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

Submission Title: [Overview of IG-DEP, SG6a, TG6a, and TG15.6ma for Revision of IEEE802.15.6-2012 Wireless BAN with Enhanced Dependability]

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Abstract: [This document summarizes IG-DEP, SG15.6a , TG6a, and TG6ma activity for revision amendment of IEEE802.15.6 - 2012 Medical Body Area Network(BAN) corresponding to increasing for enhanced dependability in wireless sensing and controlling human and car bodies for medical healthcare and automotive uses. After quick overview of IEEE802.15.6 -2012, necessity of the amendment is described in such critical use cases that various types of interference such as intra BAN interference in multiple overlaid BANs, interference among BAN and other PANs in some overlaid frequency band etc. Extension of BAN from human body for medical healthcare to car body for automotive uses and their combination are discussed as a common standard.]

Purpose: [information]

Overview of IG-DEP, SG6a, TG6a and TG15.6ma for Revision of IEEE 802.15.6-2012 Wireless BAN with Enhanced Dependability

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Agenda

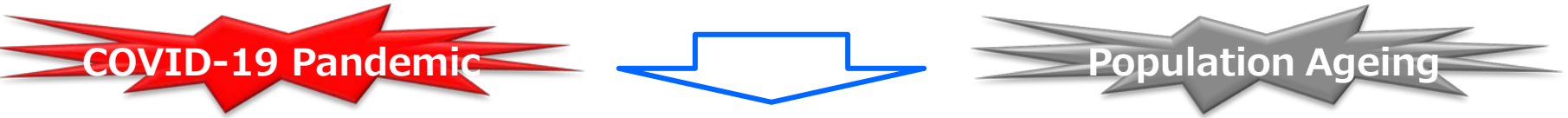
1. Demand for WBAN for Emergent Medical Healthcare Use and Huge Market of Automotive Use
2. Short Review of WBAN Standard IEEE802.15.6-2012
3. Necessity and Uniqueness for Amendment of BAN with Enhanced Dependability
4. Available Technologies in PHY and MAC Layers for the Focused Amendment of std 15.6 BAN with Enhanced Dependability
5. Technical Requirement for the Amendment of Std. 15.6 to Enhance Dependability

1. Demand for WBAN for Emergent Medical Healthcare Use and Huge Market of Automotive Use

1.1 Demand of BAN for Medical Uses

A. Emergent Problems over the world:

- **1-4% of total population in a world may be suffered by COVID-19, that is a global pandemic.**
- **Clinic are overloaded and many business are damaged seriously.**



B. Challenging but Feasible Solutions:

- **Provide Remote Vital Sensing and Therapy Using ICT and AI**
  - **➔ Prevent Epidemic and Maintain Safe and Efficient Diagnosis**
- **Promote Global Business of Medical ICT and Data Science**

C. Approach:

(1) R&D of Enable Technologies for Pandemic and Daily QoL

(2) Promote International Standard of Wireless Body Network (BAN) and Integrated Platform of BAN/5G/AI for Global Marketing

(3)Regulatory Compliance of Medical Devices & Services to Ensure Safety, Reliability, Security, i.e. Dependability by Regulatory Science

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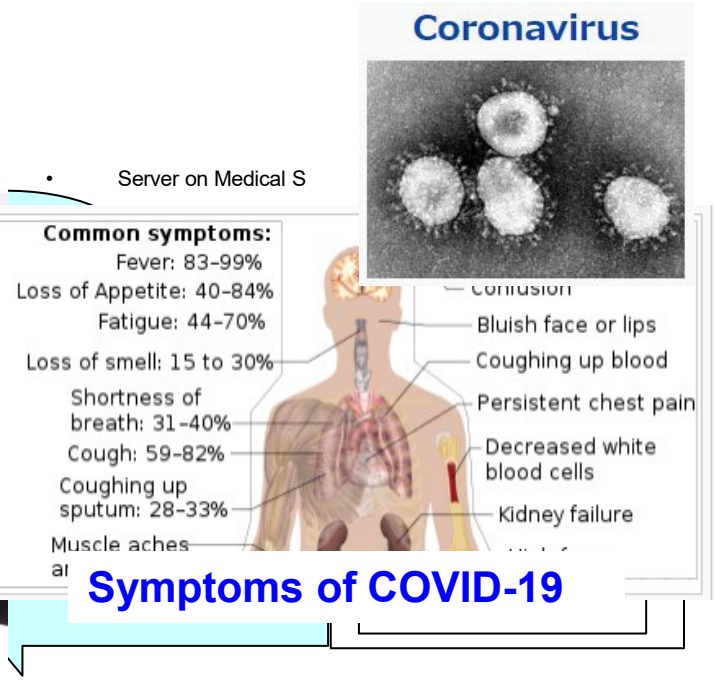
1.2 Medical Inspection and Treatment by BAN

- Medical Healthcare Using BAN can perform remote real-time medical diagnosis and therapy
- To prevent pandemic against **COVID-19** and medical care incident etc. in daily life.
- > Remote sensing vital sign and monitoring symptoms
- > Evidence based medicine for clinical and nursing actions
- •To support safe and efficient medical care for clinical staffs and patients etc.
- > Online diagnosis, PCR and other inspection
- > Protect clinical staffs and care givers with network

- **WBAN can apply for**

preventing pandemic and supporting daily care by remote sensing and therapy in digital healthcare.



1.3 Wireless BAN: Body Area Network

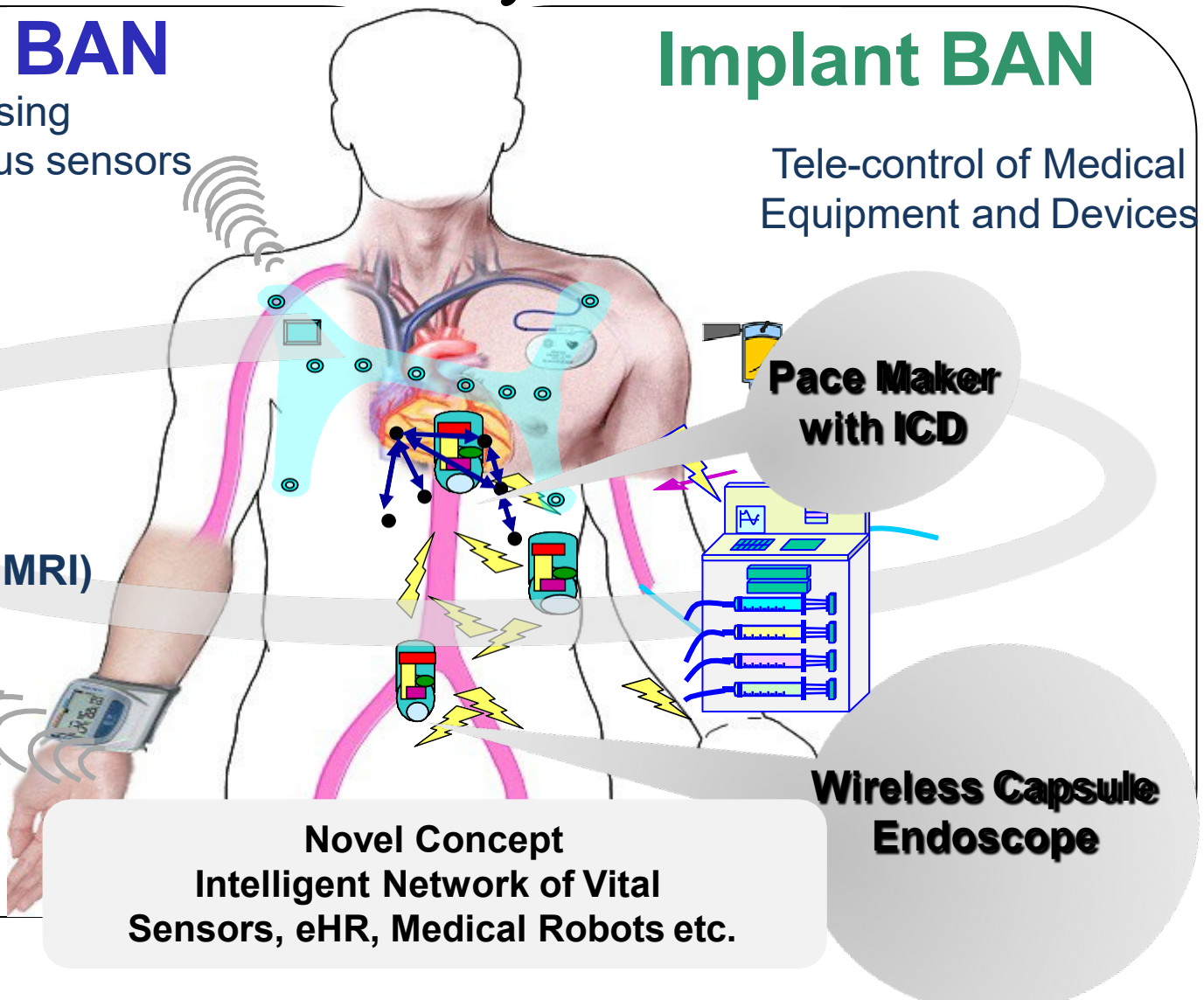
Wearable BAN

Tele-metering or sensing
vital signs with various sensors

ECG
EEG
SPO2
Blood Pressure
Heartbeat
Body temperature
Glocuse level
Medical images(X-ray, MRI) and video

Implant BAN

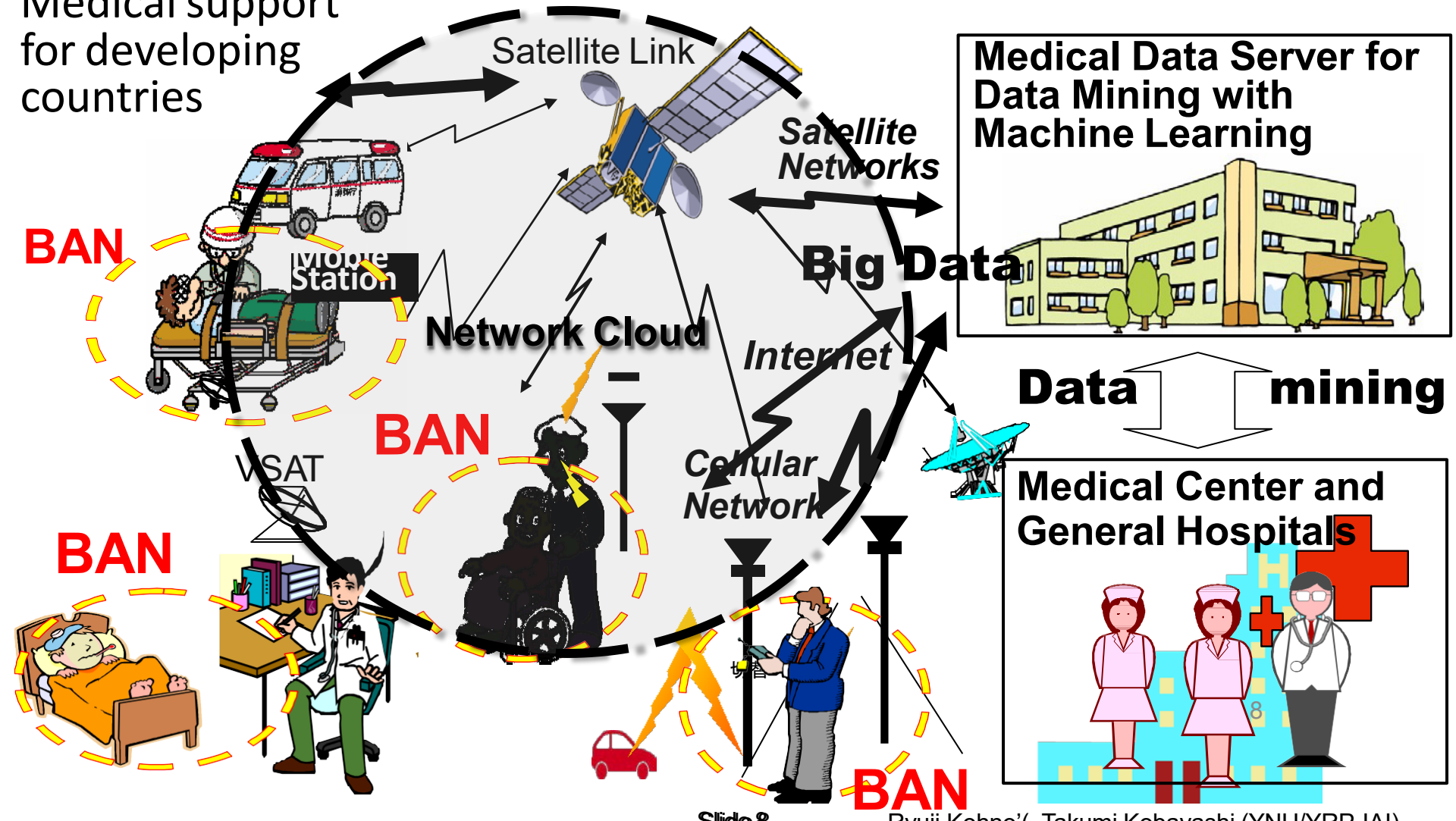
Tele-control of Medical Equipment and Devices



Novel Concept
Intelligent Network of Vital Sensors, eHR, Medical Robots etc.

1.4 BAN- Use Cases for Remote Medical Services

Medical support for developing countries



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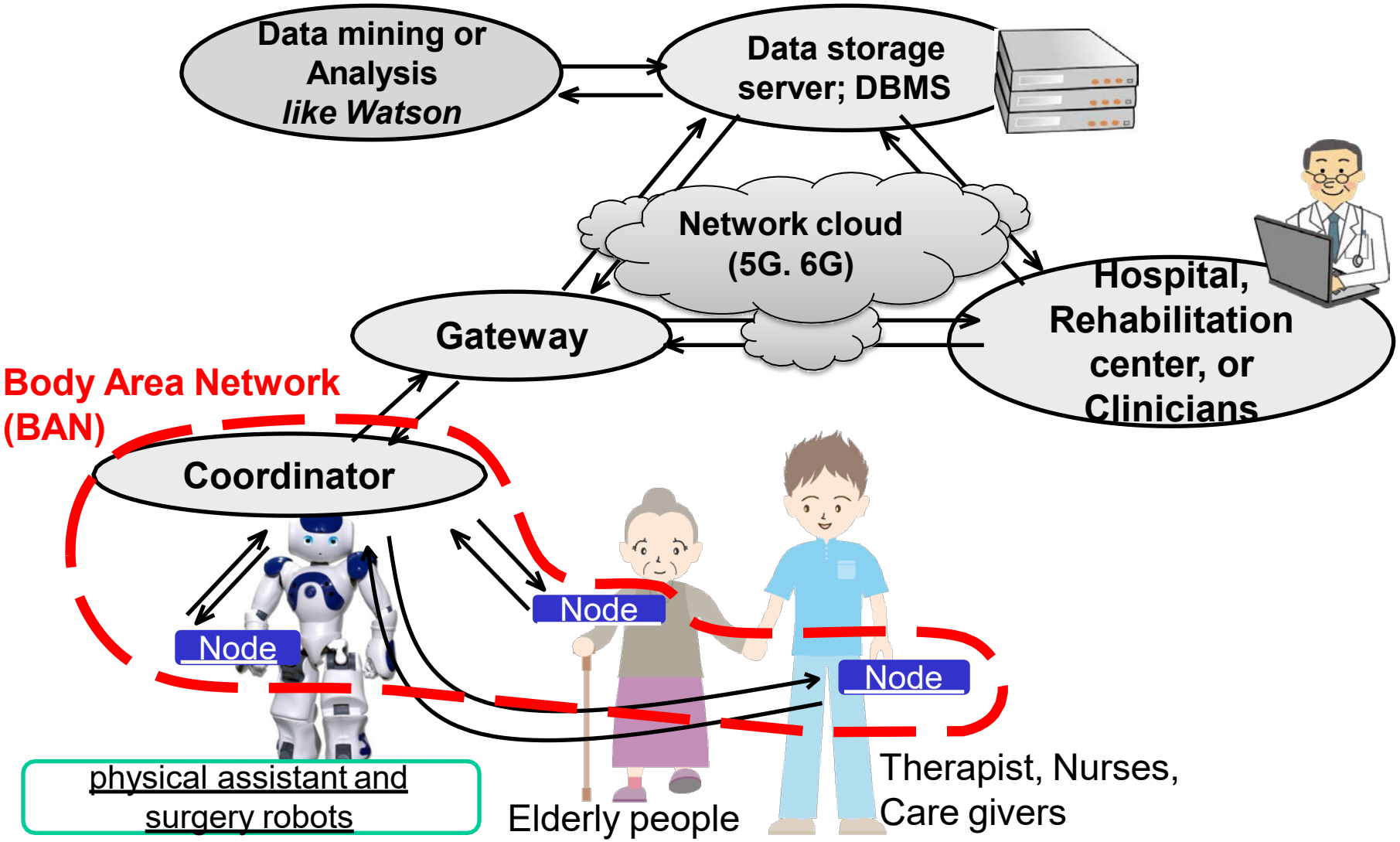
1.5 BAN-base Universal Platform with Network Cloud, Data Mining Server for Medical Healthcare



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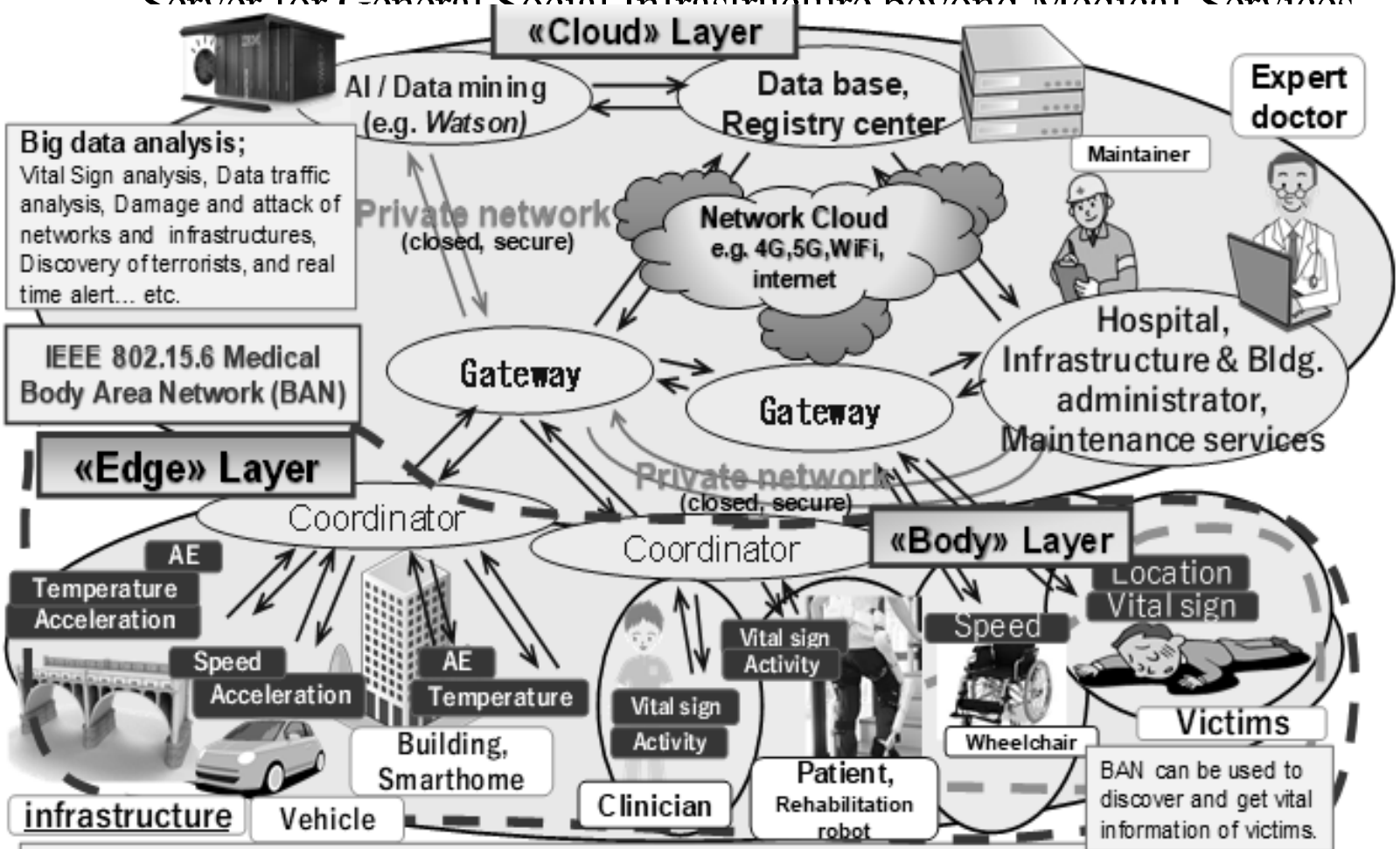
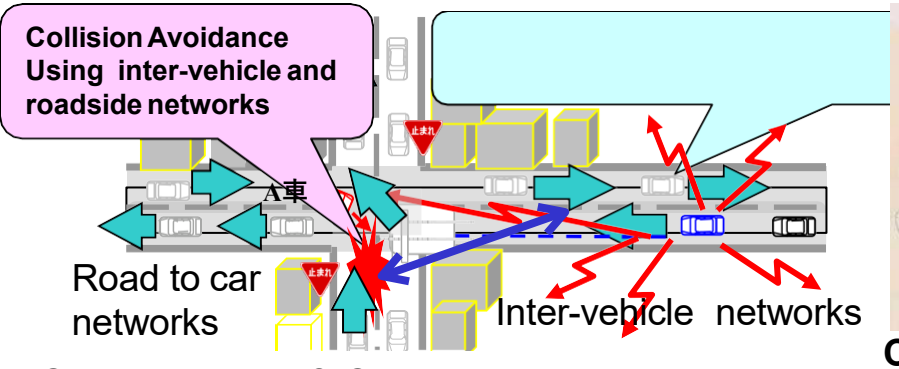
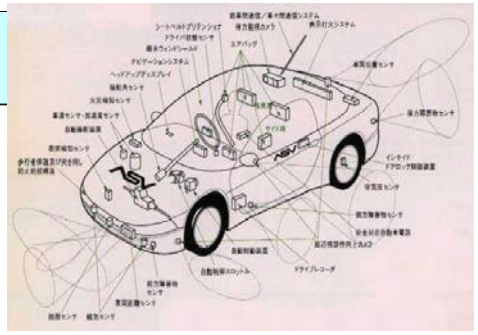
1.6 Universal Platform Based on BAN, Cloud Network, and AI Data Server for General Social Infrastructure beyond Medical Services



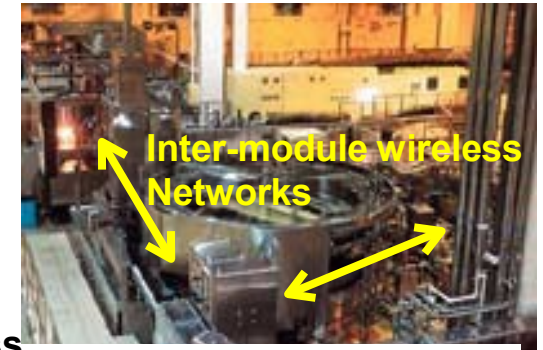
1.7 Extension of Use Cases of BAN beyond Medical Healthcare



Car Navigation & Collision Avoidance Radar



Car LAN & Wireless Harness



Factory Automation (FA)
Dependable Wireless Sensing & Controlling for Manufacturing (CIM)

Dependable Wireless Networks for Transportation

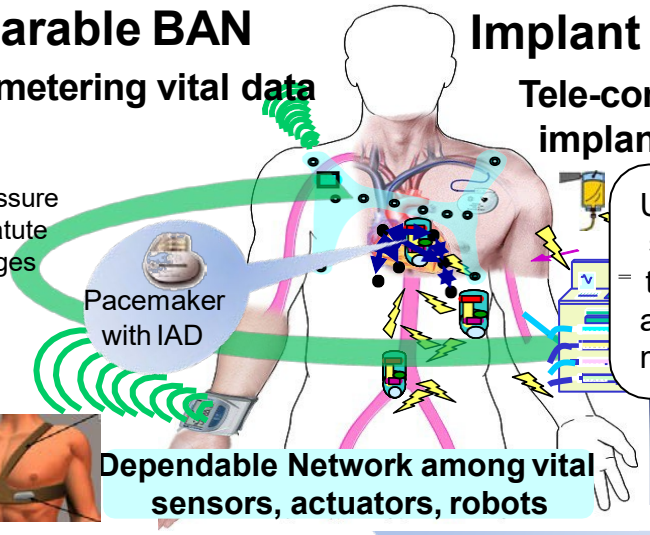
Wearable BAN

Tele-metering vital data

EEG.
ECG,
Blad Pressure
Temperatute
MRI images
Etc.

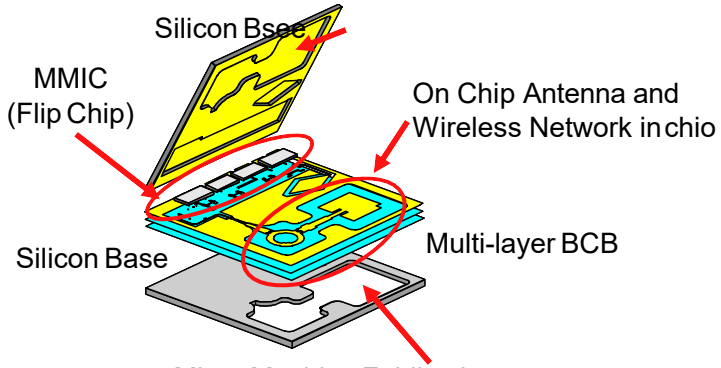
Implant BAN

Tele-controlling implant devices



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

Capsule Endoscope



Dependable Wireless System Clock in Micro Circuit & Network in Devices

Dependable BAN for Medical Healthcare

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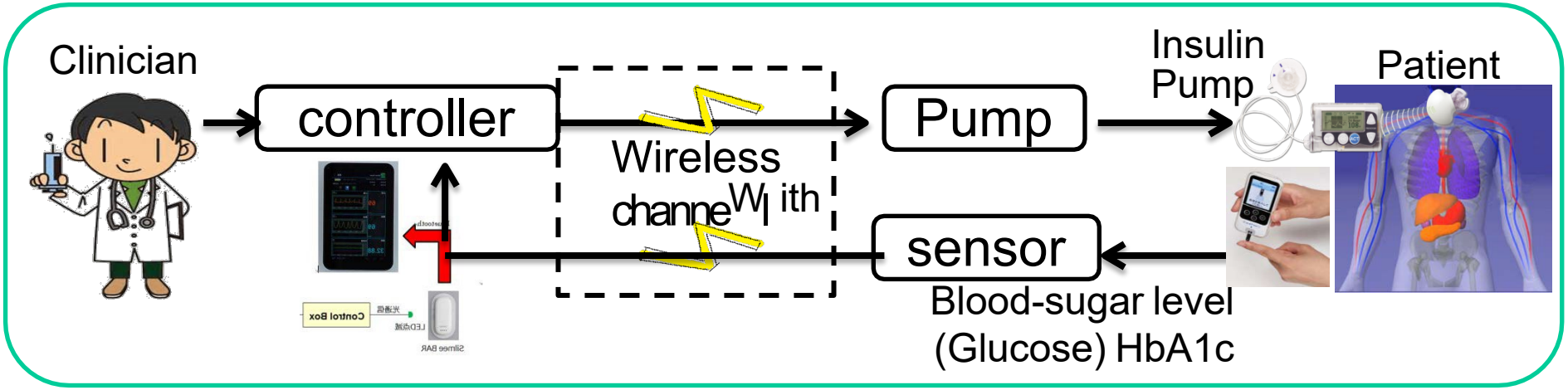
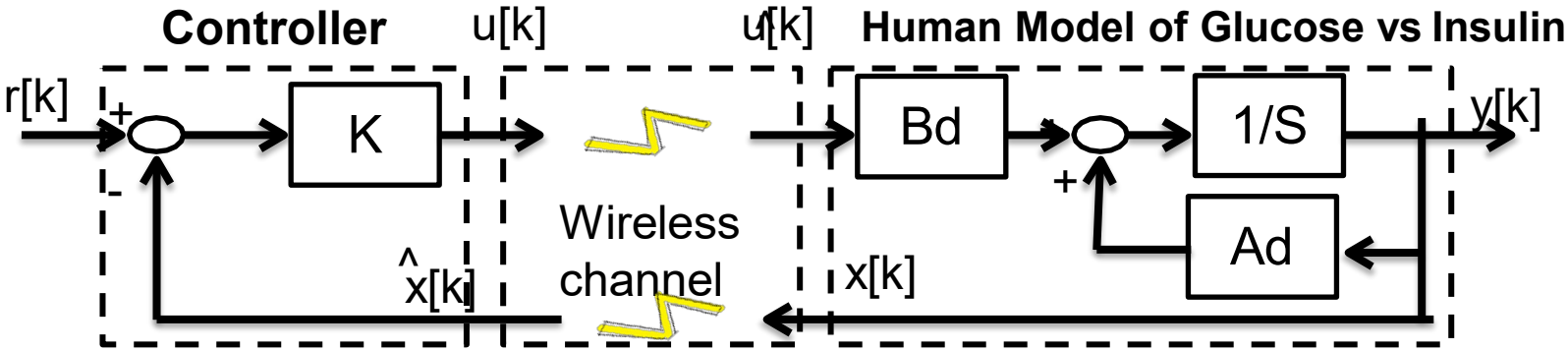
Automatic Remote Sensing Glucose and Controlling Insulin Pump for Diabetes Patients Using Wireless BAN

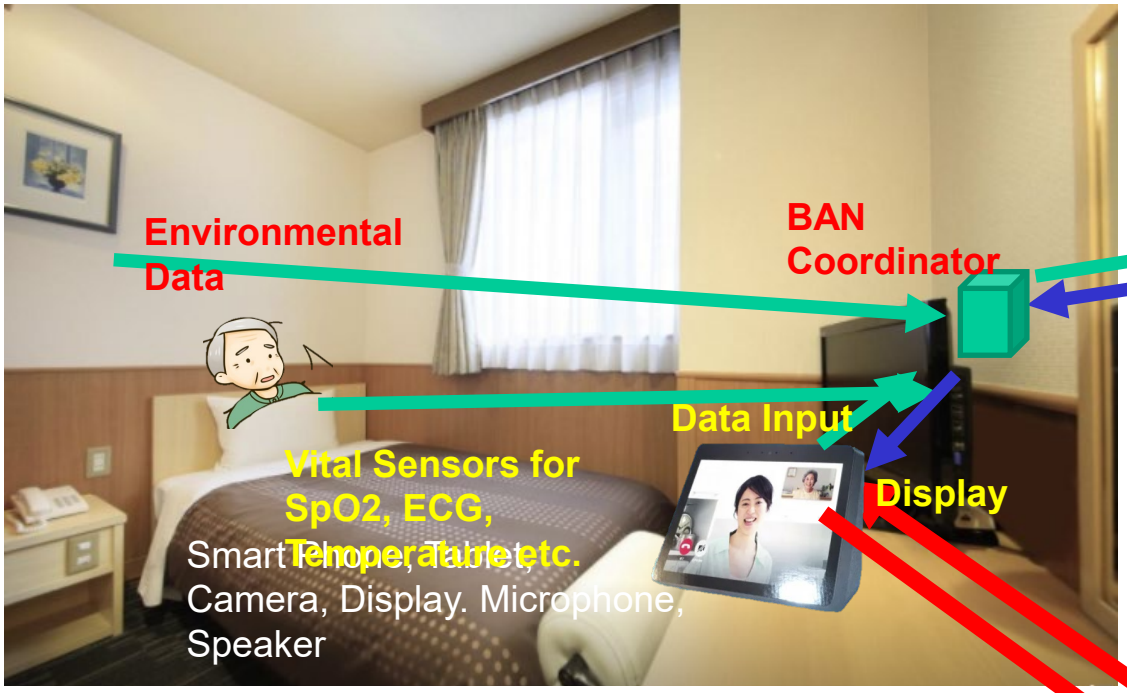


Wireless Feedback Sensing and Controlling Loop for Diabetes Patients



Feedback Delay Loop Model with Motion Equation

BAN Platform Use Cases in Remote Treatment for COVID-19 Patients under Quarantine at Home



Remote Maintenance of COVID-19 Patients at Home Using Platform of Integrated Vital Sensors/Wireless BAN/5G Cloud/AI Analysis

Family

Analyzed results for health condition

Data Collection and Analysis

Cloud Remote Monitoring Service

Without Clinical Staffs, health condition of COVID-19 patents can be monitoring and rescue them immediately.

Integrated Data

Remote Therapy and mental care keeping distance

Analyzed results

Command for care of patients

Real-time remote monitoring and care

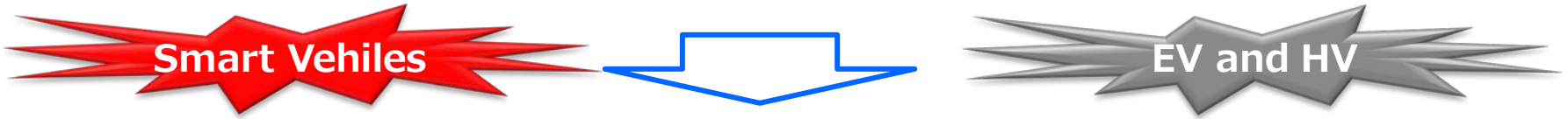
Dialog

Medical Care Center and Government Control Center

1.8 Demand of BAN for Automotive Uses

A. Increasing Demands in a world:

- **New business promotion by applying wireless ICT to vehicle by huge alliance between automotive and telecom industries such as smart key, wireless harness**
- **Autonomous car driving and safety controlling of elderly drivers by ICT and data science**



B. Challenging but Feasible Solutions:

- **Provide Remote Sensing and Controlling Using ICT and AI**
  - **➔ Prevent Traffic Accidents , Jam and Co2 Emission**
- **Promote a New Global Business of Automotive , ICT, and Electronics**

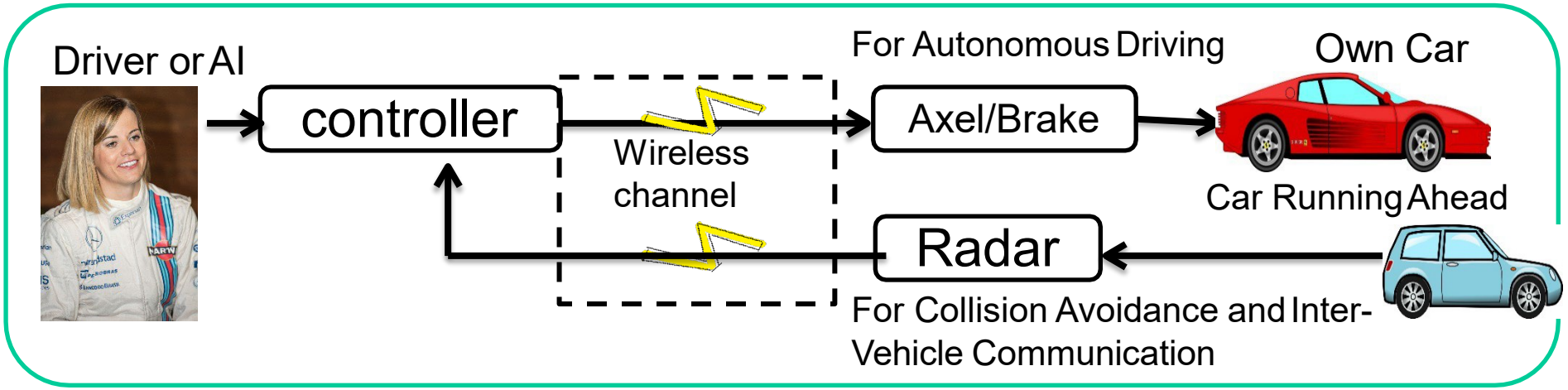
C. Approach:

(1) R&D of Enable Technologies for Smart Vehicle and City

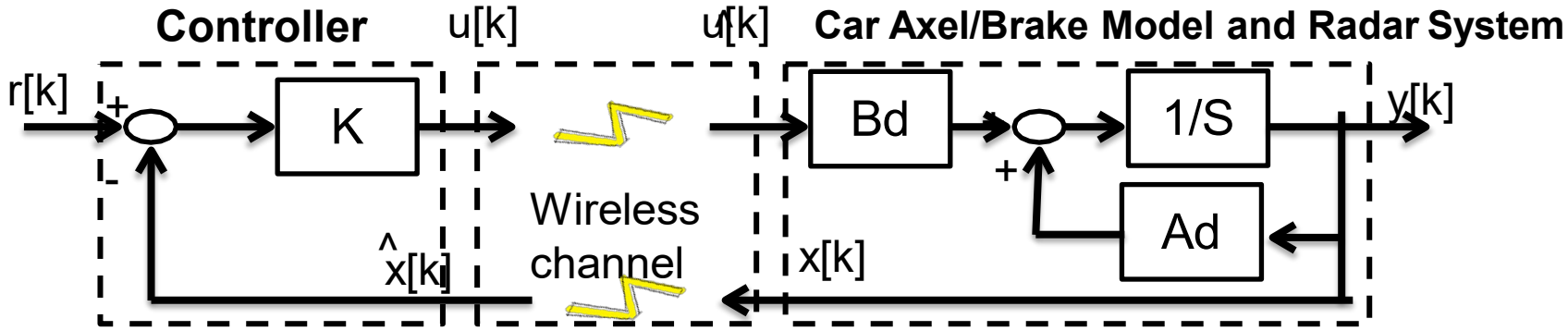
(2) Promote International Standard of Wireless Body Network（BAN) and Integrated Platform of BAN/5G/AI for Global Marketing for both Medical and Automotive uses

(3) Regulatory Compliance of Devices & Services to Ensure Safety, Reliability, Security, i.e. Dependability by Regulatory Science

1.9 Use of BAN for Autonomous Car Driving

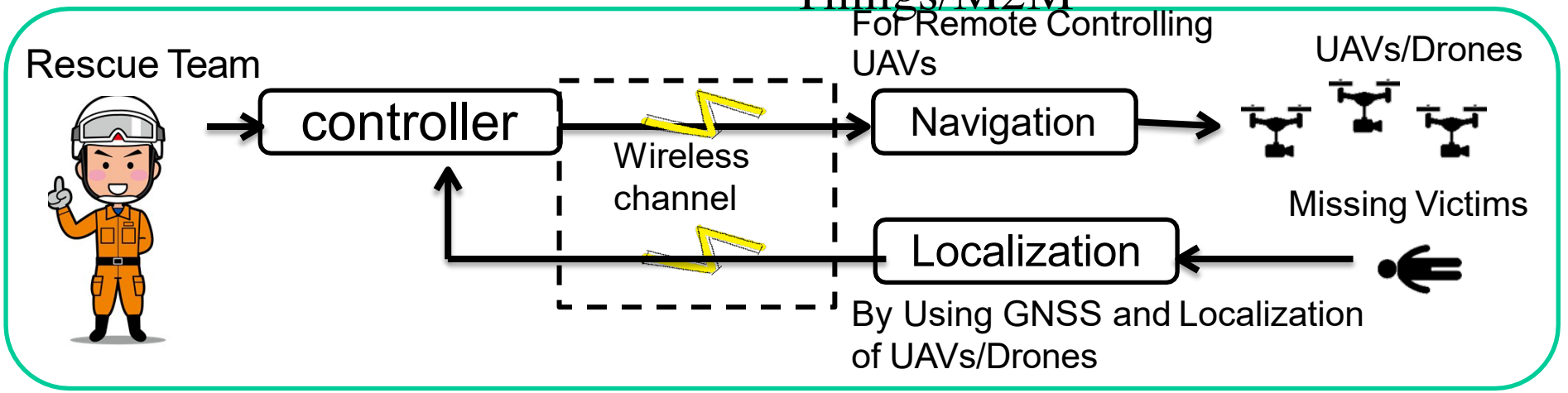


Wireless Feedback Sensing and Controlling Loop for Autonomous Driving

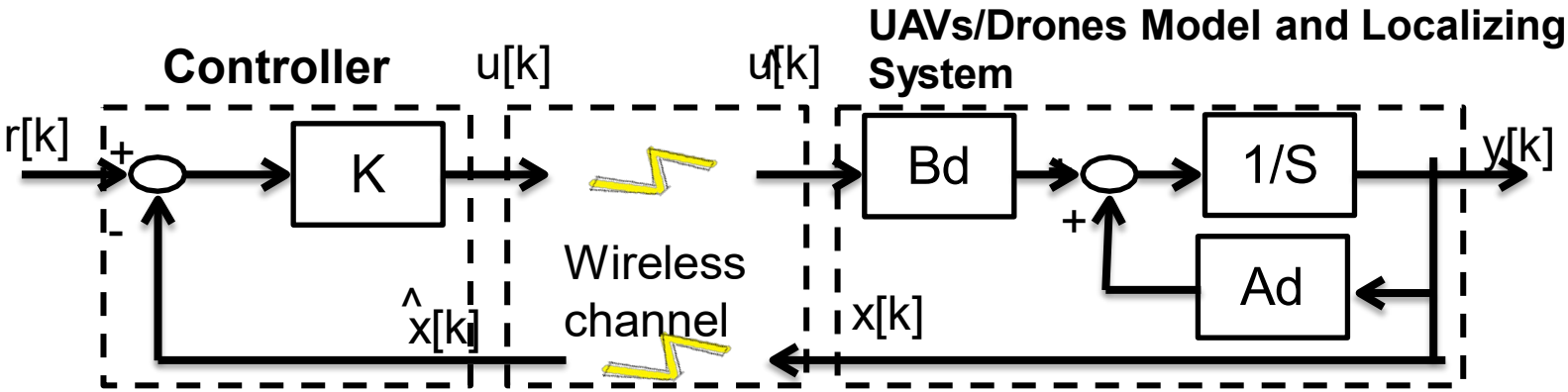


Feedback Delay Loop Model with Motion Equation

1.10 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

1.11 Body Area Network(BAN) of Vehicle Body

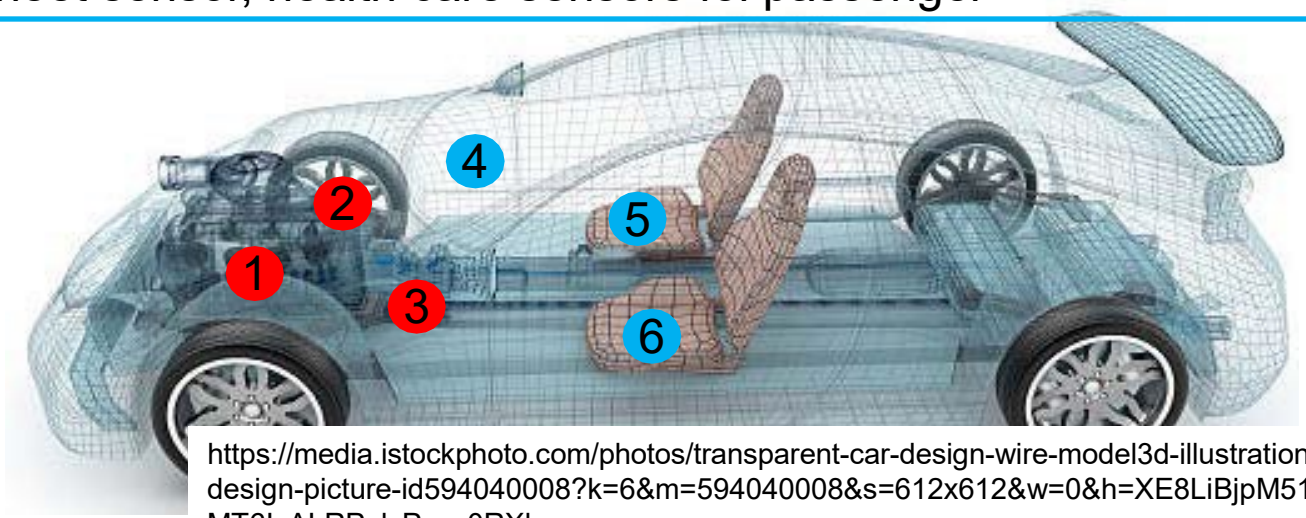
Motivation to extend human BAN(HBAN) to VBAN is to promote much dependable services by interaction between HBAN and VBAN.

Use case of Vehicle Body Area Network(VBAN) for Engine Room

1. Engine diagnostic sensor and controller
2. Air pressure sensor, wheel health sensor and controller
3. Transmission monitoring sensor and controller

Use case of Vehicle Body Area Network(VBAN) for Cabin Room

4. Cabin environment sensor (temperature, brightness, humidity etc.)
5. Sheet sensor, health care sensors for driver
6. Sheet sensor, health care sensors for passenger



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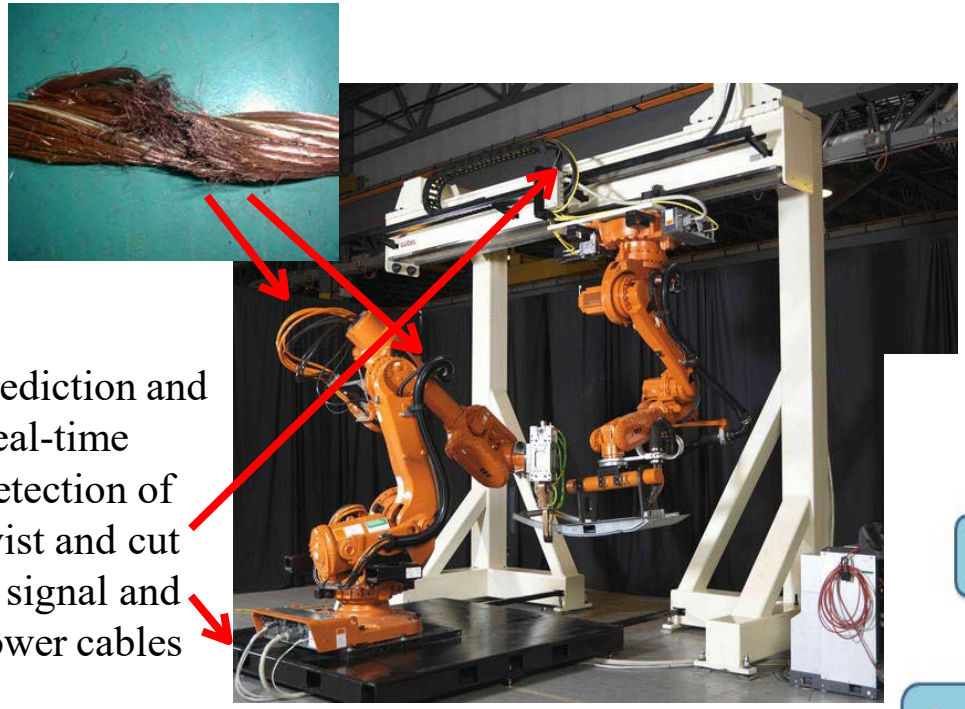
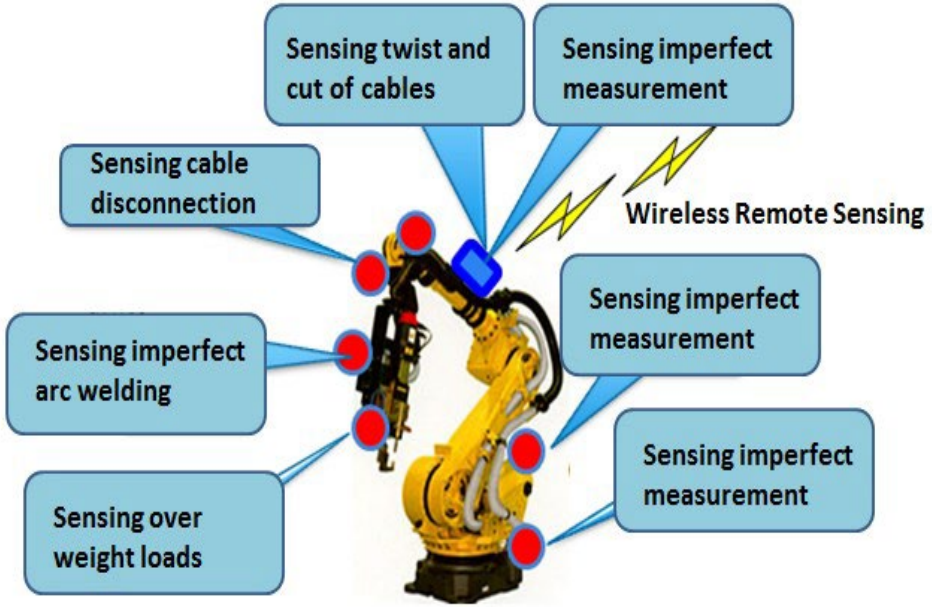
1.12 Use case in Factory Manufacturing Line; Detection of Twist and Cut of Cables



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

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



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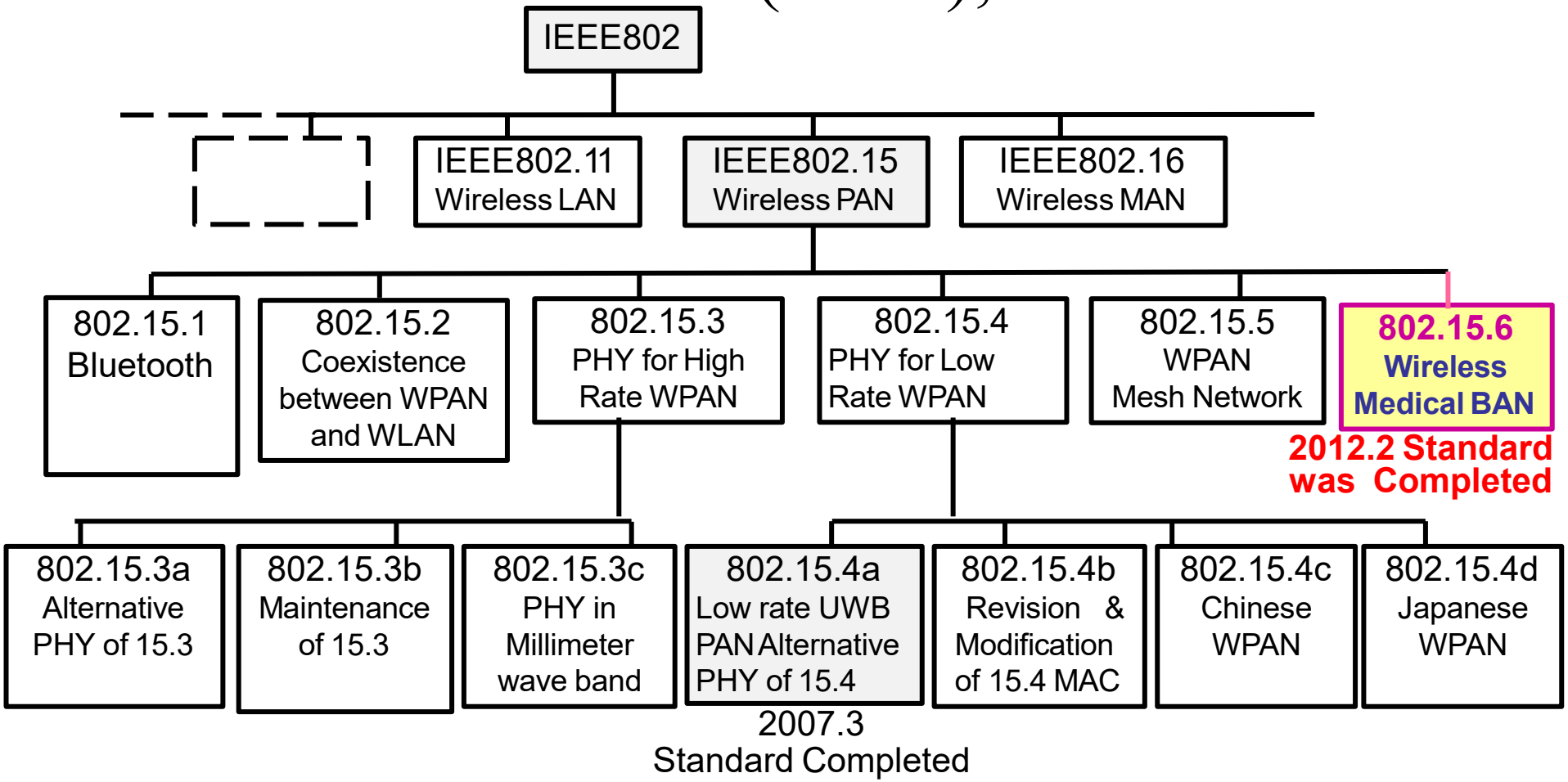
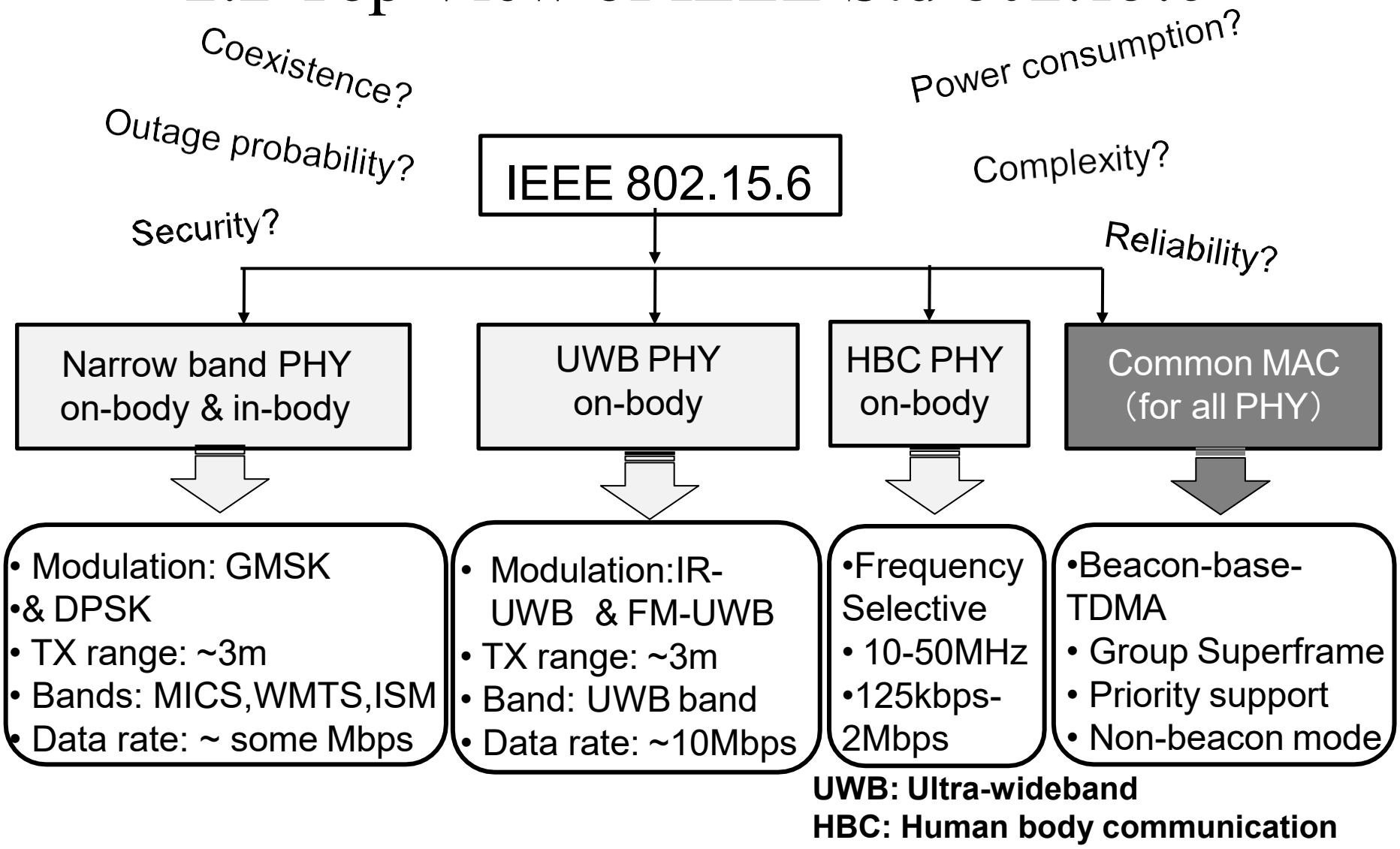
2. Short Review of WBAN Standard IEEE802.15.6-2012

2.1 Standard of Medical Wireless Body Area Network(BAN);IEEE802.15.6



2.2 Top View of IEEE Std 802.15.6



UWB: Ultra-wideband
HBC: Human body communication

2.3 User Priority Mapping

Priority level	Traffic designation	Data type
7	Emergency or medical event report	Data
6	High priority medical data or network control	Data or management
5	Medical data or network control	Data or management
4	Voice	Data
3	Video	Data
2	Excellent effort	Data
1	Best effort	Data
0	Background	Data

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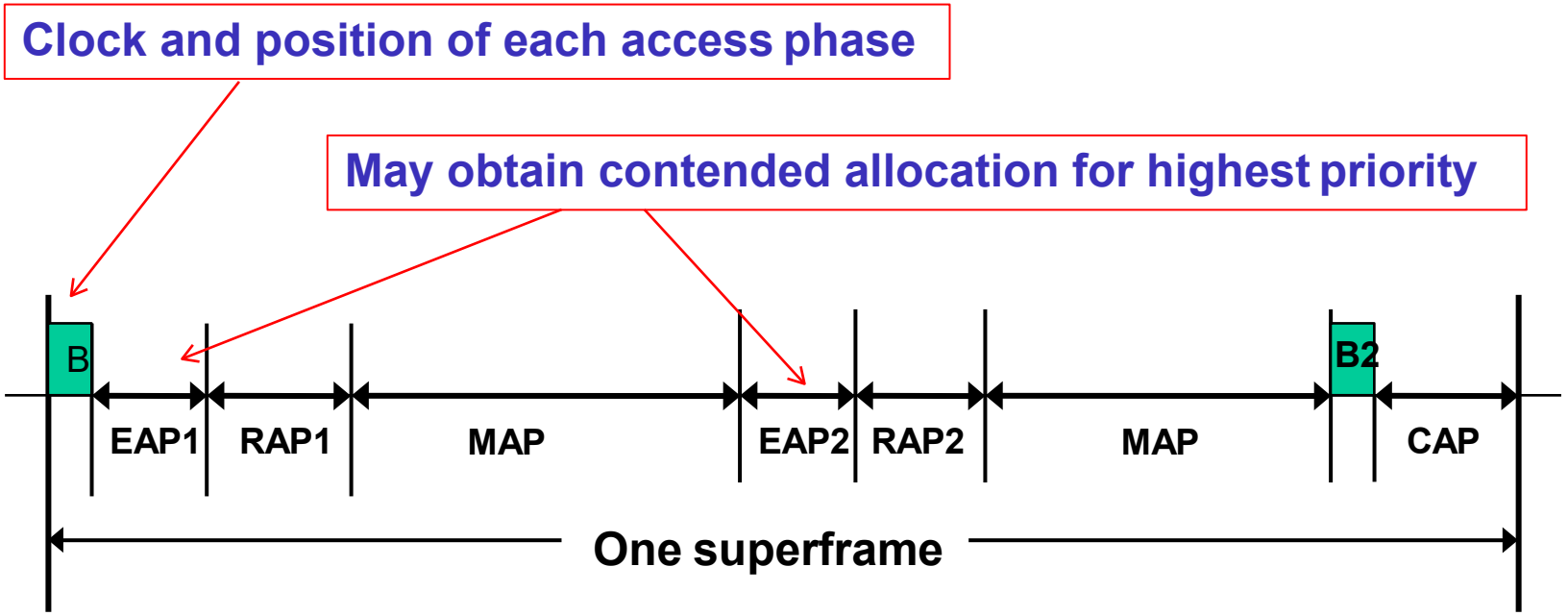
2.4 Three Channel Access Modes

Channel access mode	Time reference-based (superframe structure)	Beacon	Notes
I	Yes	Yes	Coordinator sends beacon in each superframe except for inactive superframes.
II	Yes	No	Coordinator establishes time reference but doesn't send beacon.
III	No	No	There is not time reference.

2.5 Time-referenced Superframe w/ Beacon



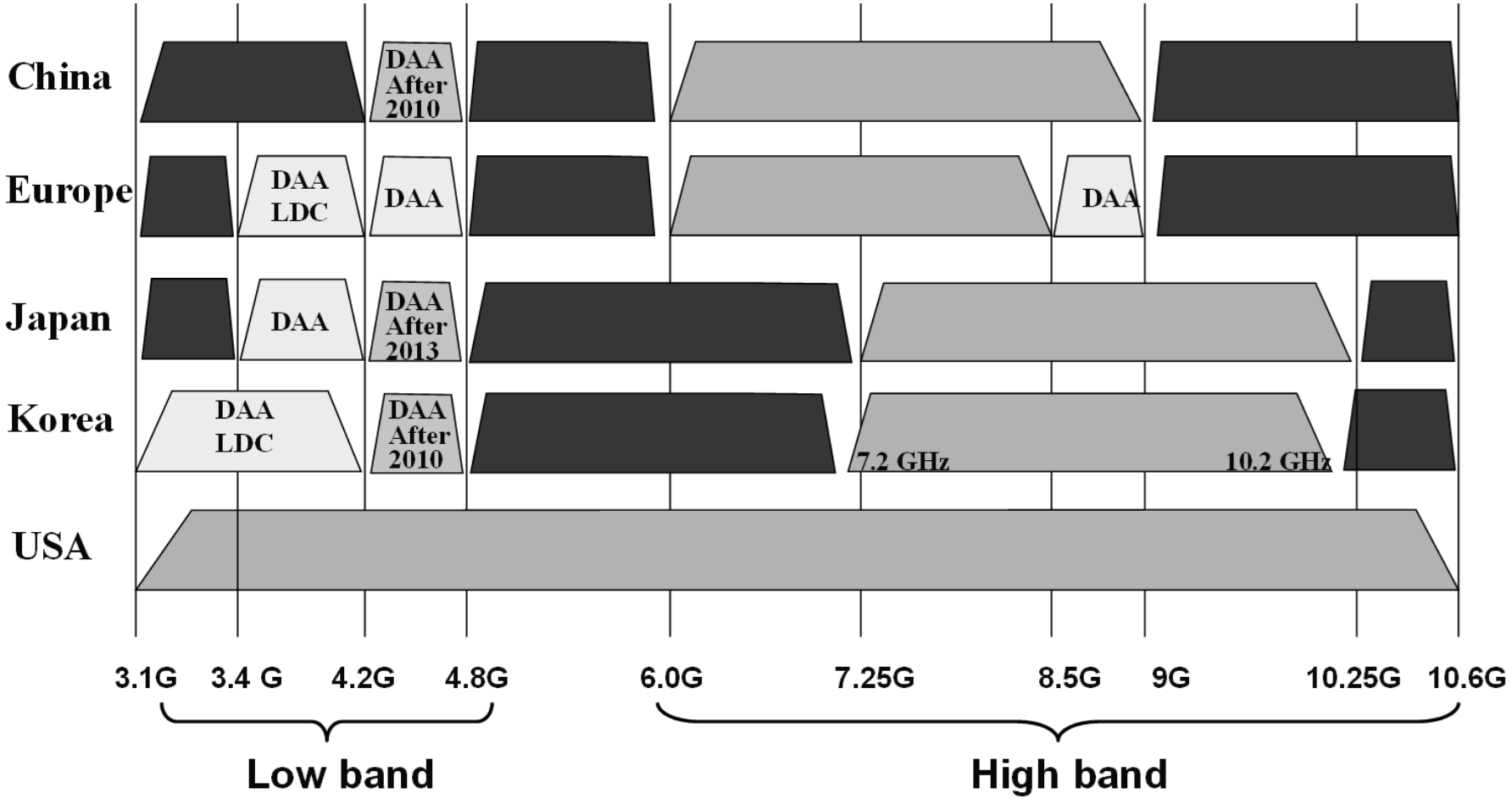
EAP: exclusive access phase

RAP: random access phase

MAP: managed access phase

CAP: contention access phase

2.6 Worldwide UWB Regulations in 2012



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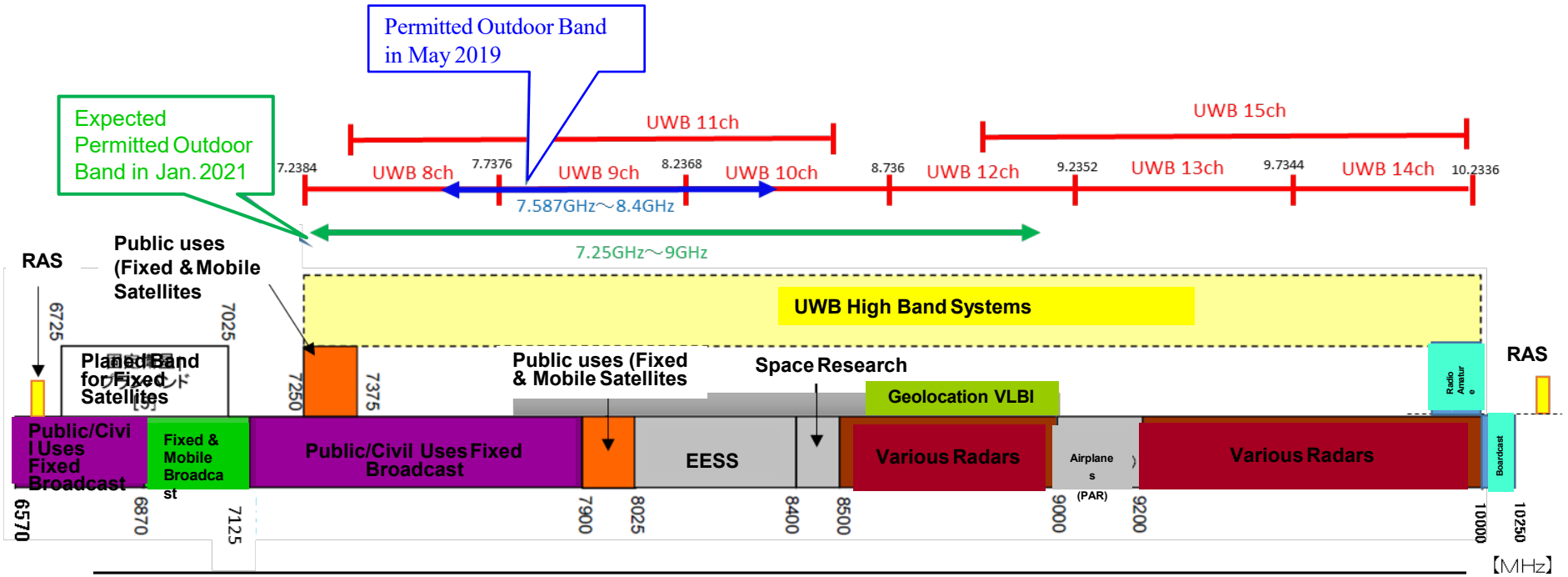
2.7 Radio Outdoor Uses in the Frequency Band 7.25-9.00GHz (January 2021)

- Red lines indicate channels defined by IEEE802.15.4a.
- Although Ch 9 in 7.587-8.4GHz **Blue line** was allowed for outdoor use in May 2019, MIC has started investigation to allow wider band 7.25-9.00 GHz **Green line** wand it is expected to allow it for outdoor use in January 2021



2.8 Summary of IEEE802.15.6-2012

- A standard, IEEE Std 802.15.6™ was completed and published in Feb. 2012. In which, specifications of three PHY and common MAC are defined to support various medical and non-medical consumer applications.

- **Commercial products of BAN have been sold as an enable technology supporting personal healthcare as a consumer electronics but not much approved for medical equipment.**

- **In PHY, ultra-wide band(UWB) is applied for high QoS use case but radio regulation for UWB results in restricting use cases.**

- **In MAC, hybrid contention base and free protocol can perform flexible delay and throughput for variable QoS levels of packets but its implementation complexity is too high for its complete protocol.**

3. Necessity and Uniqueness for Amendment of BAN with Enhanced Dependability

3.1 Necessity for Enhanced Dependability in 15.6 BAN

1. In case of coexistence of multiple BANs

- Current existing standard IEEE802.15.6 has not been designed to manage contention and interference among overlaid BANs. The more BAN uses in dense area, the more contention and inference cause performance degradation.
- Amendment of PHY and MAC for resolving these problems in coexistence of BANs is necessary.

2. In case of coexistence with other radios

- For enhanced dependability, UWB PHY of BAN should be updated to avoid performance degradation due to interference with coexisting other narrow band and UWB networks in overlapped frequency band.

3. In case of feedback sensing and controlling loop

- Remote medical diagnosis with vital sensing and therapy and control actuators and robotics need more dependable and efficient protocol.

4. Usability and Implementation Complexity

- Interoperability with other radio networks, more flexible network topology,
- Transparency with other standards such as ETSI SmartBAN
- Capability of ranging and positioning in UWB is required for mobility and security.

3.2 Technical Challenges for Enhanced Dependability

- First of all, we should recognize that any technology in PHY and MAC cannot guarantee full dependability in every use case.
- However, we can design a new standard which can guarantee a certain level of enhanced dependability in a specific defined use case.
- As an analogy of informed consent in medical doctor to a patient, a manufacturer of a dependable wireless network can describe such a specific defined use case that ***the manufacture can guarantee a defined level of dependability showing necessary cost and remained uncertainty.*** This is an honest manner and much better than no guarantee for any use case.
- Therefore, an expecting standard describes a specific use case in which ***worst performance can be guaranteed enough high while most of exiting standards have been designed with average performance base.***
- Technical requirement for the specific use case can be guaranteed.

3.3 Uniqueness different from existing standards (1/2)

1. MAC protocol for around packets and recursive access for feedback loop in remote sensing and controlling;
2. Level of dependability can be defined with showing necessary cost and remained uncertainty. This is an honest manner and much better than no guarantee for any use case.
3. Worst performance can be guaranteed enough high while most of exiting standards have been designed with average performance base.
4. Others

3.3 Uniqueness different from existing standards (2/2)

2.PHY technologies to satisfy technical requirement for enhanced dependability in the focused use cases

A) In feedback loop for remote monitoring sensors or radars and feedback controlling actuators, real-time cognition of varying condition on site and adaptive reconfiguration in relatively messy, small, and dense areas are requested to guarantee worst performance with permissible delay and errors.

B) Within a permissible limited feedback delay, propagation paths connecting between nodes and coordinator should be found to keep connectivity by diversity, channel switching etc. .

C) For such a dynamic environment and QoS requirement changing situation, sophisticated PHY technologies are requested to guarantee minimum requirement of performance.

3.4 Focused Issues in Amendment of std 15.6 BAN with Enhanced Dependability

1. MAC Protocol in case of coexistence of multiple BANs

- Amendment of MAC for resolving these problems in coexistence of BANs is necessary.
- Specified MAC protocol for feedback sensing and control loop between coordinator and nodes.

2. PHY Interference Mitigation In case of coexistence with other radios

- For enhanced dependability, UWB PHY of BAN should be updated to avoid performance degradation due to interference with coexisting other narrow band and UWB networks in overlapped frequency band.

3. Usability and Implementation Complexity

- Interoperability with narrow band and UWB PHY
- more flexible network topology,
- Transparency with other standards such as ETSI SmartBAN

4. Ranging and Positioning Capability of UWB-BAN

- Mobile nodes and coordinator of BAN need ranging and positioning of UWB-BAN

4. Channel and Environment Models for Focused Use Cases for Revision of std 15.6-2012 for Human and Vehicle BANs with Enhanced Dependability TG16.6ma

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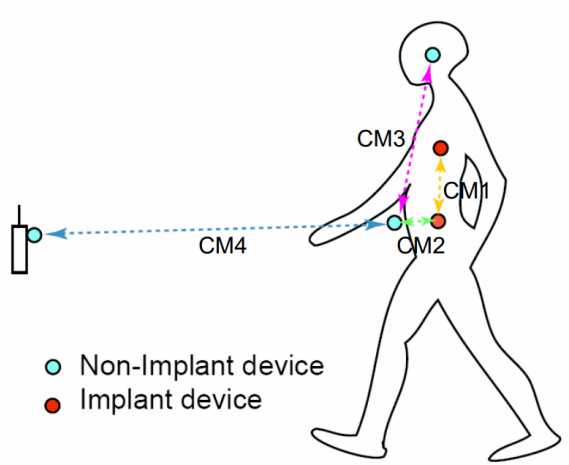
4.1 Channel models and scenarios in IEEE802.15.6ma

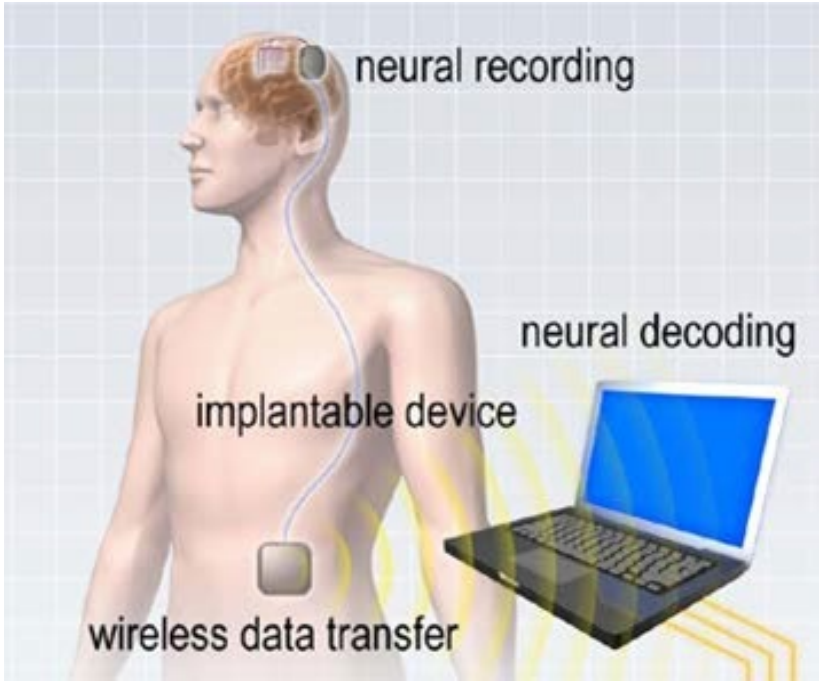


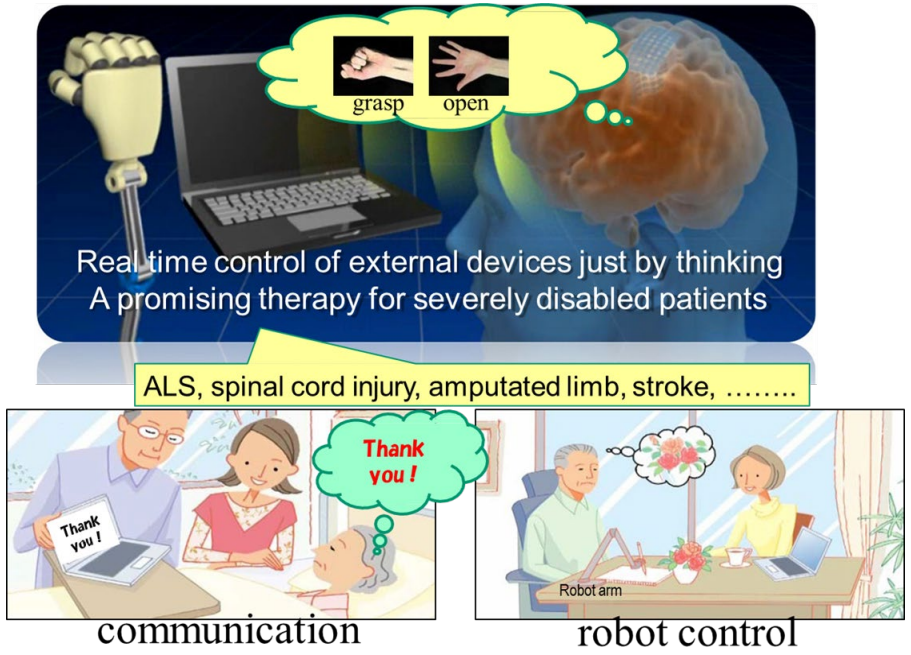
- Path loss (Mandatory)
- Optional;
  - Fading (Small scale/ large scale)
  - Shadowing
  - Power delay profile

Specific use cases
Implant to Body Surface for BCI
Implant to External for BCI
Body surface to body surface for BCI
Body Surface to External for BCI
Implant to body surface for capsule endoscopy

Scenario	Description	Frequency Band	Channel Model
S2	Implant to Body Surface	402-405 MHz,	CM2
S2.1	Implant (upper body) to Body Surface	3.1-10.6 GHz UWB	CM2.1
S2.2	Implant (head) to Body Surface	3.1-10.6 GHz UWB	CM2.2
S3	Implant to External	402-405 MHz, 3.1-10.6 GHz UWB	CM2
S4	Body Surface to Body Surface (LOS)	400, 600, 900 MHz 2.4, 3.1-10.6 GHz	CM3
S4.1	Body Surface to Body Surface (LOS)	3.1-10.6 GHz CM4.1	CM4.1
S5	Body Surface to Body Surface (NLOS)	400, 600, 900 MHz 2.4, 3.1-10.6 GHz	CM3
S6	Body Surface to External (LOS)	900 MHz 2.4, 3.1-10.6 GHz	CM4
S6.1	Body Surface (head) to External (LOS)	3.1-10.6 GHz	CM6.1
S7	Body Surface to External (NLOS)	900 MHz 2.4, 3.1-10.6 GHz	CM4

4.2 Brain-Machine-Interface(BMI): Wireless Body Area Network (BAN) with AI Machine-Learning and User-Interface

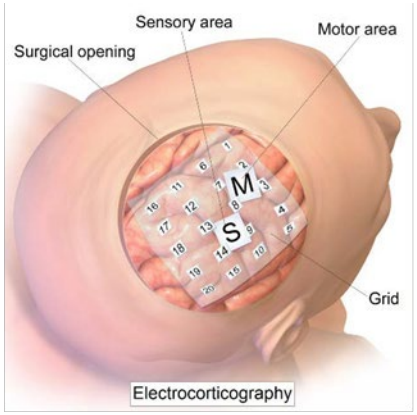


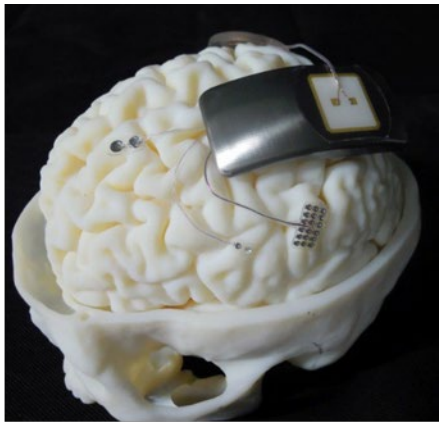


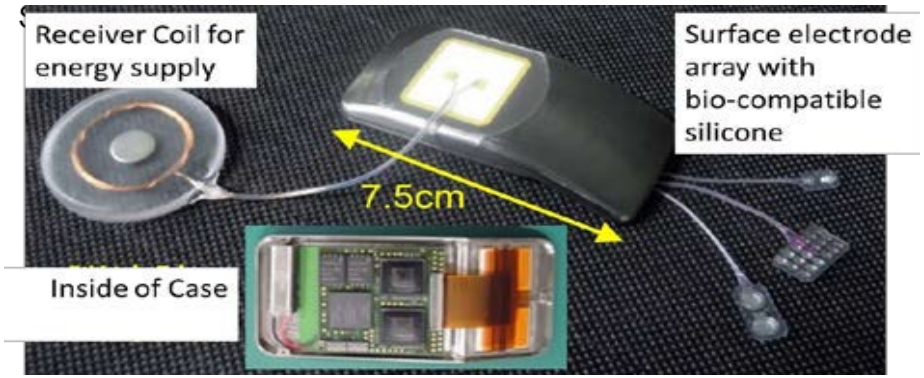
Brain-Computer-Interface(BCI) for Understanding Human Contention and Machine Control.

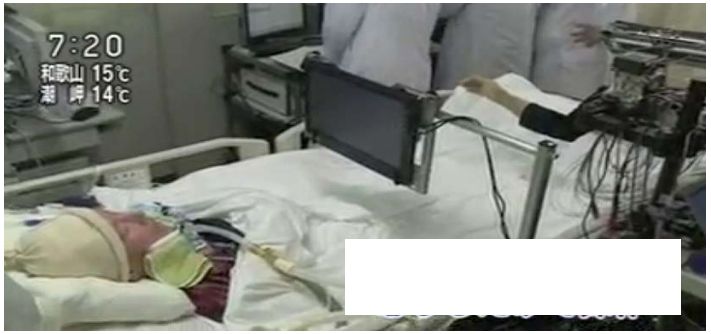
Brain-Computer-Interface(BCI) and Brain-Machine-Interface(BMI) for Clinical Support to Disability and More General Use Cases Including for Entertainment, e-Game, and Heavy Industries.

4.2 BMI with Wireless BAN with AI Machine-Learning and User-Interface









ECoG（Electrocorticogram) detected with implanted thousands of electrodes is transmitted in wireless by BAN with high capacity and dependability.

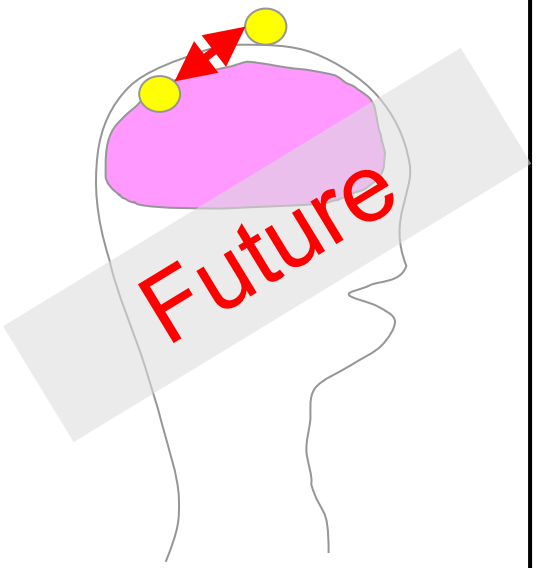
Brain-Machine-Interface(BMI) systems for Clinical Support to Disability such as autonomous robot hand control and communication assistance.

4.2 Channel models and scenarios in use case of BMI and BCI

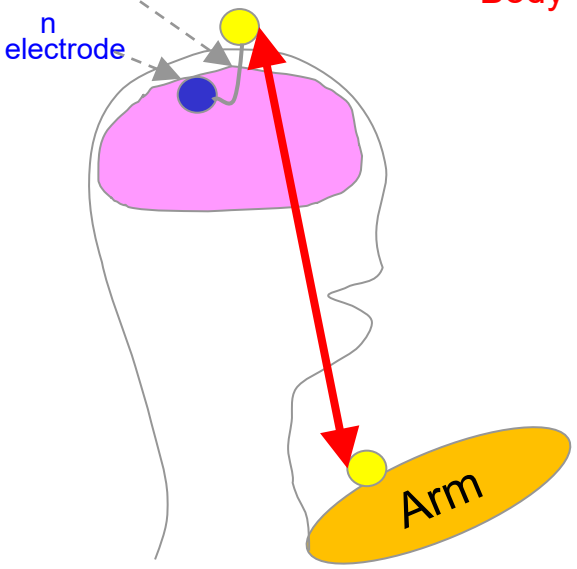
We will define what is BCI and BMI.

Specific use cases
Implant to Body Surface for BCI
Implant to External for BCI
Body surface to body surface for BCI
Body Surface to External for BCI
Implant to body surface for capsule endoscopy

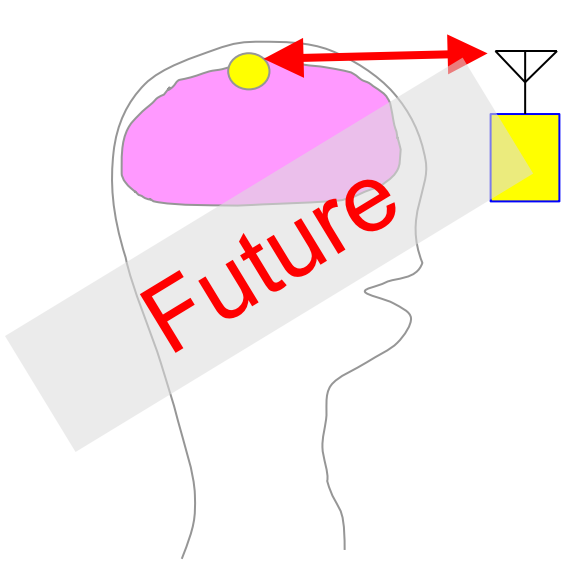
Body Surface to Body Surface for BCI



Implant to Body Surface for BCI



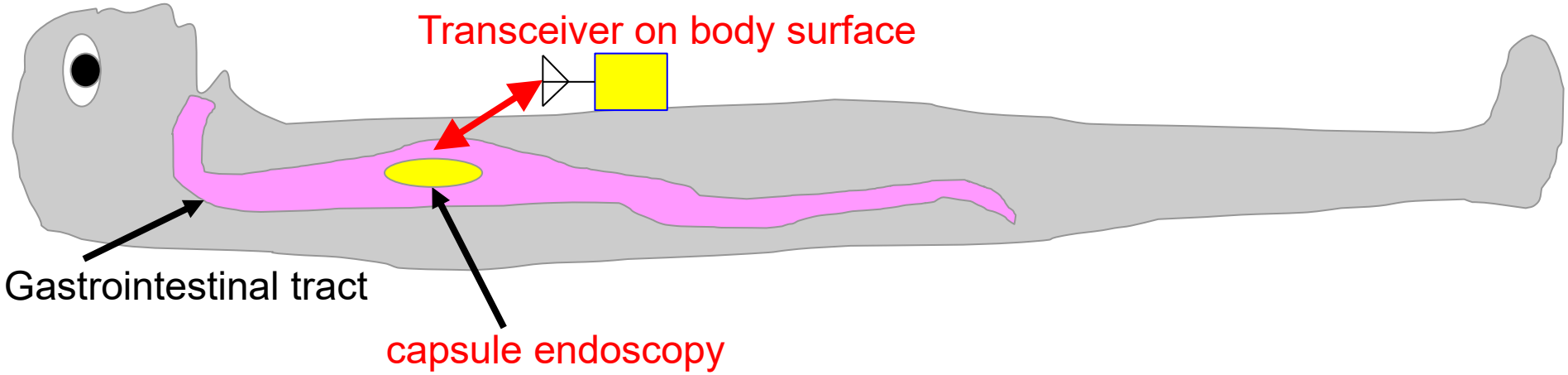
Body Surface to External on-body surface for BCI



Implant to External for BCI

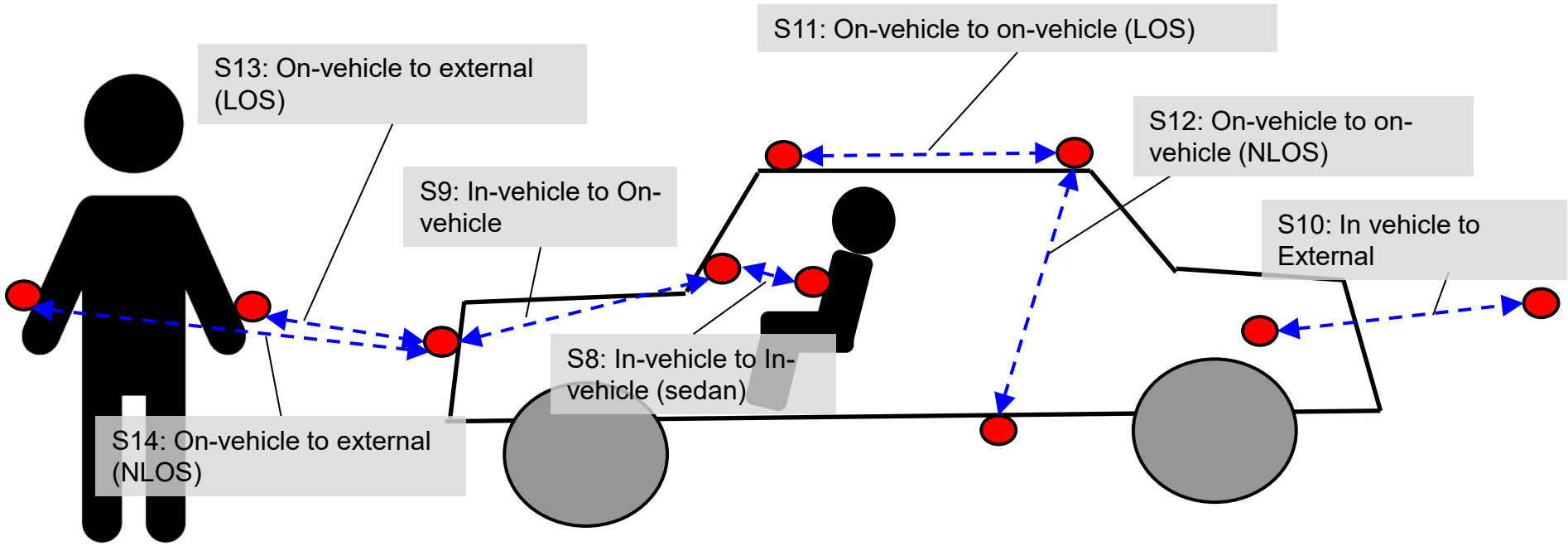
4.3 Channel models and scenarios for capsule endoscopy

Specific use cases
Implant(head) to on-body for BCI
Implant to External for BCI
Body surface to body surface for BCI
Body Surface to External for BCI
Implant to body surface for capsule endoscopy



Implant to Body Surface for Capsule Endoscopy

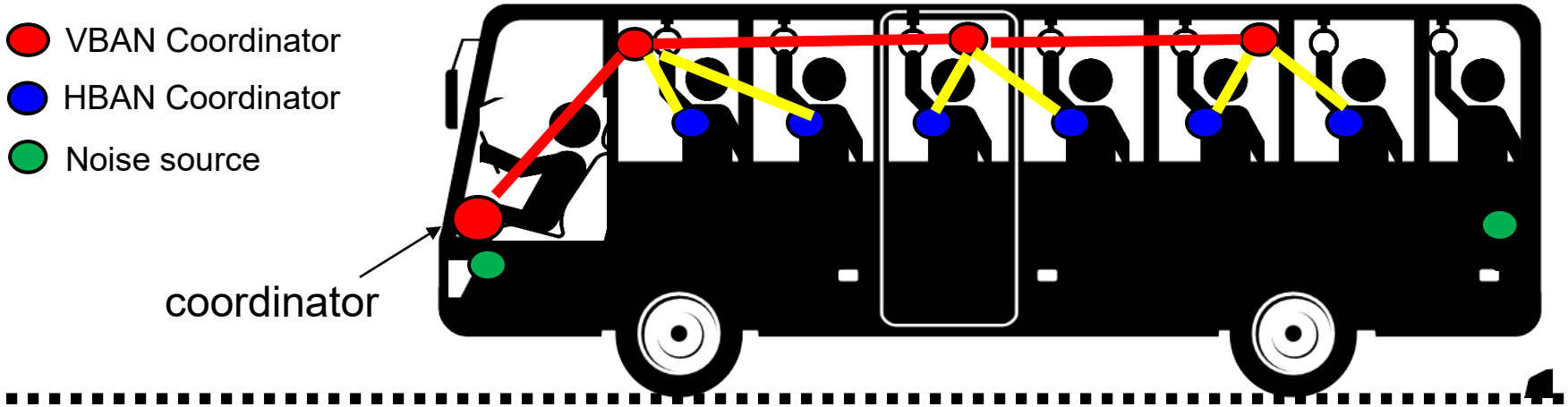
4.4 Channel and Environmental models of VBAN



4.4 Use Case of Coexisting Multiple HBAN and VBAN

Nodes and coordinator are in cabin room Geometrical configuration

➡ Original channel models, common channel model to IEEE 802.15.4a and IEEE802.15.6-2012

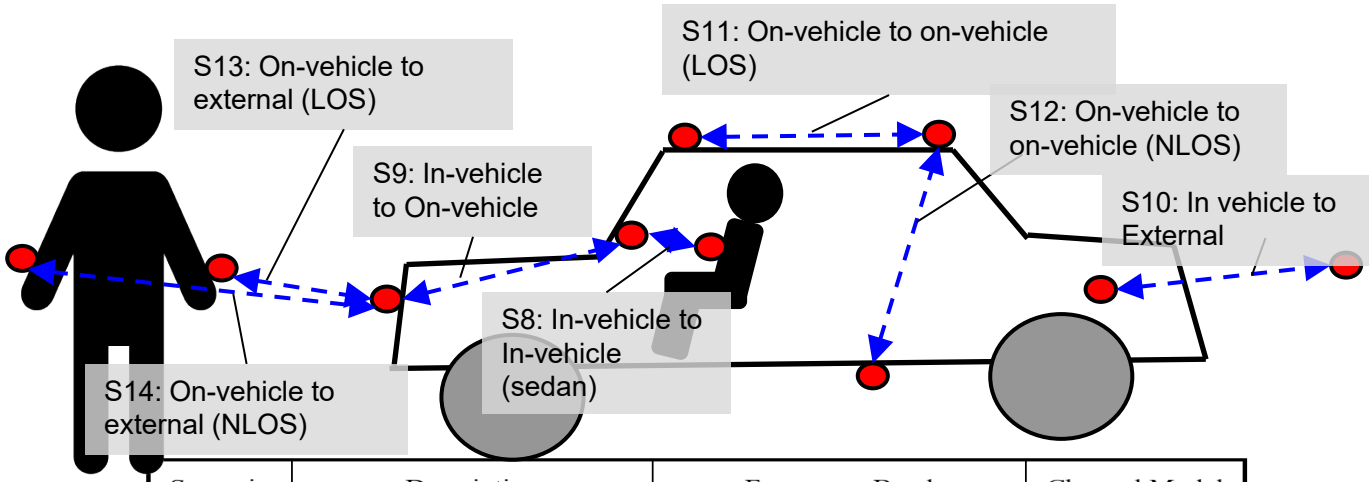


Use case

- Entertainment for passengers
  - Nodes are in cabin room / coordinator is in cabin room.

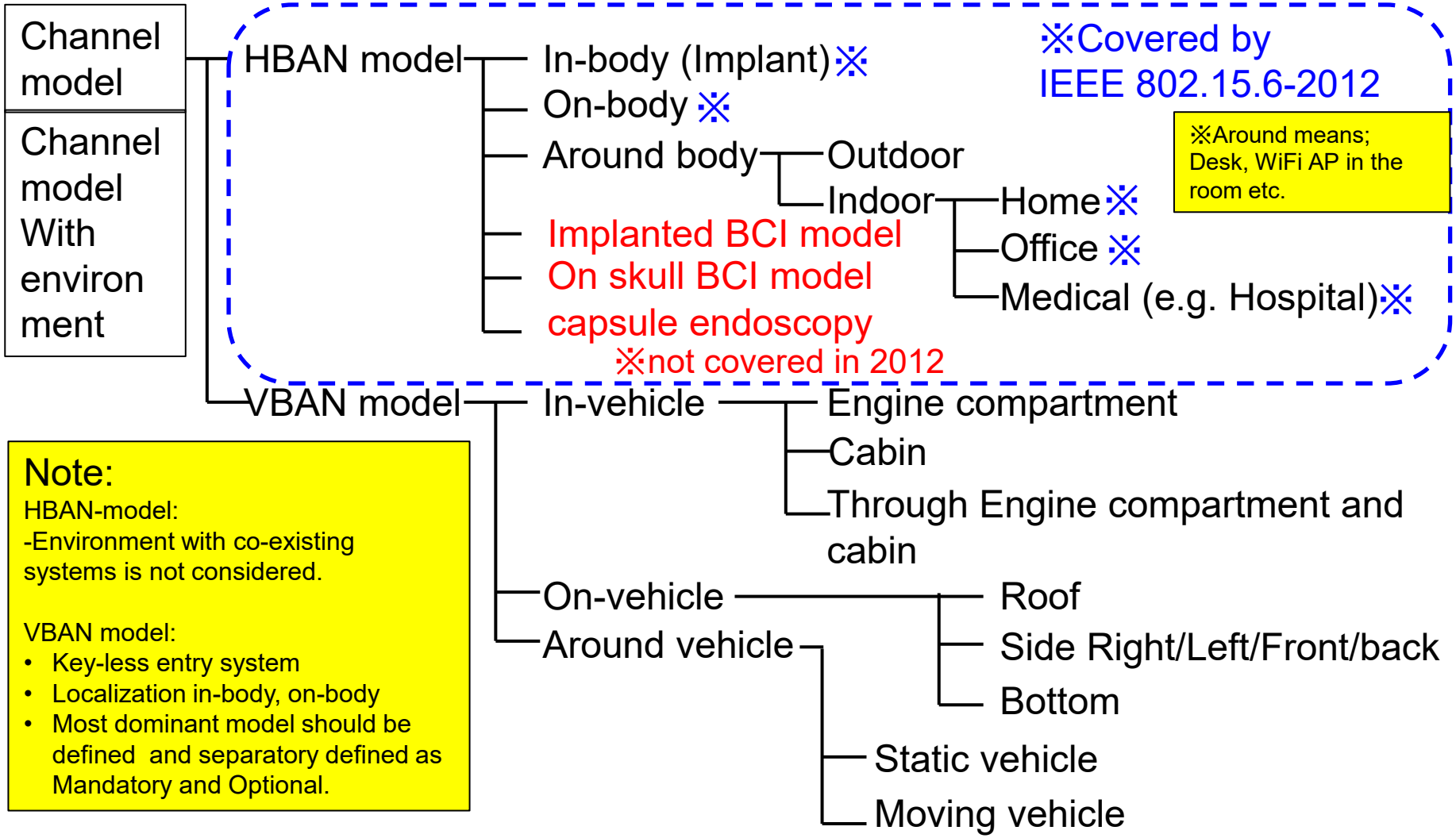
scenario		Sedan/RV / SUV with engine	Sedan/RV / SUV without engine	Bus	Cargo / pickup	Special purpose
8.1 vv	**VBAN coordinator and VBAN coordinator**	Case 3.1a		Case 3.1a	Same as 3.1a	---

4.4 Channel models and scenarios in IEEE802.15.6ma



Scenario	Description	Frequency Band	Channel Model
S8	In-vehicle to In-vehicle (sedan)	2.4, 3.1-10.6 GHZ	CM8
S8.1	In-vehicle to In-vehicle (passenger bus)	2.4, 3.1-10.6 GHZ	CM8.1
S9	In-vehicle to On-vehicle	2.4, 3.1-10.6 GHZ	CM9
S10	In vehicle to External	2.4, 3.1-10.6 GHZ	CM10
S11	On-vehicle to on-vehicle (LOS)	2.4, 3.1-10.6 GHZ	CM11
S12	On-vehicle to on-vehicle (NLOS)	2.4, 3.1-10.6 GHZ	CM12
S13	On-vehicle to external (LOS)	2.4, 3.1-10.6 GHZ	CM13
S14	On-vehicle to external (NLOS)	2.4, 3.1-10.6 GHZ	CM14

4.5 Classification of Channel and Environment Models for Human and Vehicle Body Area Networks (HBAN&VBAN)



Note:

HBAN-model:
-Environment with co-existing systems is not considered.

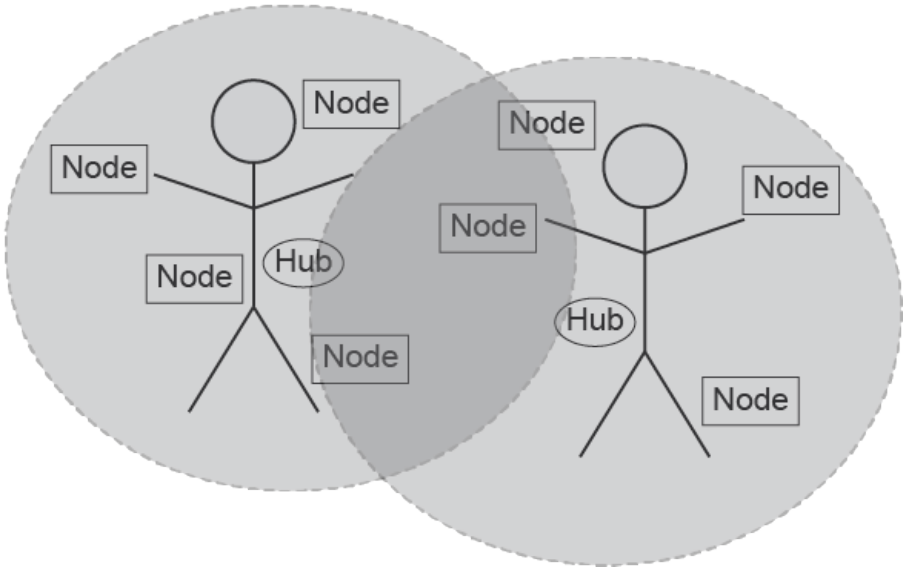
VBAN model:
- Key-less entry system
- Localization in-body, on-body
- Most dominant model should be defined and separatory defined as Mandatory and Optional.

5. Requirement for Revision of 15.6 MAC for Human and Vehicle BANs with Enhanced Dependability TG16.6ma

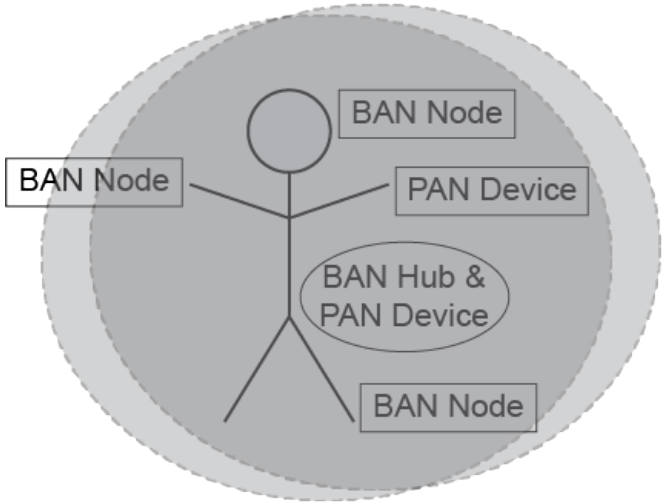
Ryuji Kohno’(, Takumi Kobayashi (YNU/YRP-IAI)

5.1 Interference among BANs or BAN and other systems

- There would be cases where BANs or BAN and other networks are spatially collapsed.

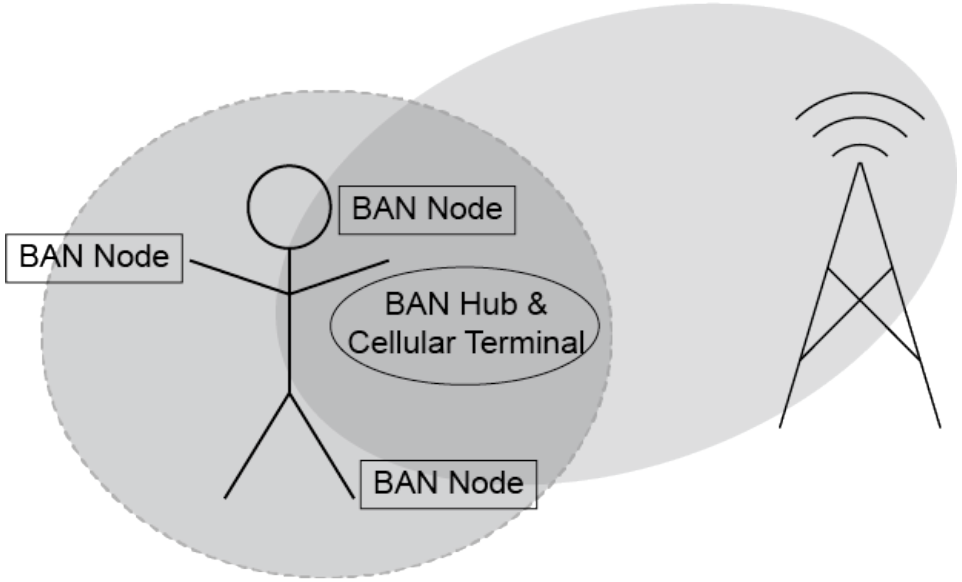


Case 1: BANs, using same frequency bands

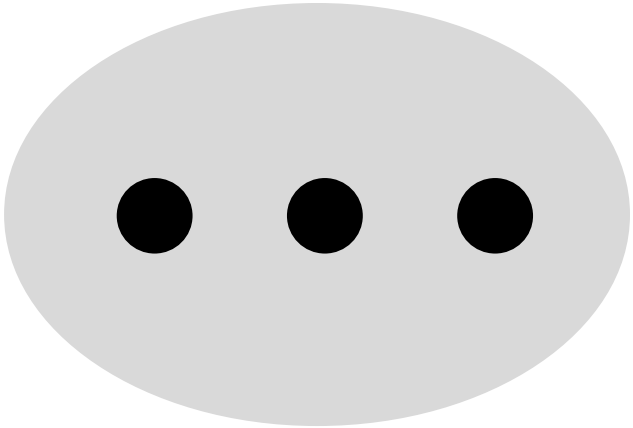


Case 2: BAN and PAN, using same frequency bands

5.2 Interference among BANs or BAN and other systems



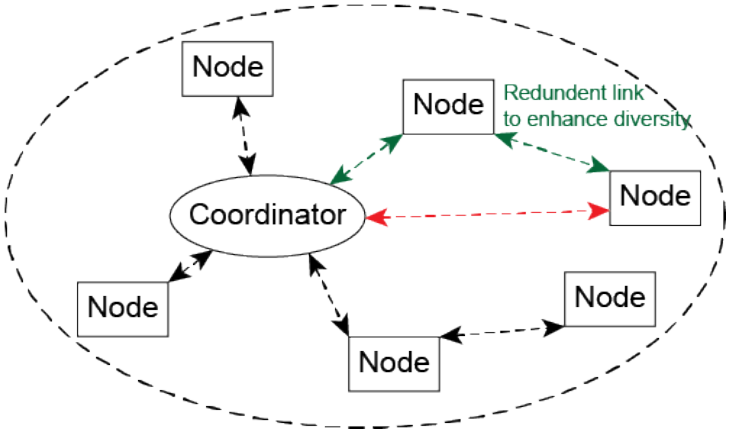
Case 3: BAN and other piconets such as cellular network or Wi-Fi, some part of their frequency bands are overlapped.



Case 4: Case 1 to 3 combined

- The concept of 802.1 MAC Bridge can be extended to enhance dependability.
- The coordinator can manage interference or packet collision among same or different BANs (VBAN and/or HBAN), PANs, and other piconets.

5.3 Two-hop star topology extension

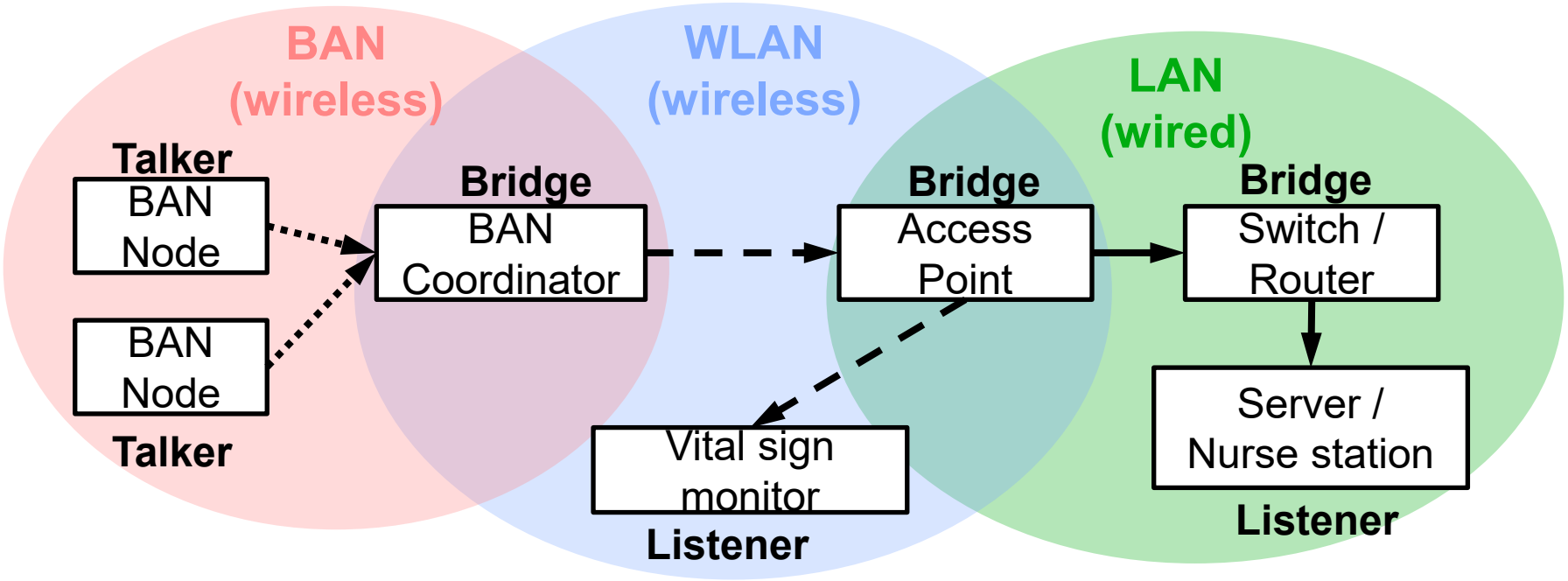


- Star topology + one hop (current std.)
  - Since there is no Line-of-Sight link between back and front of a human body, as well as a vehicular body
- Star topology + multiple hops (may be introduced in the amendment)
- TSN concept may be applicable.
  - **Frame Replication and Elimination (802.1CB)**
    - When the amendment introduces using more than 2 relay nodes simultaneously.
  - **Link Control (802.1Qca)**
- Note: The relaying described in this slide operates on MAC layer, though corresponding 802.1 Stds define routing in the network layer.

5.4 TSN Possibility in WBAN 15.6ma

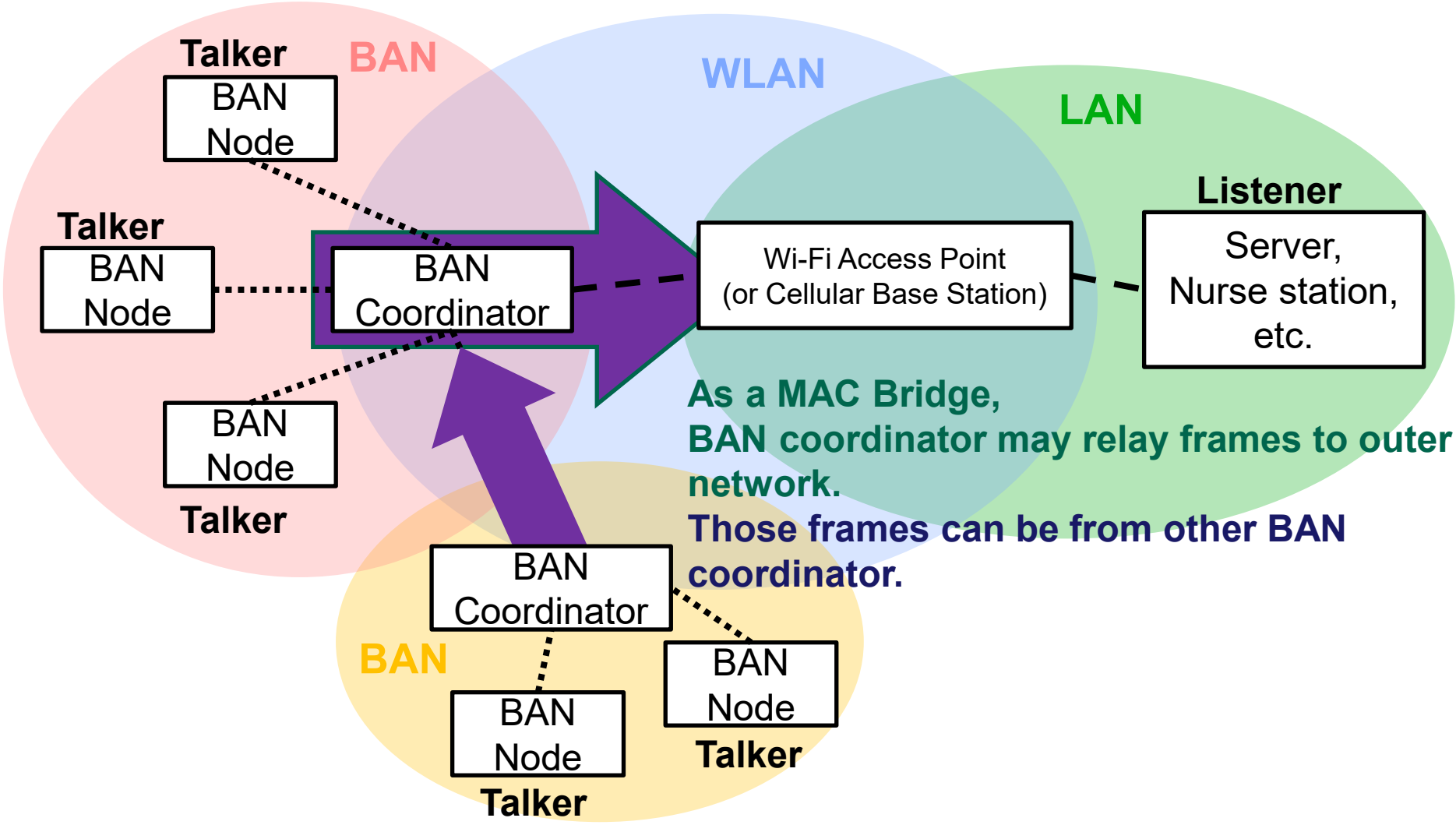
- 802.15.6 has BAN coordinator (hub) which can perform MAC bridge which connects two separate networks as 802.1 TSN(Time Sensitive Network).
- A coordinator connects to nodes in its own network.
  - Not only same nodes operate on the same PHY, but also different PHYs.
- The revision may enable a coordinator to connect to other coordinators, to avoid interference and enhance dependability.
  - Unlike wired network, wireless network shares same medium and collision occurs which plays significant role in dependability.

5.4 Possible bridging in 802.15.6ma

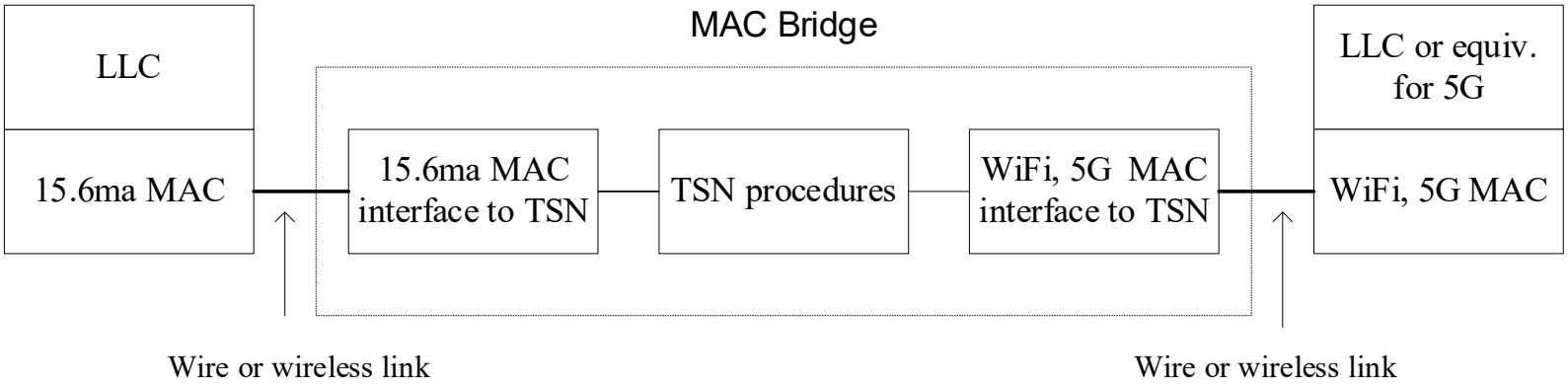


- BAN coordinator may relay frames to outer network as a MAC Bridge.

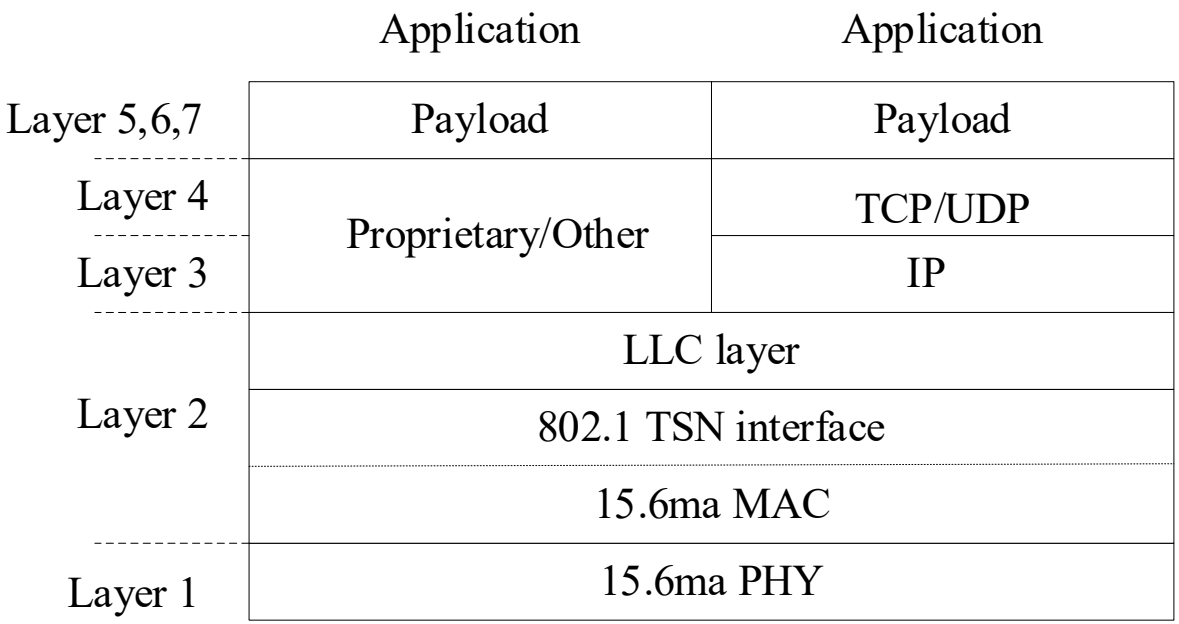
5.5 Coordinator to Coordinator Bridging



5.6 TSN equipment to infrastructure

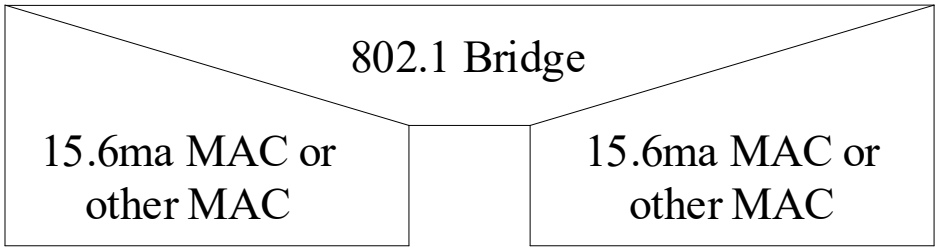


5.7 TSN in the 15.6ma protocol stack



5.7 TSN switch

15.6ma should focus on the MAC layer



Fortunately, there is no conflict with 802.1 MAC addresses.

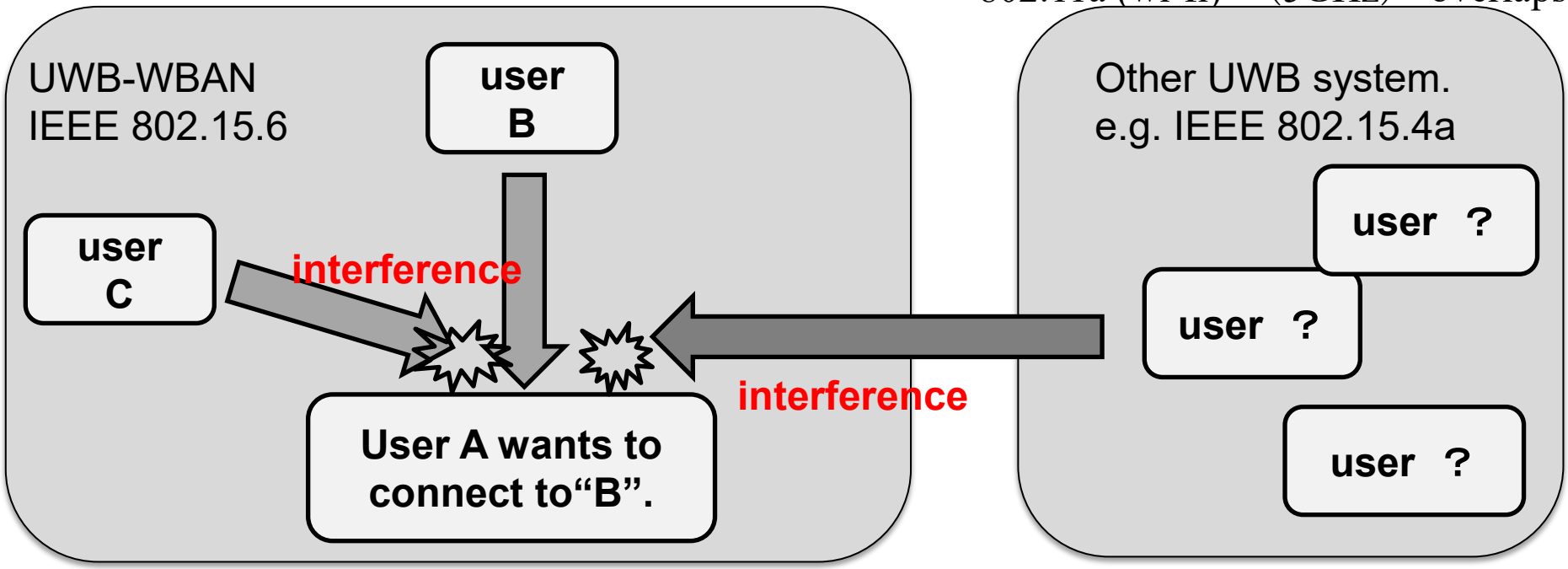
6. Available Technologies in PHY and MAC Layers for the Focused Use Cases for Revision of std 15.6-2012 for Human and Vehicle BANs with Enhanced Dependability TG16.6ma

Ryuji Kohno’(, Takumi Kobayashi (YNU/YRP-IAI)

6.1 Intra and Inter System Interference among BAN and Other PANs

- *Inter-user interference*
  - IR-UWB uses the same pulse as all users signal in the same standard.
  - Other users signal and/or the other network signal would be interference.
- *Inter-system interference*
  - Interference from the other wreless system using overlapped frequency band. ⇒ Unknown

＊ 802.11a (wi-fi) （5GHz） overlaps



6.2 Approach for Intra and Inter System Interference among BAN and Other PANs

- **Sparate** and **Recognize** each interference from different source.
  * Apply suitable interference mitigation method according to source of interference.
- Using both of Spatial and Temporal signal processing.

Inter-user interference
"IUI" in this presentation
Interference from a system using the same pulse

known → **Recognize and demodulate**
Pulse shape multiple access
Multi-user detection

Inter-system interference
"ISI" in this presentation
Interference from a system using overlapped frequency

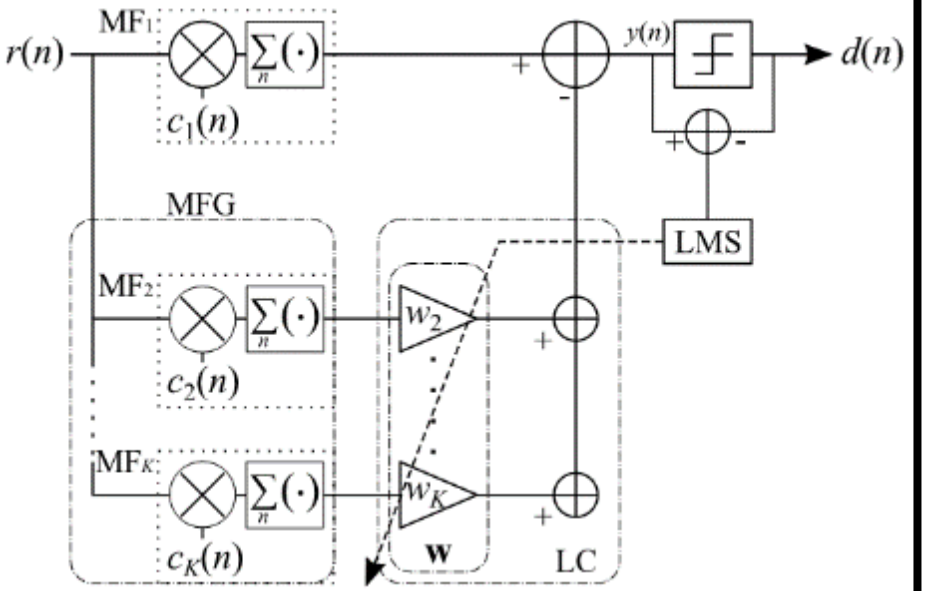
unknown → **Remove**
Interference canceller

6.3 Time Domain Interference Mitigation

OMF ; orthogonal matched filter

- consists a matched filter （MF_1） and MF Group（MFG）
- Tap coefficients of MF_1 are the same as sequence of desired signal.
- Coefficients of MF_1 and each MF_k that constituting MFG are orthogonal.
- Desired signal does not through $MF_{2\sim K\text{-}1}$ because orthogonality.
  →only interference can through.
- MFG makes replica of interference signal by lenear combination with weight vector w of linear combiner; LC.
- Subtract interference replica from the output of MF_1.

Principle of OMF



OMF can remove interference without any pre-knowledge of interference.

6.4 Space Domain Interference Mitigation

TDL-AA ; Tapped delay line array antenna

(Tapped delay line array antenna)

- Array antenna by using multiple antenna elements and tapped delay line.
- Each antenna branch has coefficients.
- Transfer function of this antenna has parameters of signal incoming angle;θ and frequency; ω.

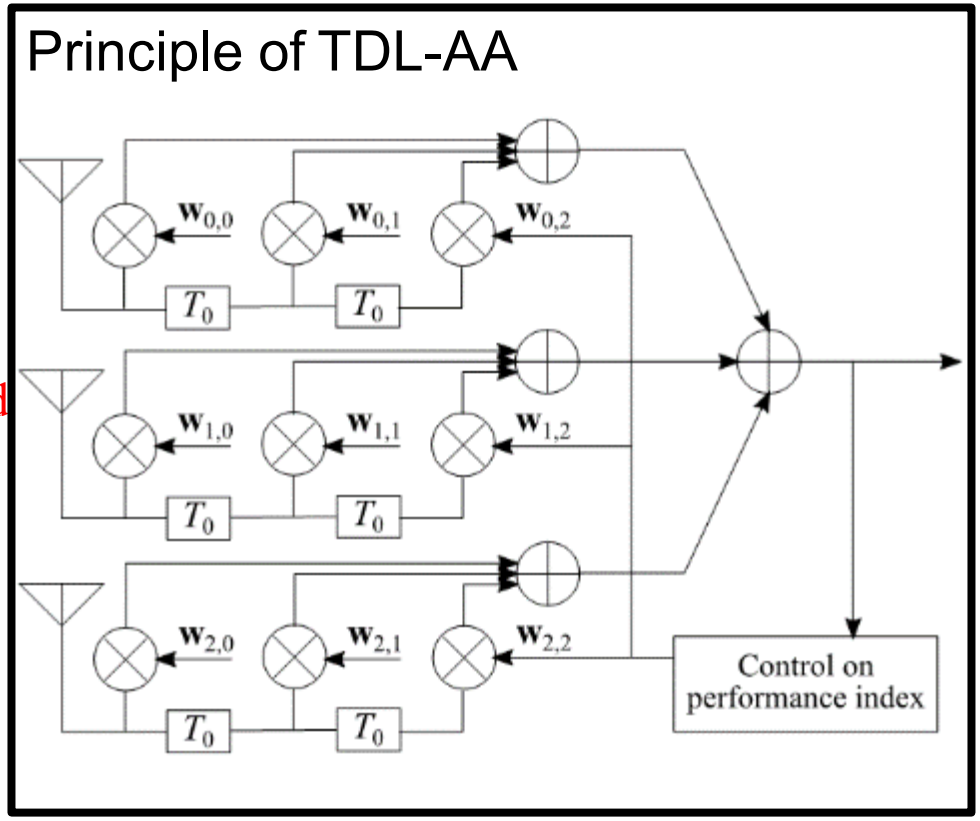
$\Rightarrow$ h a s characteristics of both of spatial and time domain.

$$\tau_n = n\frac{d}{c}\sin\theta,$$

$$y(t) = \exp(j\omega t)\sum_{n=0}^{N-1}\sum_{m=0}^{M-1}\exp(-j\omega(\tau_n + mT_0))w_{n.m},$$

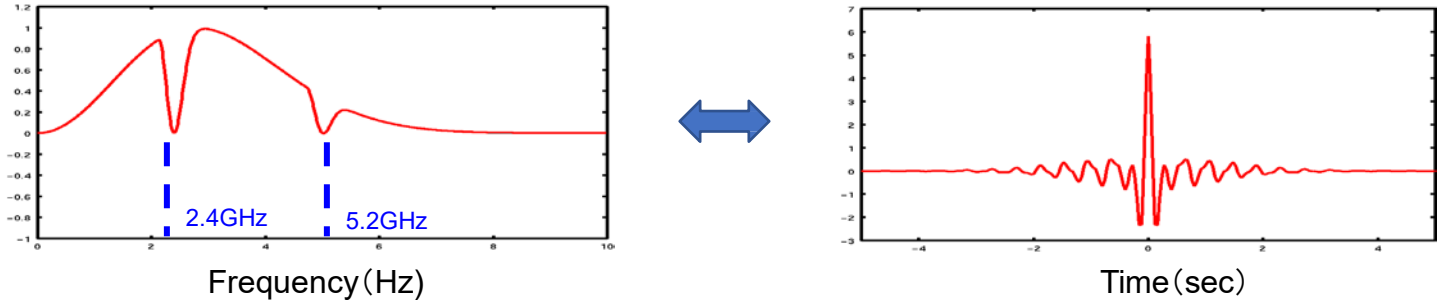
$$= \exp(j\omega t) \times H(\theta,\omega),$$

$$H(\theta,\omega) = \sum_{n=0}^{N-1}\sum_{m=0}^{M-1} w_{n,m}\exp(-jm\omega T_0)\exp(-jn\omega\frac{d}{c}\sin\theta).$$

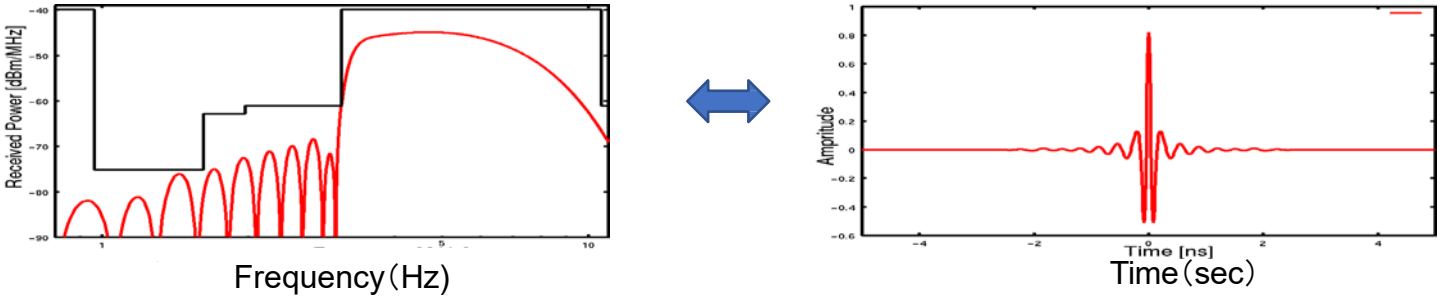


TDL-AA can work as interference canceller on both of time and space domains

6.5 Interference Mitigation among Other Radios



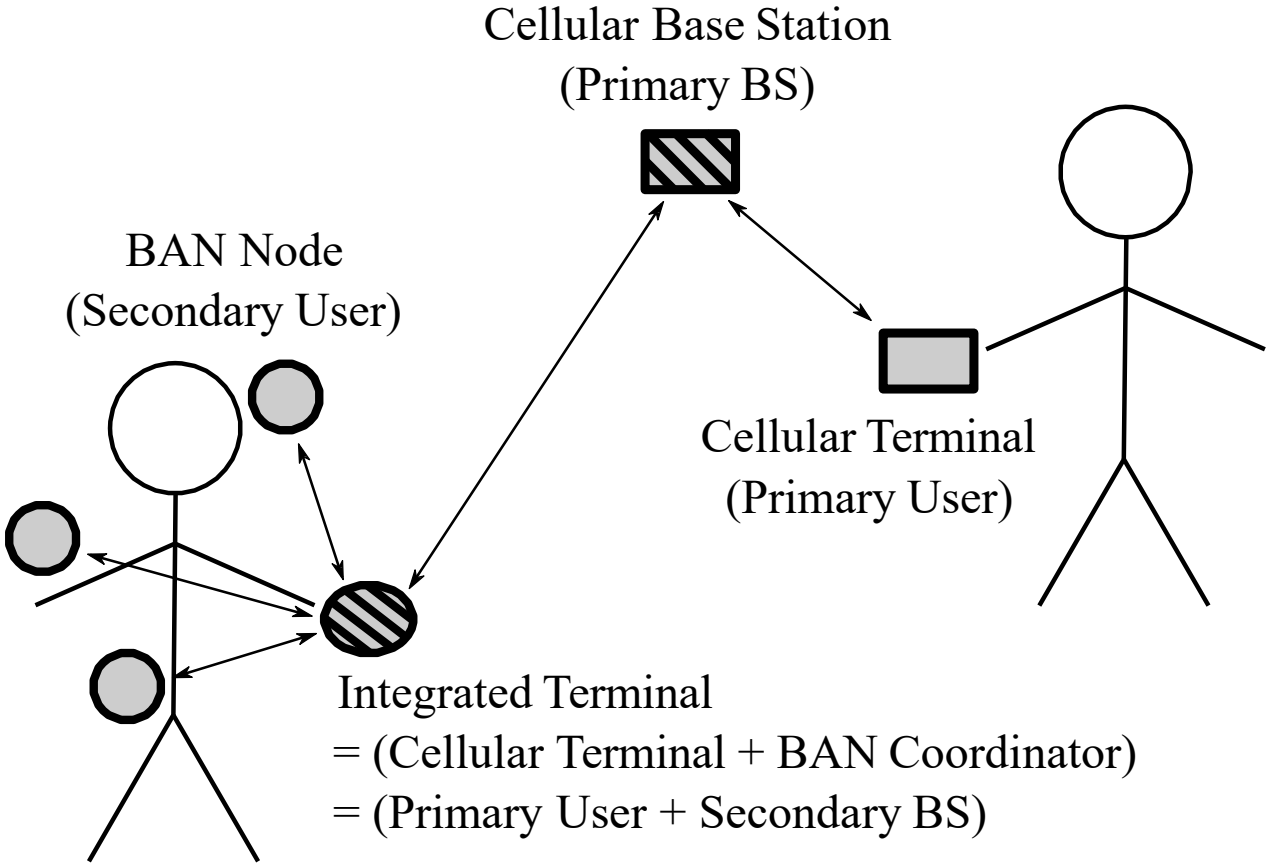
(a) Time Waveform of Pulse (right figure) and its Frequency Spectrum with notches in 2.4 and 5.2GHz for WLAN (left figure)



(b) Time Waveform of Pulse (right figure) and its Frequency Spectrum satisfying spectrum mask (left figure)

Ref. R.Kohno, H.Zhang, H.Nagasaka, "Ultra Wideband impulse radio using free-verse pulse waveform shaping , Soft-Spectrum adaptation, and local sine template receiving," doc.: IEEE 802.15-03/097r1, March 3, 2003.

6.6 Integrated Terminal to Avoid Mutual Interference in case of overlaid coexisting BAN and other Radios such as UWB-BAN and 4G/5G



M. Kim, T. Kobayashi, C.Sugimoto, R Kohno, "Transmission Power Control of UWB -WBAN for Avoidance of Interference to Cellular Networks Using Integrated Terminal for Both Networks," International Journal of Computer Science and Telecommunications, ISSN 2047-3338 (Online) , Vol. 11, Issue 02, pp.8-15, March 2020

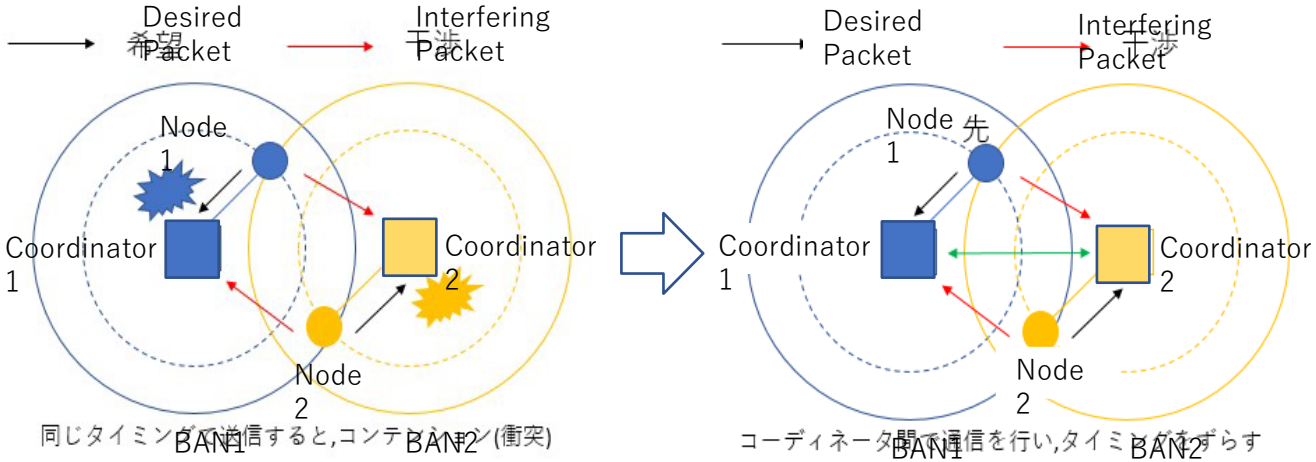
6.7 Contention among Overlaid BANs

Issue

- Interference problem in the case where multiple BANs overlap (specifically, situations where people with BAN approaching)
  - Because the schedule adjustment between the coordinators has not been done

Solution

- Negotiation between coordinators, scheduling between different BANs, to prevent deterioration due to inter-BAN interference



- What is interference at the MAC layer
  - Sensor nodes within the communication range try to transmit packets at the same timing, causing collisions, making it impossible to communicate correctly

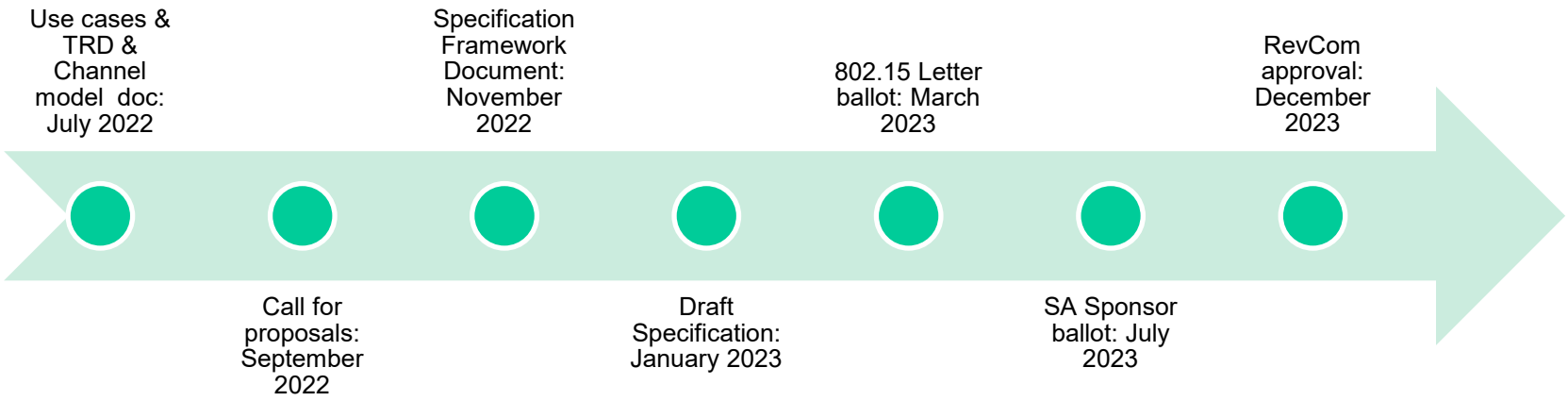
Ref. R.Kohno, S.Ogawa, "MAC Protocol with Interference Mitigation Using Negotiation among Coordinators in Multiple Wireless Body Area Networks (BANs)," IEEE802.15 doc.#15-19-0119-00-0dep-ig-dep, Vancouver, Canada, March 12, 2019

7. Concluding Remark

- Corresponding request from ETSI smart BAN and smart M2M, IG-DEP and its successive SG15.6a have discussed to focus on internal car network for IoT/M2M connections that is focused on BAN for human and car bodies.
- As revision of IEEE802.15.6, MAC for multiple BANs can be guaranteed to satisfy permissible delay or back-off time and throughput of high QoS packets for human and vehicle BANs while maintaining average performance.
- As revision of IEEE802.15.6, PHY for UWB radios should be revised for updated UWB regulation. In particular, coexistence among different UWB radios of IEEE802.15 such as 15.4a, 15.4f, 15.4z can be supported. For instance, during CCA, types or features of these UWB radios can be analyzed to control access of packets from each radio.
- To include new use cases with enhanced dependability such as the 2nd Generation of ECoG for Brain-Machine-Interface(BMI), technical requirement has been updated to cover higher data rate and more units of ECoG sensors .
- We focus on revision of IEEE802.15.6 for enhanced dependability in PHY and MAC, call for proposals satisfying TRD and establish IEEE802.15.6ma.
- If you have any question and comment, you are welcome to discussion in TG15.6ma and send content contributions to

Ryuji Kohno <kohno@ynu.ac.jp> and Takumi Kobayashi <Kobayashi-takumi-ch@ynu.ac.jp>

Timeline for IEEE802.15.6 Revision (6ma)– Enhanced Dependability Body Area Network (ED-BAN)



Contacts and Conference call

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- **Thank You !**
- **Any Questions ?**