Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing and Controlling of Medical Devices, Cars and Others]

Date Submitted: [6 November 2017]

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Email:[1: kohno@ynu.ac.jp, 2: Ryuji.Kohno@oulu.fi, 3: ryuji.kohno@cwc-nippon.co.jp]

Abstract: [This document describes new use cases which need dependability of wireless networks for dynamic sensing and controlling devices and systems for machines in factories, robotics, cars, UAVs, buildings, etc. for smart city, smart energy, smart car, smart society as well as medicine, factory, social infrastructure etc. that are cores for 5G, Industry4.0, and Society5.0.]

Purpose: [information of the plenary keynote speech in IEEE Communications Society PIMRC2017]

IEEE 802.15 IG DEP

Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing & Controlling of Medical Devices, Cars & Others

Orlando, Florida, USA
November 6th, 2017

Ryuji Kohno(YNU/CWC-Nippon)

Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing & Controlling of Medical Devices, Cars & Others

Agenda

1. **Demand of Ultra Reliability or Dependability in Wireless Networks**

2. Applications of Dependable Networks

    2.1 Dependable Wireless Body Area Network (BAN) for Advanced Medical Healthcare

    2.2 Dependable Wireless Sensing & Controlling for Disaster Rescue Using Multiple UAVs

3. New International Standard for Dependable Wireless Network for Automotive Industry

Internet of Things (IoT)

Machine Centric Network (M2M; Internet of Everything)

Internet of Things(IoT) = 10^{12}
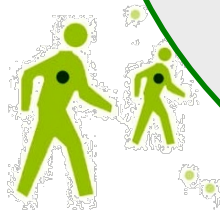
Scale Merit for Business

Fringe Internet = 10^9

AMI/AM

Automation/ Security

Conventional Internet
Human Centric Network

Core Internet = 10^6

Utility Companies
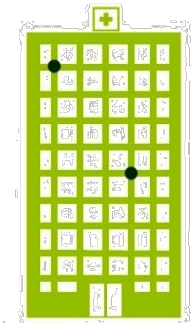
Building Automation/ Healthcare

RFID Backbone
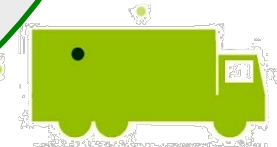
Asset Tracking/ Logistics

IoT for Global System Platform
with Regiliant Social Service and Business Roles

Key Components
- Resource Directory
- Entity Directory
- Semantic Query Resolver
- WS&AN gateways
- Resource End Points
- Heterogeneous resources (6lowPAN, ZigBee, IEEE802.15.4 based WS&AN islands)
- **Reliability, Safety and Security, so-called Dependability Mechanisms** to enable controlled access to components
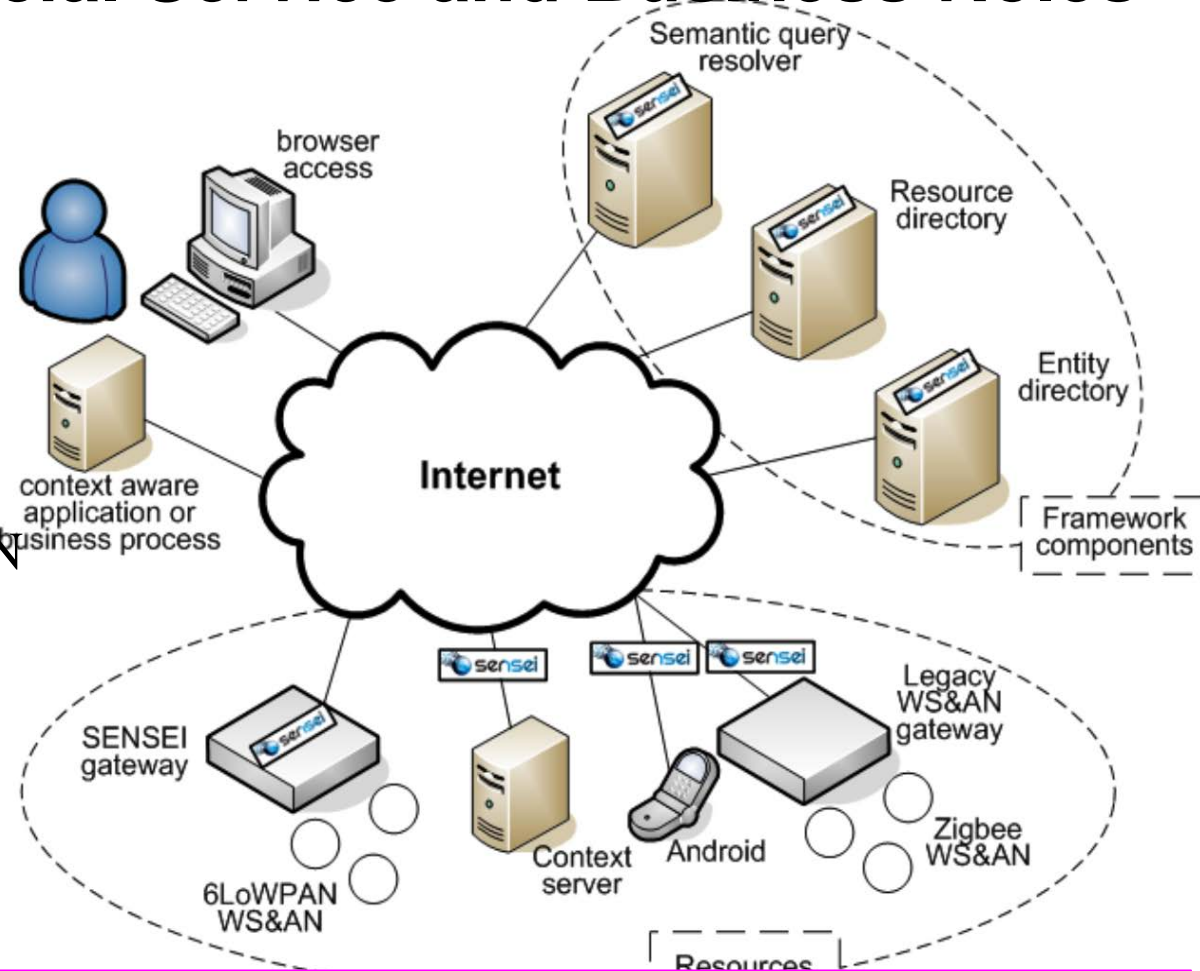
Dependability of IoT should be guaranteed.

Key Technical Requirements for 5G: Focused Ultra Reliability or Dependability

10000 x more traffic

10-100 x more devices

↓**1** millisecond latency
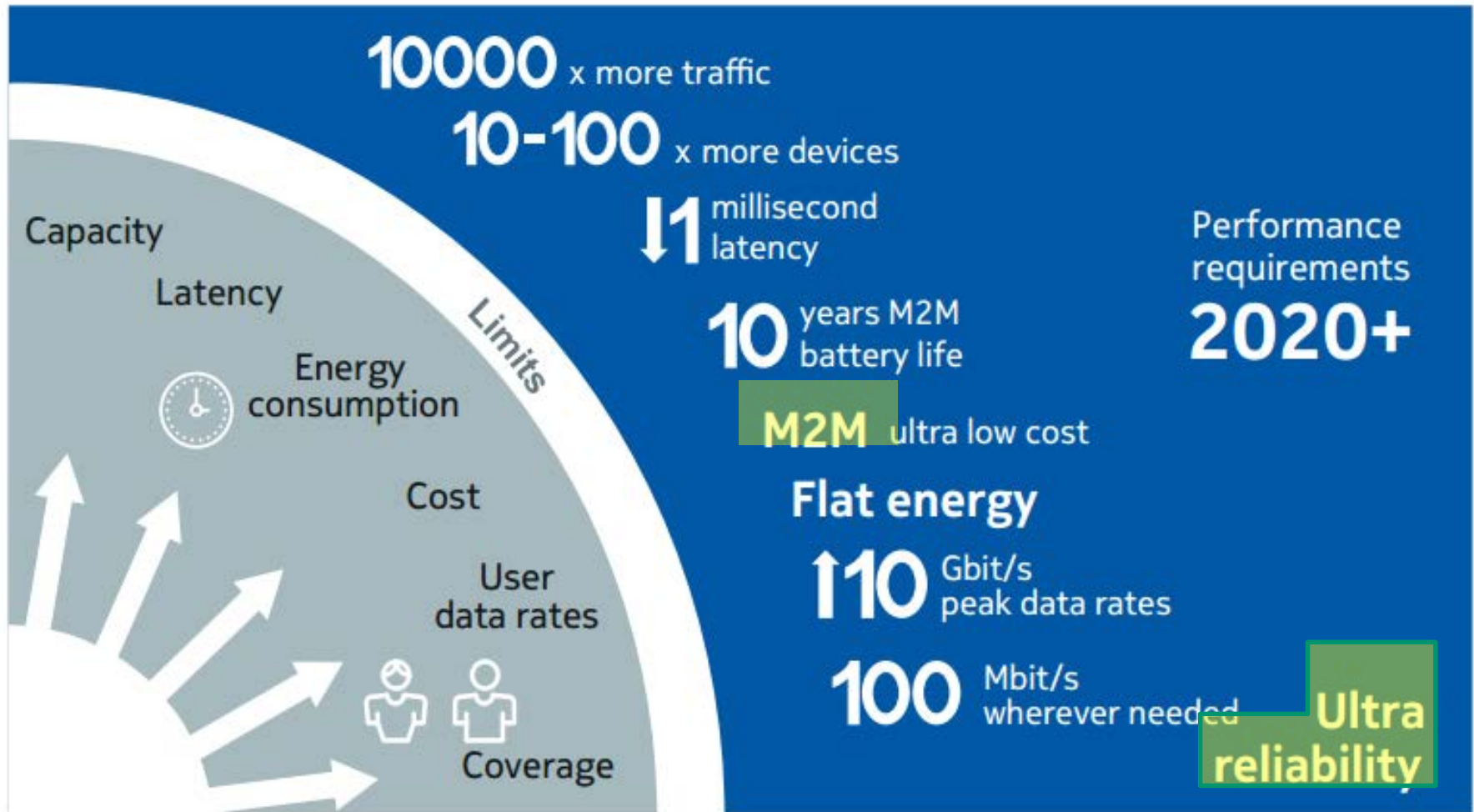
10 years M2M battery life

M2M ultra low cost

Flat energy

↑**10** Gbit/s peak data rates

100 Mbit/s wherever needed

Ultra reliability

Performance requirements **2020+**

Capacity

Latency

Energy consumption

Cost

User data rates

Coverage

Limits

Ref. "5G Use Cases and Requirements," NOKIA, Co,

Services, Use Cases & Requirements for 5G
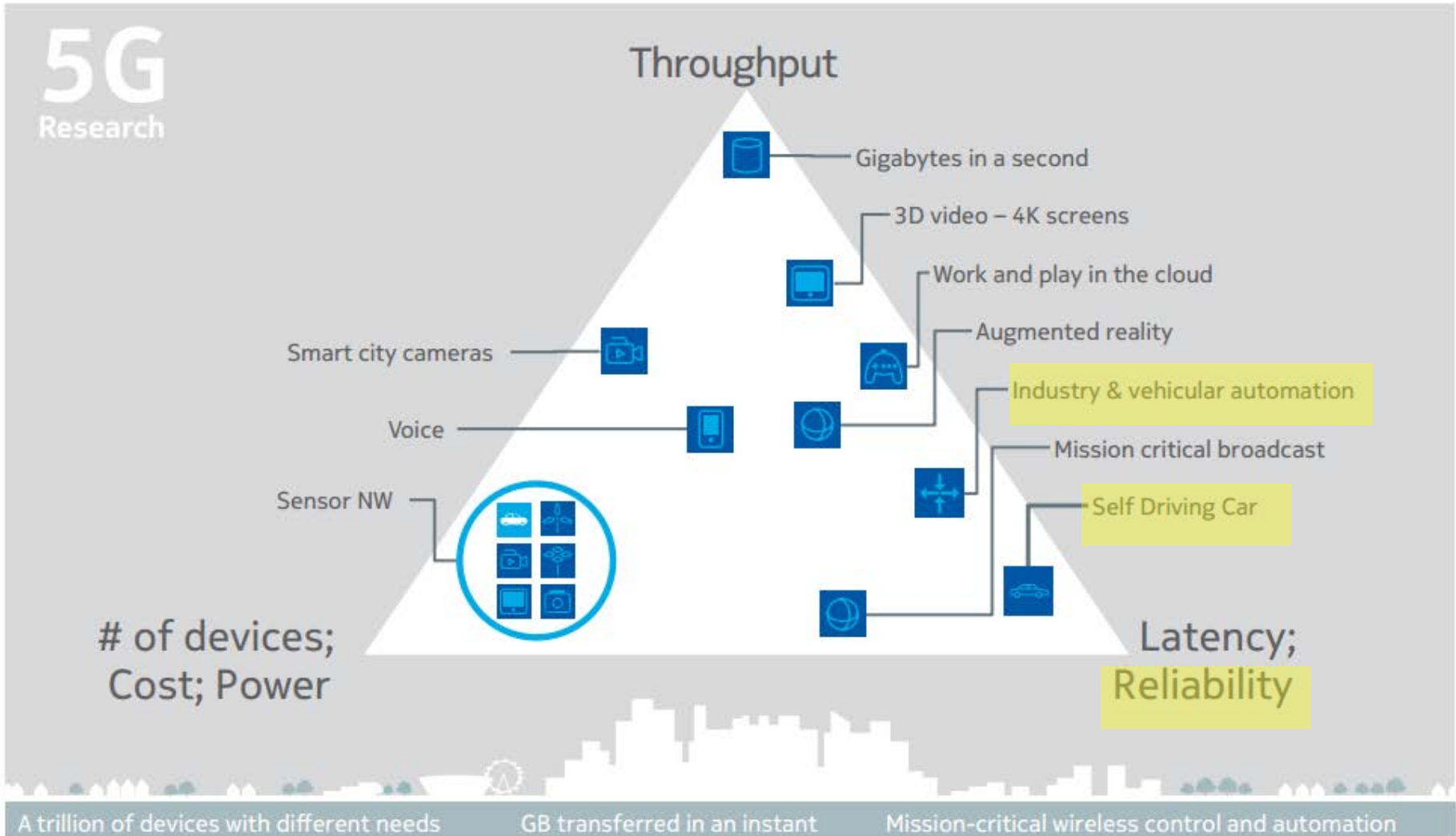
Ref. "5G Use Cases and Requirements," NOKIA, Co,

Industry 4.0
Revolution by Cyber Physical Systems

Industry 4.0
Machine Centric Communications for Cyber Physical Systems

Dependability is the most important issue in Industry4.0.

Dependablity in Wireless Networks

- ## *Meanings of Dependability*:
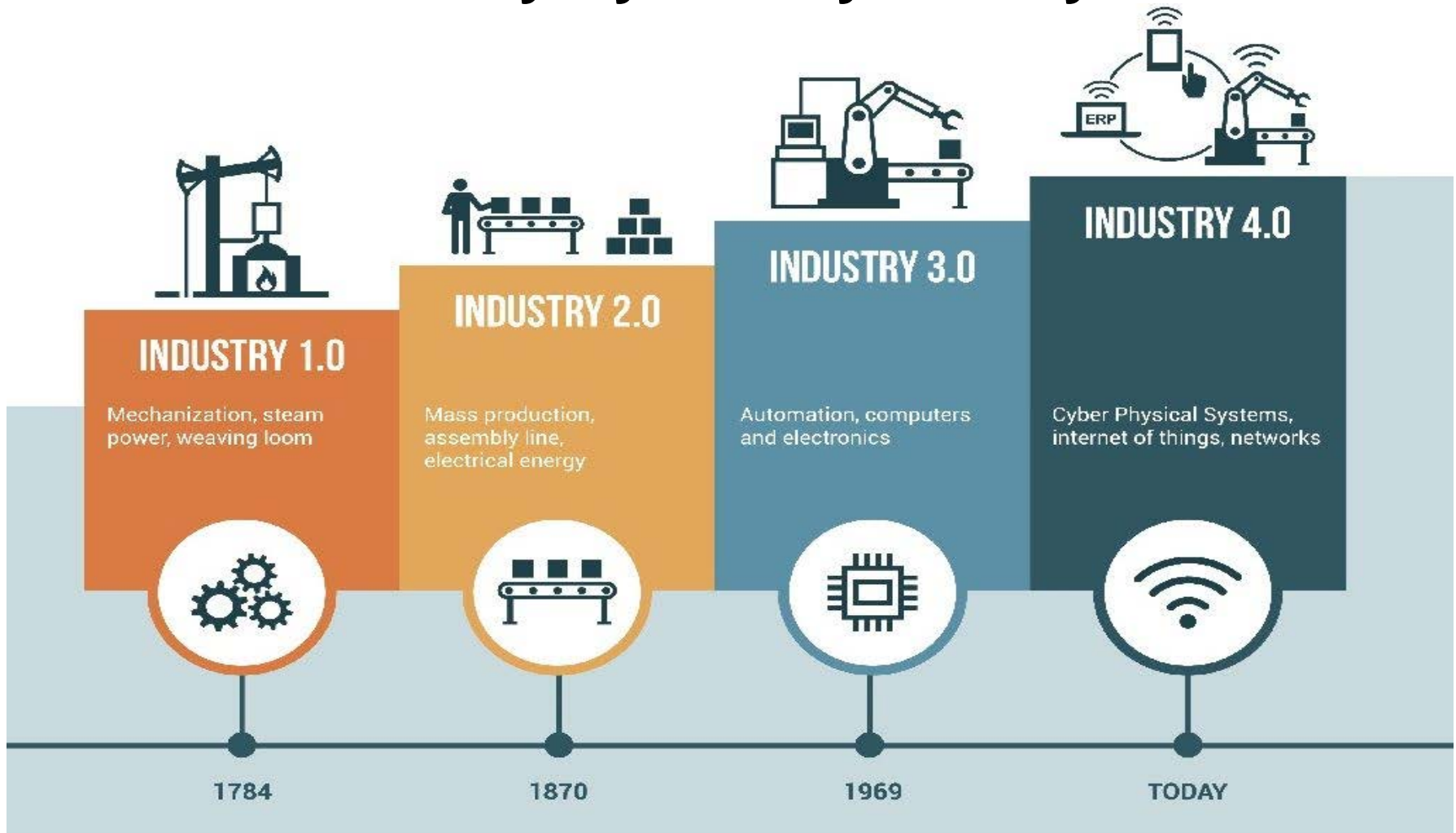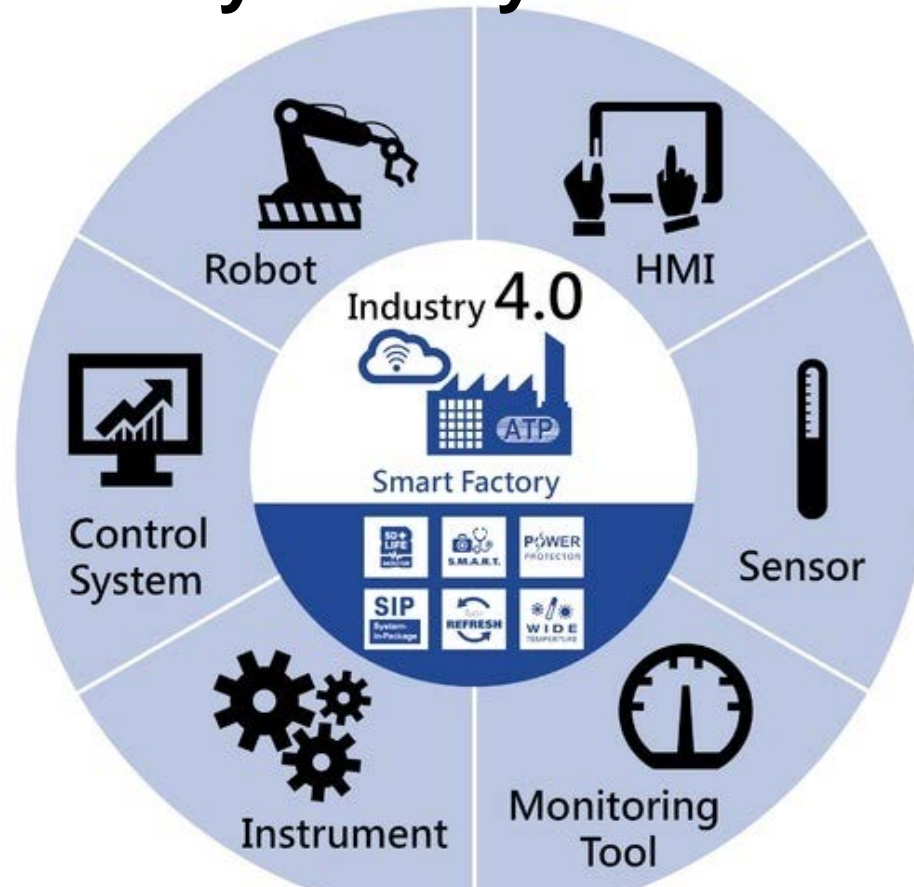 - – **"Dependability in network" means to guarantee lowest performance enough high that is different from average performance in a sense of highly reliable, safe, secure, fault tolerant, robust or trustworthy services in any predictable and even unpredictable worse environments.**

- ## *Demand for Enhanced Dependability in Networks*:
  - – Need for **Highly Reliable, Robust and Dependable Machine Centric M2M communications** different from Human centric communications
  - – Highly reliable, safe, secure and robust communications for **M2M Sensing & Controlling Feedback Loop** is necessary.
  - – Traditional **Communication & Control Theories** should be integrated to guarantee overall dependability.
  - – **Dependability** can be served by **combination of ICT and Data Science** including **Data Mining** and **Deep Learning**

Importance of Dependable Wireless in Industry and Academic

- # Importance in Industry

  - Ultra reliable, trustworthy or **Dependable Wireless for M2M sensing & controlling** must open innovation in business for customer satisfaction with dynamic change of requirement.

  - **Dependable Wireless** has wide variety of clean, efficient and ecological applications such as **medicine, robot, ITS, energy supply, factory automation in macro infrastructure** and **integrated circuit, embedded and implanted devices in micro networks.**

- # Importance in Academia

  - **Multi-Layer Joint Optimization** for Dependable Networks

  - Inter-Disciplinary R&D subjects among **Control Theory and Communication Theory**

  - Inter-Disciplinary R&D subjects among **ICT and Data Science**

Demands of Dependability for Sensing and Controlling for M2M

Human Body Area Network (BAN)

Tele-metering vital data
Wearable BAN

EEG.
ECG,
Blood Pressure
Temperature
MRI images
Etc.

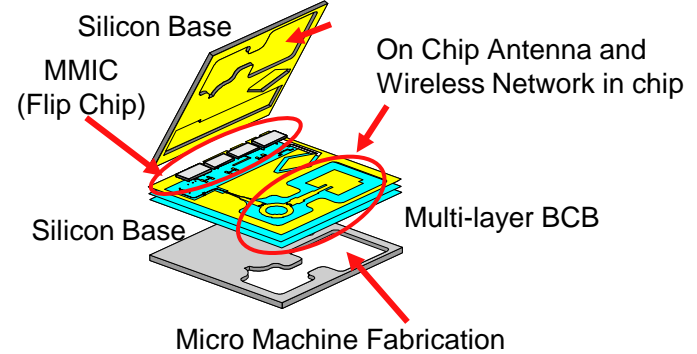Pacemaker with IAD

Tele-controlling implant devices
Implant BAN

UWB can solve such a problem that radio interferes a human body and medical equipments

Dependable Network among vital sensors, actuators, robots

Capsule Endoscope

Dependable BAN for Medical Healthcare

Inter & Intra Devices

Silicon Base

MMIC (Flip Chip)

On Chip Antenna and Wireless Network in chip

Silicon Base

Multi-layer BCB

Micro Machine Fabrication

Dependable Wireless System Clock in Micro Circuit & Network in Devices

Manufacturing Line of Factory

Inter & Intra Cars

Collision Avoidance Using inter-vehicle and roadside networks

Collision Avoidance and safe driving by inter-vehicle networks

Road to car networks

B車

Inter-vehicle networks

Inter-module wireless Networks

Car Navigation & Collision Avoidance Radar
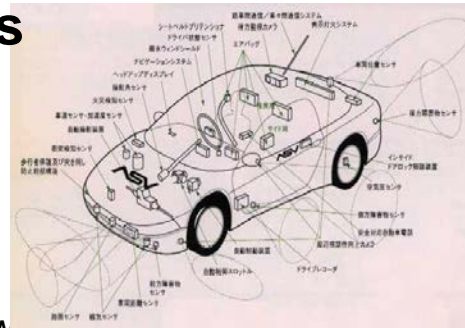
Car LAN & Wireless Harness
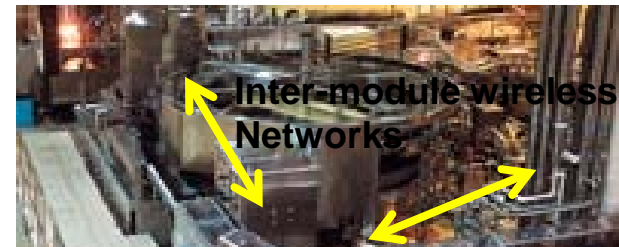
Factory Automation (FA)

Dependable Wireless Networks for Transportation

Dependable Wireless Sensing & Controlling for Manufacturing (CIM)

Future Vision of Dependable Social Infrastructures Based on ICT& Data Science

Major 5 Infrastructures of Communications, Transportation, Energy, Commerce and Medicine

A. Information Traffic （Telecommunications）

B. Vehicular Traffic（Transportation）

C. Energy Traffic(Power & Energy Supply）

D. Money Traffic （Commerce）

E. Patient, Drag Traffic(Medicine)

should be integrated to control all flows in future infrastructure

（Example）

A+B ➔ **ITS** (Intelligent Transport System)

A+C ➔ **Smart Grid** (Flexible Energy Network)

A+D ➔ **E-Commerce** (Borderless Secure Trade)

A+E ➔ **Medicine ICT** (Ubiquitous Medicine)

To Dependable Support for Social Services and Business
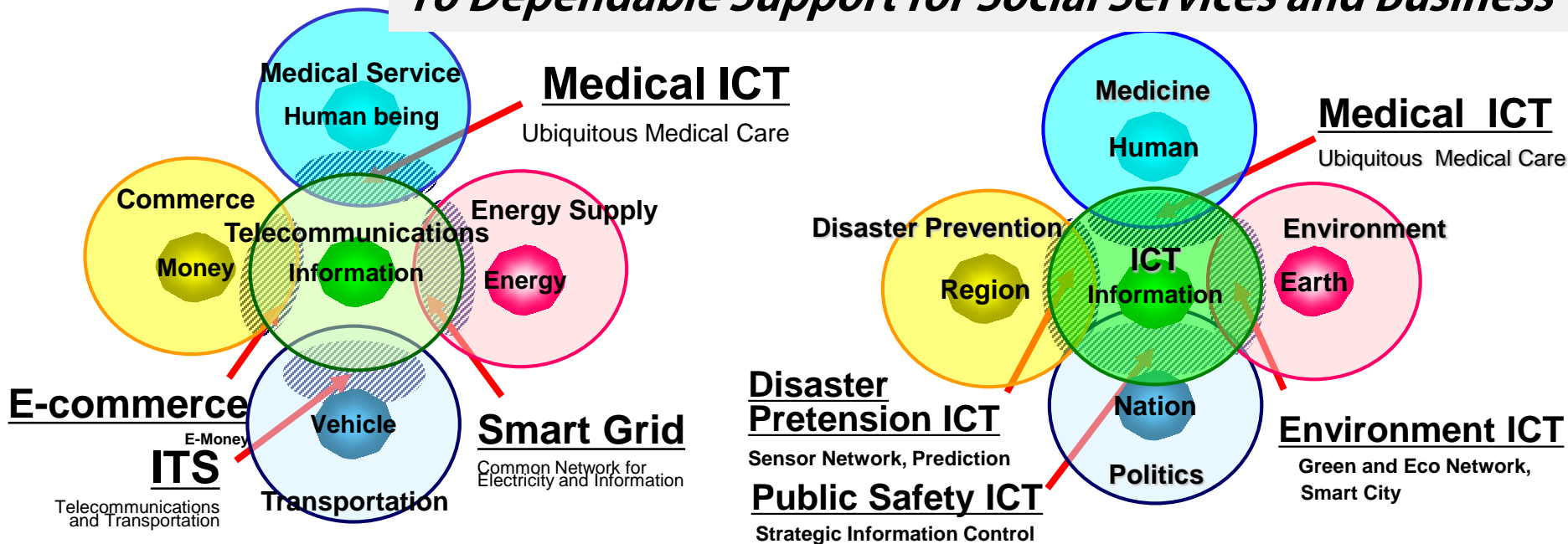
Demands of Dependable IoT and M2M for Sustainable Social Services

Population Ageing & Medical crisis
Healthcare Service(Medical ICT)

Cost of energy … fuel supply & demand
Energy Network(Smart Grid)

Increasing environmental requirements
CO_2 Reduction, Green Innovation

Escalating security concerns
Public Safety, National Defense

Heightened investor demands
Global Borderless Economics

Driving Technology

Dependable IoT & M2M

Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing & Controlling of Medical Devices, Cars & Others

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3. **New International Standard for Dependable Wireless Network for Automotive Industry**

Ubiquitous Medicine Based on BAN Connected with Existing Infra Networks

Remote Medicine Using Internet Satellite WINDS
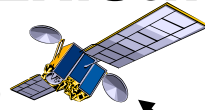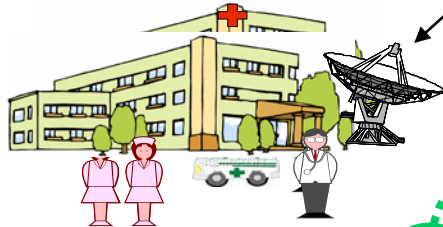
BAN Coordinator

Pendant Type BAN-ECG Sensor

Insulin Pomp BAN Controller
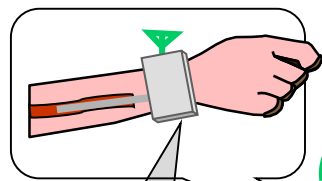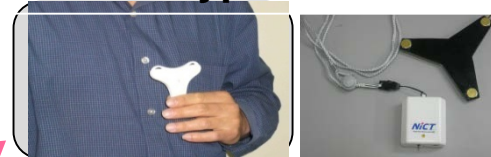
Capsule Endoscope

Wrist Watch Type BAN SpO2 Sensor

Wireless BAN: Body Area Network

Wearable BAN

Implant BAN

Tele-metering or sensing vital signs with various sensors

Tele-control of Medical Equipment and Devices

ECG
EEG
Blood Pressure
Heart Beat
Body temperature
Sugar rate
Medical images
And video
Etc.

A Break Thru Tec. for Dependability : Ultra Wide Band (UWB) Radio can solve a EMC human body impact of Radio in, on and around a body.

Pace Maker with ICD

Wireless Capsule Endoscope

Novel Concept
Intelligent Network of Vital Sensors, eHR, Medical Robots etc.
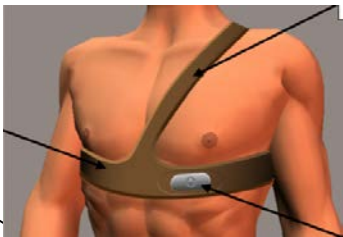
BAN Universal Platform with Multiple RF and Sensors for Field Trial Testing
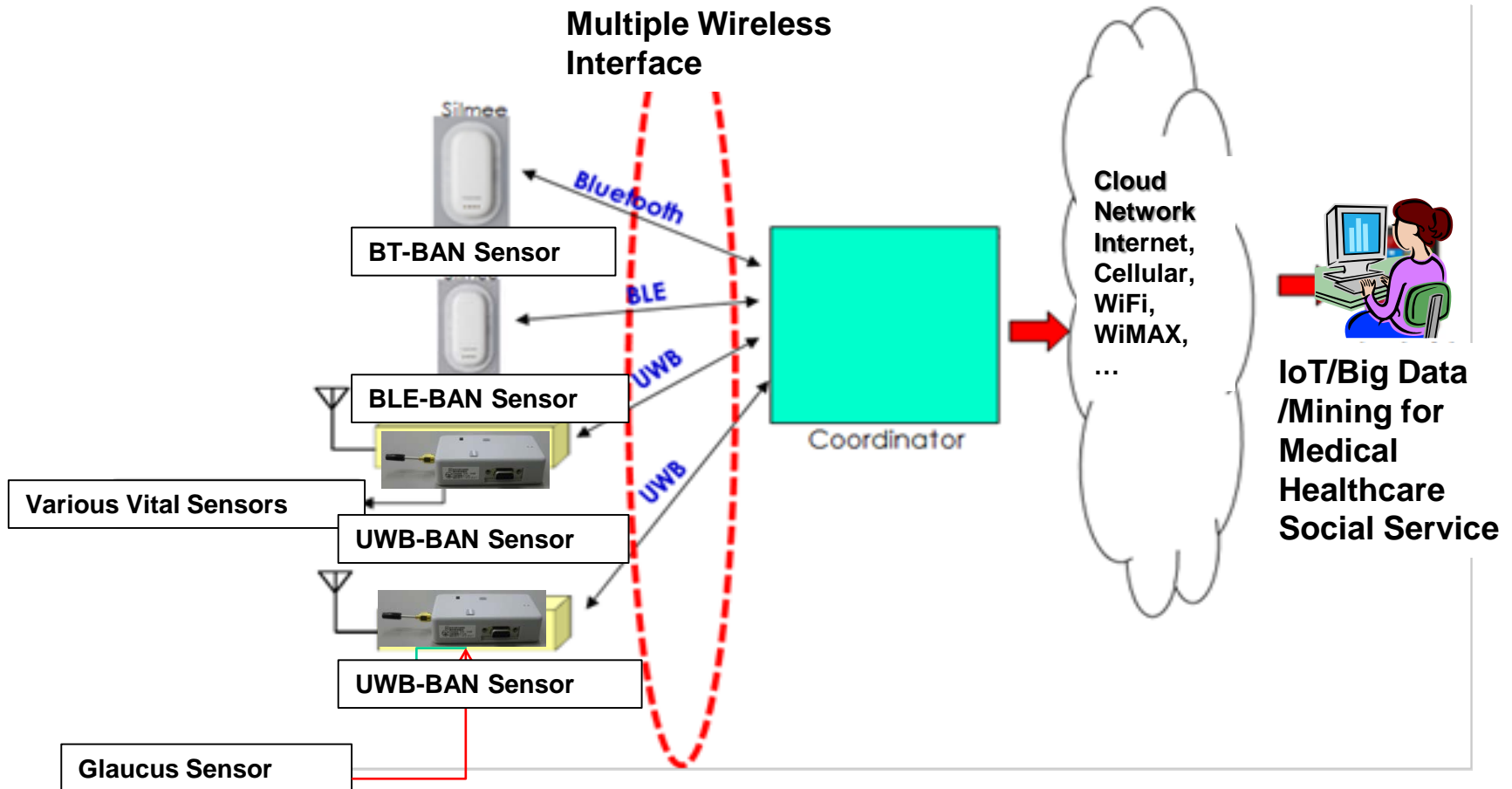
Ubiquitous Medicine Based on Medical IT with BAN

Medical support for developing countries
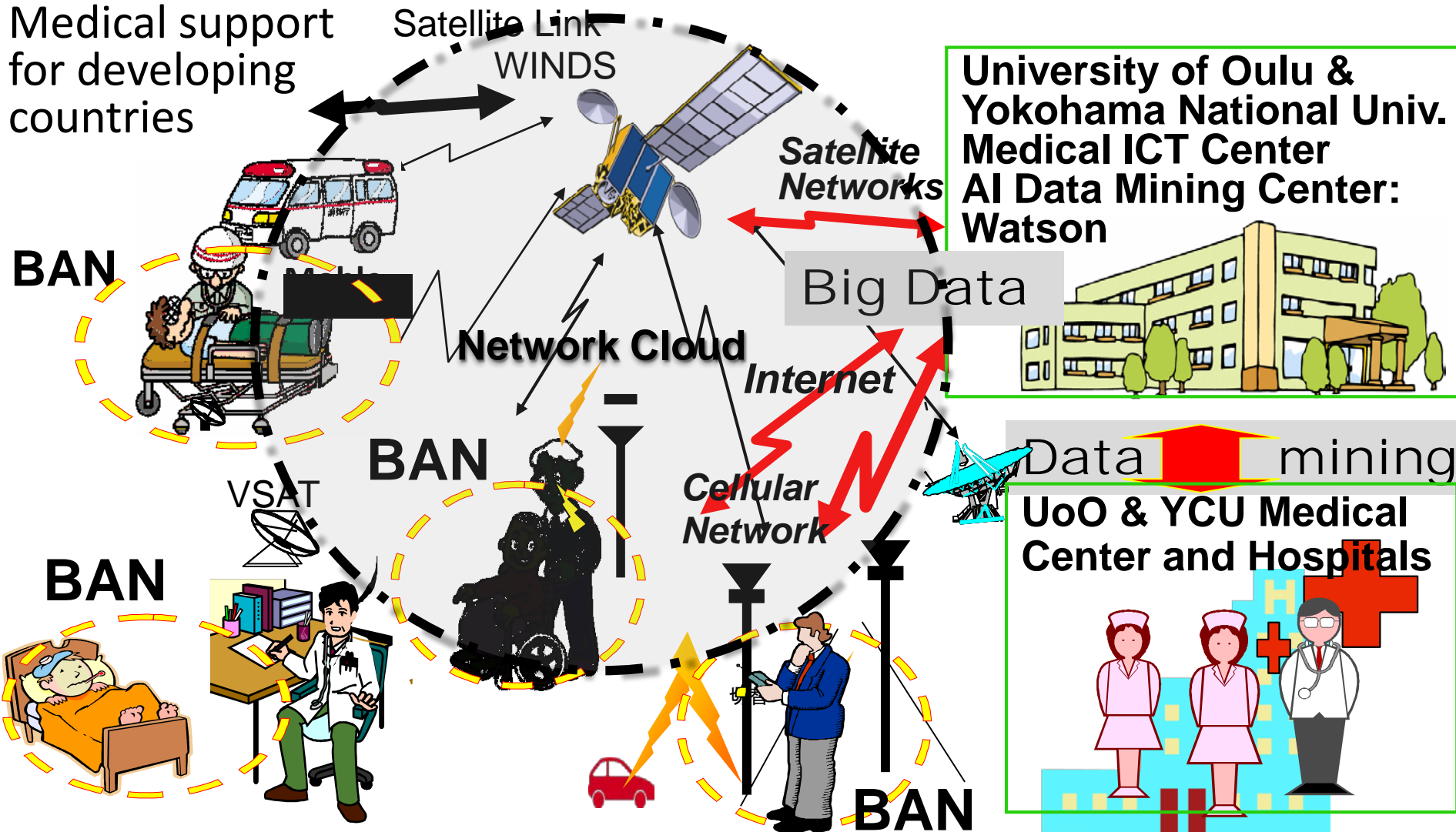
Satellite Link WINDS

University of Oulu & Yokohama National Univ. Medical ICT Center AI Data Mining Center: Watson

Satellite Networks

BAN

Big Data

Network Cloud

Internet

BAN

VSAT

Cellular Network

Data **mining**

UoO & YCU Medical Center and Hospitals

BAN

BAN

Remote Medical Healthcare System Based on Universal Platform by Wireless BAN, Network Cloud, Data Server with Data Mining
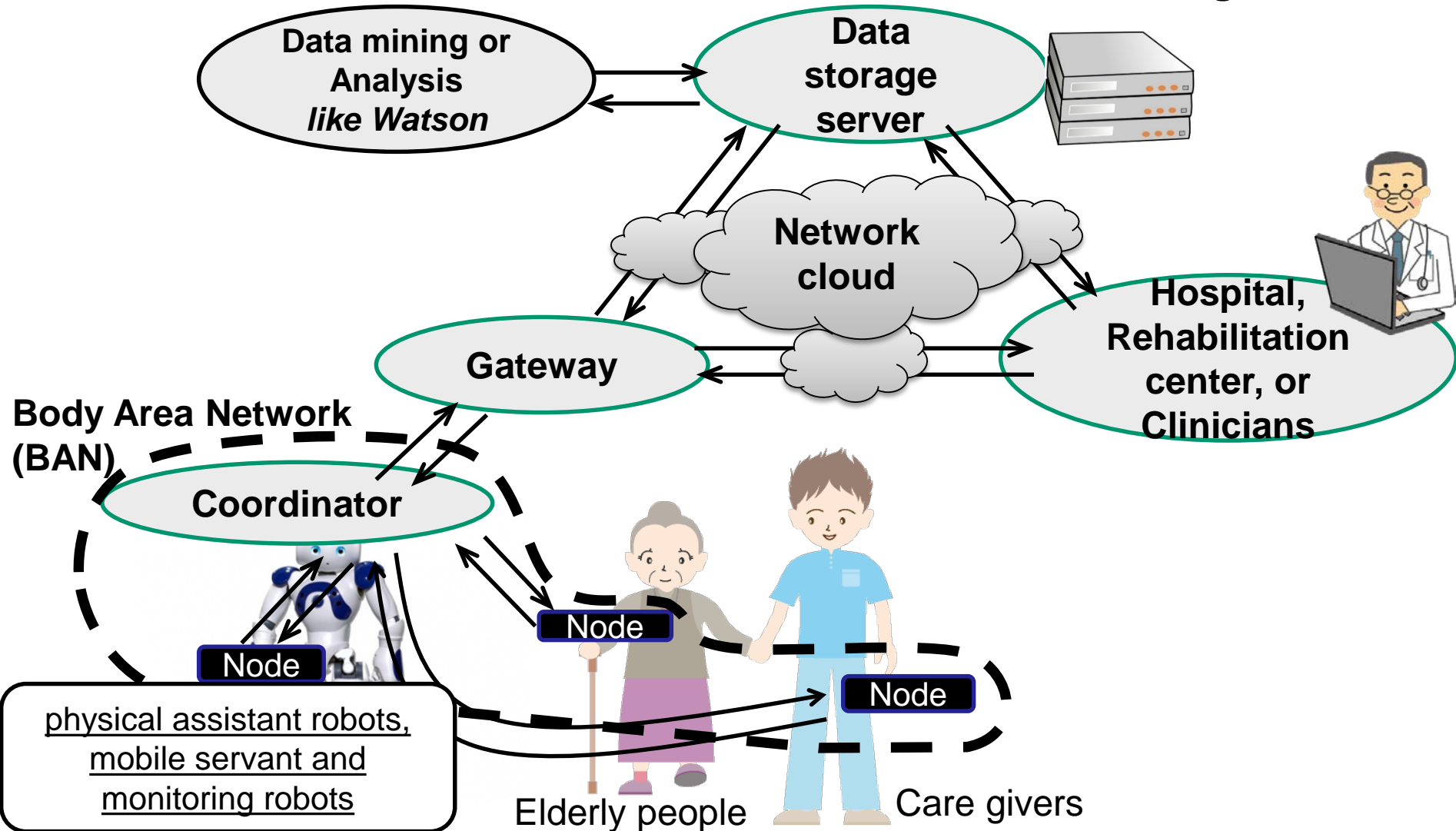
Remote Medical Healthcare System Based on Universal Platform by Wireless BAN, Network Cloud, Data Server with Data Mining

Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing & Controlling of Medical Devices, Cars & Others

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- **2.2 <u>Dependable Wireless Sensing & Controlling for Disaster Rescue Using Multiple UAVs</u>**

- **3. New International Standard for Dependable Wireless Network for Automotive Industry**

Emergency in Disasters e.g. Earthquake, Tsunami

- In case of **emergent disaster environment** such as earthquake and Tsunami, **Dependable networks** must be important to rescue victims and recovering infrastructure.

- Most of existing infrastructure networks are not available to find and rescue victims.

- **Dependable and cost effective emergency networks** are necessary to guarantee life and life line for human living.

Search and Rescue for Victims in Disaster

- Due to damage of buildings, it is very difficult that to find victims remained in broken buildings.

- To deliver rescue team and robot, victim location should be found.
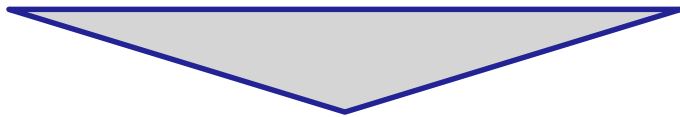
- **UAVs** (Unmanned Aerial Vehicles) or **Drones** can be applied by cost effective manner.

2016-2017 NZ(UC)-Japan(YNU) Joint Project；
Dependable Wireless Body Area Networks to Support Search and Rescue and Medical Treatment in Disaster Scenarios Using Multiple UAVs

GNSS：GPS, GLONAS, BeiDou, QZS（Quasi-Zenith Satellite System）

Step2；Expanding UWB ranging area by recursive process

Step3；Localization of victim by TDOA ranging with UWB-BAN

Victim

Unexplored area episode bldgs.

Step1；Positioning for anchor node UAVs using GNSS

Step4；Triage using sensed vital signs from UWB-BAN

Anchor nodes

Base station

Step5；Wireless power transmission to recharge battery of UAVs

mobile's base station

Flowchart to Search Casualties
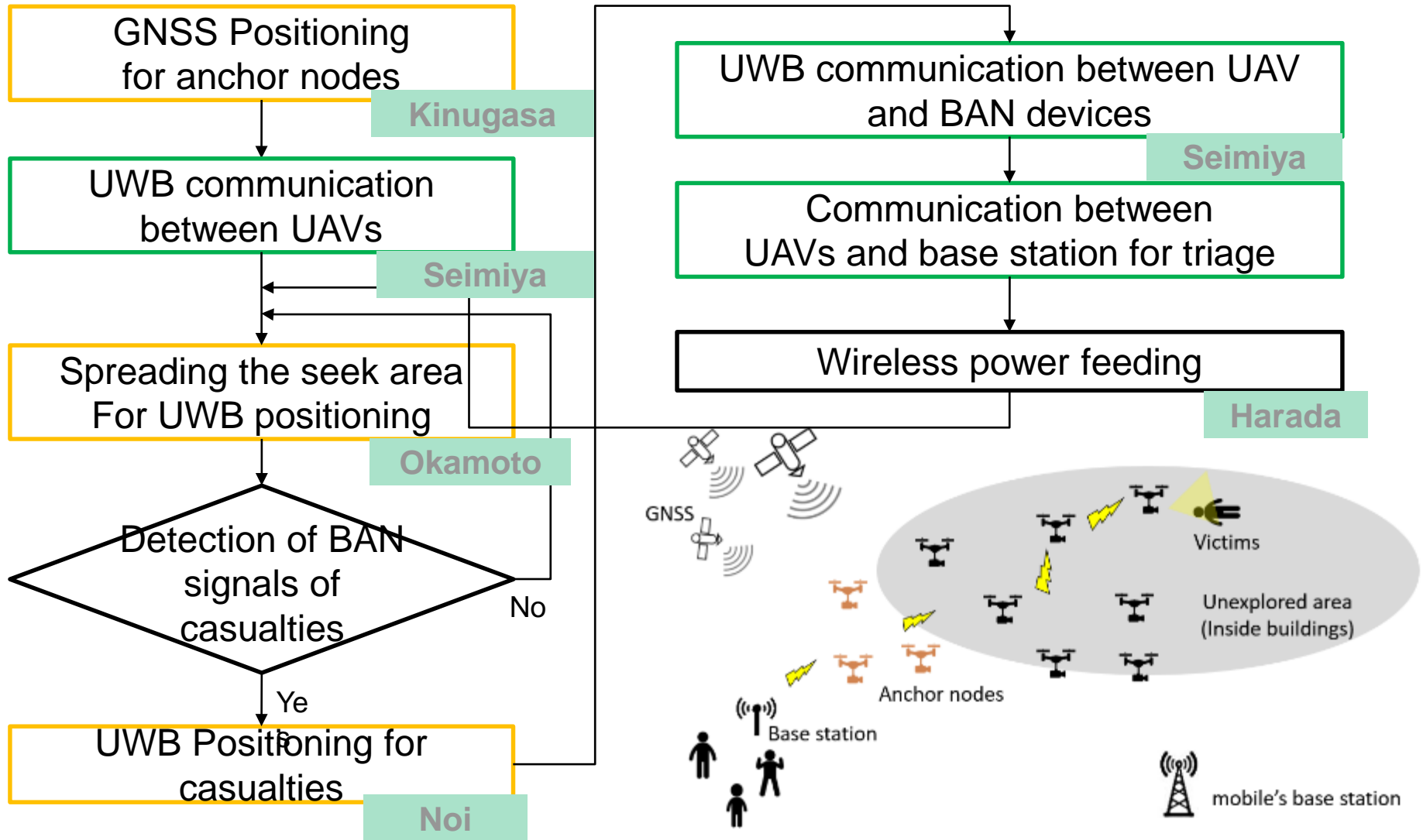
GNSS Positioning
for anchor nodes

Kinugasa

UWB communication
between UAVs

Seimiya

Spreading the seek area
For UWB positioning

Okamoto

Detection of BAN
signals of
casualties

No

Ye

UWB Positioning for
casualties

Noi

UWB communication between UAV
and BAN devices

Seimiya

Communication between
UAVs and base station for triage

Wireless power feeding

Harada

GNSS

Victims

Unexplored area
(Inside buildings)

Anchor nodes

Base station

mobile's base station

Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing & Controlling of Medical Devices, Cars & Others

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3. **<u>New International Standard for Dependable Wireless Network for Automotive Industry</u>**

Dependable BAN of Things/M2M for Automotive Industry

・ Current **IoT/M2M** mainly assumes **sensing and data acquisition** but cannot be applied to **remote sensing & controlling UAVs, cars, and robots**.

・ Because current IoT/M2M **cannot guarantee lowest performance and too opportunistic**.

・ **Dependable BAN of Things/M2M** has been applied for wireless **sensing and controlling for car and automotive industry** as well as **Disasters.**

・ **Dependable BAN of Things/M2M** can be applied for **dependable wireless sensing and controlling of inter & intra cars and car factory automation.**

Dependable BAN of Things for Autonomous Driving Cars

- 4-6 Mono Cameras
- 1-2 Stereo Cameras
- 2-4 Mid-Range Radar
- 2 Long Range Radar
- 8-16 Ultrasonic Sensors, 4 Wheel Speed Sensors
- Redundant Data Center
    - Number Crunchers for Data Fusion
    - ABS, ESP, …
    - Some ECUs we can't tell you details today ☺
- Interaction with Powertrain, Body Domain, Navigation, Airbag, CAR2CAR, CAR2Infrastructure

Automated Driving is leaving the Research Labs. Soon it will be in mass production.

Does this look familiar to data centers?
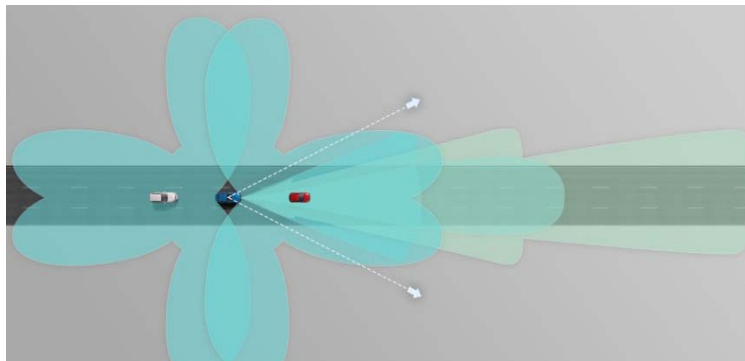
For automotive, Inter-vehicle communications(IVC) and Machine-to-Machine(M2M) inside a car like brake-axcel control must be core applications of Dependable BAN of Things.

Demands for Dependable Wireless Network in Factory Automation(FA)

Demands for Internet of Things increase but Machine-to-Machine (M2M) should be reliable and secure, so Dependable BAN for Medicine can be applied for Dependable BAN of Things.

Automatic Remote Sensing Glucose and Controlling Insulin Pump for Diabetes Patients Using Wireless BAN

Clinician

controller

Wireless channel With

Pump

Insulin Pump

Patient

sensor

Blood-sugar level (Glucose) HbA1c
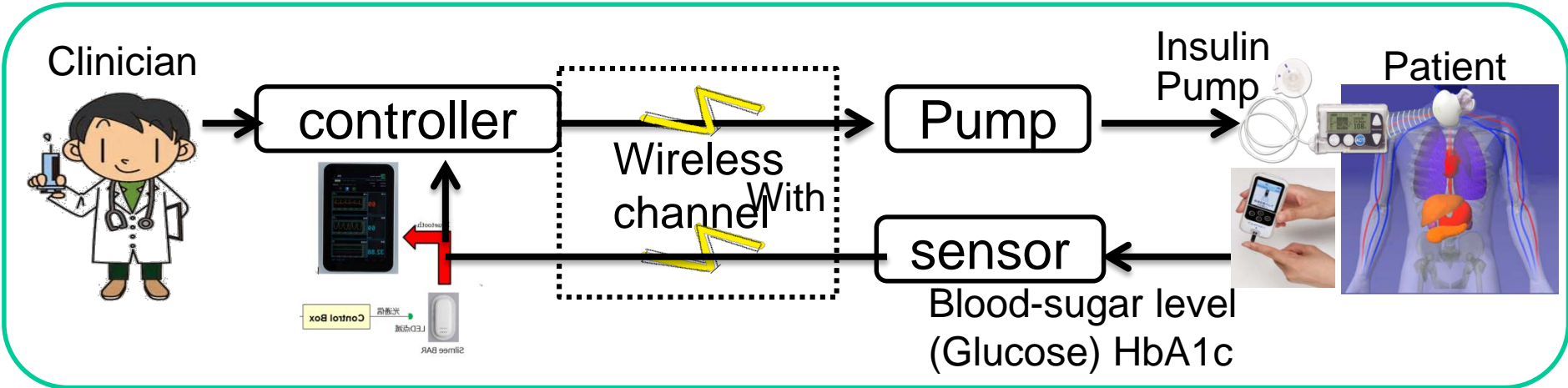
Wireless Feedback Sensing and Controlling Loop for Diabetes Patients

Controller $u[k]$ $\hat{u}[k]$ **Human Model of Glucose vs Insulin**

$r[k]$

$+$ $-$ K

$\hat{x}[k]$

Wireless channel

Bd $+$ 1/S $y[k]$

Ad

$x[k]$
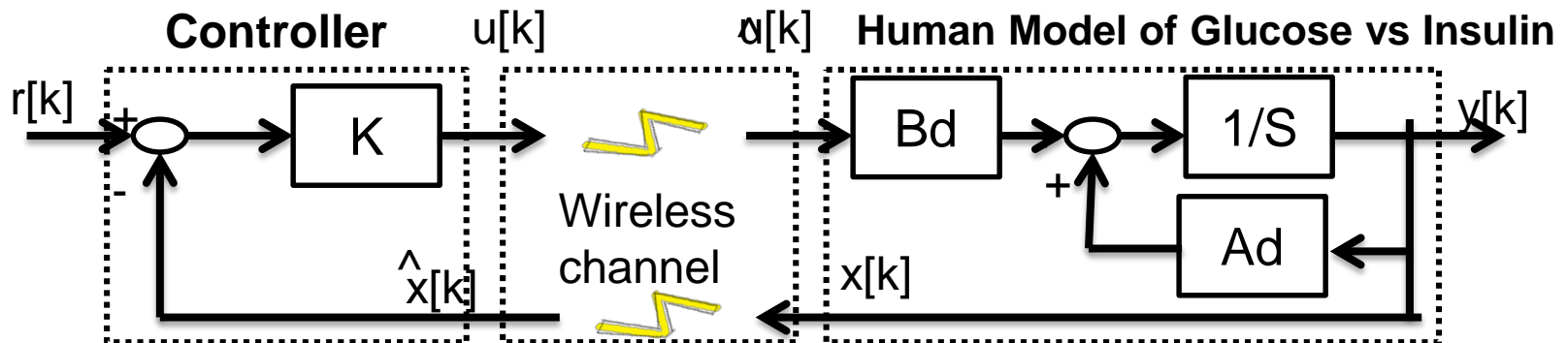
Feedback Delay Loop Model with Motion Equation

Remote Localization and Rescue of Missing Victims Using Wireless Dependable BAN of Things/M2M

Rescue Team

For Remote Controlling UAVs

UAVs/Drones

controller → Wireless channel → Navigation → UAVs/Drones

Missing Victims

Localization

By Using GNSS and Localization of UAVs/Drones
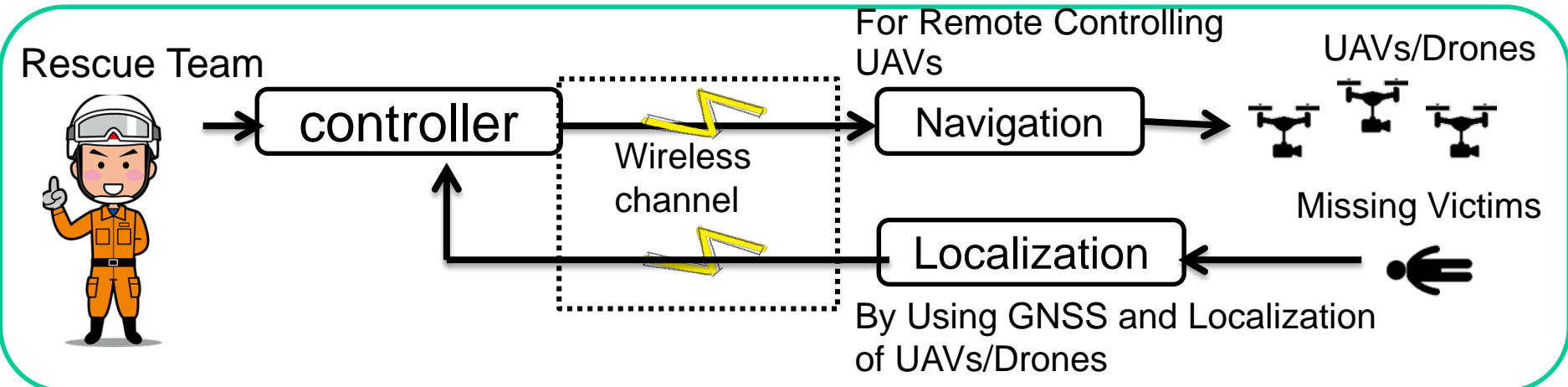
Wireless Feedback Sensing and Controlling Loop for Rescue of Victims

Controller   u[k]   û[k]   **UAVs/Drones Model and Localizing System**

r[k] → + − → K → Wireless channel → Bd → + → 1/S → y[k]
                                              Ad

x̂[k]   Wireless channel   x[k]
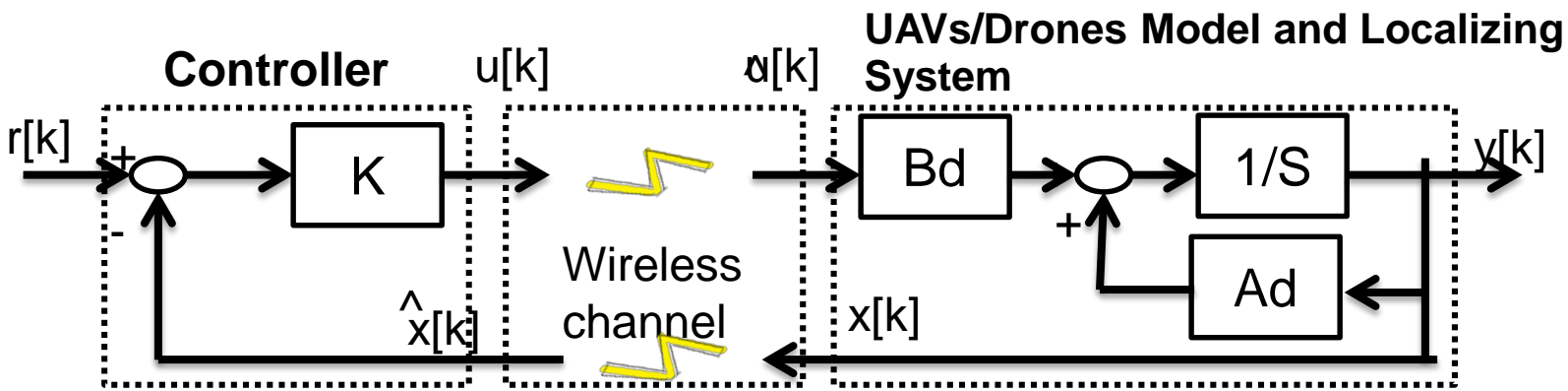
Feedback Delay Loop Model with Motion Equation

Collision Avoidance Radar and Automatic Brake Using Wireless Dependable BAN of Things/M2M

For Autonomous Driving

Own Car

Driver

controller

Wireless channel

Axel/Brake

Car Running Ahead

Radar

For Collision Avoidance and Inter-Vehicle Communication
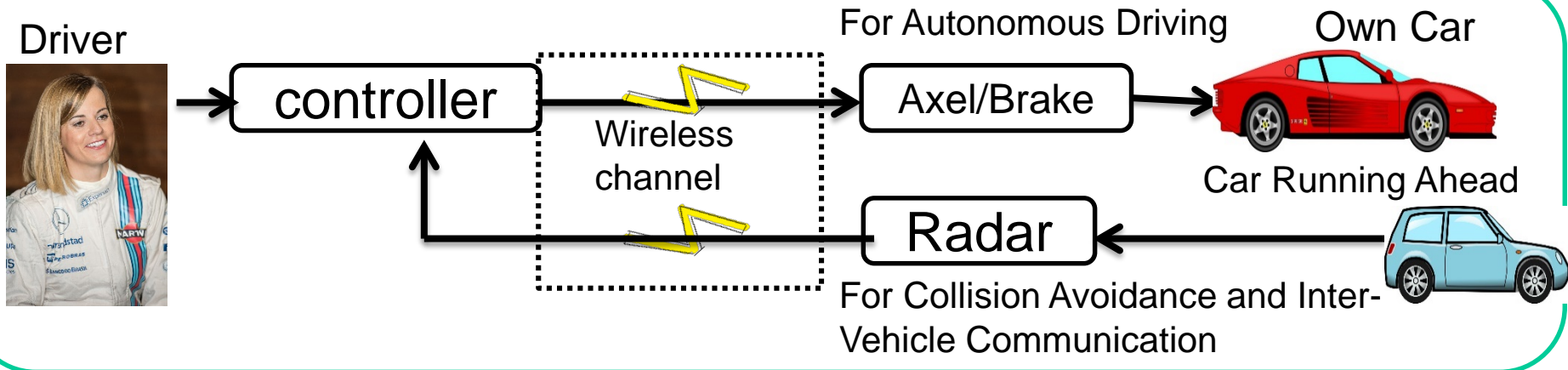
Wireless Feedback Sensing and Controlling Loop for Autonomous Driving

Controller   u[k]   ȗ[k]   **Car Axel/Brake Model and Radar System**

r[k]   +   −   K   Wireless channel   Bd   +   1/S   y[k]

^x[k]   x[k]   Ad
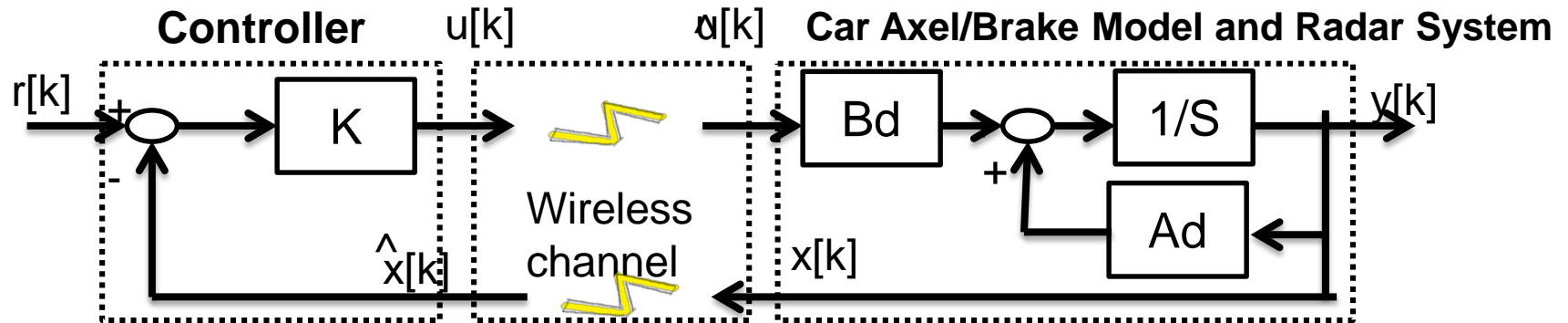
Feedback Delay Loop Model with Motion Equation

Standardization of BAN(IEEE802.15.6 Amendment and ETSI Smart BAN)

IEEE802.15 IG-DEP Started Amendment of BAN Standard（IEEE802.15.6）for MAC, Security and Others Issues since July 2012.

IEEE802

| IEEE802.11 Wireless LAN | IEEE802.15 Wireless PAN | IEEE802.16 Wireless MAN |

| 802.15.1 Bluetooth | 802.15.2 Coexistence between WPAN and WLAN | 802.15.3 PHY for High Rate WPAN | 802.15.4 PHY for Low Rate WPAN | 802.15.5 WPAN Mesh Network | **802.15.6 Wireless Medical BAN** |

2012.2 Standard was Completed

| 802.15.3a Alternative PHY of 15.3 | 802.15.3b Maintenance of 15.3 | 802.15.3c PHY in Millimeter wave band | 802.15.4a Low rate UWB PAN Alternative PHY of 15.4 | 802.15.4b Revision & Modification of 15.4 MAC | 802.15.4c Chinese WPAN | 802.15.4d Japanese WPAN |

2007.3 Standard Completed

IEEE 802.15 IG DEP
Scope and Focused Applications of Dependable Networks with Different QoS Levels

Ryuji Kohno
(Yokohama National University/CWC-Nippon Co.)

Atlanta, GA, USA
January 20th, 2016

Proposed Applications of New Standard for Dependable Wireless Networks

1. Remote healthcare monitoring
2. Remote sensing and controlling robots and UAVs for disasters
3. Recovering infrastructure networks after disasters
4. Resilient, reliable and robust IoT network against disasters
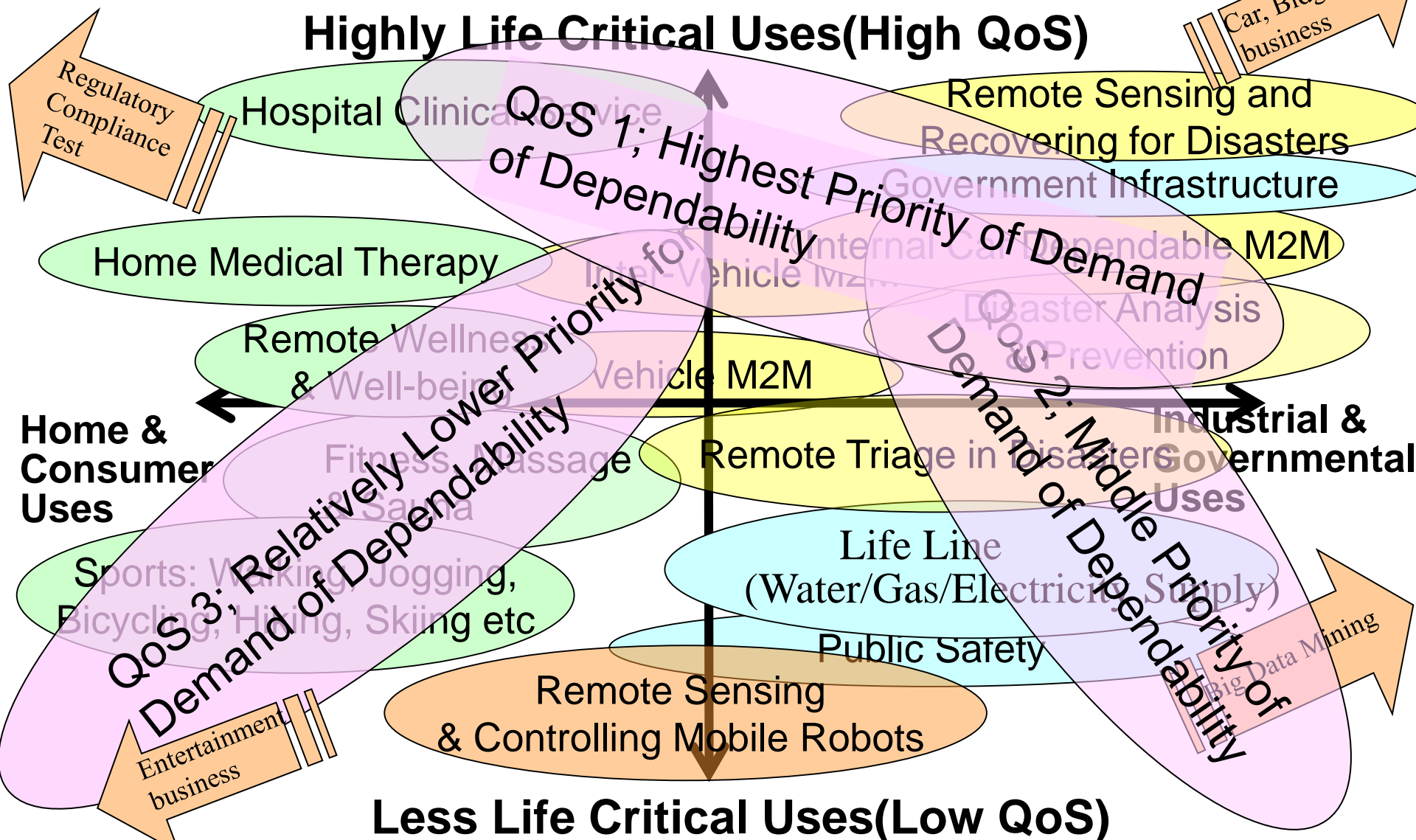5. **Vehicle internal sensing and controlling**
6. **Collision avoidance radar**
7. **Inter-vehicle communications and ranging**
8. Wearable and implant wireless medical sensing and controlling
9. Wearable healthcare sensing
10. Secure remote healthcare and medicine
11. **Wireless sensing system for Factory with feedback control**
12. **Dependable multi-hop inter-vehicle communications**
13. **Inter-navigation and inter-vehicle information sharing in normal and emergency conditions**
14. Single wireless communication network solution that functions both in normal and in disaster environments
15. Disaster prevention, emergency rescue and recovery

Ryuji Kohno(YNU/CWC-Nippon)

Visualizing Portfolio of Focused Applications

Highly Life Critical Uses(High QoS)

Regulatory Compliance Test

Car, Bldg Care business

Hospital Clinical Service

Remote Sensing and Recovering for Disasters

Government Infrastructure

QoS 1; Highest Priority of Demand of Dependability

Home Medical Therapy

Internal Car Dependable M2M

Inter-Vehicle M2M

Disaster Analysis & Prevention

QoS 2; Middle Priority of Demand of Dependability

Remote Wellness & Well-being

Home & Consumer Uses

QoS 3; Relatively Lower Priority of Demand of Dependability

Vehicle M2M

Remote Triage in Disasters

Industrial & Governmental Uses

Fitness, Massage & Sauna

Life Line (Water/Gas/Electricity Supply)

Sports: Walking, Jogging, Bicycling, Hiking, Skiing etc

Public Safety

Big Data Mining

Entertainment business

Remote Sensing & Controlling Mobile Robots

Less Life Critical Uses(Low QoS)

Three Classes of Focused Potential Applications

We have classified focused potential applications into three classes according to demands of dependability.

QoS 1 Class: Highest Priority Level for Demand of Dependability
    1.1 Car Internal M2M
    1.3 Remote Diagnosis in Factory
    2.3 Professional Medicine
    3.2 Public Safety
QoS 2 Class: Meddle Priority Level for Demand of Dependability
    1,2 Inter-vehicle M2M
    2.2 Healthcare
    3.1 Life Line (Water/Gas/Electricity Supply)
    4.1 Remote Diagnosis of Infra(bridge/bldg./train)
QoS 3 Class: Low Priority Level for Demand of Dependability
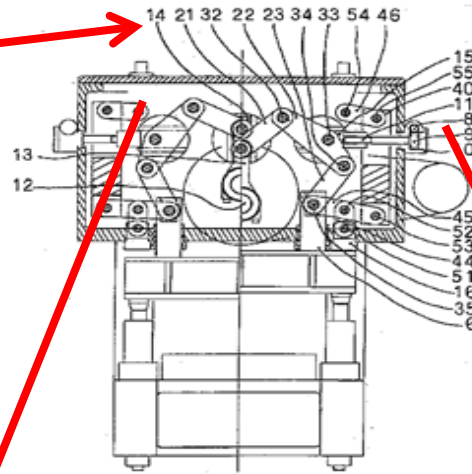   2.1 Wellness, Wellbeing
    3.3 Government System
    4.2 Remote Sensing and Controlling Mobile Robots
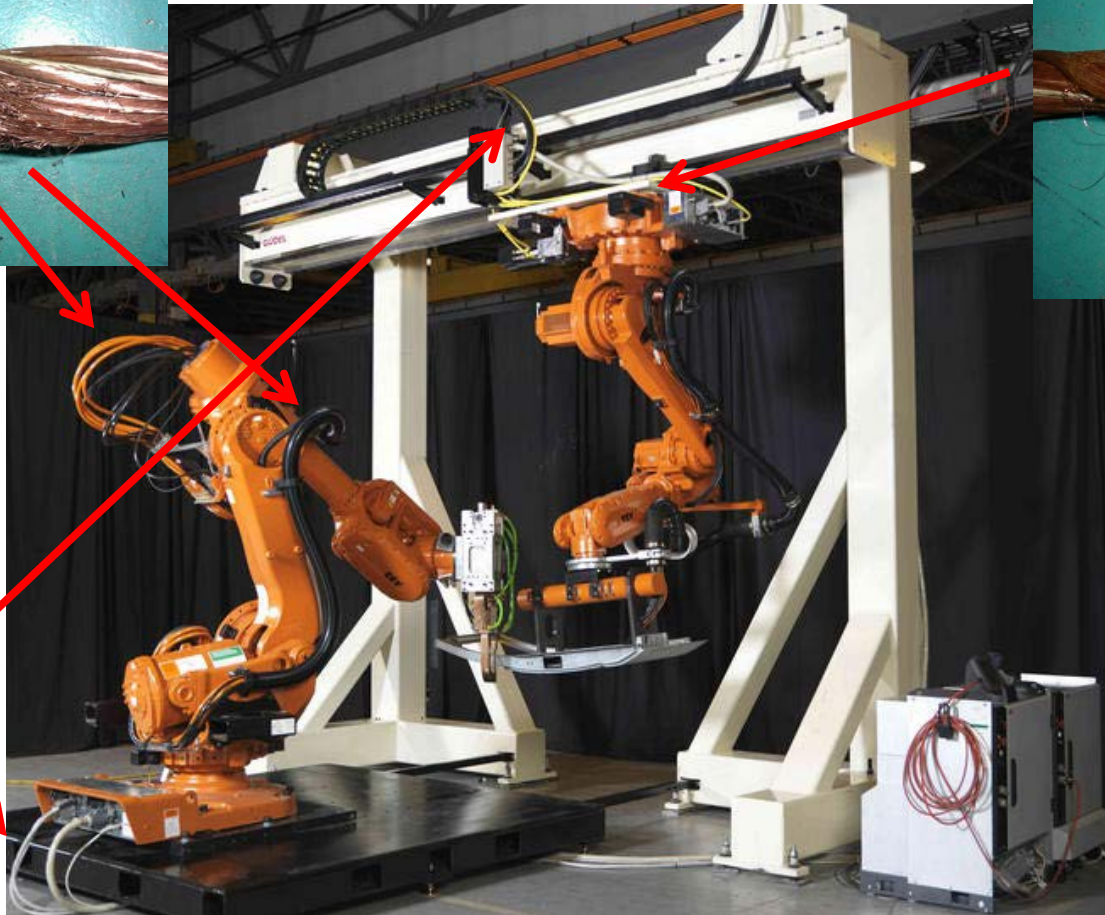   4.3 Disaster Analysis and Prevention

Use case 1; Detection of Cracks in Press Machine

Prediction of cracks and any damages in press machines is keen to keep stable operation of lines in factory automation.

Ryuji Kohno(YNU,/CWC-Nippon)

# Use case 2; Detection of Twist and Cut of Cables

Prediction and Real-time Detection of twist and cut in signal and power cables

Use case 3; Real-time Monitoring or/and Controlling Robots

In order to improve QoS of controlling robots in factory lines, real-time sensing and controlling with permissible feedback control loop must be important requirement
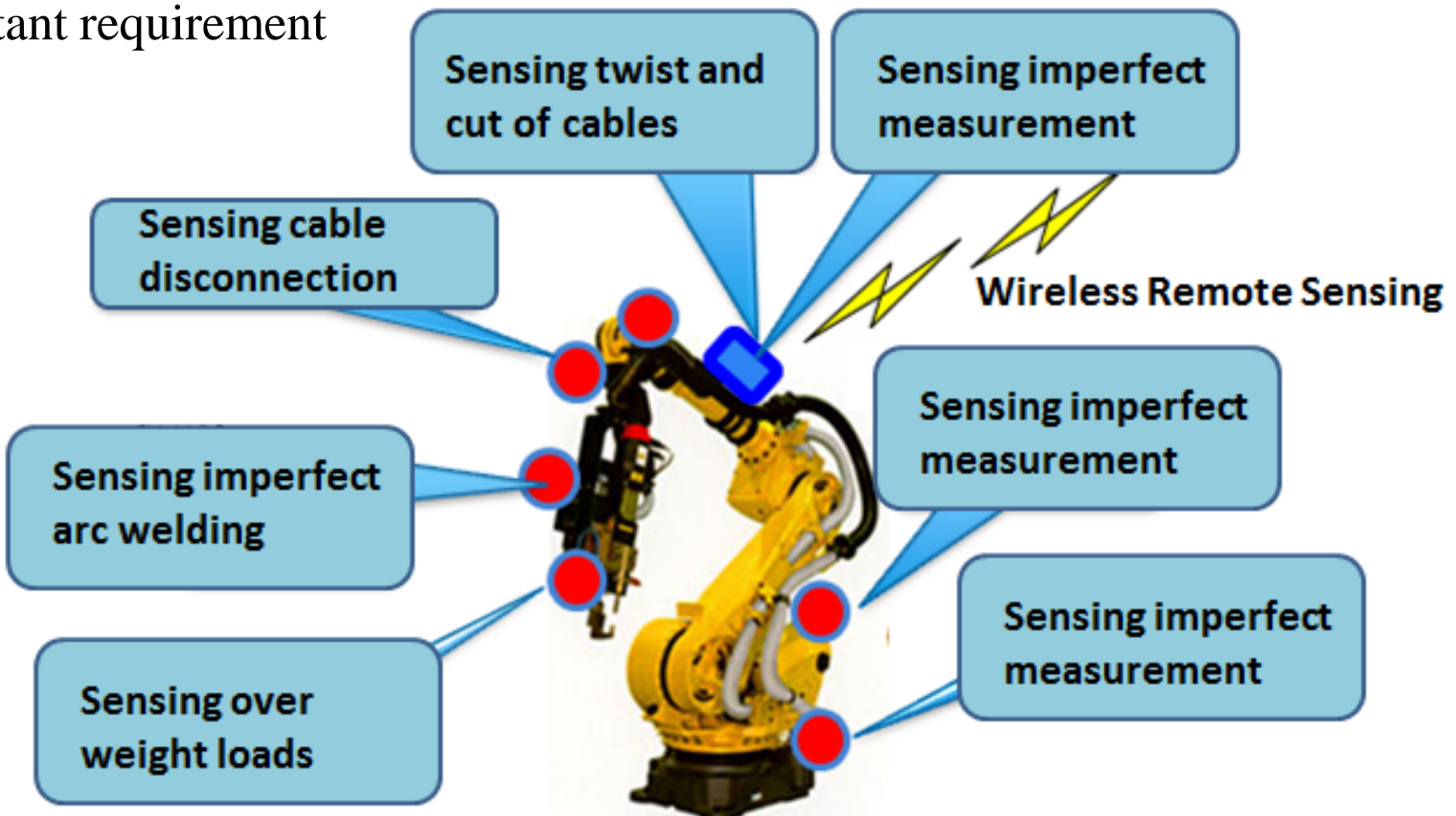
Promotion of a New Standard of Dependable Wireless Network: IEEE802.15 IG-DEP

Please download CFI Call for Interest and send your Comments to Chairman Prof. Kohno
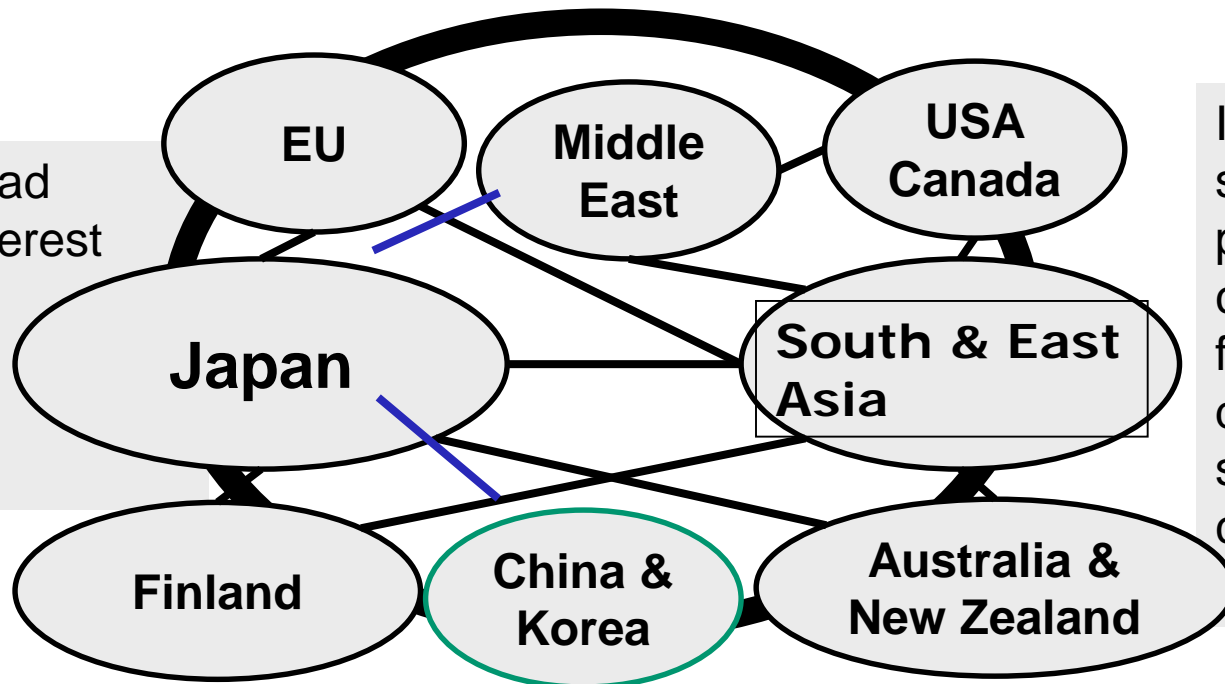
International standard can promote collaboration for medical devices and speed up its clinical use and business.

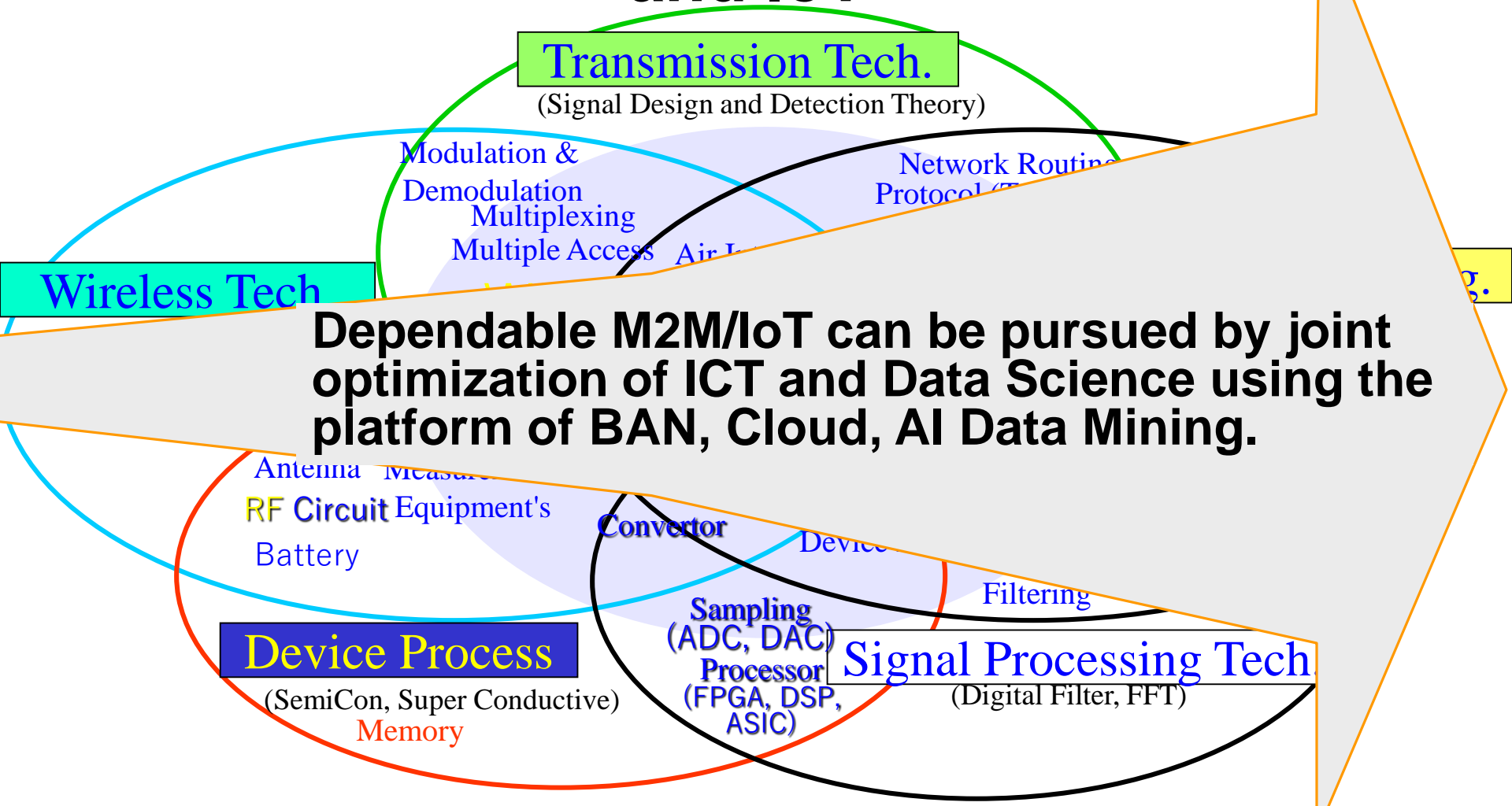https://mentor.ieee.org/802.15/documents?is_dcn=DCN%2C%20Title%2C%20Author%20or%20Affiliation&is_group=0dep

Call for Interest(CFI)； IEEE P802.15-14-0449-06-0dep-call-for-interest.doc

Summary；15-15-0217-06-0dep-ig-dep-review-of-responses-to-call-for-interest-cfi.ppt

Necessary Technologies for Dependable M2M and IoT

Transmission Tech.

(Signal Design and Detection Theory)

Modulation & Demodulation

Multiplexing

Multiple Access

Network Routing
Protocol

Air Int

Wireless Tech

Dependable M2M/IoT can be pursued by joint optimization of ICT and Data Science using the platform of BAN, Cloud, AI Data Mining.

Antenna Measure

RF Circuit Equipment's

Battery

Convertor

Device

Filtering

Sampling
(ADC, DAC)

Processor
(FPGA, DSP, ASIC)

Device Process

(SemiCon, Super Conductive)

Memory

Signal Processing Tech

(Digital Filter, FFT)

Concluding Remark

1. Dependable Wireless IoT and M2M

- Demand of dependability for 5G, IoT/M2M, Industry 4.0
- Multiple layer of ICT and Data Science for dependable IoT/M2M
- Dependable Sensing and Controlling Feedback Loop with Deep Learning.

2. Dependable BAN for Advanced Medical Healthcare

- Research & Education of Medical BAN by MEXT GCOE Program
- International Standard of BAN by IEEE802.15
- Prototyping and Business of BAN by CWC-Nippon and Toshiba
- Clinical Regulatory Compliance by Regulatory Science Center

3. Dependable Wireless Sensing and Controlling for Disaster Rescue Using Multiple UAVs

- Localization and Control of UAVs(Drones) by JP-NZ Program
- Wireless Power Transfer for UAVs(Drome's) by JP-NZ Program

4. International Standard of Dependable IoT/M2M in Car Industry

- **<u>Let us promote a new standard for global business of Dependable IoT and M2M by IEEE802.15 IG-DEP.</u>**