information Authority of Japan
GOV CO., LTD.
HANEX Co., Ltd.
Hangzhou Homewell Intelligence Control Co., Ltd. (China)
HASHIBA GRAND CO., LTD.
Hitachi Information Systems, Ltd.
Hitachi Solutions, Ltd.
Humela Corporation
The Impossible Dream, Inc.
INTAGE Inc.
Japan Association for International Racing and Stud Book
KAKUMARU CORPORATION
Kamiina Wide Area Union
Kanazawa Institute of Technology
KDDI CORPORATION
Kobayashi Woven Labels Co., Ltd.
KYOSEMI CORPORATION
Kyoto egg and chicken safety promotion conference
LINCREA CORPORATION
MARS TECHNO SCIENCE Corporation
MARUEI CONCRETE INDUSTRY CO., LTD.
MENOX Co, Ltd.
Mitsubishi Tanabe Pharma

http://www.t-engine.org/

Mitsui Fudosan Co., Ltd.
NEC Engineering, Ltd.
NEWJEC Inc.
Nexco-East Engineering Company Limited
NIHON DEMPA KOGYO CO., LTD.
NIPPON TELEGRAPH AND TELEPHONE EAST CORPORATION
Nippon Yusen Kabushiki Kaisha
NISSIN UNYU KOGYO CO., LTD.
Nomura Research Institute, Ltd.
NTT COMWARE CORPORATION
NTT DATA CORPORATION
OMRON SOFTWARE Co., Ltd.
Peking Ubiquitous IC Tag Technology Co., Ltd. (China)
Ring coco co., ltd.
RIPRO Corporation, Japan
SANDEN Corporation
Sealex Corporation
SHARP CORPORATION
SPC.Co., Ltd.
Sumitomo Osaka Cement Co., Ltd.
TAO Co., Ltd.
TAIHEIYO CEMENT CORPORATION
TAMURA Corporation
TECHNOLOGY CENTER HERMIA Oy (Finland)
Tekes-Finnish Funding Agency for Technology and Innovation (Finland)
Toko Kagaku CO., LTD.
TOPPAN FORMS CO., LTD.
Toyo Seikan Kaisha, Ltd.
TSUBAKIMOTO CHAIN CO.
UNIADEX, Ltd.
Village Nishiawakura
Yamato Packing Co., Ltd.
YAZAKI RESOURCES CO., LTD
WindSpring, Inc. (USA)

Supporting members 1

Panasonic System Networks Co., Ltd.

Academic members 88

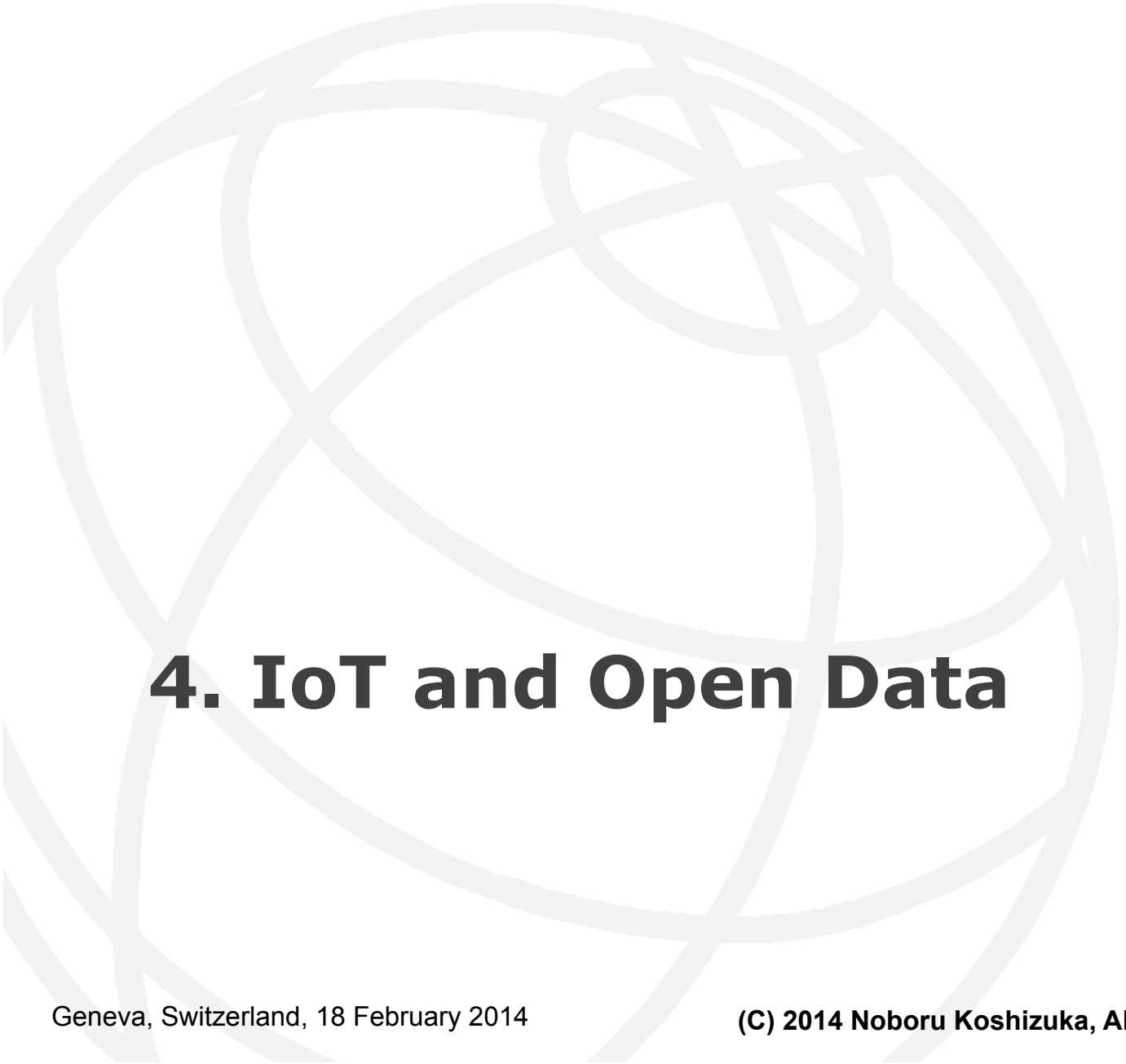
Araki Laboratory, Department of Electronics and Photonic Systems Engineering, Faculty of Engineering, Hiroshima Institute of Technology
Aso Business Computer College
Centre for High Performance Embedded Systems, Nanyang Technological University, Singapore (Singapore)
Cybermedia Center, Osaka University
Dalian Martime University (China)
Department of Civil Engineering, HanYang University (Korea)
Department of Computer Science, University of Yamanashi
Department of Control and Computer Engineering, Numazu College of Technology
Department of Electrical and Electronics Engineering, Kokushikan University
Department of Electrical and Electronic Engineering, School of Electrical and Computer Engineering, National Defense Academy of Japan
Department of Information Science, Osaka Institute of Technology
EHIME ELECTRONIC BUSINESS COLLEGE
Electronics Design Lab., Hanoi University of Technology (Vietnam)
Employment and Human Resources Development Organization of Japan Tochigi
Environmental Design and Information Technology Laboratory, Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University
Faculty of Information Technology, Ho Chi Minh City University of Technology (Vietnam)
Farm Management, Division of Natural Resource Economics, Graduate School of Agriculture, Kyoto University
Field Monitoring Research Team, National Agricultural Research Center, National Agriculture and Food Research Organization
Fu Jen Catholic University (Taiwan)
Fukuda Laboratory, Department of Micro-Nano Systems Engineering, Nagoya University
Fukuyama University
Furukawa Laboratory, GRADUATE SCHOOL OF MEDIA DESIGN, KEIO UNIVERSITY
Future Robotics Technology Center, Chiba Institute of Technology
Graduate School, Gunma University, Shiraishi Laboratory
Haruyama Laboratory, The Graduate School of System Design and Management, Keio University
Hiroshima City University
Hong Kong R&D Centre for Logistics and Supply Chain Management Enabling Technologies (China)
Hongo Laboratory, Department of Frontier Information Engineering, Faculty of Advanced Engineering, Hokkaido Institute of Technology
HOSHI Lab., TOKAI Univ.
Hunan University,School of Computer and Communication, Embedded System&Laboratory (China)
Iijima Laboratory, Faculty of Science and Technology, Keio University
Inaba-Inamura laboratory, Dept. of Mechano-Informatics, Faculty of Engineering, Univ. of Tokyo
Industrial Technology Research Institute/Identification and Security Technology Center(ISTC)(Taiwan)

T-Engine®

Information-technology Promotion Agency, Japan
Inha University (Korea)
Institute for Information Industry (Taiwan)
Integrated System Design Lab. (IMAI Lab.), Osaka University
Intelligent robot laboratory, University of Tsukuba
Japan Electronics College (Nihon Densi Senmon Gakko)
Kanagawa Prefectual Fujisawa Vocational Training School
Kasetsart University (Thailand)
Koshizuka Laboratory, The University of Tokyo
Kuninaka Labo, Institute of Space and Astronautical Science
Kyung-Pook National Univ. (Korea)
Minoru KUBOTA Laboratory, Chiba Institute of Technology
Miyanaga Lab., Tokyo University of Science MOT
Mizuno Labo, Institute of Space and Astronautical Science
Mizusawa Laboratory, Aoyama Gakuin University
National Institute of Advanced Industrial Science and Technology (AIST)
Niigata Institute of Technology
Oporto University-Faculty of Science (Portugal)
Oya Laboratory, Information Science, Shonan Institute of Technology
Peking University & Renesas T-Engine Joint Lab (China)
Pukyong National University (Korea)
Pusan National University (Korea)
Republic Polytechnic (Singapore)
Research Collaboration Center, Kochi University of Technology
Research Initiative for Advanced Infrastructure with ICT
Research Institute of Computer Applications, South China University of Technology (China)
Research Institute of Management and Information Science, Shikoku University
RFID CENTER in Ajou University (Korea)
RFID Center, Head of the Business Informations Systems Institute, Haute Ecole Valaisanne (Switzerland)
Ryukoku University, Faculty of Science and Technology, Department of Media Informatics
Semyung University (Korea)
Sakamura Laboratory, The University of Tokyo
School of Computer Science and Information Systems, Birkbeck College (UK)
School of Computing University of Tasmania, Australia (Australia)
School of communication, Xidian (China)
School of Science, Nagoya University
Shanghai Institute of Compting Technology (China)
Shigesada Laboratory, Hosei University
Software School of Fudan University, China (China)
Southern Taiwan University of Technology (Taiwan)
Takahashi Laboratory, Graduate School, Chuo Gakuin University
THAMMASAT UNIVERSITY (Thailand)
The Department of Computer Science, The Hebrew University, Jerusalem, Israel (Israel)
The Japan Forest Engineering Society
The University of Aizu
The University of Seoul (Korea)
Tokyo Denki University
Tokyo Metropolitan University
Tokyo University of Technology, School of Computer Science
University of Electronic Sci.& Tech. of China (China)
University Politehnica of Bucharest (Romania)
Urban and Architectual Design Lab.
Yashiro Lab., Institute of Industrial Science, The University of Tokyo
Yokohama National University Kuramitsu Lab
Yoshidome Laboratory, Department of Robotics and Mechatronics, Faculty of Creative Engineering, Kanagawa Institute of Technology

Liaison members 1

Japan Electric Measuring Instruments Manufacturers' Association



4. IoT and Open Data

4-1. Live Transportation Map Tokyo (doko-sil)

Necessary information of Public Transportation for passengers

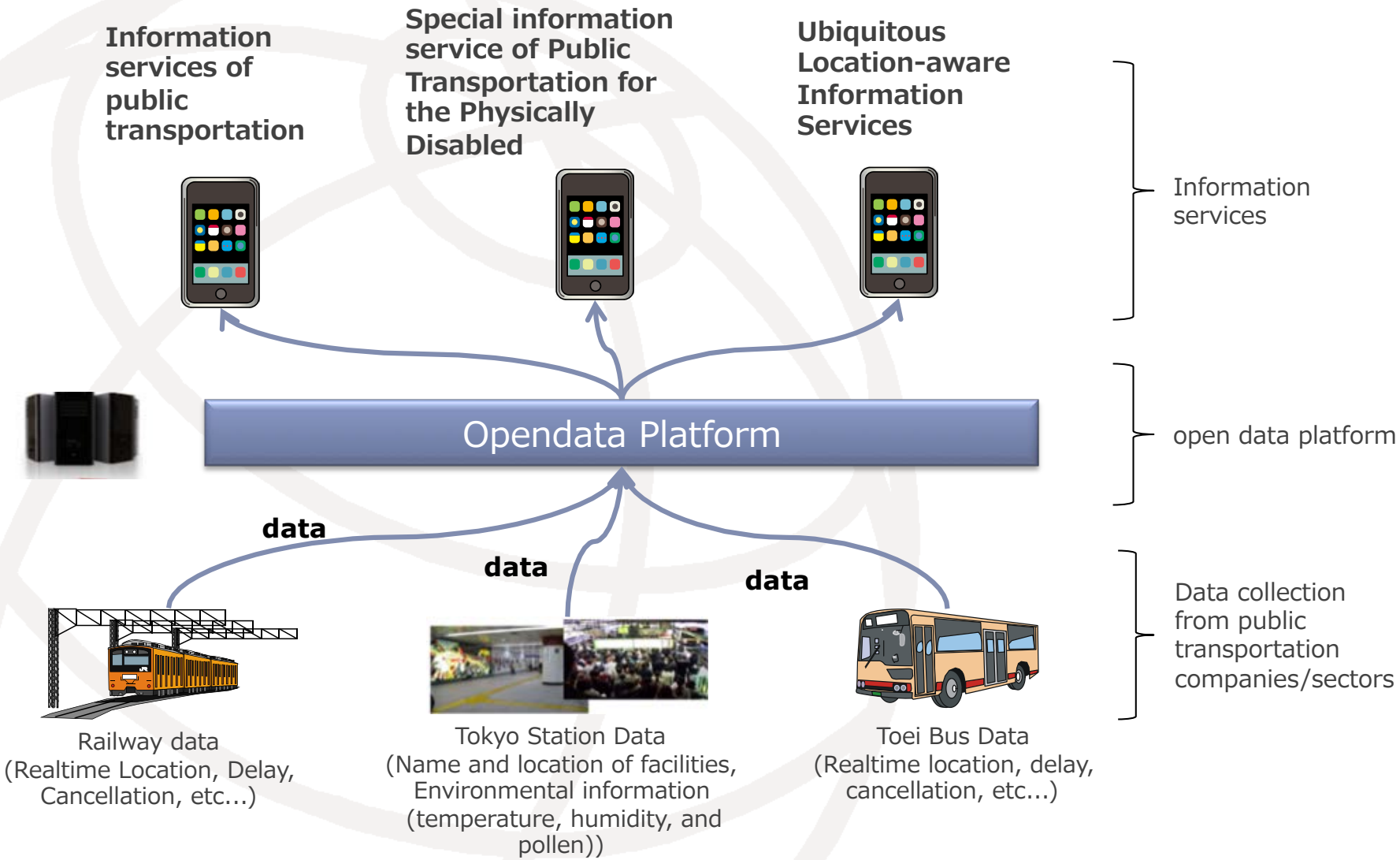
- Arrival time (realtime location information)
- Congestion information
- Temperature of train/bus cars
- Delay information
- Change transfer information using realtime information

- etc...

Overview of Live Transportation Map Tokyo

- Realtime location information of railways and buses
  - In the experimental operation 2013-2014, information of Yamanote Line (JR East) and Toei Bus (Tokyo Metropolitan Government) were provides.
  - Estimated location of each train/car is displayed with an icon on a map.
    - Realtime location data has a delay about one minutes.
- Timetable information
  - Timetable of each station and bus stop is shown by pointing railway station and bus stop.
- Operation information
  - Railway lines in trouble are displayed on a map.

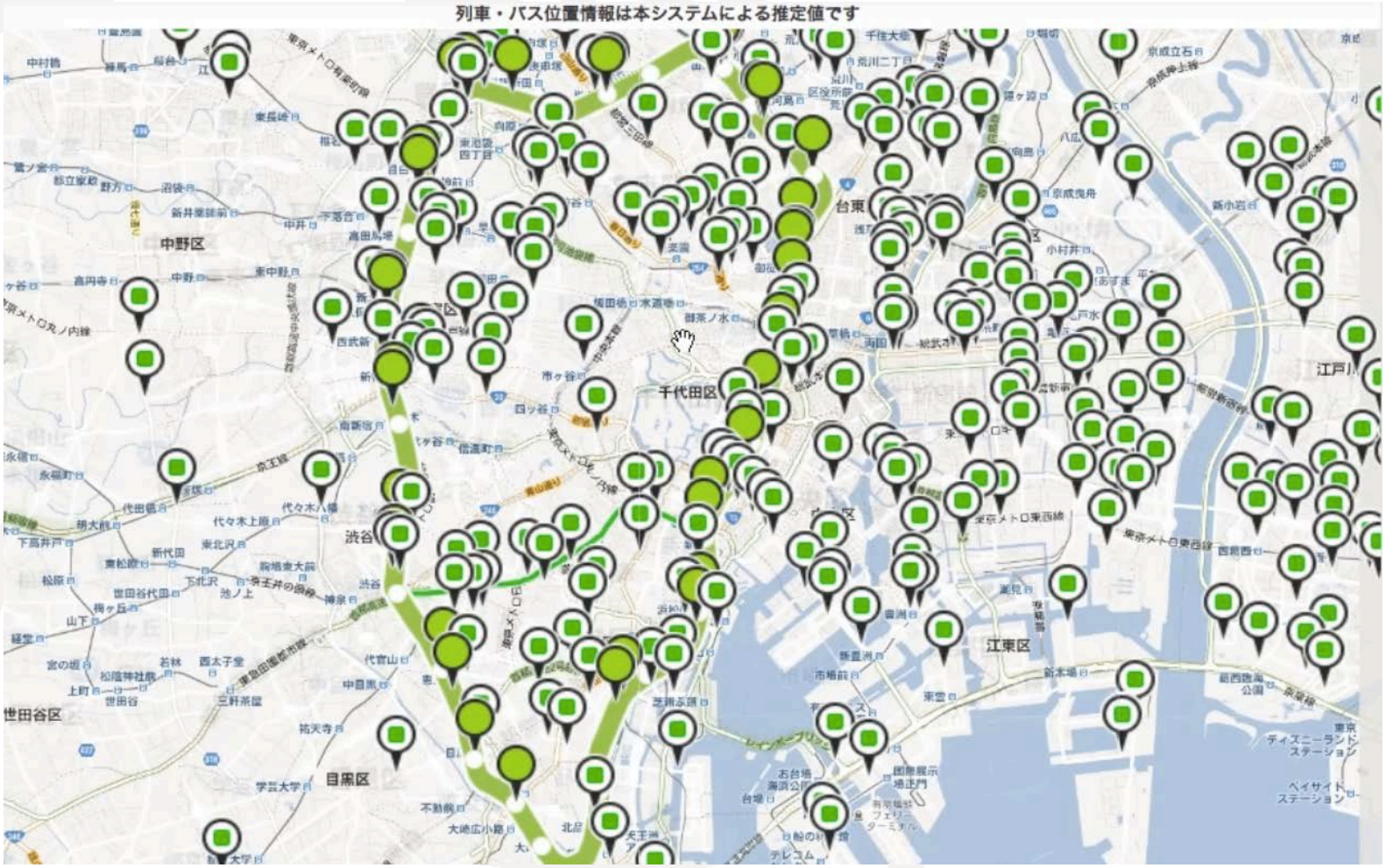
IoT/Open Data System Architecture of Live Transportation Map Tokyo




au
ドコシル
12:19 現在
12:20PM
運行情報
現在位置
列車・バス位置情報は本システムによる推定値です
大手町
日本工業倶楽部会館
和田倉門
東京
東京
三菱ビルヂング
JPタワー
東京国際フォーラム西
東京国際フォーラ
新東京ビルヂング
丸の内二丁目
鍛冶橋
©2013 Google, ZENRIN

Realtime Location Information of Trains and Buses

Live Transportation Map Tokyo
（March 31, 2013, Tokyo）



Collected Data are Opened via API for App. Developers

- Opened Data

- Public Transportation Data
  - Time table, operation status, realtime location information, etc...
  - Information of facilities such as railway stations, bus stops/ terminals, etc...

Developed apps (1/3)

OpenData+RailMaping

TOREBASA!

Eki-Tei Navi

Busreq

Collecting Trains Yanamote-Line
Collecting train cars stopping at stations

LapppinPedia
Collecting wrapping trains running in Yamanote Line

Developed apps (2/3)

HyperTransfer

OriNavi

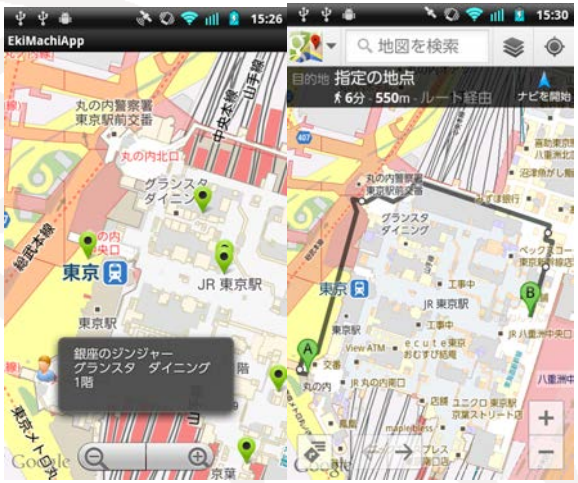
SpotNavi
Mushing-up information of tourism and bus operation

SuggestingSensor

TokyoStationNavi

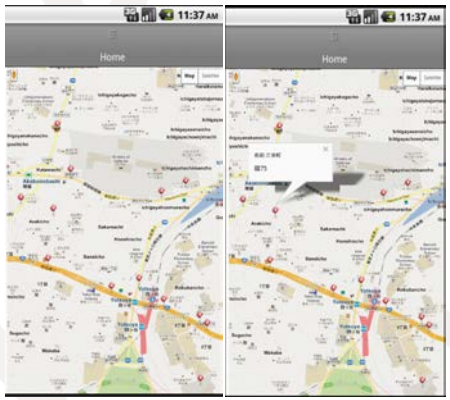
Developed apps (3/3)

EkiSen (Eki-Sensors)
Filtering facility information using sensors in the station



Ekimachi-App (Waiting at the station)

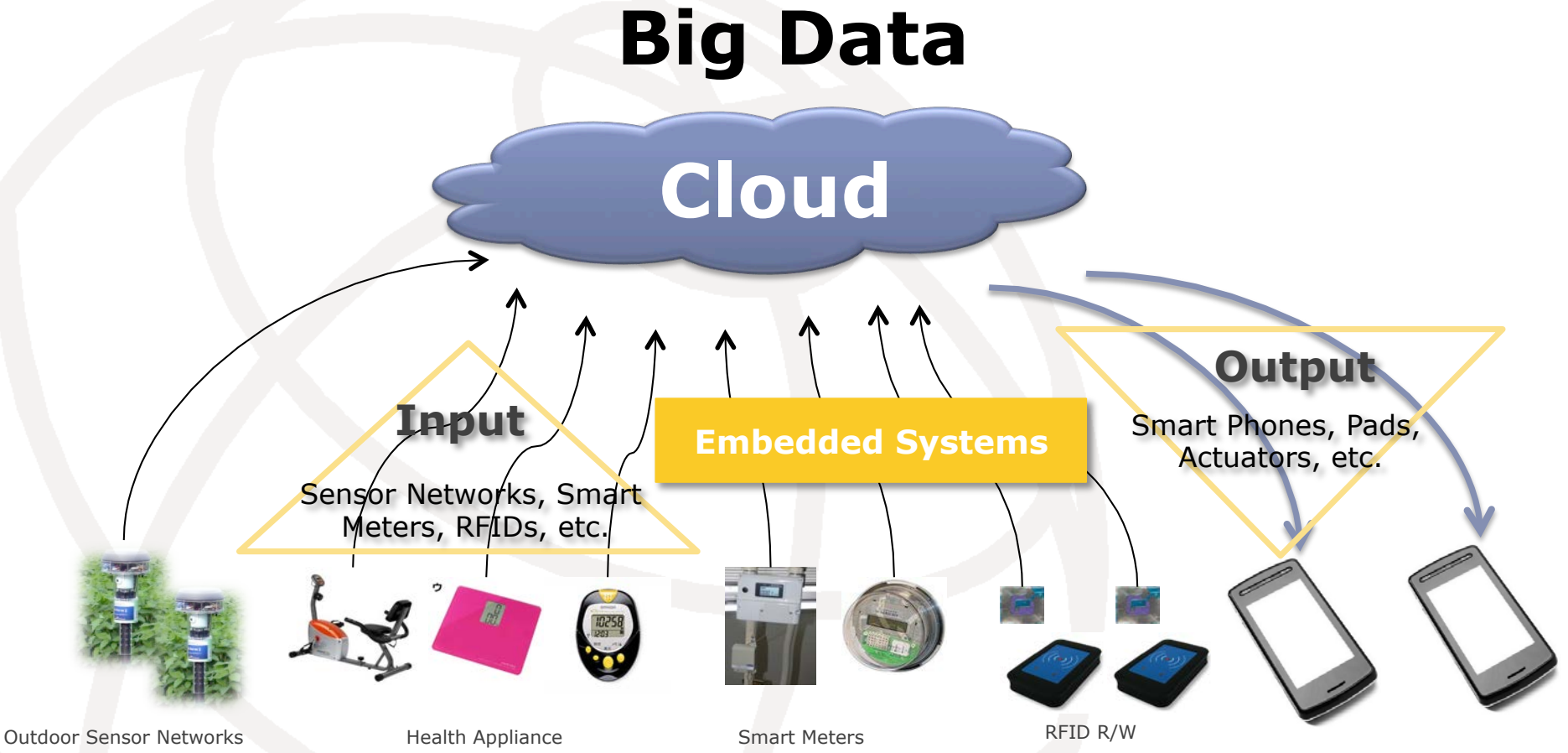
Realtime Operation Status Display App



BusMap
Visualizing Bus Operation

FixtheStation App

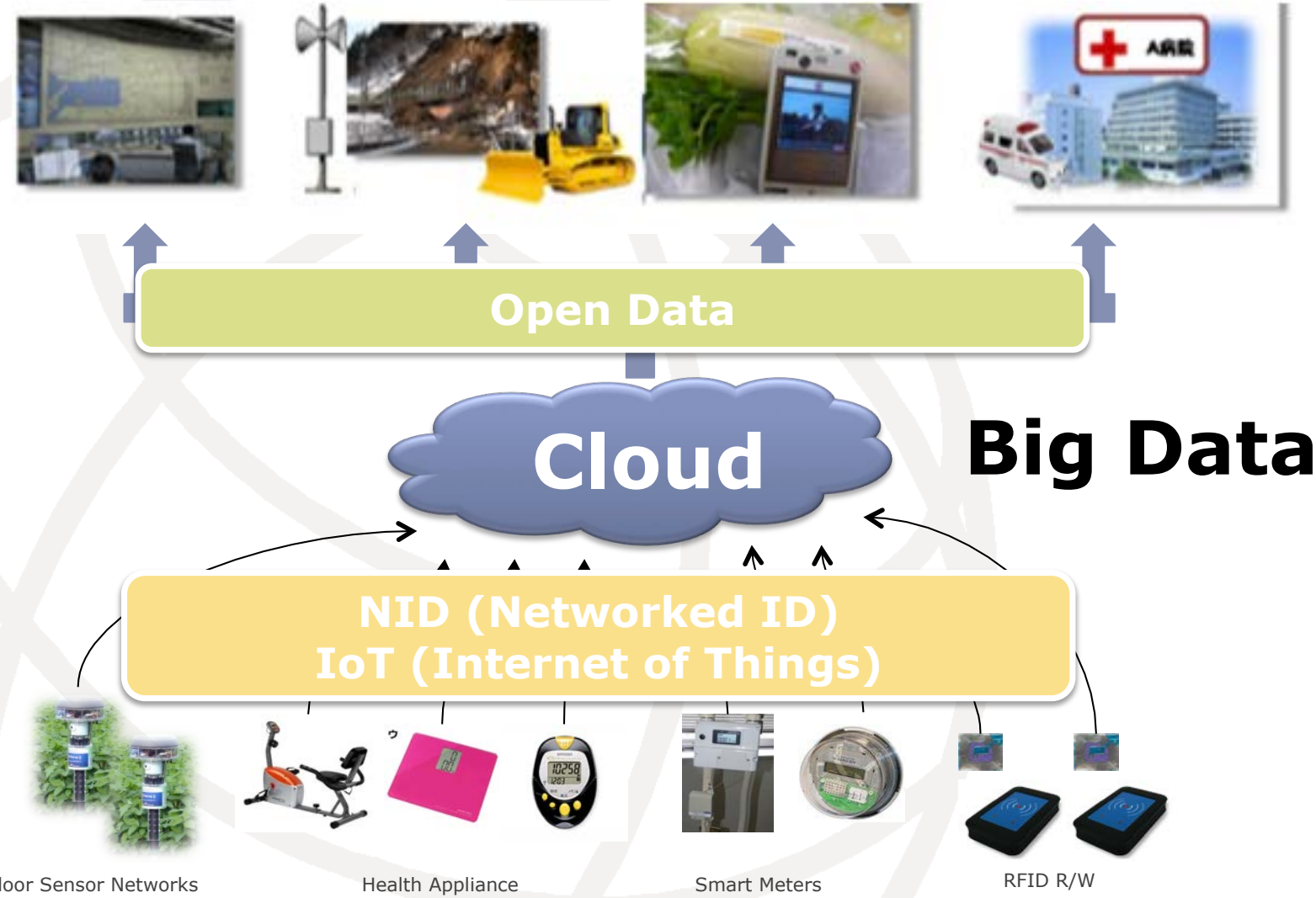
IoT (Internet of Things) Paradigm



USNs **RFIDs**

Embedded Systems **Smart Phones**

NEXT: “IoT + Opendata” Paradigm



5. Proposal for International Standardization

For the next steps of IoT issues, Open Data Issues are necessary

- Standardization Issues

- Architecture
- Data Model
  - Semantic Web, RDF, ...
- Vocabularies
- Identifiers
- Access Interface = API
  - Web API such as RESTful API
  - Query Language such as SPARQL

For more information, ...

koshizuka@sakamura-lab.org

http://www.utacs.org/koshizuka/

http://www.t-engine.org/