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

Submission Title: [IG DEP Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing and Controlling of Medical Devices, Cars, UAVs & Others for Industry4.0]

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Abstract: [This a part of the authort's plenary keynote in the 28th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC2017), Montreal, QC, Canada October 10, 2017. As a typical use case of dependable wireless networks, reliable machine centric sensing and cotrolling of medical devices, cars, UAV, and others is introduced]

Purpose: [information]

Wireless Dependable IoT/M2M for Reliable Machine Centric Sensing and Controlling of Medical Devices, Cars, UAVs & Others for Industry4.0

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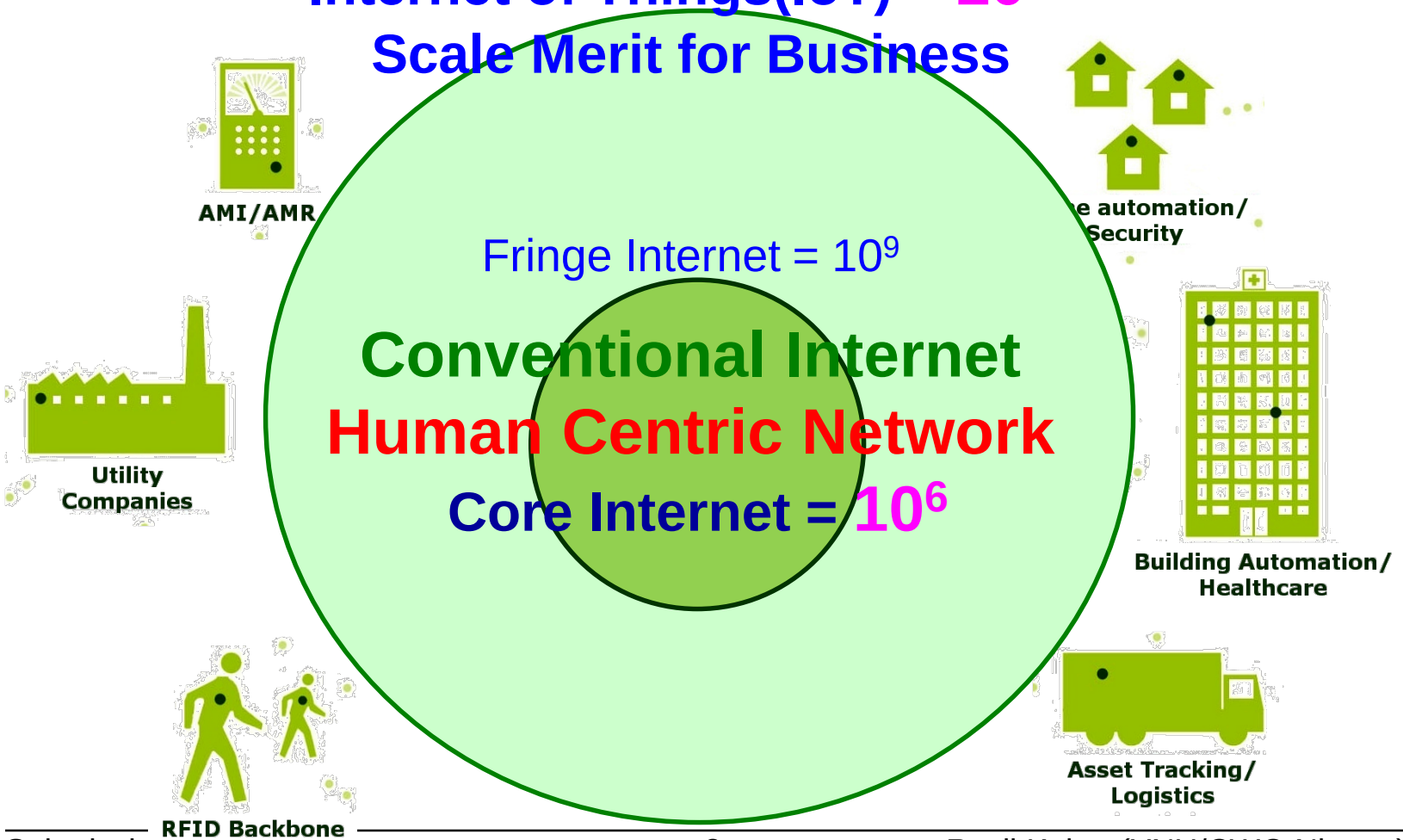
A part of plenary keynote speech in the 28th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC2017), Montreal, QC, Canada October 8-13, 2017

Internet of Things (IoT)

Machine Centric Network (M2M; Internet of Everything)

Internet of Things(IoT) = 10^{12}

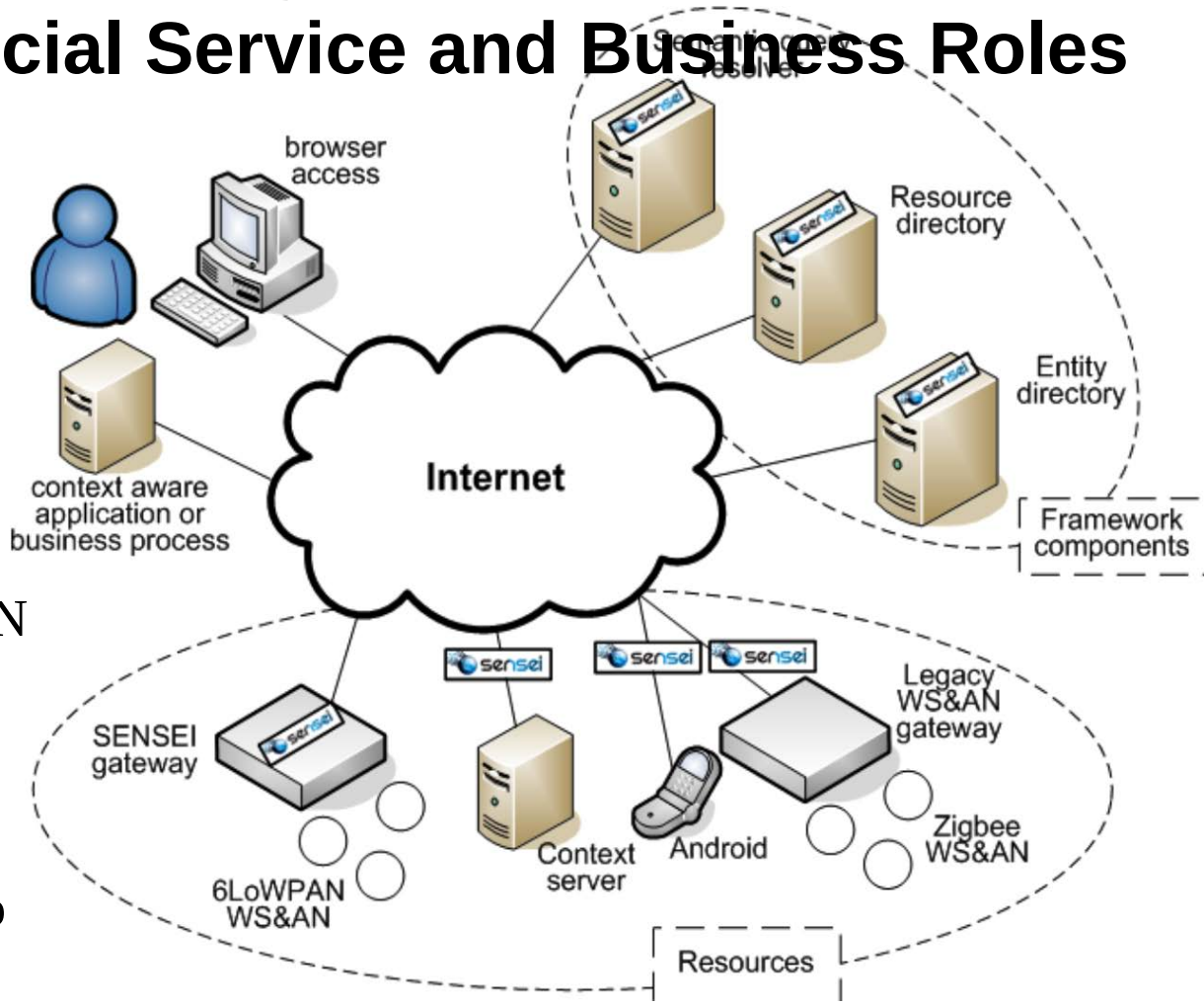
Scale Merit for Business



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

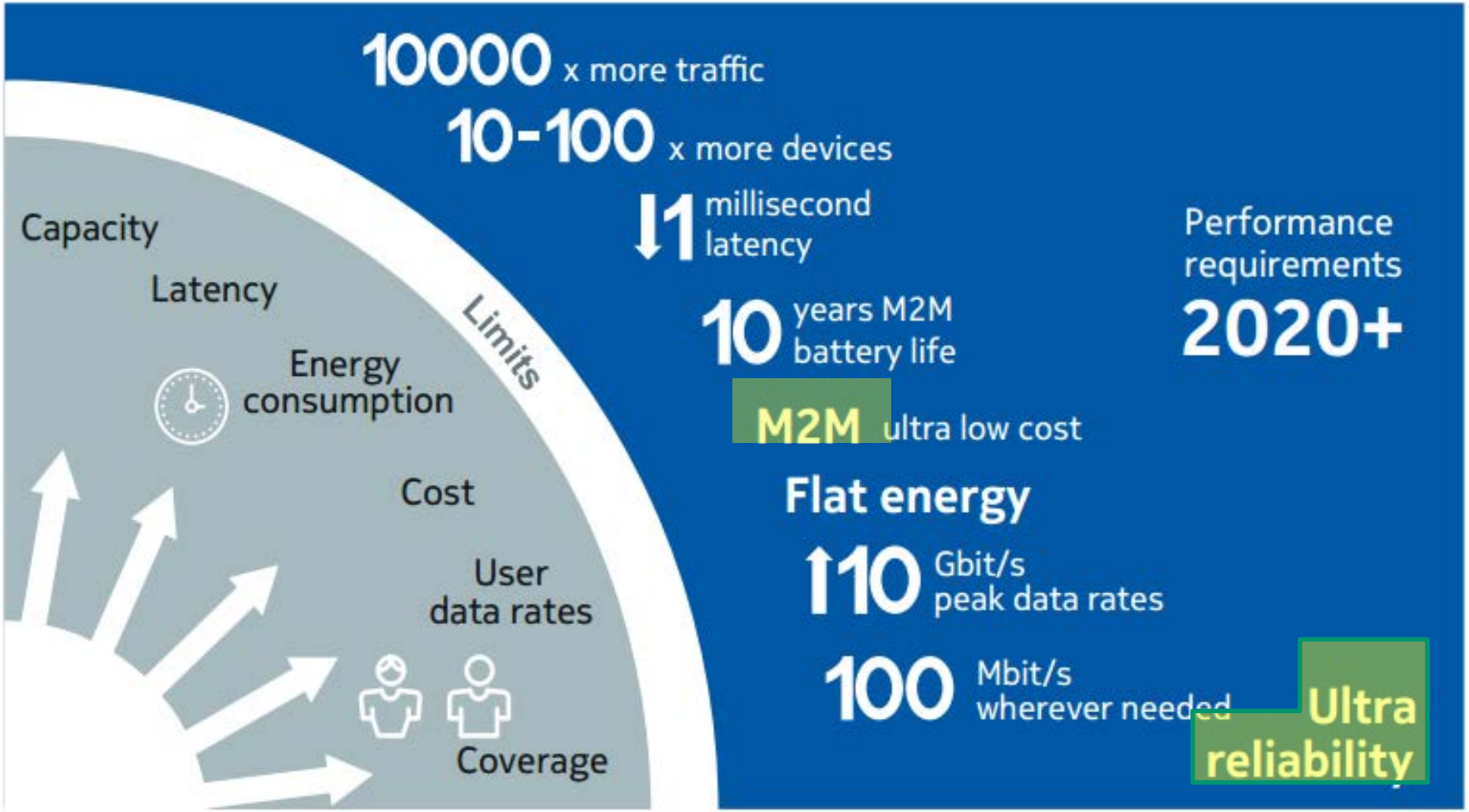
Key Components

- 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



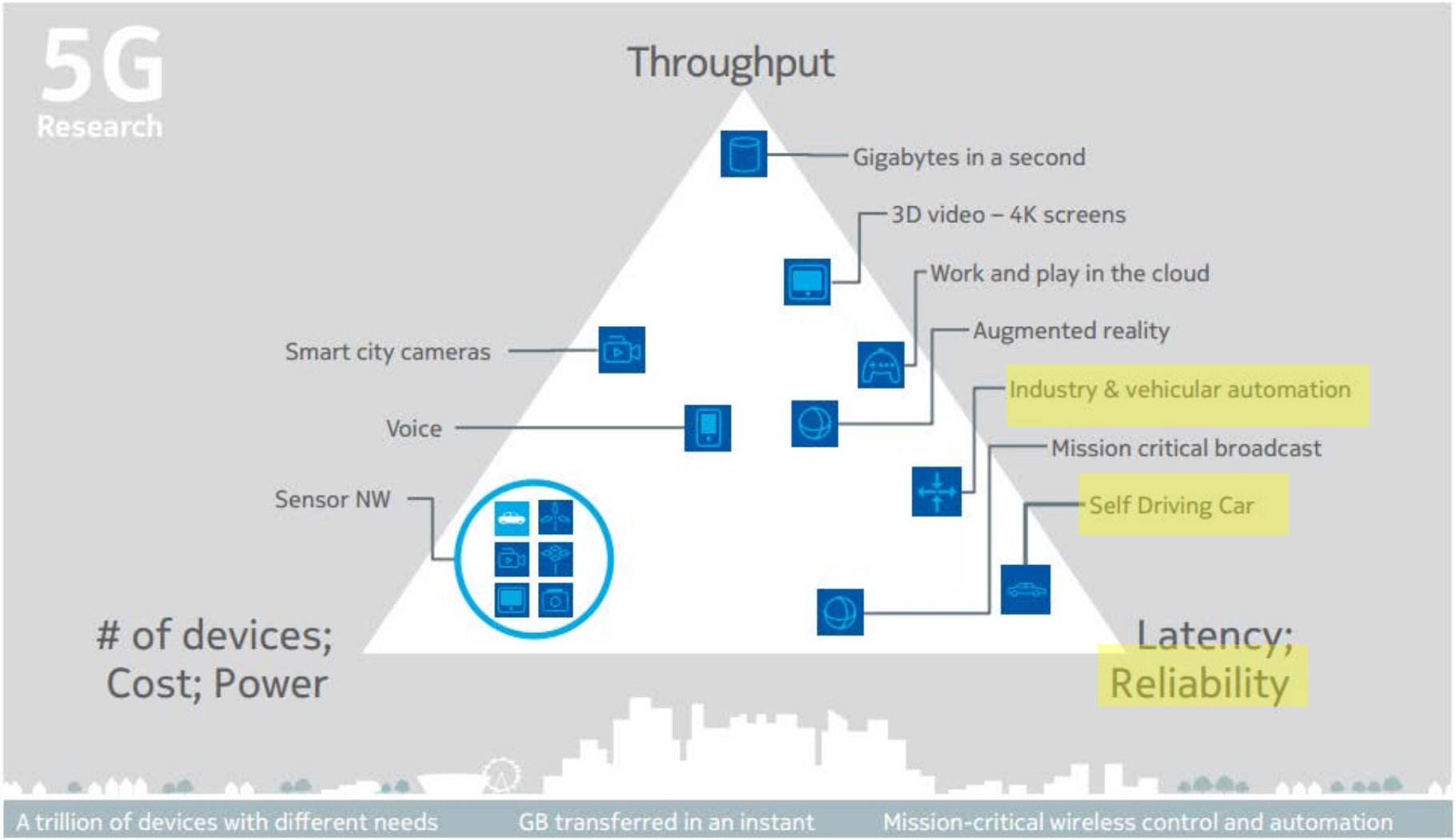
Dependability of IoT should be guaranteed.

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



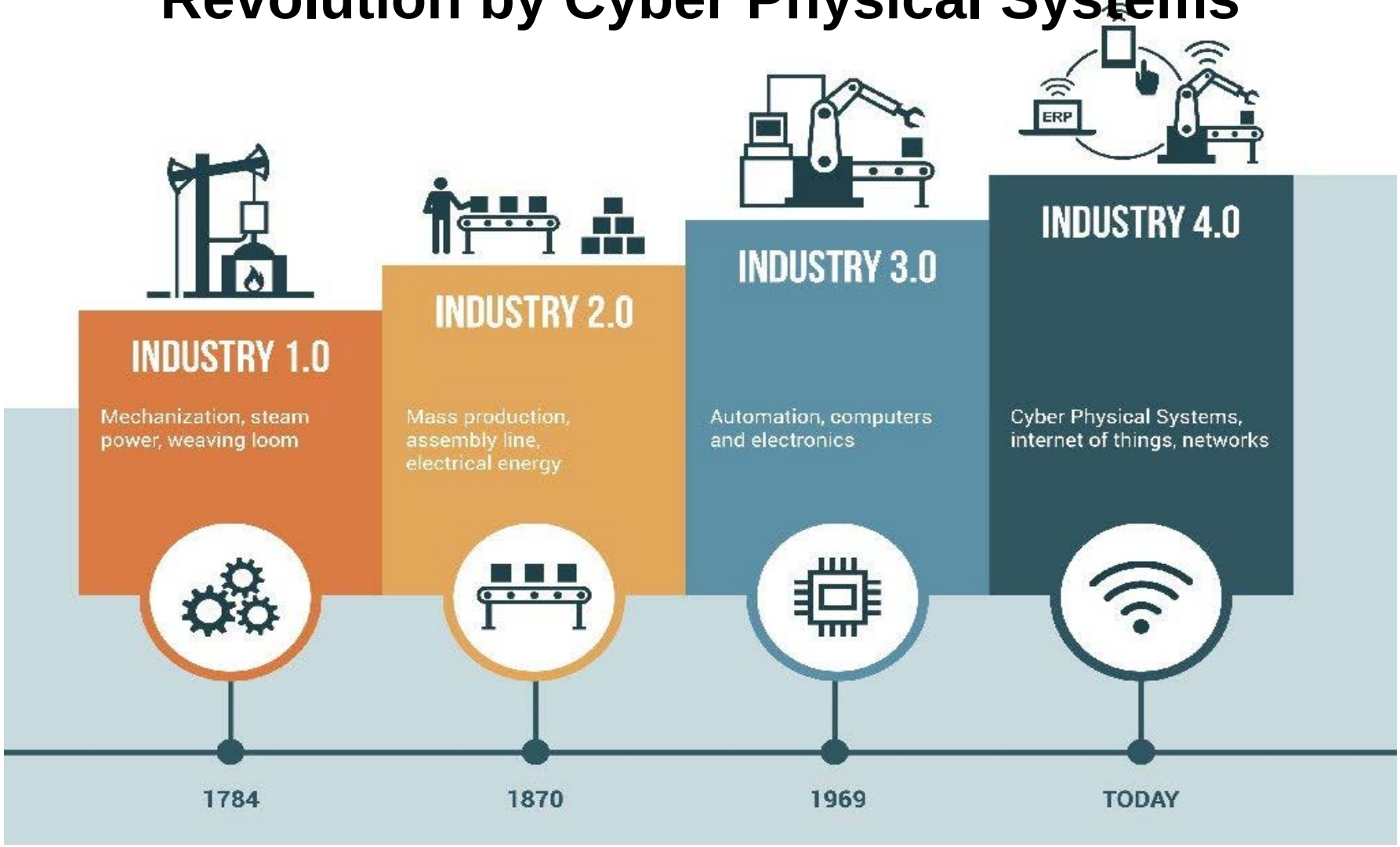
Ref. “5G Use Cases and Requirements,” NOKIA, Co,

Services, Use Cases & Requirements for 5G

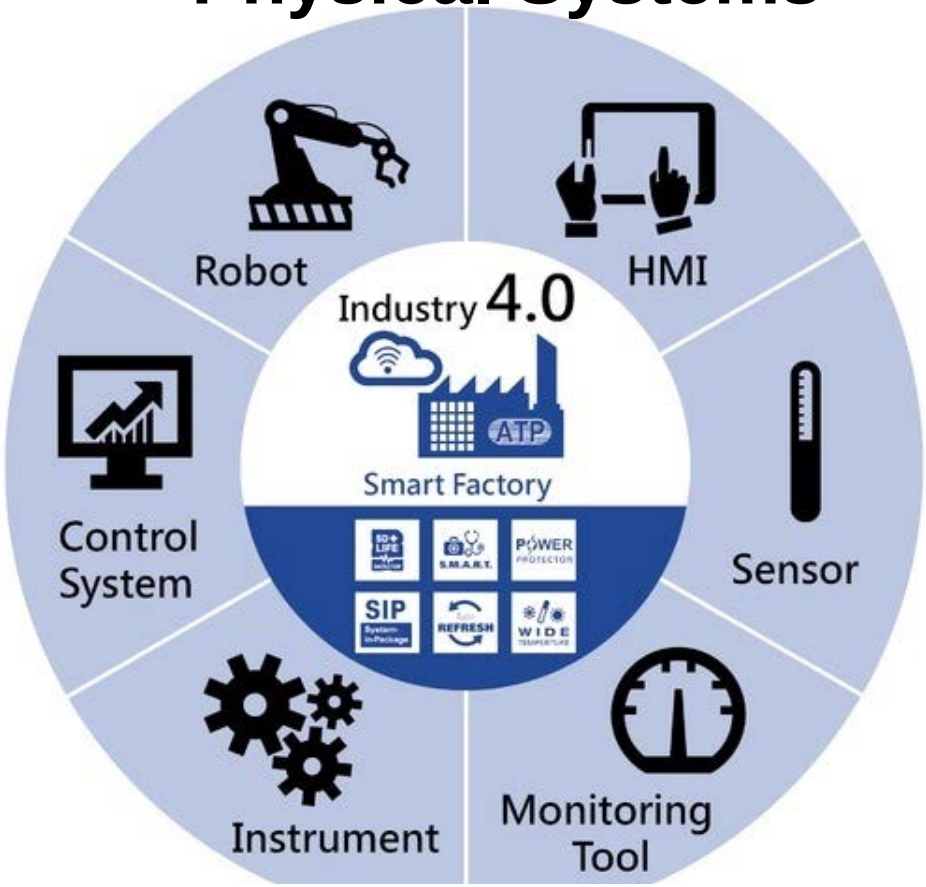


Ref. “5G Use Cases and Requirements,” NOKIA, Co,

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**

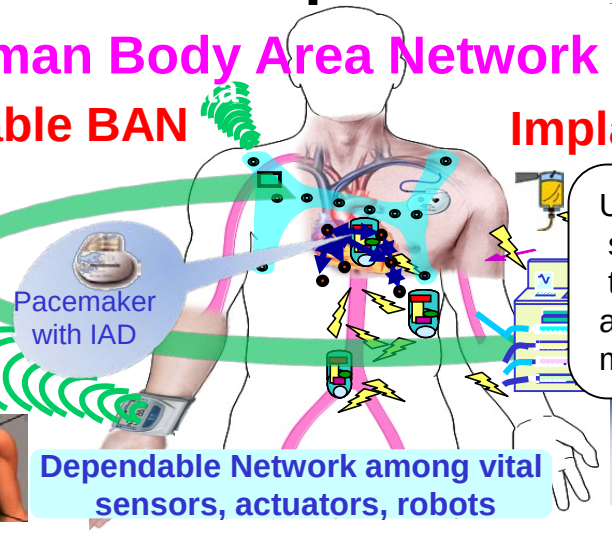
Demands of Dependability for Sensing & Controlling for M2M

Human Body Area Network (BAN)

Wearable BAN

EEG,
ECG,
Blood Pressure
Temperature
MRI images
Etc.

Implant BAN



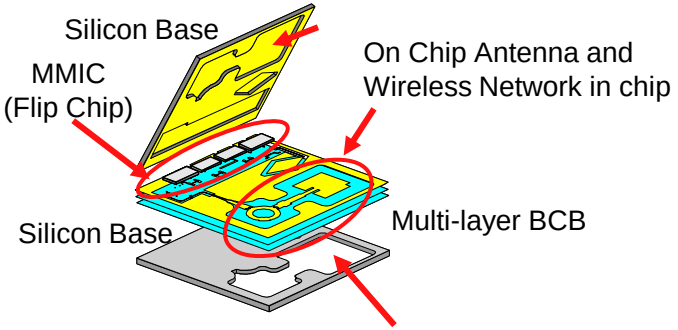
UWB can solve such a problem that radio interferes a human body and medical equipments

Capsule Endoscope

Dependable Network among vital sensors, actuators, robots

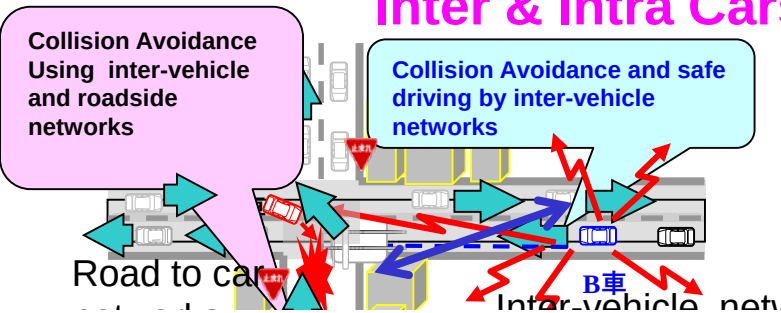
Dependable BAN for Medical Healthcare

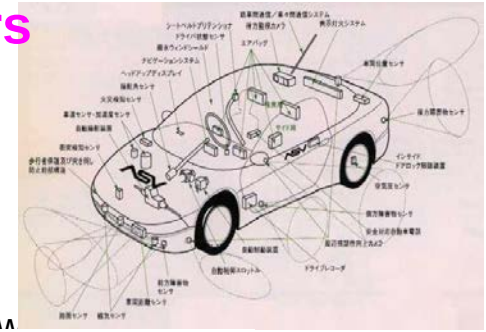
Inter & Intra Devices



Dependable Wireless System Clock in Micro Circuit & Network in Devices

Inter & Intra Cars

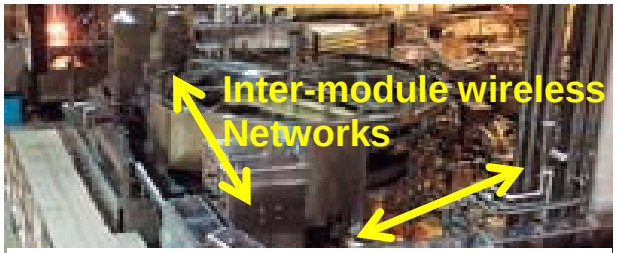




Car Navigation & Collision Avoidance Radar

Car LAN & Wireless Harness

Manufacturing Line of Factory



Factory Automation (FA)

Dependable Wirfor Manufacturing eless Sensing & Controlling (CIM)

Dependable Wireless Networks for Transportation

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

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

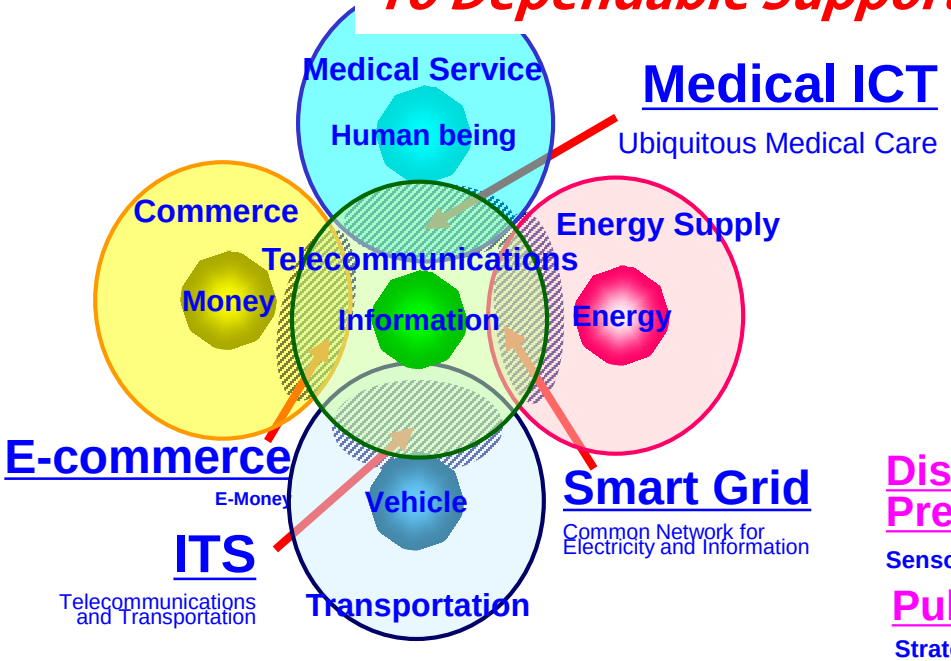
A. Information Traffic（Telecommunications）
B. Vehicular Traffic（Transportation）
C. Energy Traffic(Power & Energy Supply）
D. Money Traffic（Commerce）
E. Patient, Drag Traffic(Medicine)

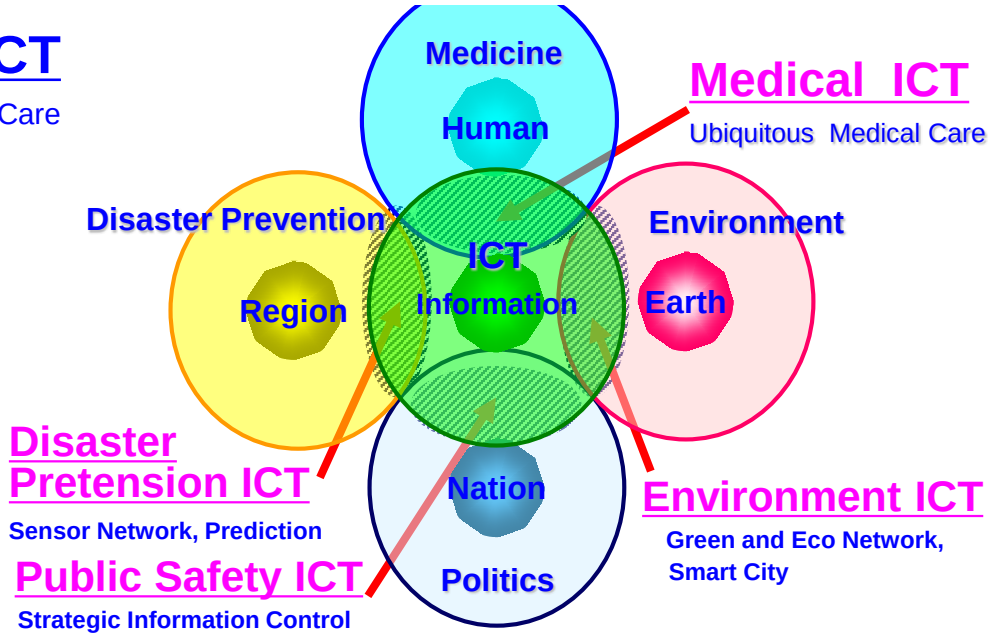
should be integrated to control all flows in future infrastructure

（Example）

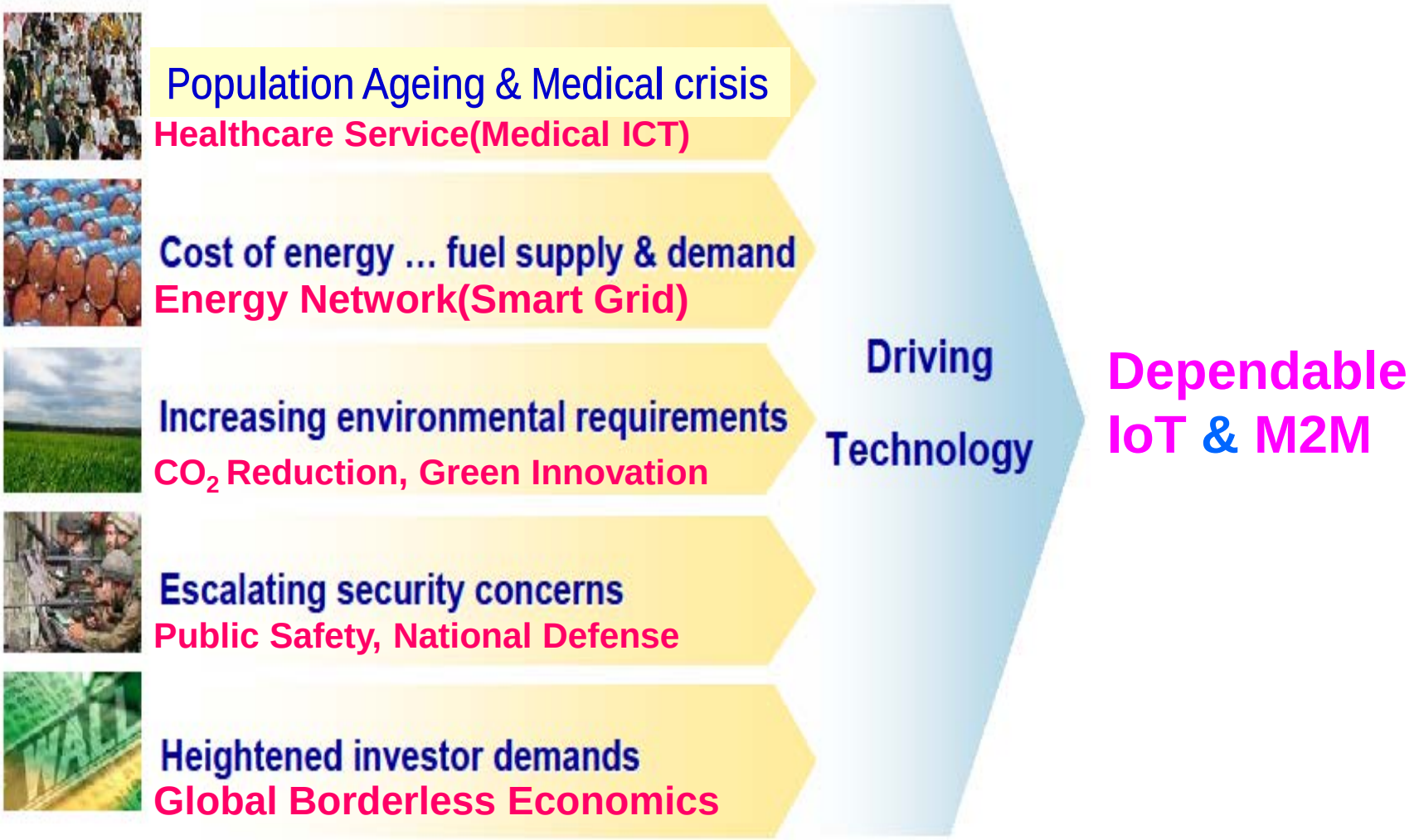
A+B ➔ ITS (Intelligent Transport System)
A+C ➔ Smart Grid (Flexible Energy Network)
A+D ➔ E-Commerce (Borderless Secure Trade)
A+E ➔ Medicine ICT (Ubiquitous Medicine)

To Dependable Support for Social Services and Business

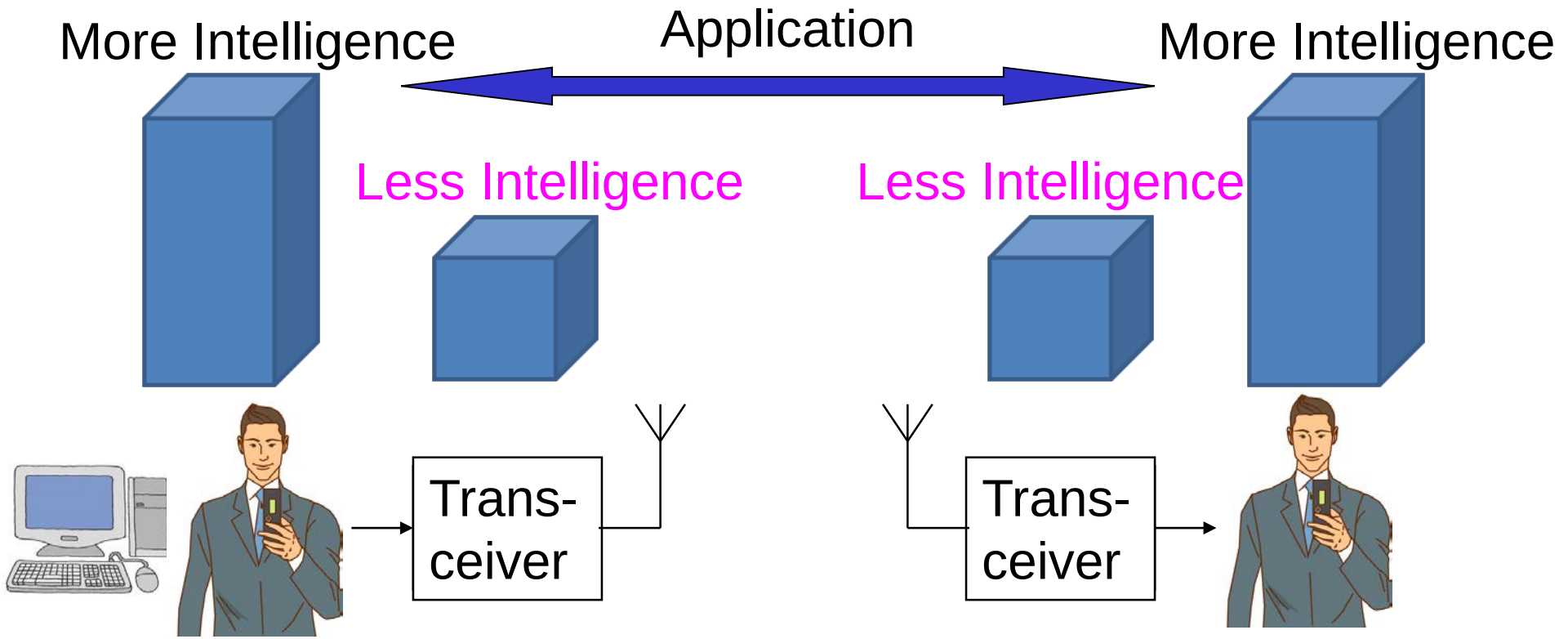




Demands of Dependable IoT and M2M for Sustainable Social Services

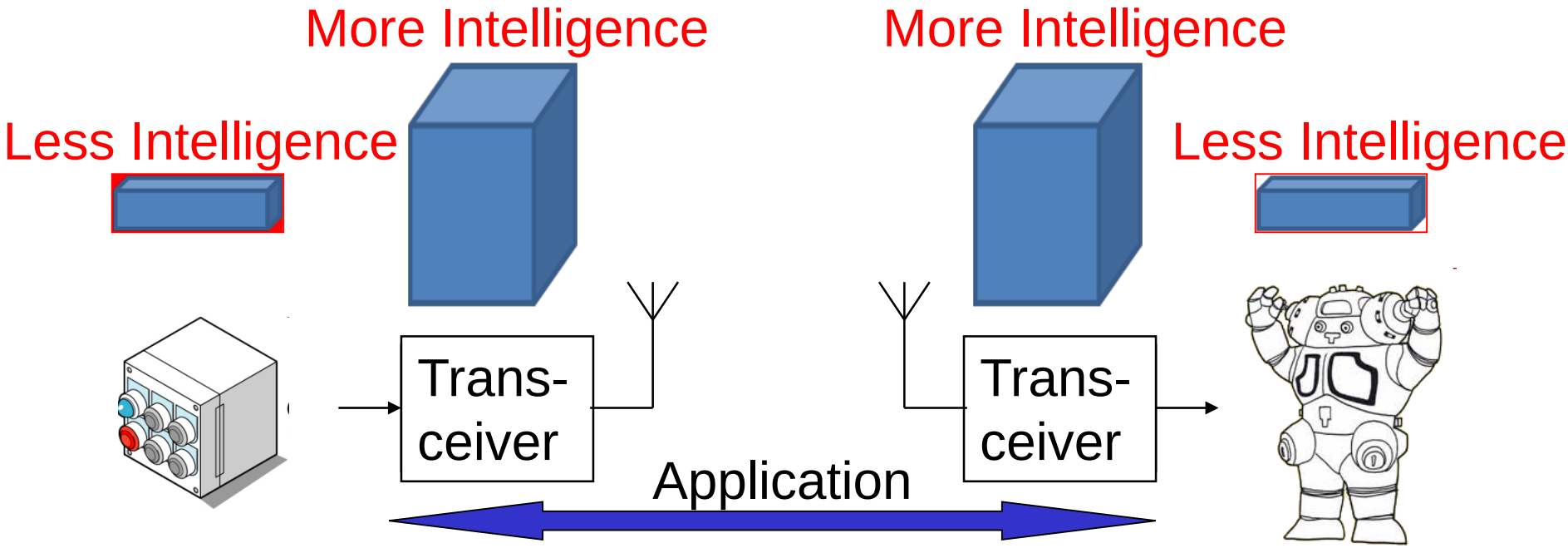


Usual Human-Base Communication through Networks



Transceiver has less need of intelligence to understand the meaning of the application in usual Human-base communications because human intelligence can be used to keep dependability .

Machine Centric M2M Communication Different from Usual Human-base Communication



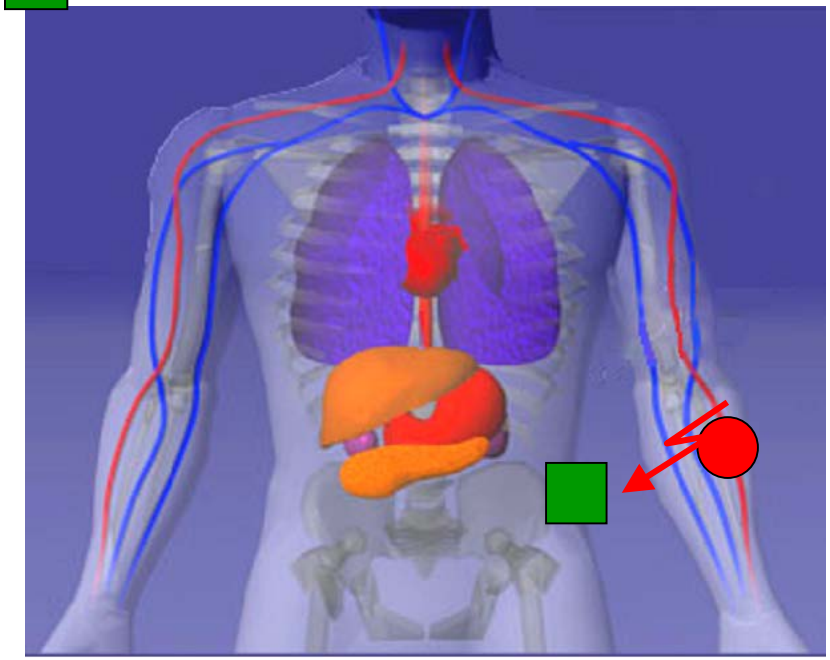
Dependable Machine Centric M2M communications needs more intelligence in transceiver to understand the aim and the meaning of the application between source and destination machines.

Cognitive Network and Machine Learning

Remote Medicine of Types I & II of Diabetes Patients Using Wireless BAN with Glucose Sensor & Insulin Pump

Sensor with wireless transceiver

Insulin injector and controller

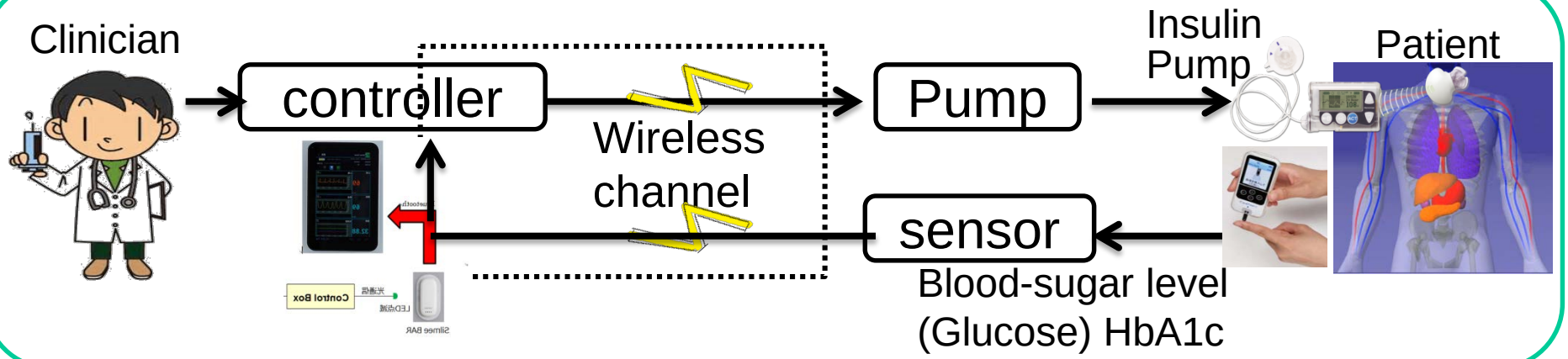


Sensor and data transmission unit

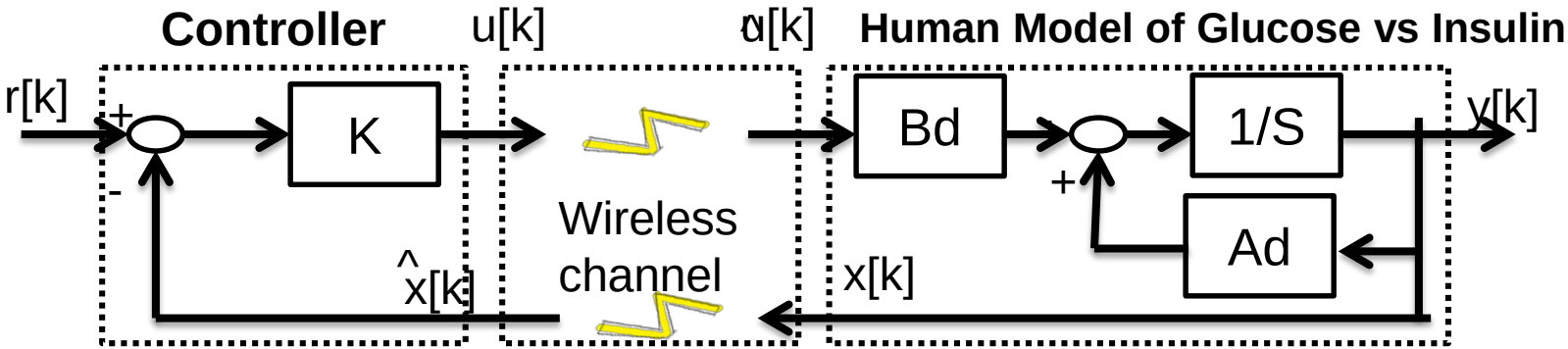
Injector controller adjusts the amount of insulin to be injected according to the blood sugar level provided by sensors.

Automatic management for diabetes

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



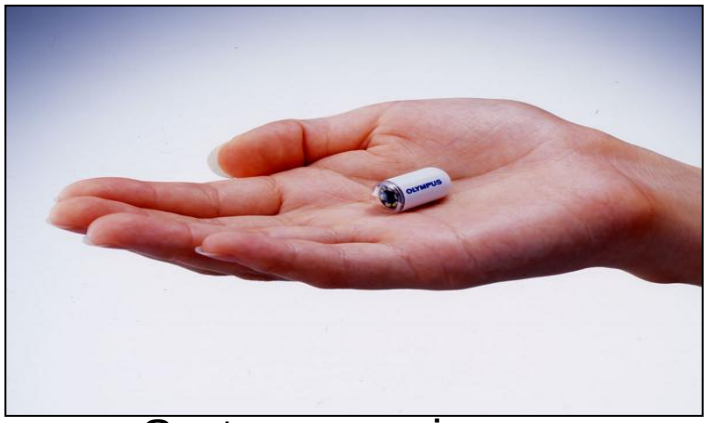
Wireless Feedback Sensing and Controlling Loop for Diabetes Patients



Feedback Delay Loop Model with Motion Equation

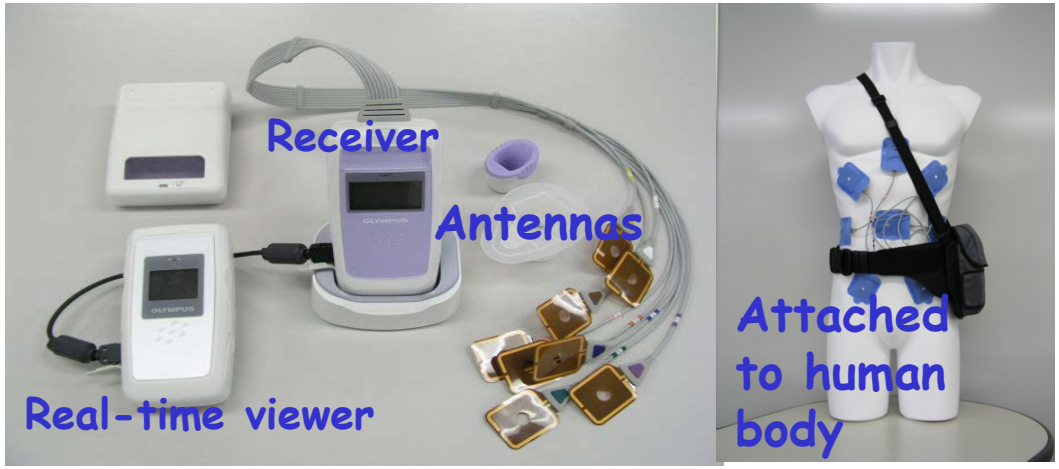
Wireless Capsule Endoscope

This capsule endoscope enables to monitor the small intestine without invasive manner.

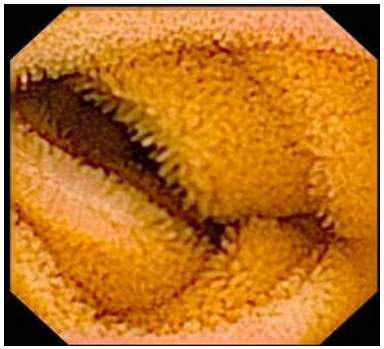


[Characteristics]
Diameter: 11mm
Length: 26mm
Camera: 2 frame/sec, operation time is around 8 hours
By using MEMS technology, elements including lens, sensors, buttery, lights are integrated.

System overview

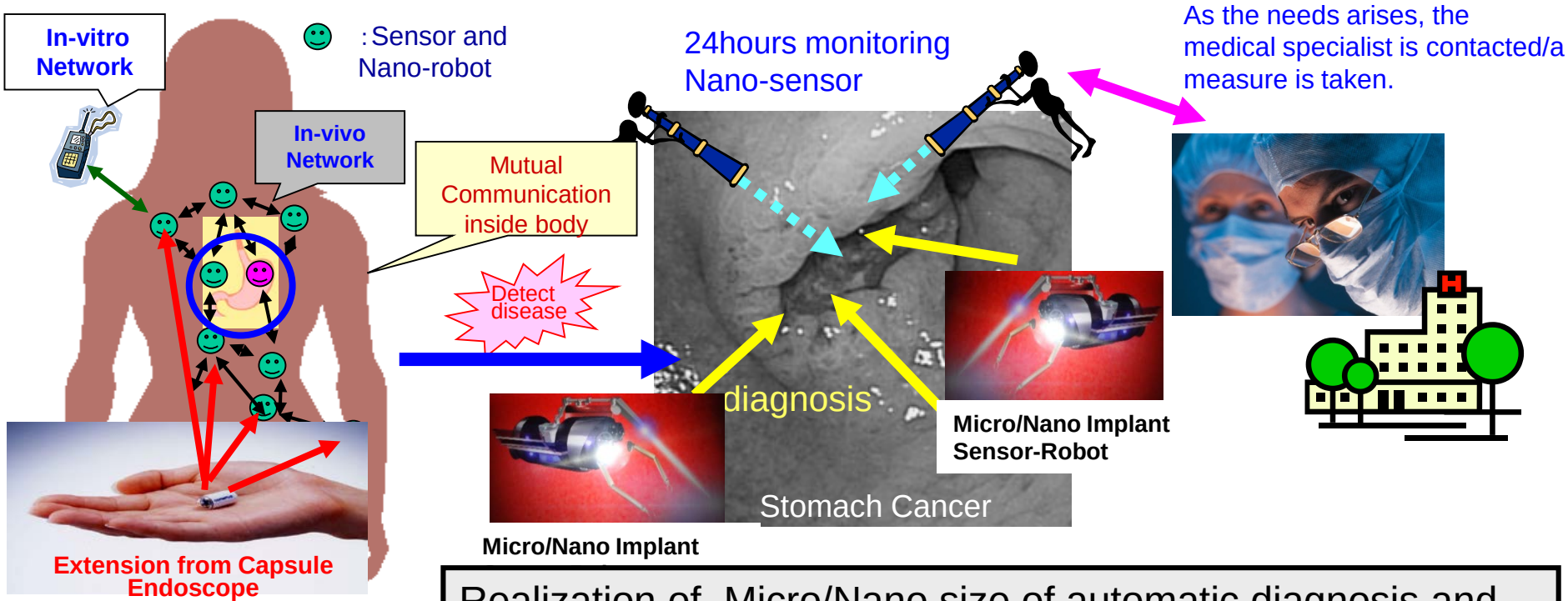


Captured pictures in the small intestine



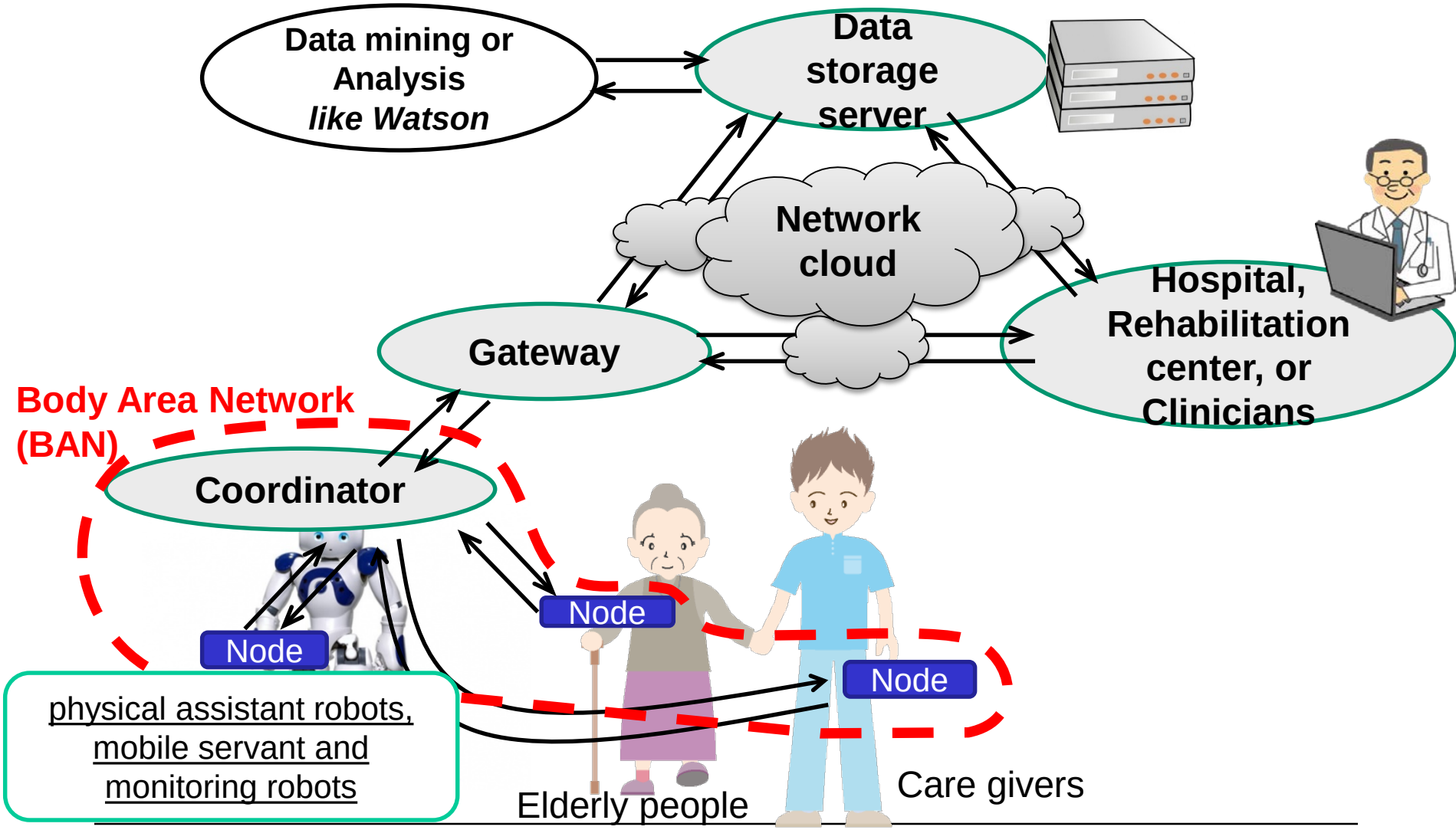
Micro/Nano Implant Sensor-Robot beyond Wireless Capsule Endoscopy

- **Based on wireless UWB communication, geolocation and sensor networks technology, a current wireless capsule endoscopy inside a body for real time monitoring can be extended to micro/Nano implant sensor-robot which can be remotely controlled outside a body with multifunctional sensors and intelligent micro-robot.**

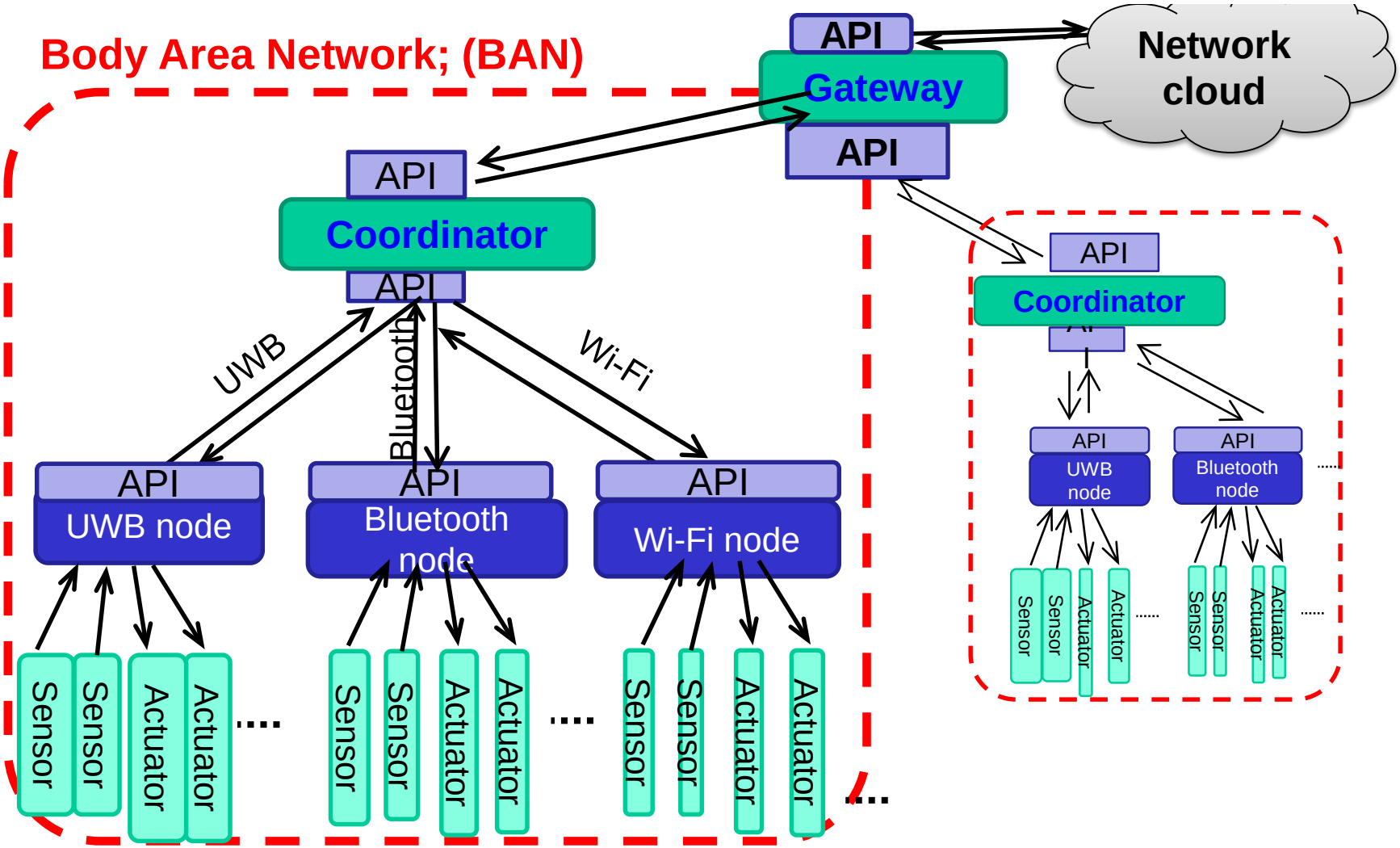


Realization of Micro/Nano size of automatic diagnosis and therapy using wearable and implantable sensor-robot.

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



General Classification and Application Types of Medical Devices for Regulatory Compliance

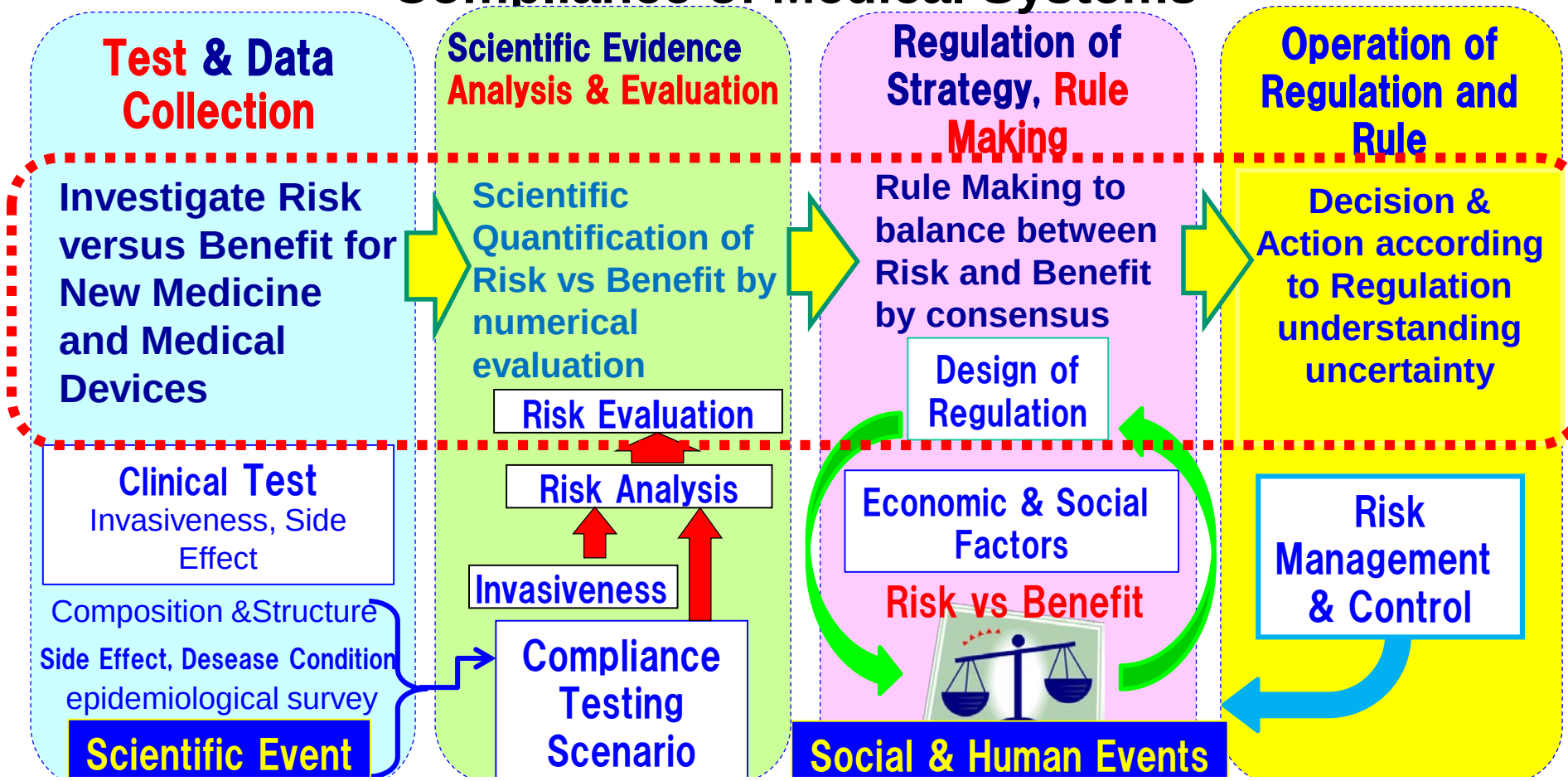
Higher Benefit & Risk

Class in Japan	Global Class	Classification according to risk for body	Compliance Test	Testing Body
Ordinary medical devices	Class I	Extremely low risk for human body even in case of broken	Submission only	Self test
Managed medical devices	Class II	Relatively low risk for human body in case of broken or unpredictable cases	Registration	RCB*1
Highly managed Medical Devices	Class III	High risk for human body in case of broken or unpredictable cases	Regulatory Compliance Test Approval	PMDA*2
	Class IV	Very high risk for human body and dangerous in case of broken or unpredictable		

Longer Time for Compliance Test

To shorten time for compliance testing for medical devices, Regulatory Science is the most useful for making regulation and compliance testing.

Regulatory Science to Guarantee Dependability and Compliance of Medical Systems



・Speed up procedure of regulatory compliance test of medical devices by Regulatory Science.

*・ **Regulatory Science** can protect not only patients but also manufactures for safe medical threatment and business operation.*

Human Impact vs BER according to Radio Emission Power

Pennes's Thermal Propagation Equation

$$c\rho\frac{\partial T}{\partial t} = \nabla\cdot(\kappa\nabla T) + A_0 + Q_v - b(T-T_b) \Rightarrow \kappa\nabla^2 T + \rho SAR - \rho\rho_b c_b F(T-T_b)$$

1st term; Thermal Propagation

2nd Term; Thermal Radiation to keep proper temperature

3rd Term; Thermal Volume by Millimeter wave

4th term; Thermal Change due to Blood Stream

EIRP of Emission Power P_t and Antenna Gain G_t for a distance R

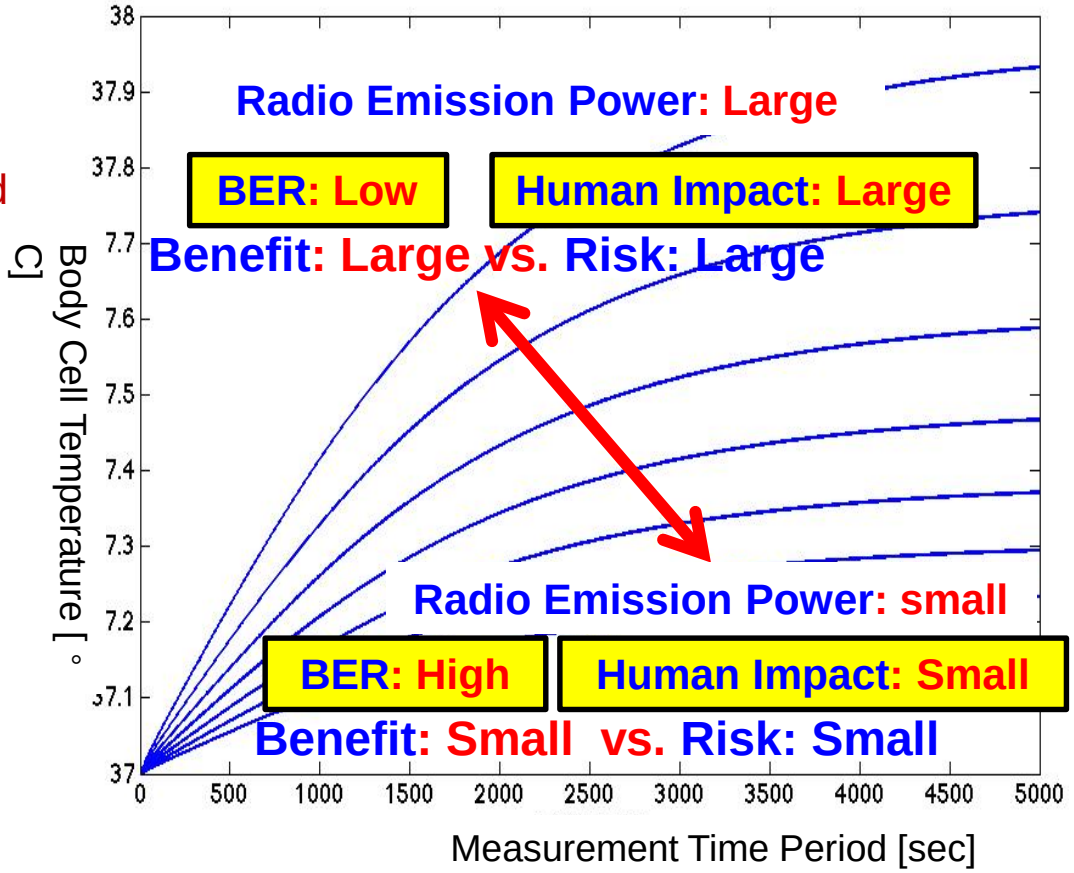
SAR(Specific Absorption Rate)

The larger radio emission, the stronger impact a human body has been damaged while BER creases.

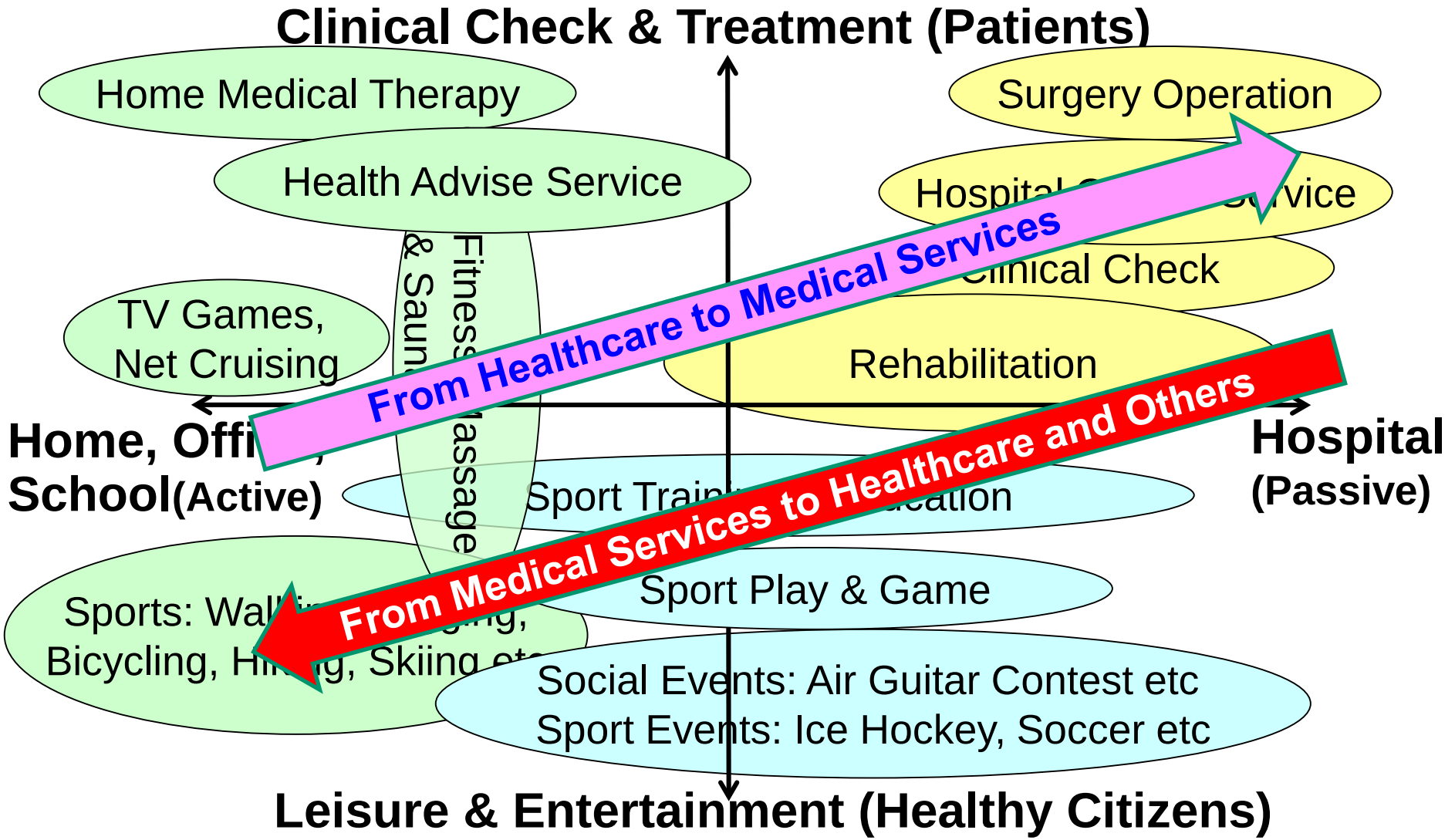
$$E = \frac{\sqrt{49P_tG_t}}{R}$$

$$SAR \propto Pt \propto E^2$$

Then, radio emission power or SAR must be a numerical parameter to evaluate risk versus benefit of radio medical devices.



Scalable Extension from Medical Services to Healthcare and Other Social Services



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.

Joint Japan and New Zealand Project forSearch and Rescue in Disaster by Using Multipole UAVs(Drones)

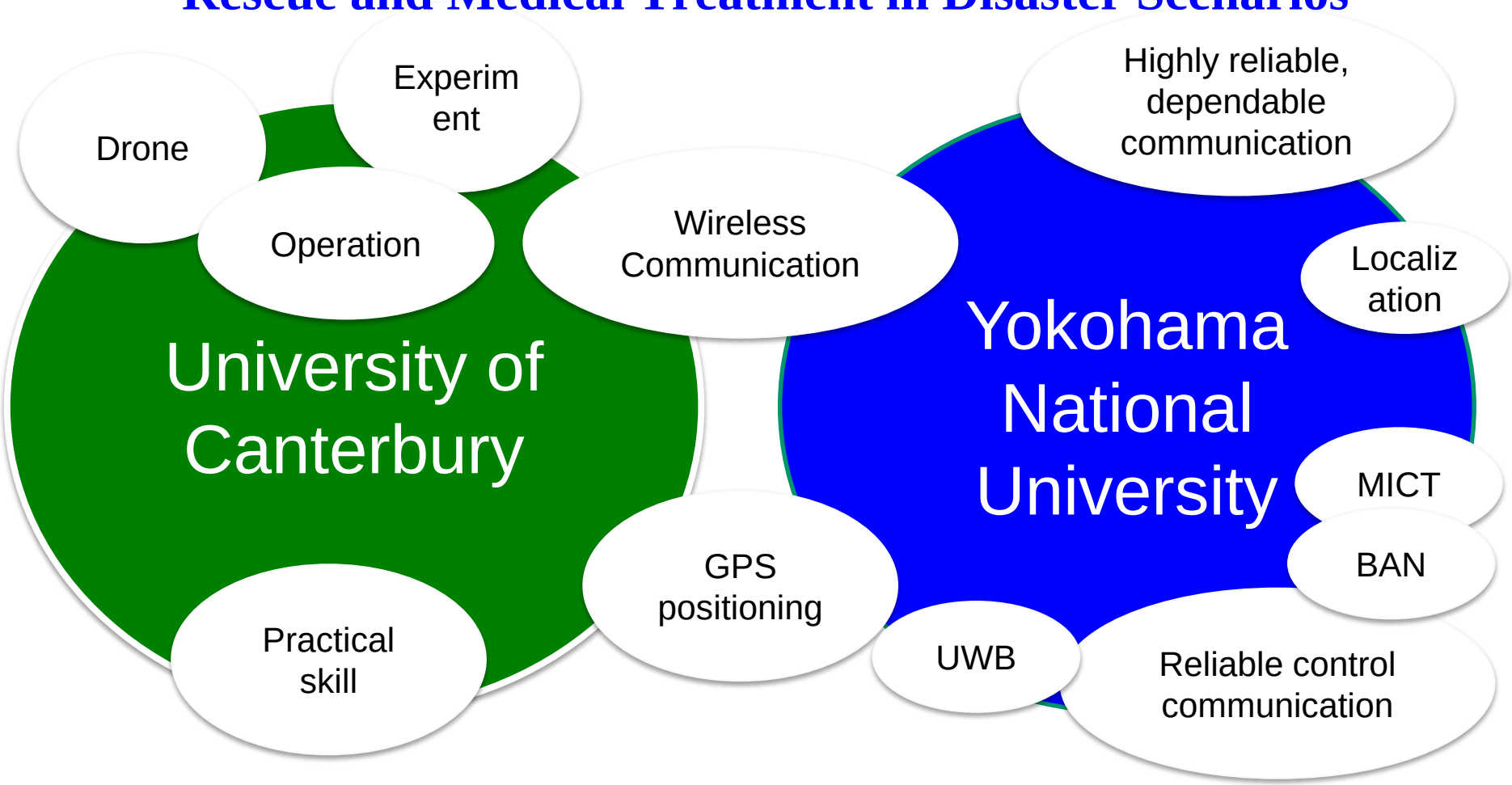
- UAVs or drones which can…
  - be used indoor and outdoor
  - be operated by anyone
  - hover in mid air stably
  - be easy remote controllable

is suitable for search and rescue victims.

Subject: Dependable Sensing and Controlling Multiple Drones

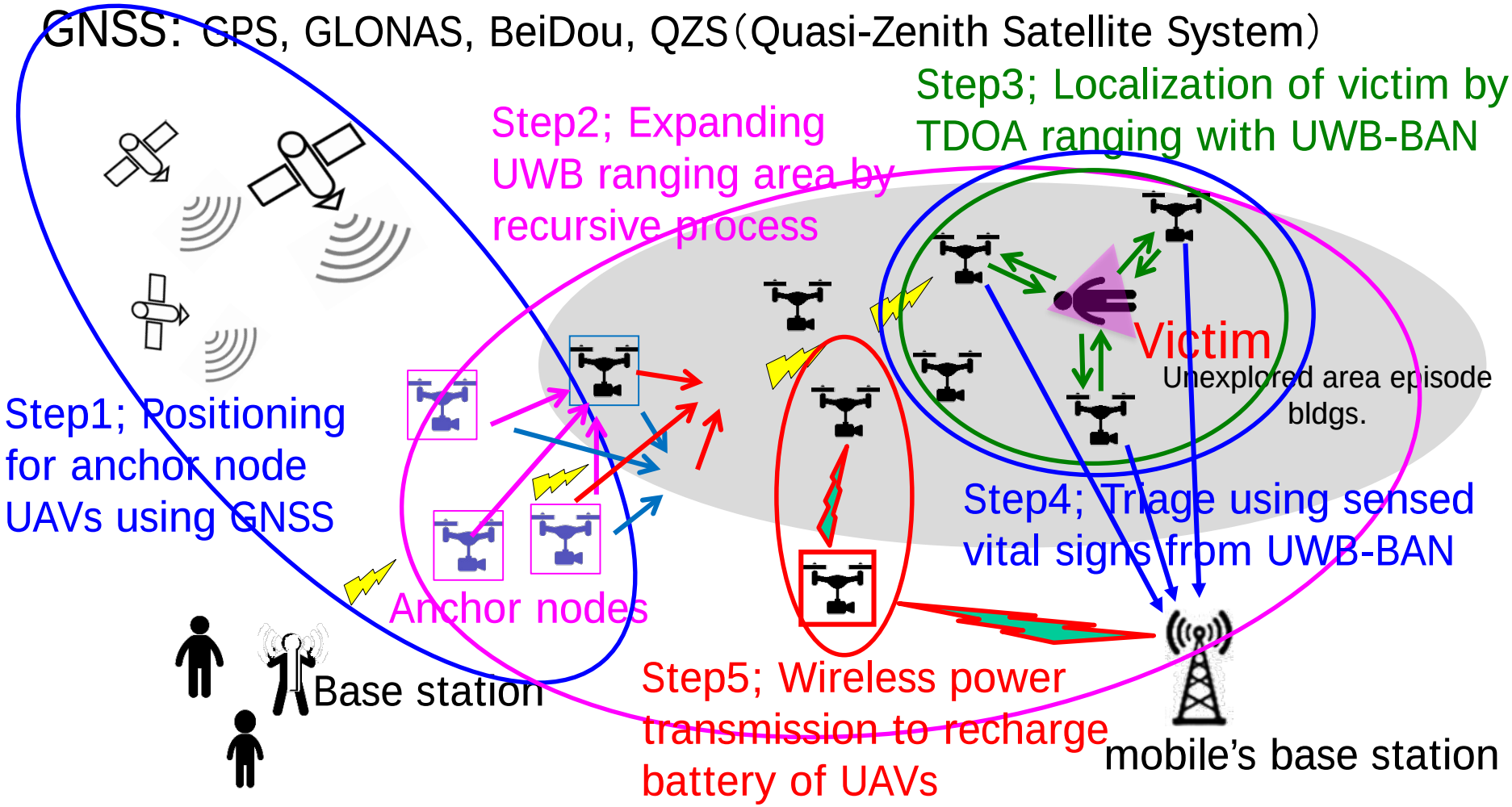
2016-2017 NZ(UC)-Japan(YNU) Joint Project ;

Dependable Wireless Body Area Networks to Support Search and Rescue and Medical Treatment in Disaster Scenarios



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



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

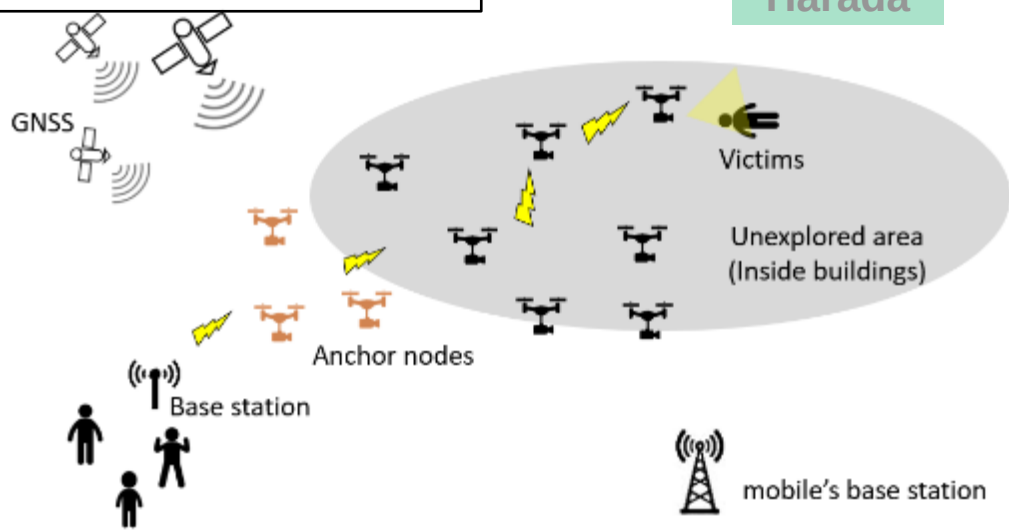
UWB communication between UAV and BAN devices

Seimiya

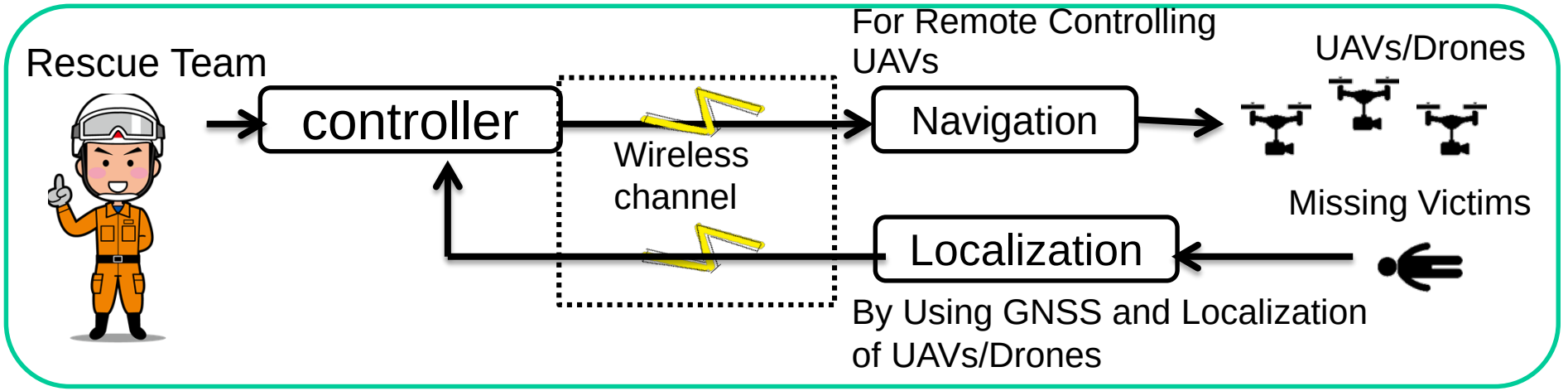
Communication between UAVs and base station for triage

Wireless power feeding

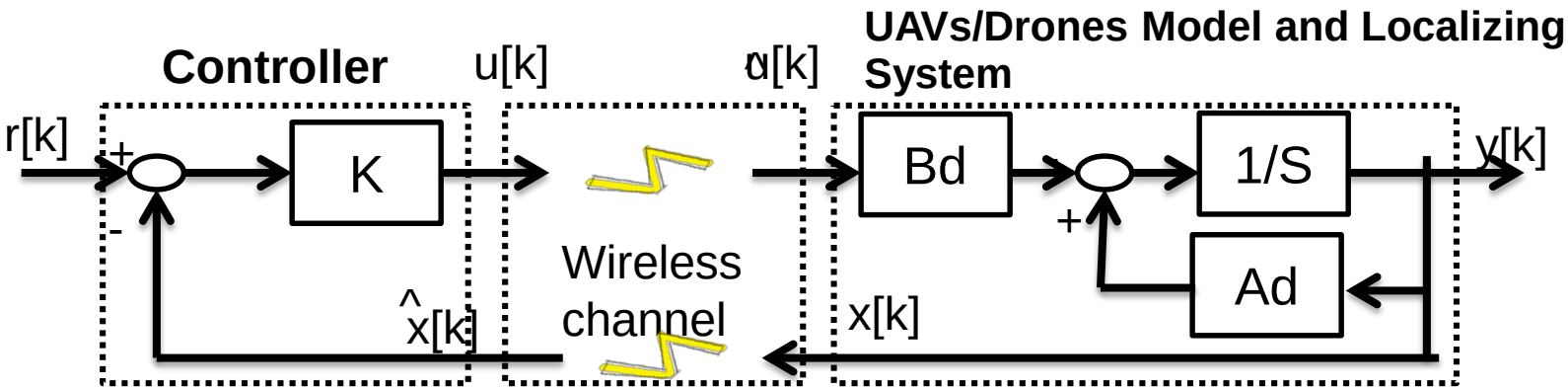
Harada



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



Wireless Feedback Sensing and Controlling Loop for Rescue of Victims



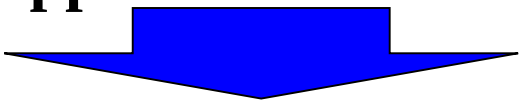
Feedback Delay Loop Model with Motion Equation

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

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**.

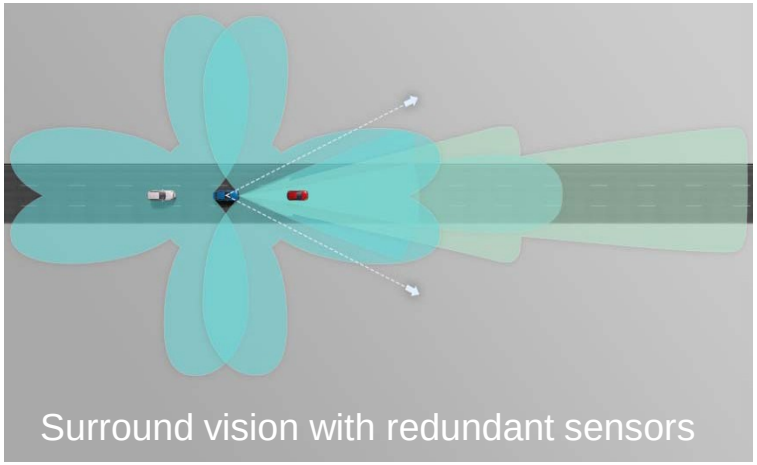


- **Dependable BAN of Things/M2M** has been applied for wireless **sensing and controlling for car and automotive industry** as well as **Disasters.**
- **Dependable BAN of Things/M2M** can be applied for **dependable wireless sensing and controlling of inter & intra cars and car factory automation.**

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.



Surround vision with redundant sensors

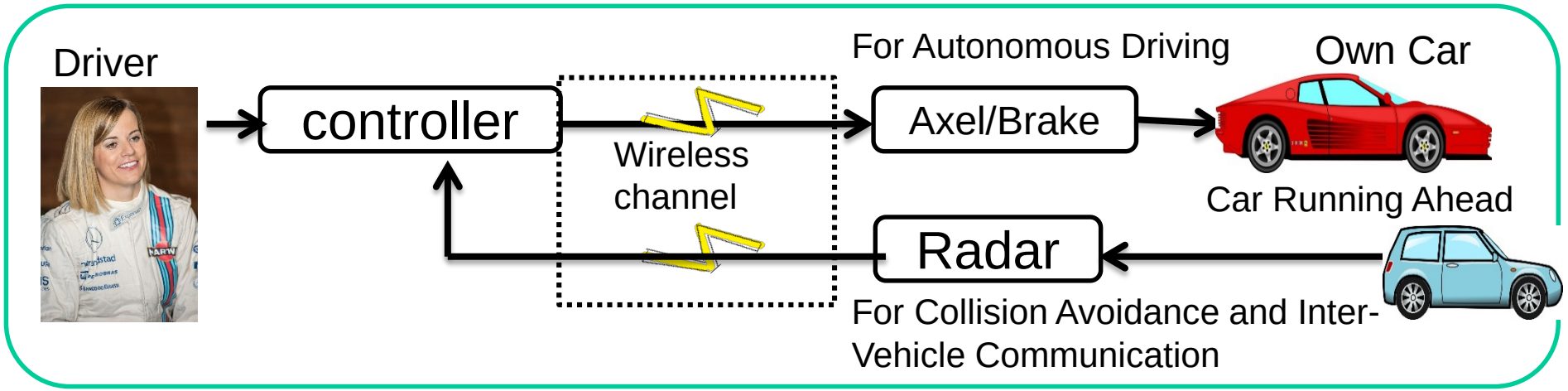
Does this look familiar to data centers?

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.

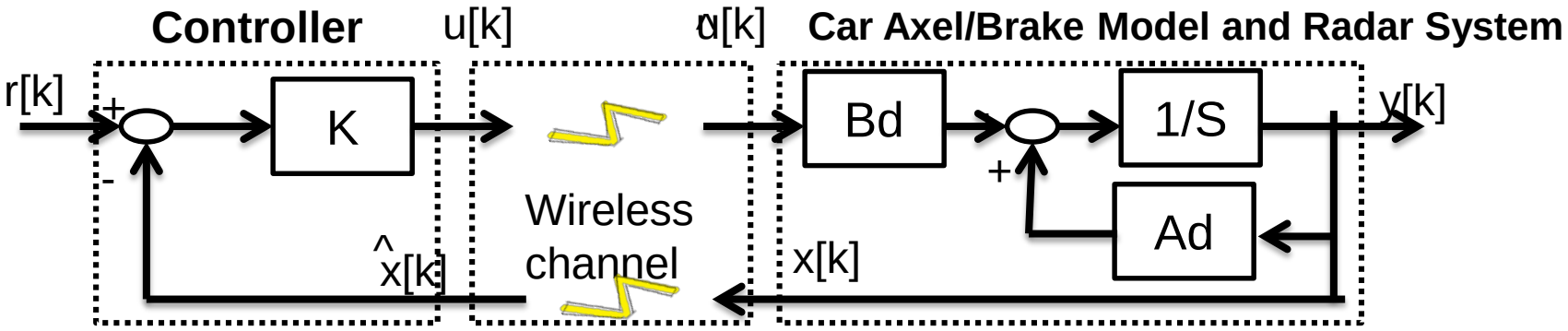
Demands for Dependable Wireless Network in Factory Automation(FA)

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.

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



Wireless Feedback Sensing and Controlling Loop for Autonomous Driving



Feedback Delay Loop Model with Motion Equation

Dependable Resilient Social Infrastructure Platform by Integration among AI Data Mining Server, Cloud Network, and BAN Installed in Bridge, Car and People for Daily Maintenance and Emergency Rescue and Support

AI Big Data Mining Server with Deep Learning ex. : *Watson*

Data Base Registry Centre

In daily life, for safety condition of social infrastructure such as bridge, bldgs. In disaster, for rescue of victims big data can be mined with AI.

Private Network

4G, 5G, WiFi Network Cloud

Gateway

Gateway

City Government, Maintenance Company,

Private Network

Body Area Network; (BAN)

Coordinator

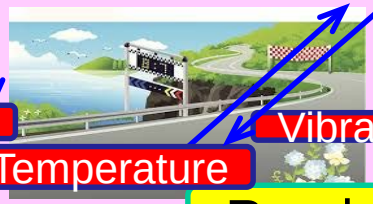
Coordinator

Vibration

AE

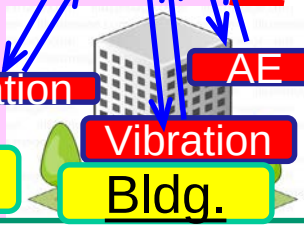
Temperature

Bridge



Vibration

Road



AE

Vibration

Bldg.

Location

Speed

Car

Location

Vital Sign

Victim

Emergency Rescue of Victims in Disaster

In daily life, BAN can monitor resilient level of social infrastructure while in disaster environment, BAN can be instantaneous ad-hoc networks for emergency rescue.

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, Cars and Others

- Research & Education of Medical BAN by MEXT GCOE Program
- Amendment of International Standard of BAN (IEEE802.15.6)
- Prototyping and Business of BAN by CWC-Nippon
- 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

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