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

Submission Title: [Overview of Activity of IEEE802.15 TG15.6ma for Revision of IEEE802.15.6-2012 Wireless BAN with Enhanced Dependability]

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Abstract: [This document summarizes standardization activity of IEEE802.15 Task Group(TG)6ma for revision of IEEE802.15.6 - 2012 Medical Body Area Network(BAN) corresponding to increasing for enhanced dependability in wireless sensing and controlling human and vehicle bodies for medical healthcare and automotive uses. After quick overview of IEEE802.15.6 -2012, necessity of the revision 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 networks in some overlaid frequency band etc. Extension of BAN from human body for medical healthcare to car body for automotive uses and their combination makes a larger market and a new application in medical and automotive industries with a common standard.]

Purpose: [information]

Overview of Activity of IEEE802.15 TG15.6ma for Revision of IEEE802.15.6-2012 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 Revision of BAN with Enhanced Dependability**
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**
5. **Requirement for Revision of 15.6 MAC for Human and Vehicle BANs with Enhanced Dependability TG16.6ma**
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**
7. **Timeline of TG6ma**

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.**

COVID-19 Pandemic **Population Ageing**

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

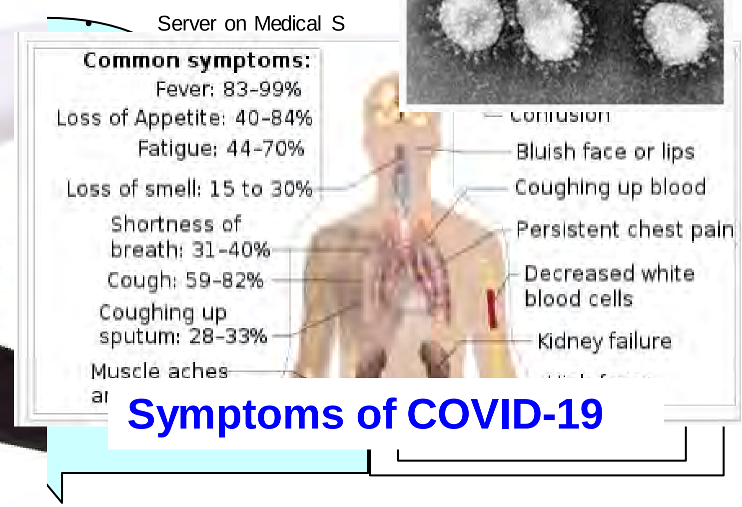
1.2 Medical Inspection and Treatment by BAN

- 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

Coronavirus

- **WBAN can apply for**

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



Symptoms of COVID-19

1.3 Wireless BAN: Body Area Network

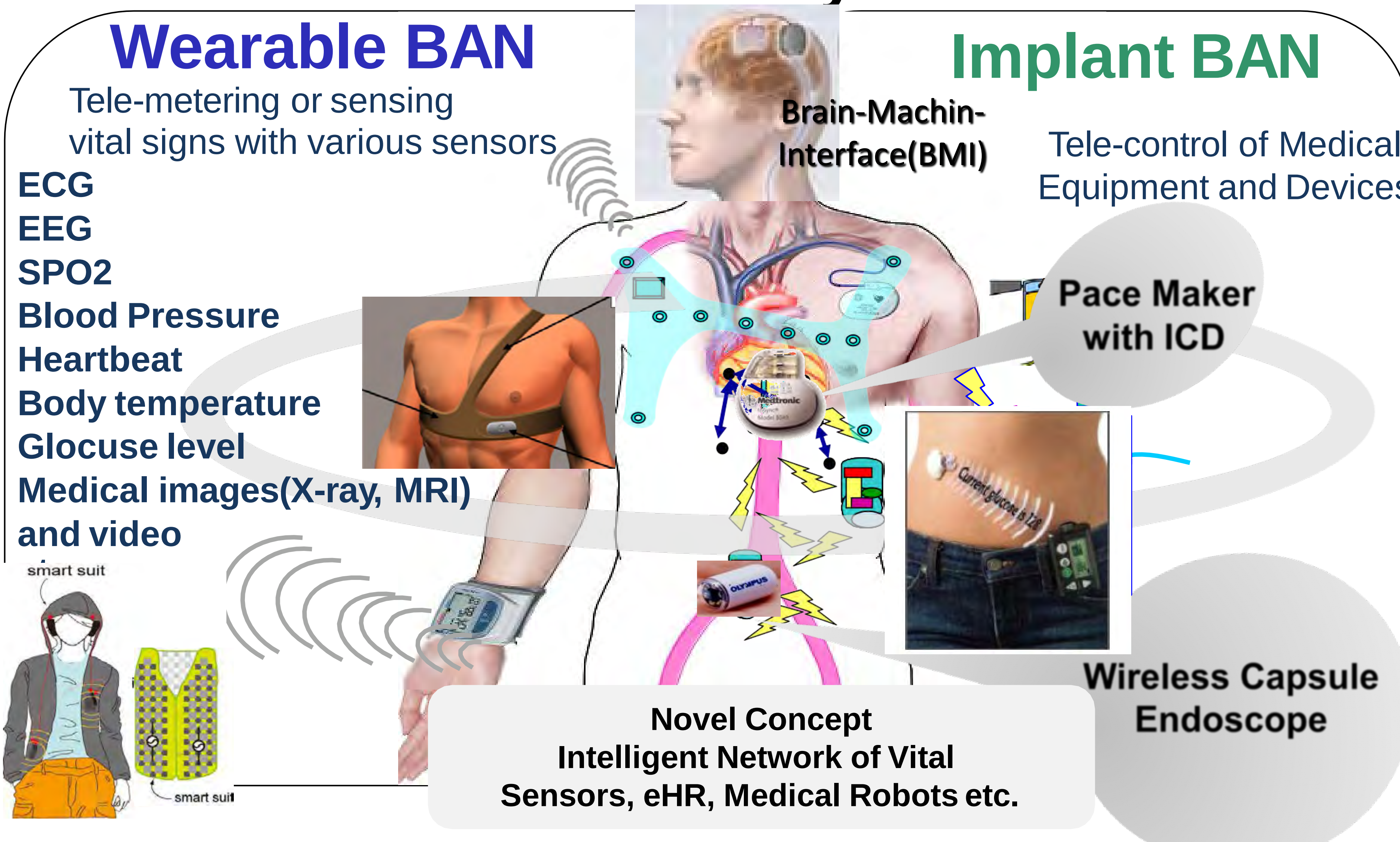
Wearable BAN

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

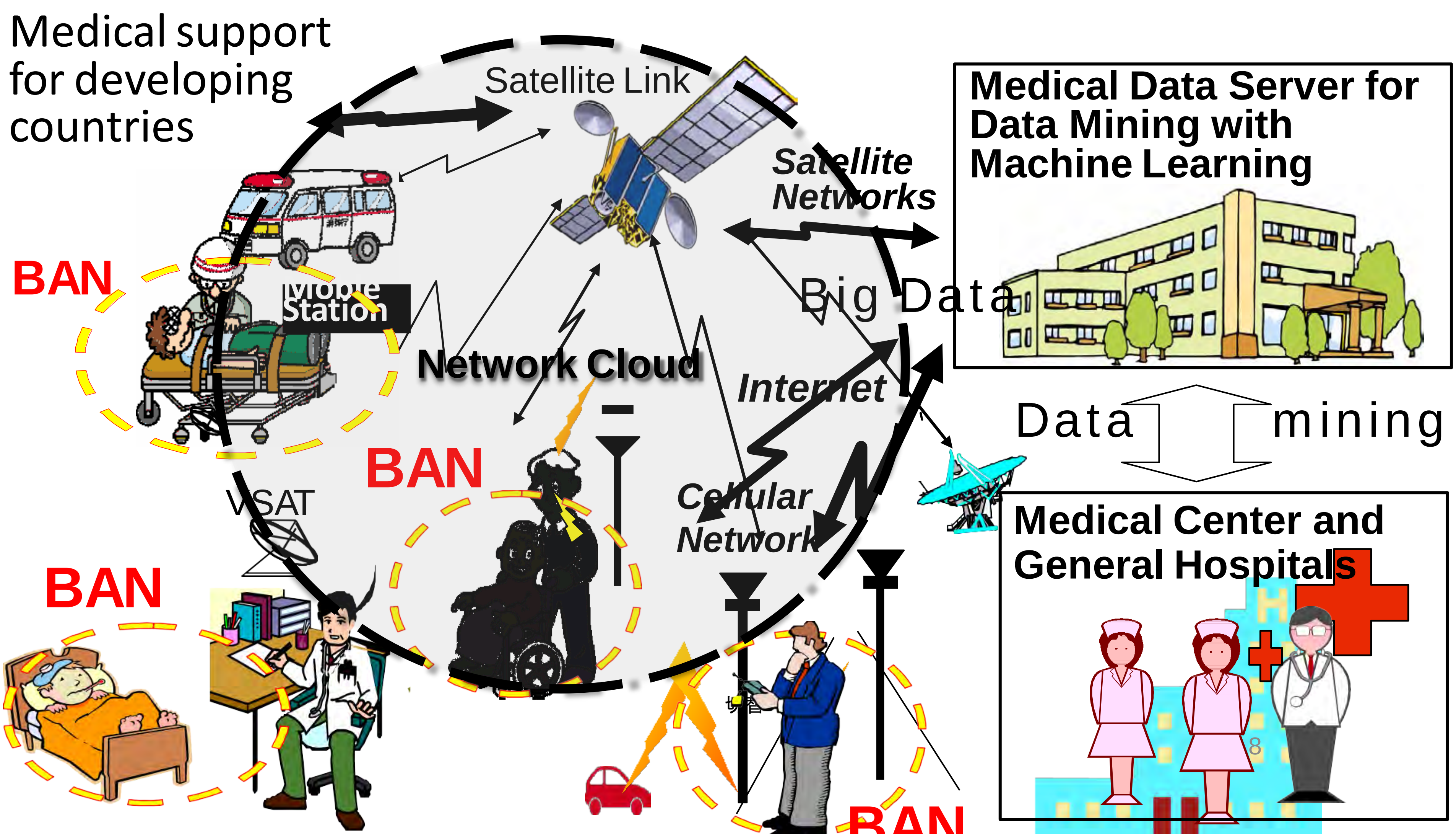
Implant BAN

Tele-control of Medical
Equipment and Devices

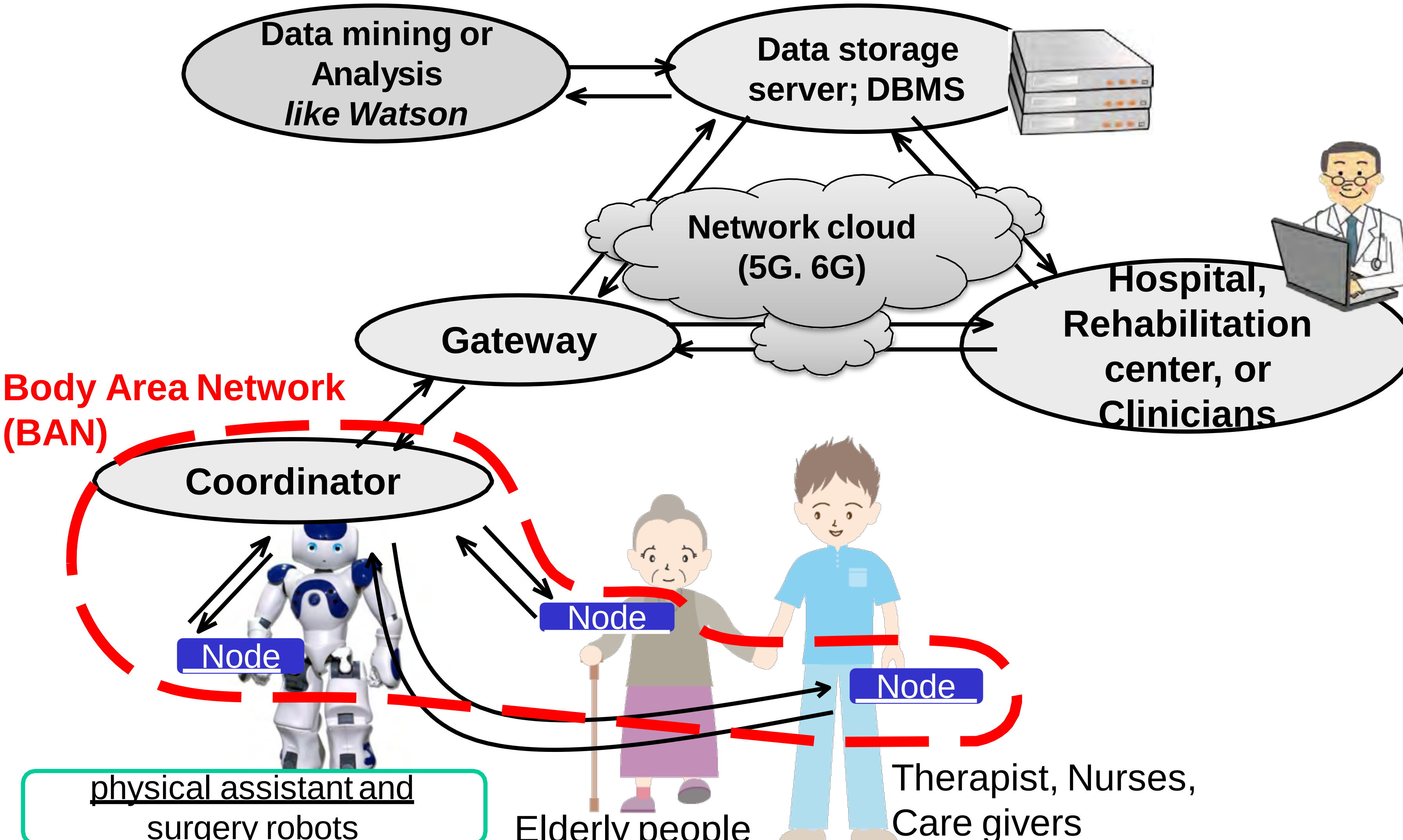


Novel Concept
Intelligent Network of Vital
Sensors, eHR, Medical Robots etc.

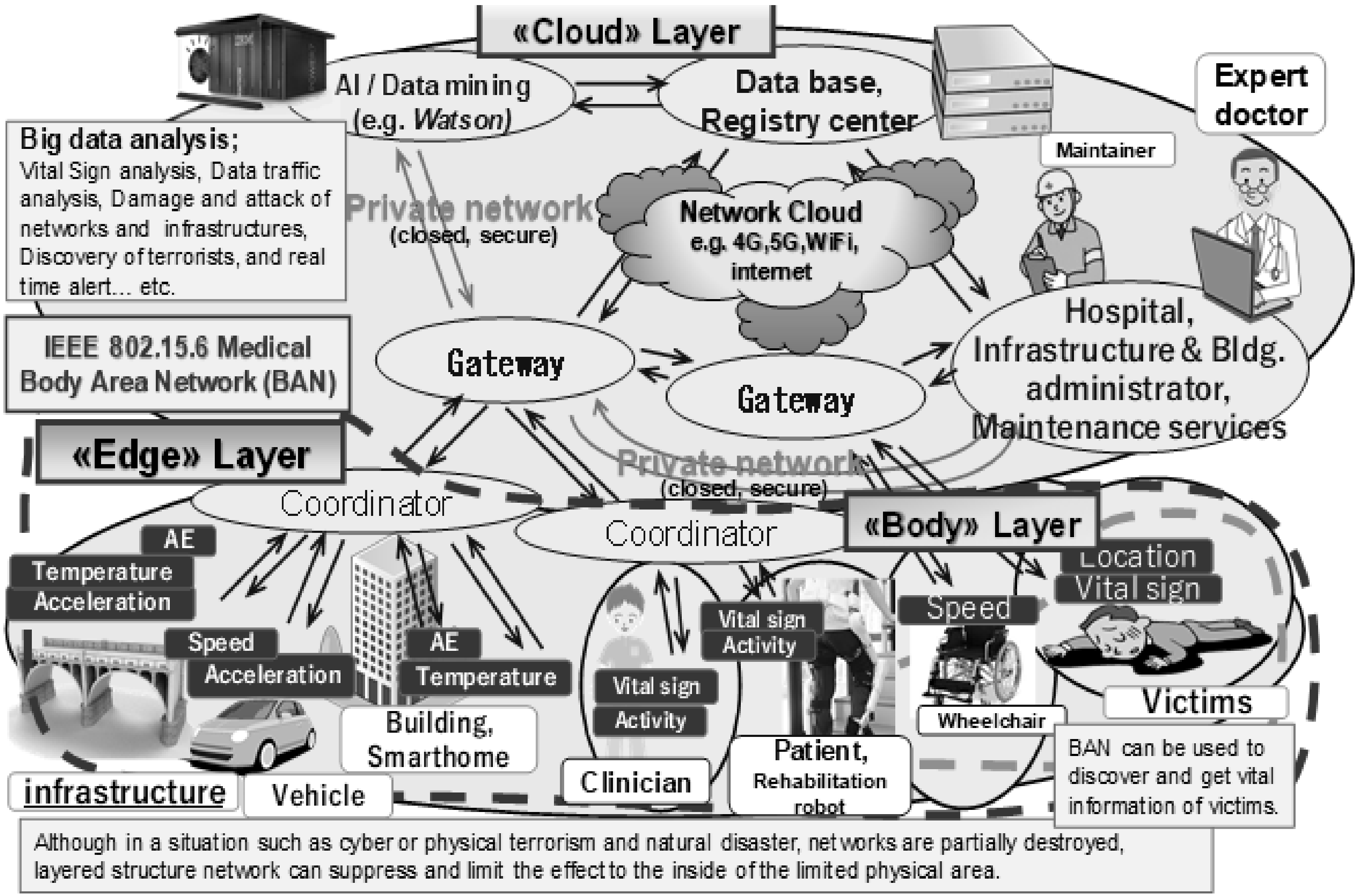
1.4 BAN- Use Cases for Remote Medical Services



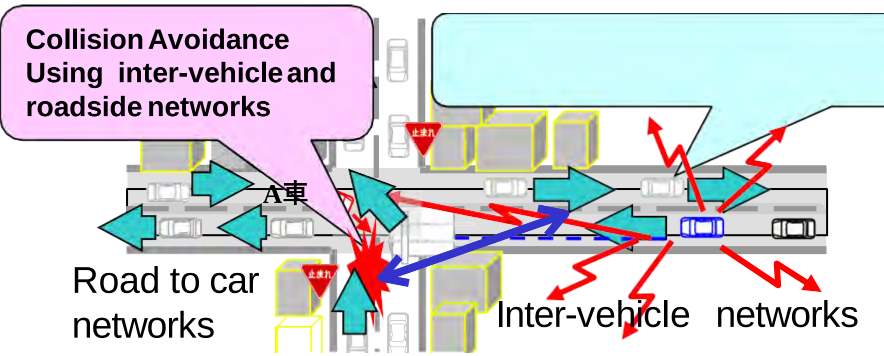
1.5 BAN-base Universal Platform with Network Cloud, Data Mining Server for Medical Healthcare



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



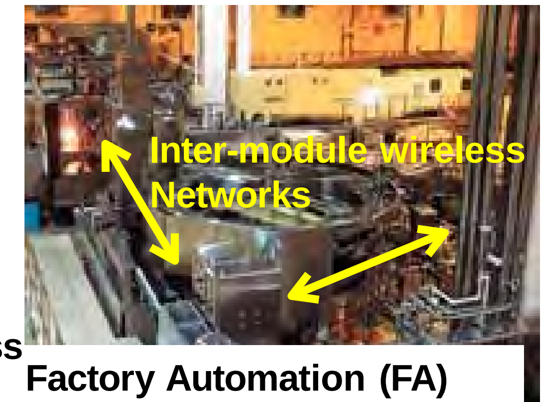
1.7 Extension of Use Cases of BAN beyond Medical Healthcare



Car Navigation & Collision Avoidance Radar

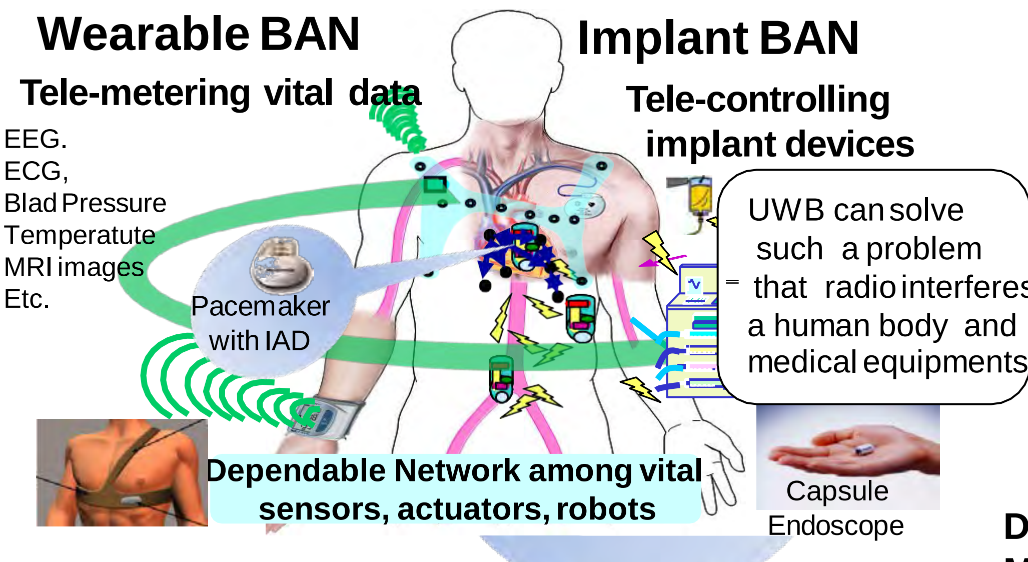
Car LAN & Wireless Harness

Dependable Wireless Networks for Transportation

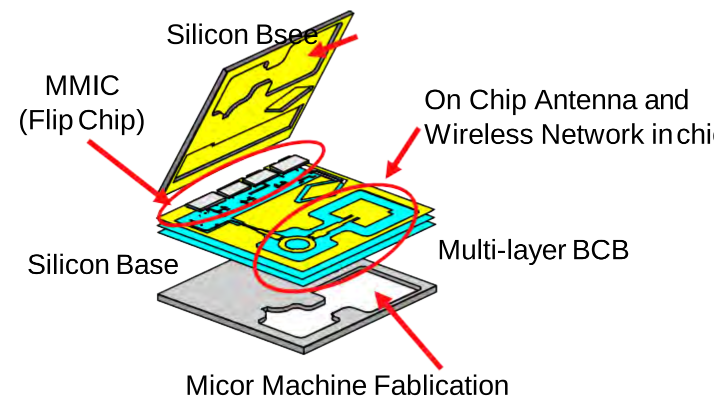


Factory Automation (FA)

Dependable Wireless Sensing & Controlling for Manufacturing (CIM)

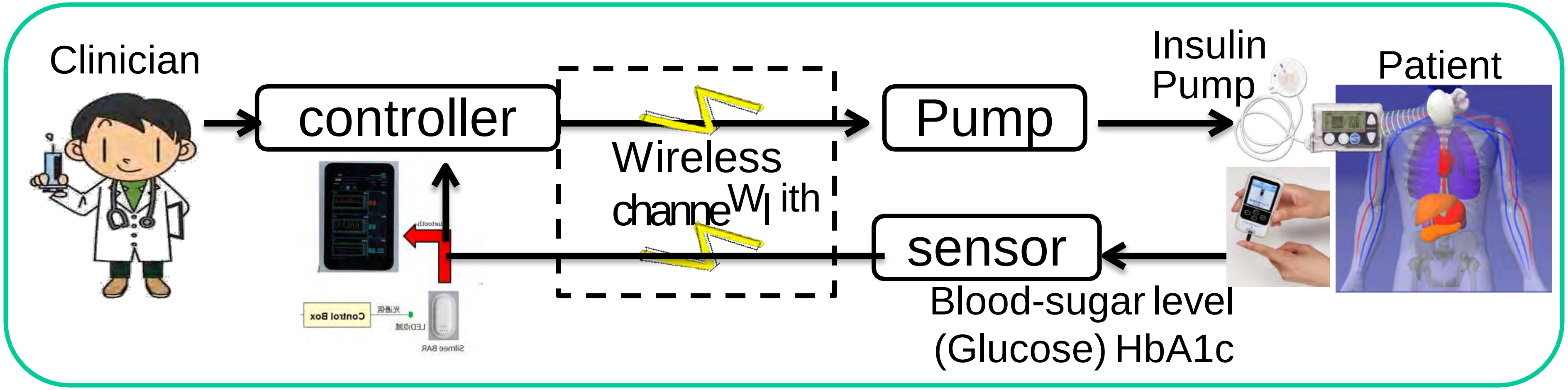


Dependable BAN for Medical Healthcare

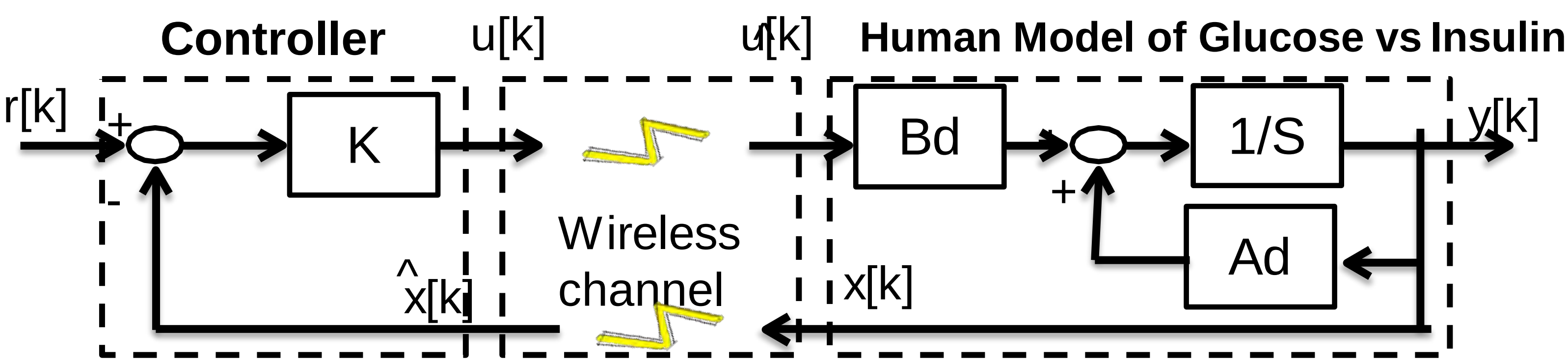


Dependable Wireless System Clock in Micro Circuit & Network in Devices

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

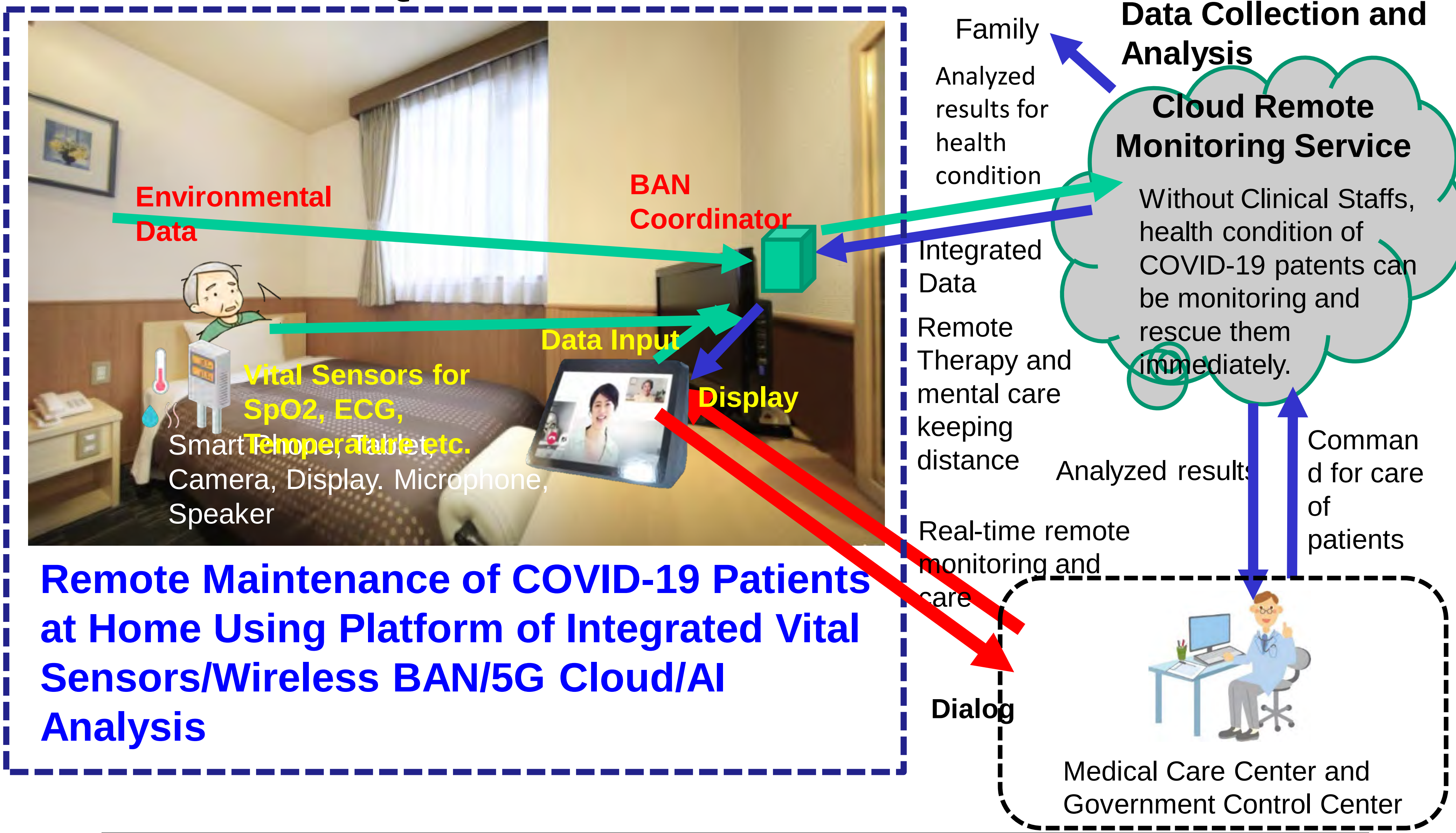


Wireless Feedback Sensing and Controlling Loop for Diabetes Patients



Feedback Delay Loop Model with Motion Equation

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



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

Smart Vehiles

EV and HV

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

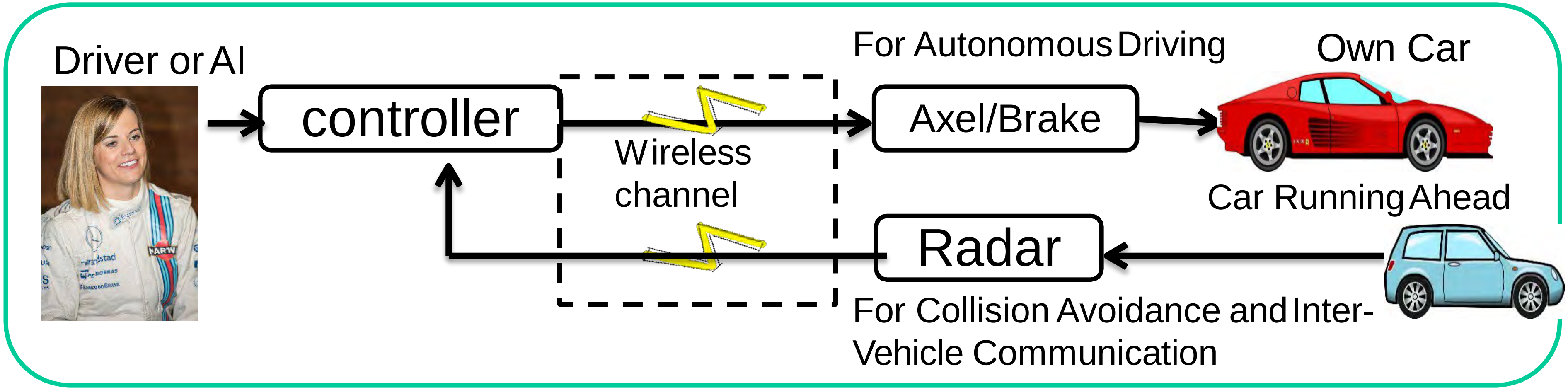
C. Approach:

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

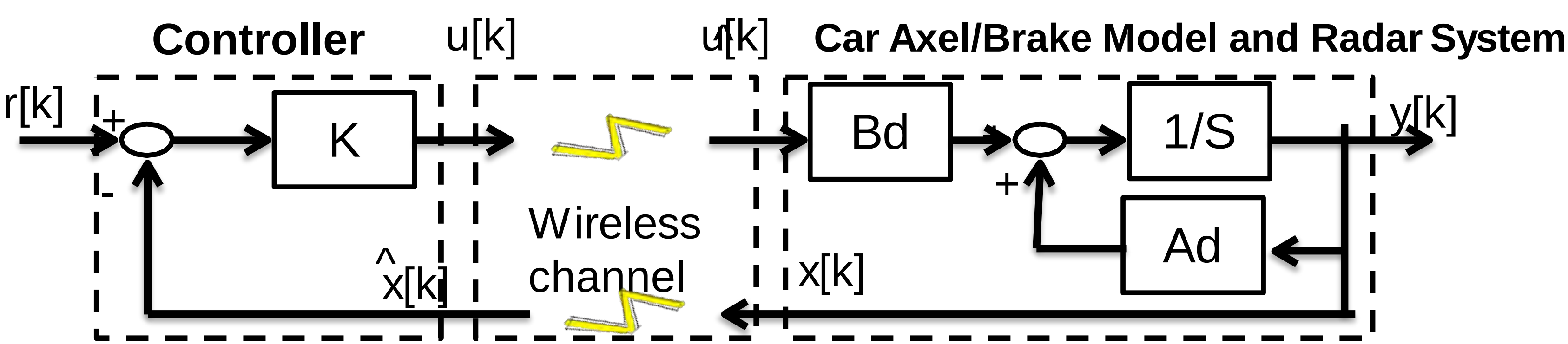
(2) Promote International Standard of Wireless Body Network（BAN) and Integrated Platform of BAN/5G/AI for Global Marketing for both Medical and Automotive uses

(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

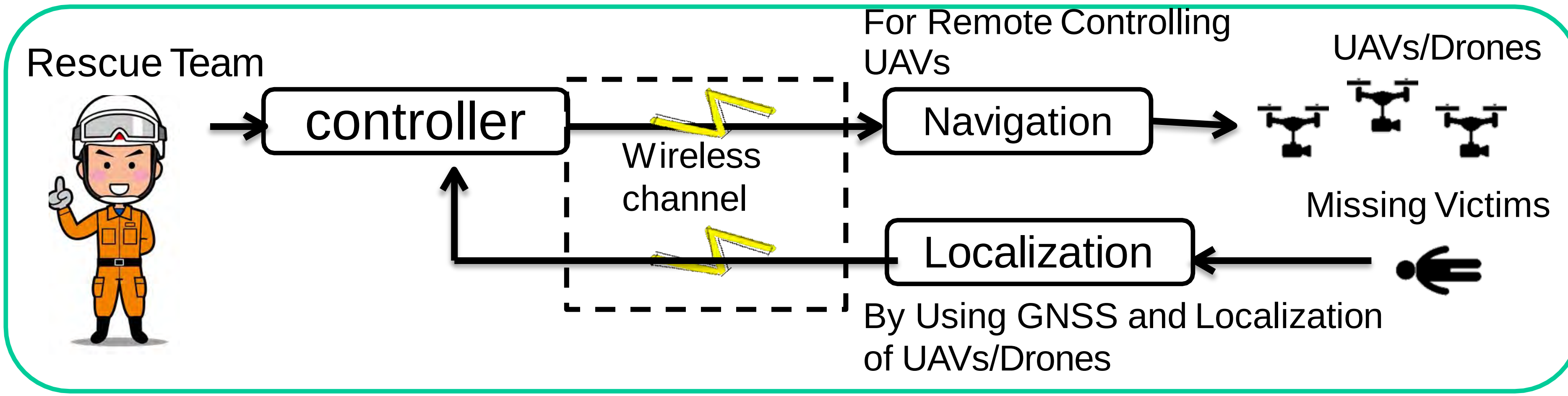


Wireless Feedback Sensing and Controlling Loop for Autonomous Driving

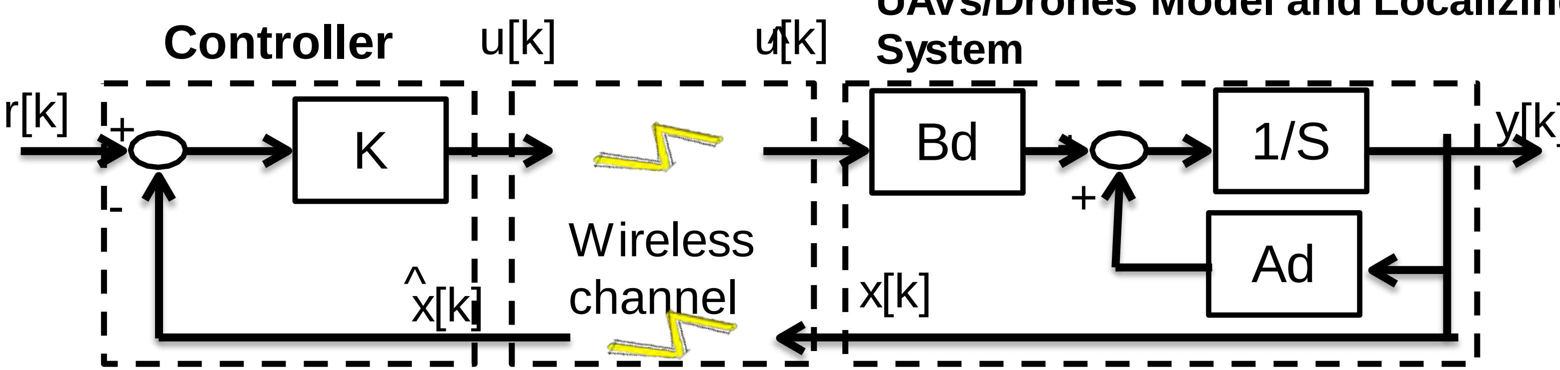


Feedback Delay Loop Model with Motion Equation

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

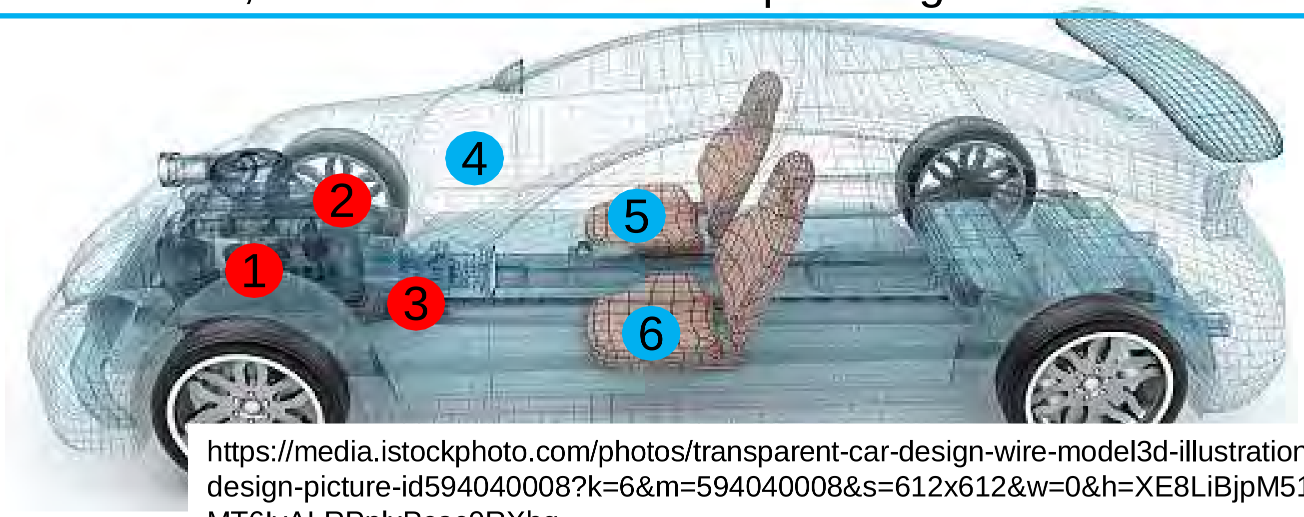
Motivation to extend human BAN(HBAN) to VBAN is to promote much dependable services by interaction between HBAN and VBAN.

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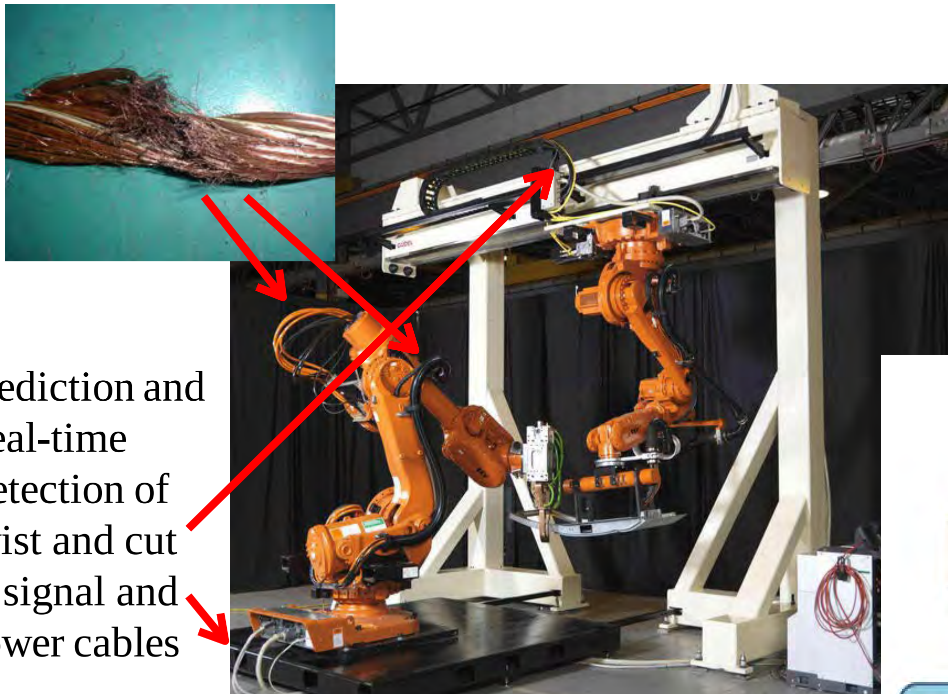
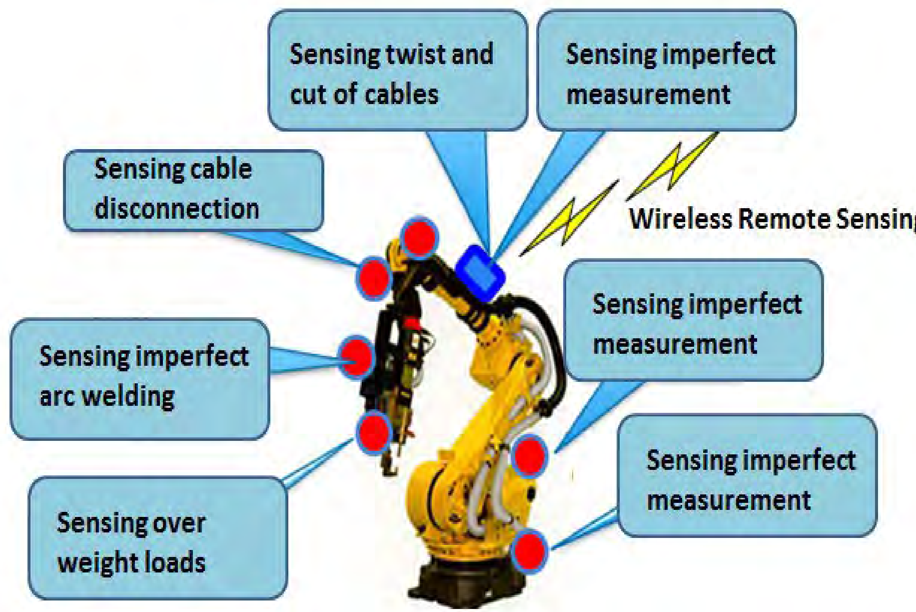
1.12 Use case in Factory Manufacturing Line; Detection of Twist and Cut of Cables



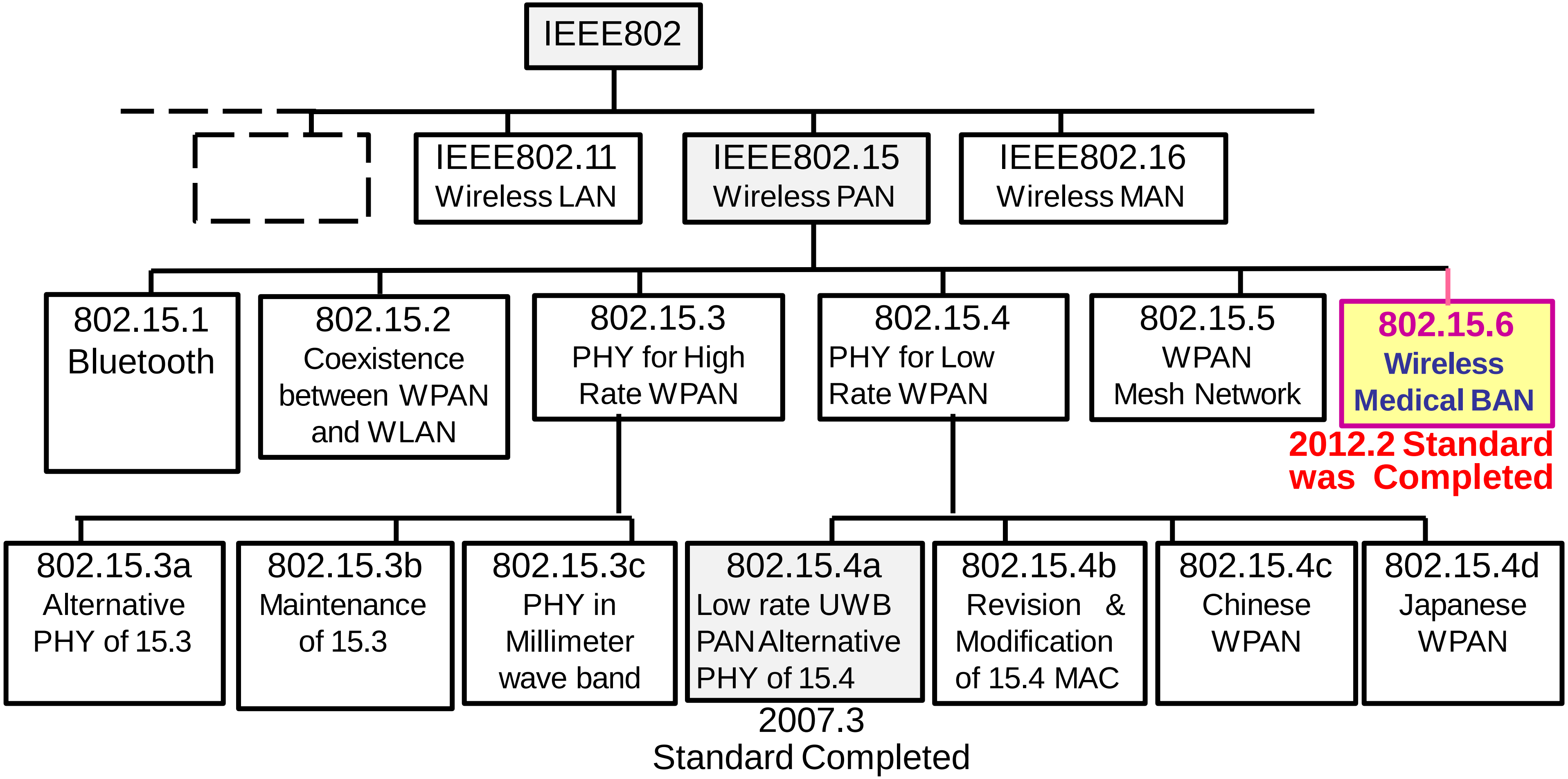
Prediction and Real-time Detection of twist and cut in signal and power cables

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

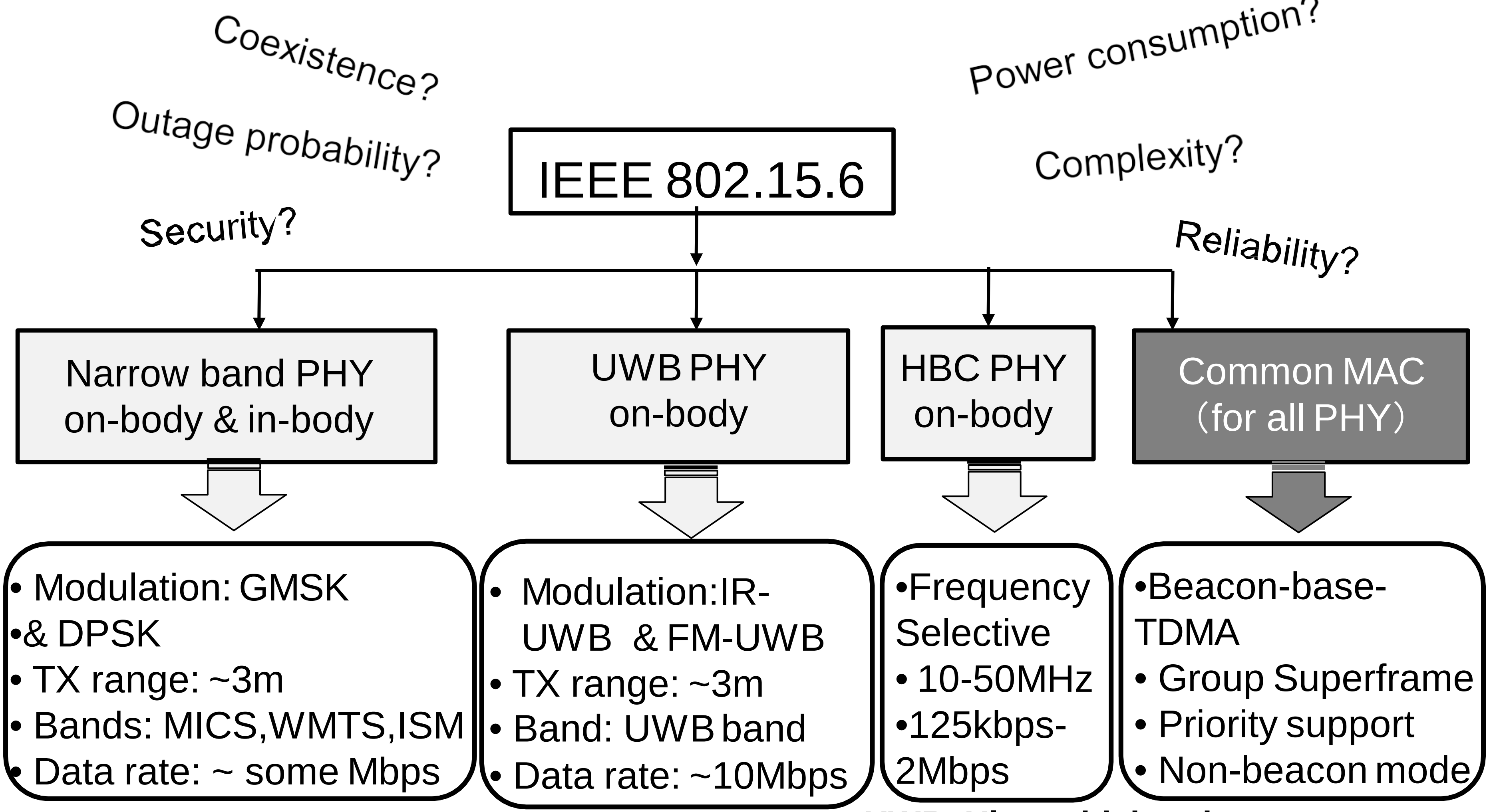


2. Short Review of WBAN Standard IEEE802.15.6-2012

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

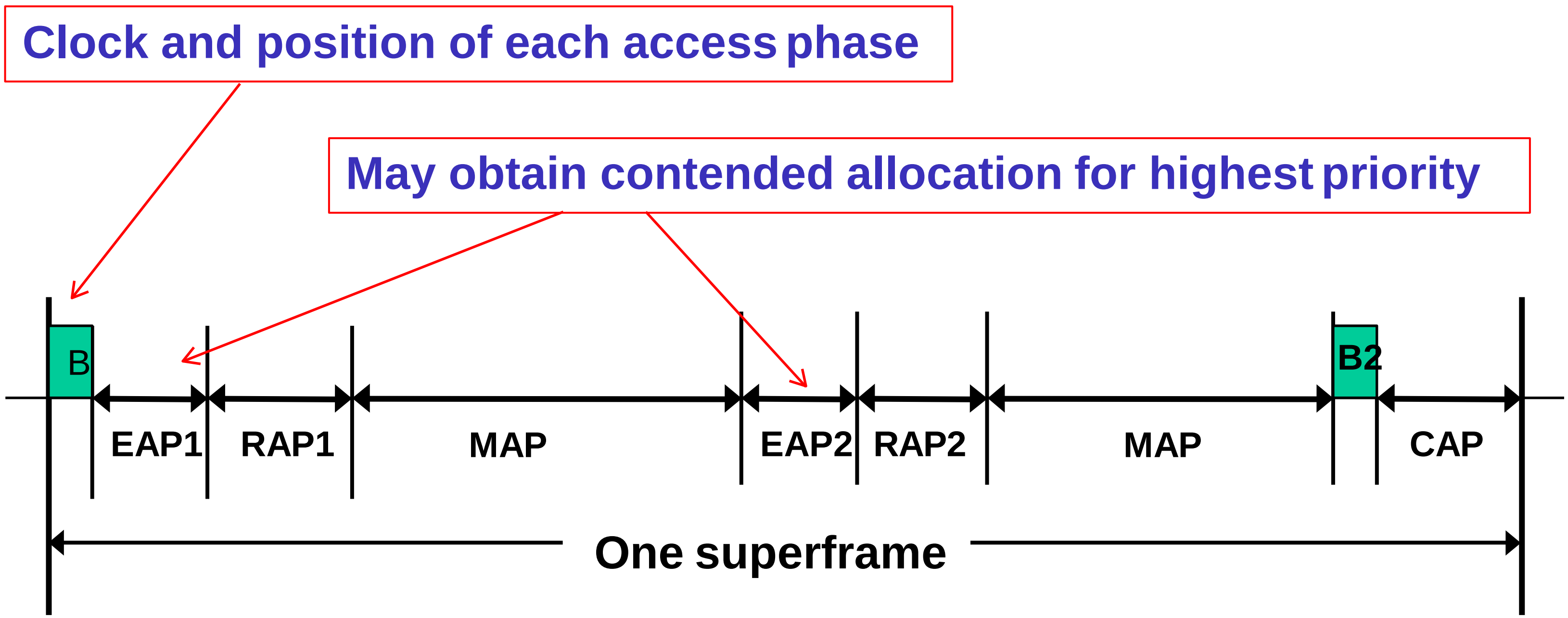
2.3 User Priority Mapping

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

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



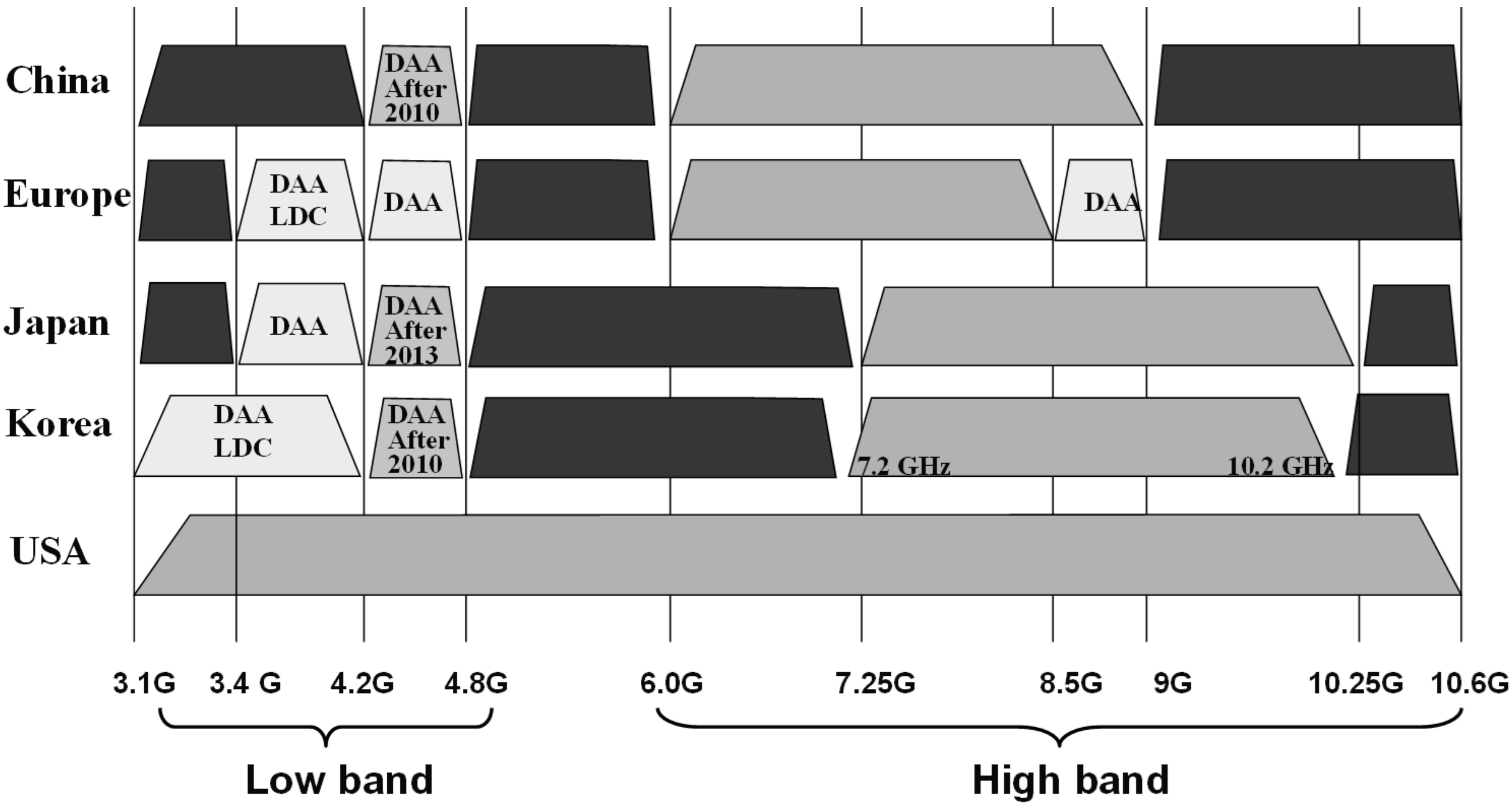
EAP: exclusive access phase

RAP: random access phase

MAP: managed access phase

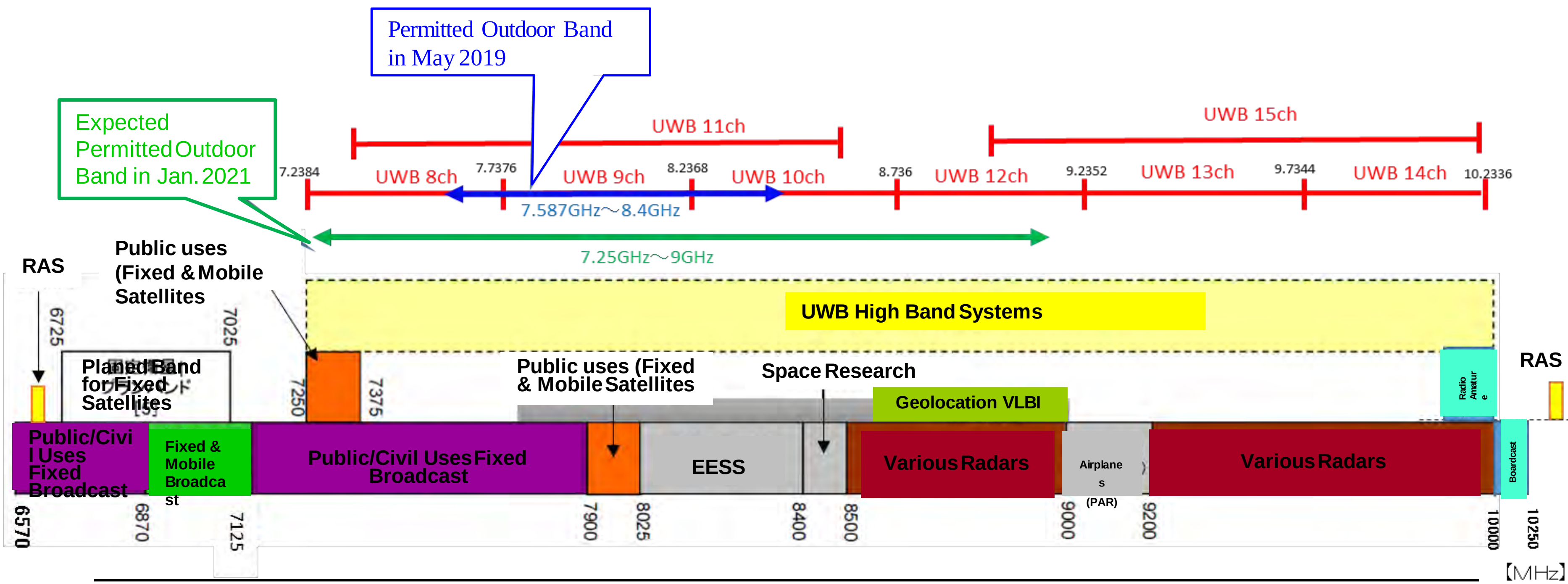
CAP: contention access phase

2.6 Worldwide UWB Regulations in 2012



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 Revision 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)

Physical(PHY) layer 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

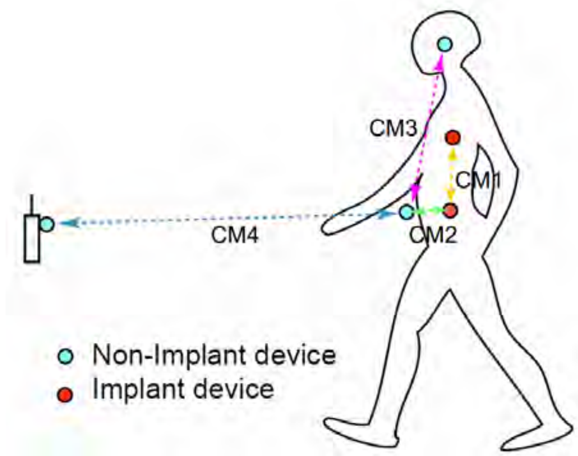
- Interoperability with narrow band and UWB PHY
- more flexible network topology,
- Transparency with other standards such as ETSI SmartBAN

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

4.1 Channel models and scenarios in IEEE802.15.6ma

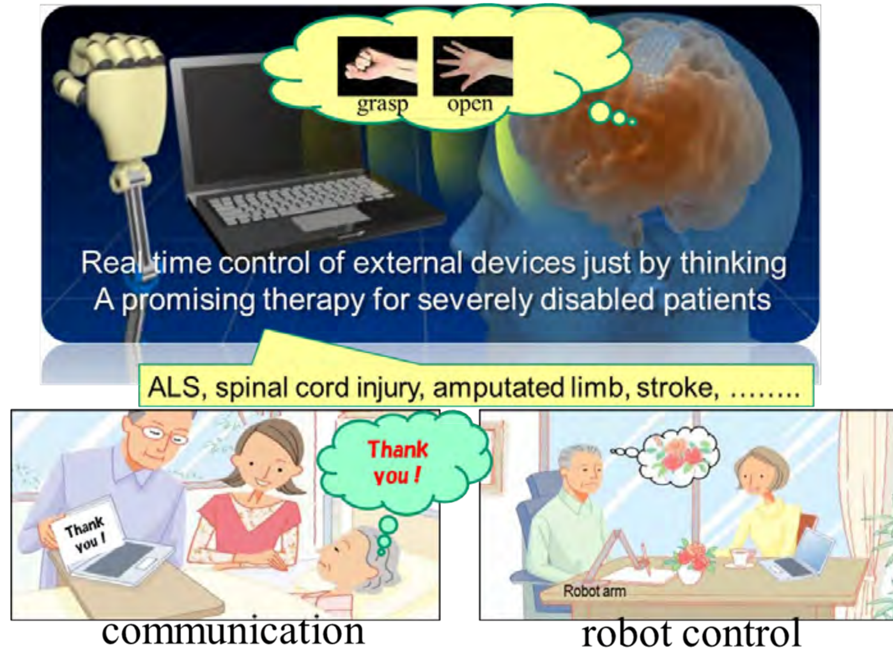


- Path loss (Mandatory)
- Optional;
  - Fading (Small scale/ large scale)
  - Shadowing
  - Power delay profile

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

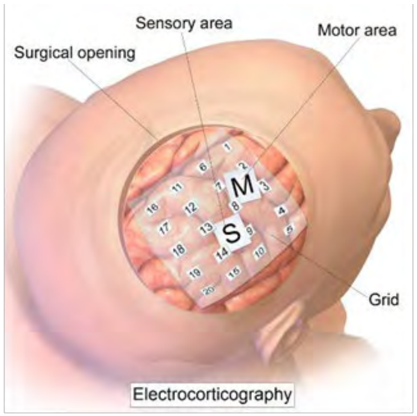
4.2 Brain-Machine-Interface(BMI): Wireless Body Area Network (BAN) with AI Machine-Learning and User-Interface

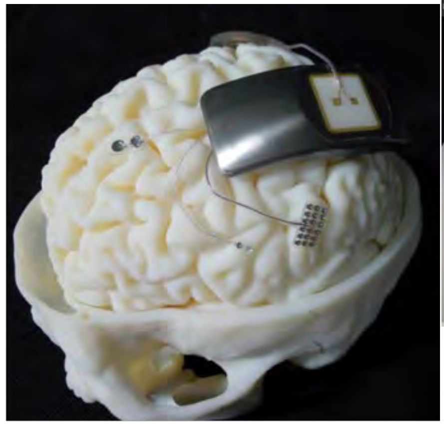


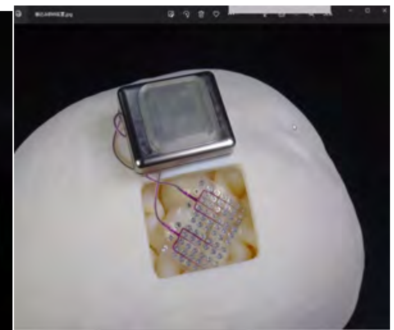
Brain-Computer-Interface(BCI) for Understanding Human Contention and Machine Control.

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







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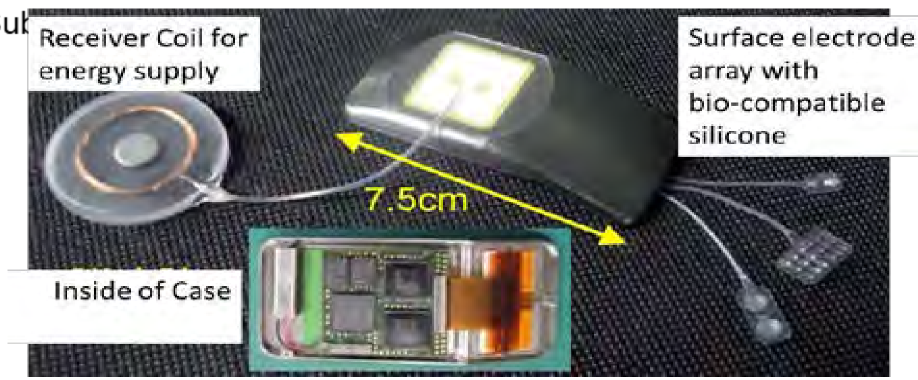
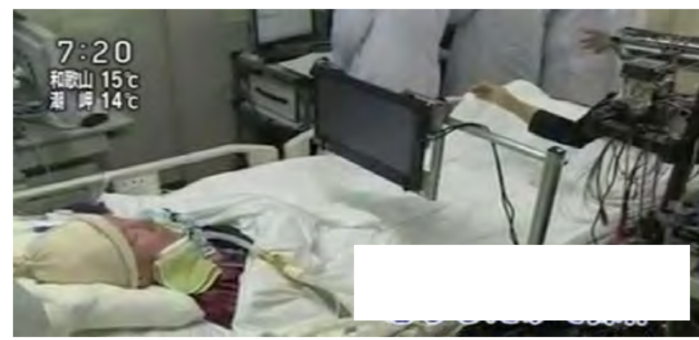




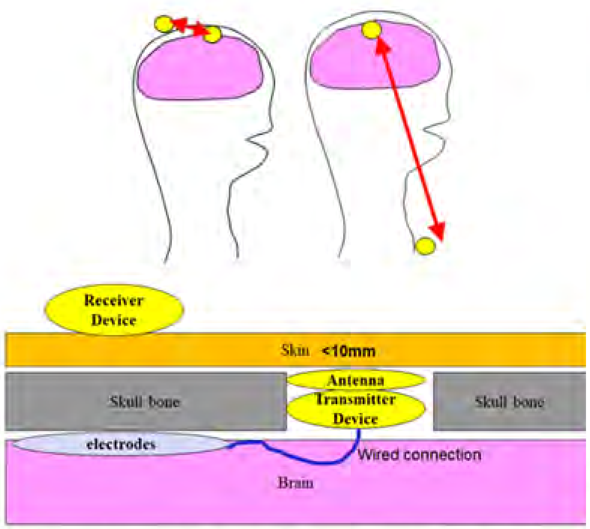
ECoG（Electrocorticogram) detected with implanted thousands of electrodes is transmitted in wireless by BAN with high capacity and dependability.

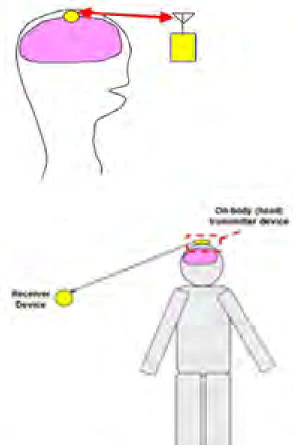
Brain-Machine-Interface(BMI) systems for Clinical Support to Disability such as autonomous robot hand control and communication assistance.

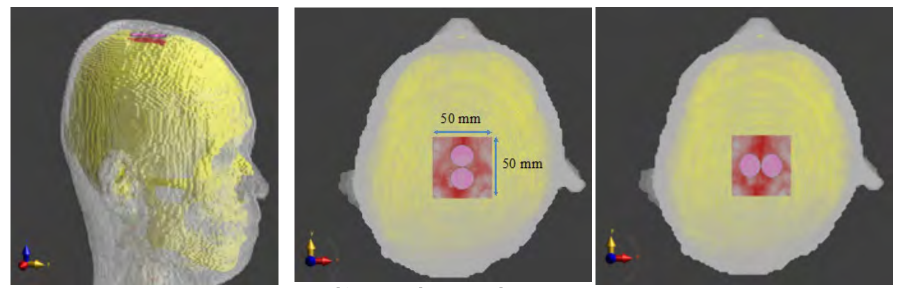
4.2 Channel models and scenarios in use case of BMI and BCI(Brain-Computer-Interface)

We will define what is BCI and BMI.

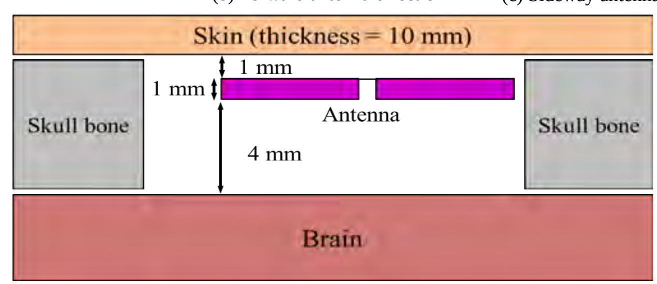
Specific use cases
Implant to Body Surface for BCI
Implant to External for BCI
Body surface to body surface for BCI
Body Surface to External for BCI
Implant to body surface for capsule endoscopy







(b) Forward antenna direction (c) Sideway antenna direction

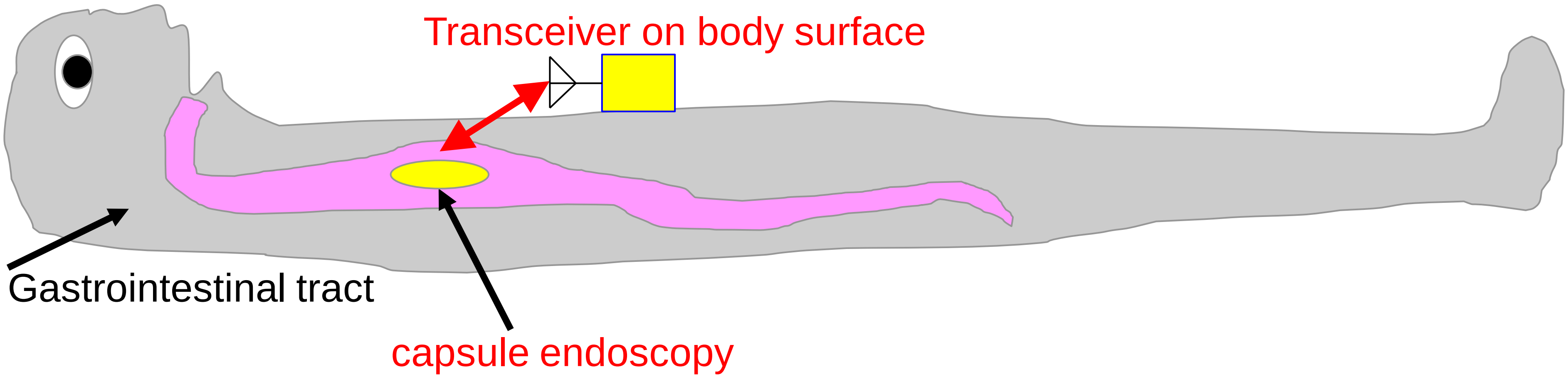


- Implant to Body Surface for BCI
- Body Surface to External on-body surface for BCI
- Implant to External for BCI

Simulation and measured models of implant transmitters

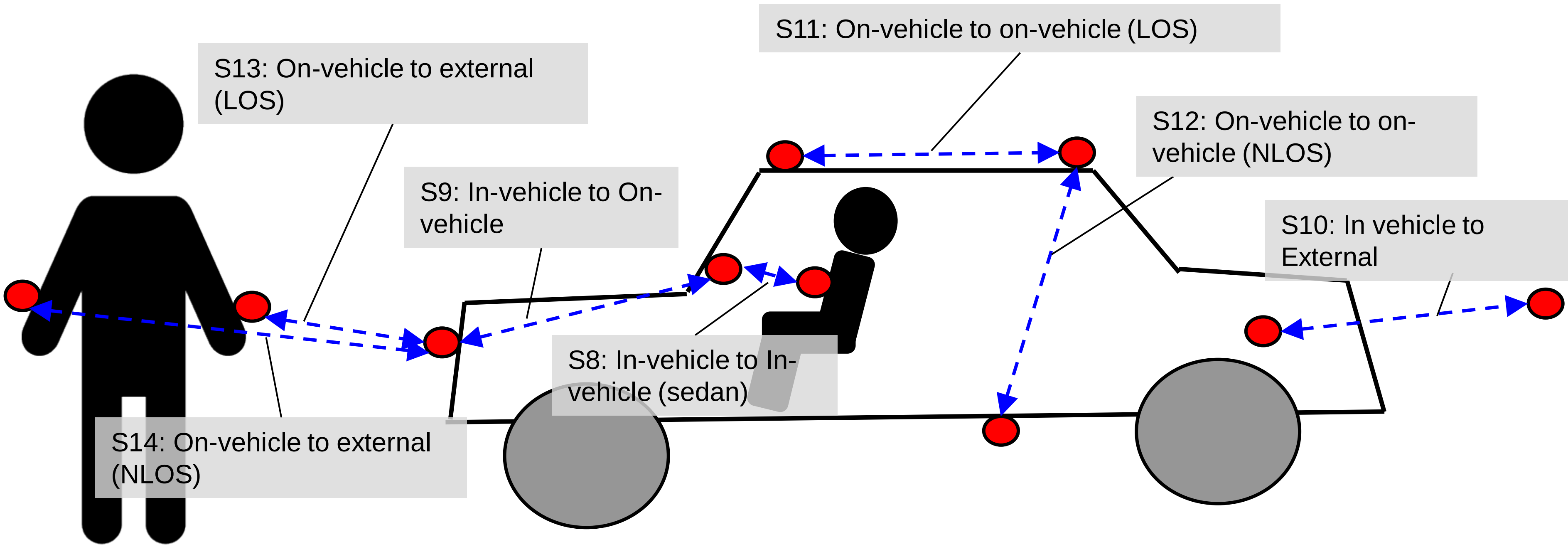
4.3 Channel models and scenarios for capsule endoscopy

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

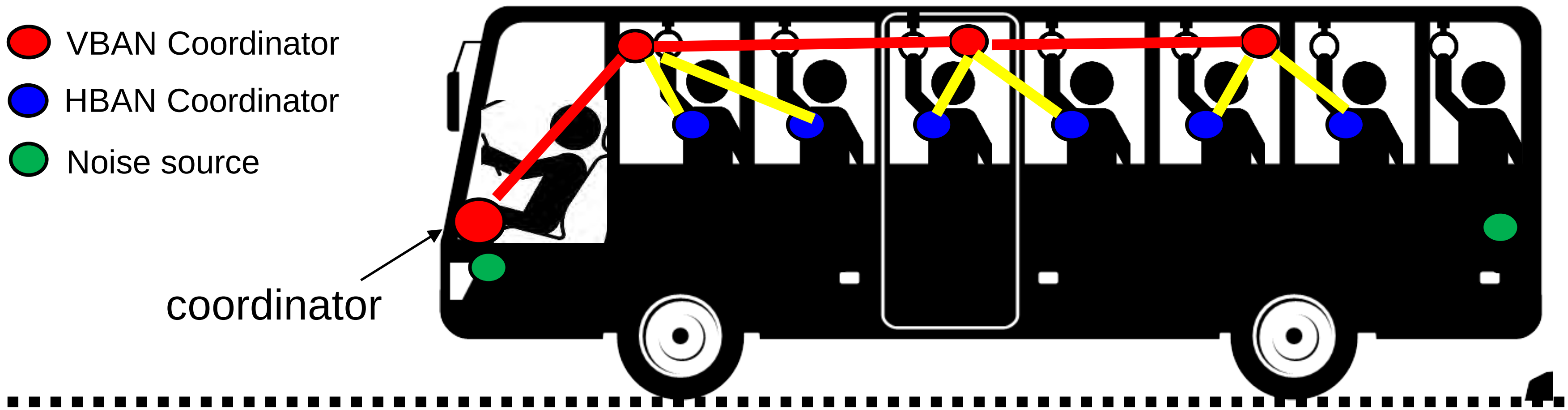


Common Standard of Dependable BAN IEEE802.15.6ma for human and car bodies makes a new market for both medical devices and automotive industries.
For instance, autonomous car safety control for elderly divers' driving failure to avoid accidents.

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

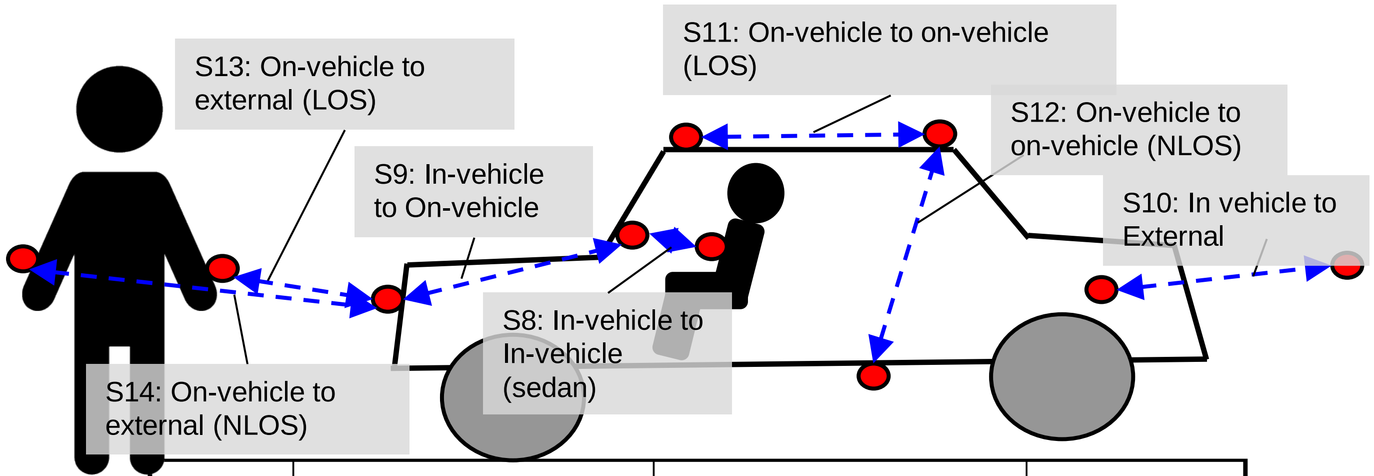


Use case

- 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
8.1vv	**VBAN coordinator and VBAN coordinator**	Case 3.1a		Case 3.1a	Same as 3.1a	---
8.1vh	**VBAN coordinator and HBAN coordinator**	Case 3.1b				---

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)

Channel model

Channel model With environment

- HBAN model
  - In-body (Implant)※
  - On-body ※
  - Around body
    - Outdoor
    - Indoor
      - Home※
      - Office ※
      - Medical (e.g. Hospital)※
  - Implanted BCI model
  - On skull BCI model
  - capsule endoscopy

※not covered in 2012

※Covered by IEEE 802.15.6-2012

※Around means; Desk, WiFi AP in the room etc.

- VBAN model
  - In-vehicle
    - Engine compartment
    - Cabin
    - Through Engine compartment and cabin
  - On-vehicle
    - Roof
    - Side Right/Left/Front/back
    - Bottom
  - Around vehicle
    - Static vehicle
    - Moving vehicle

Note:

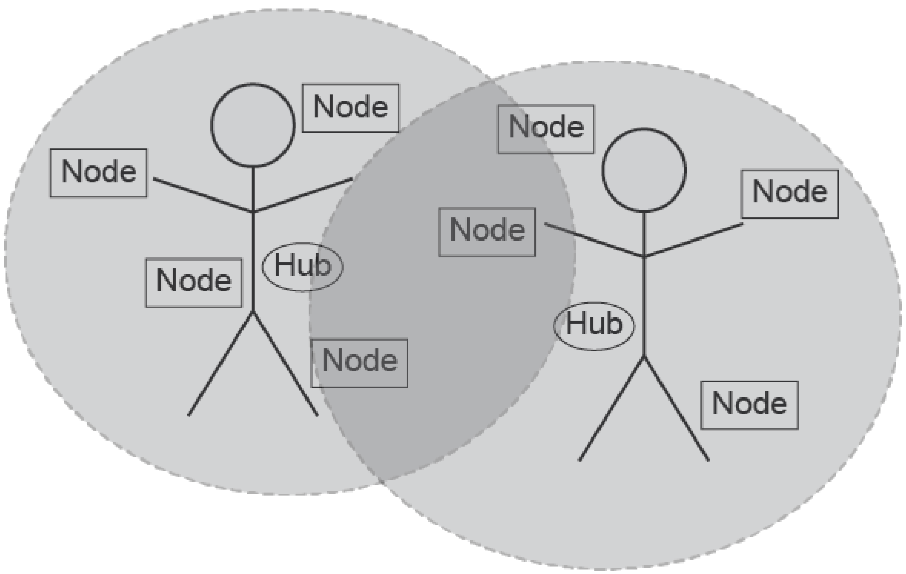
HBAN-model:
-Environment with co-existing systems is not considered.

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

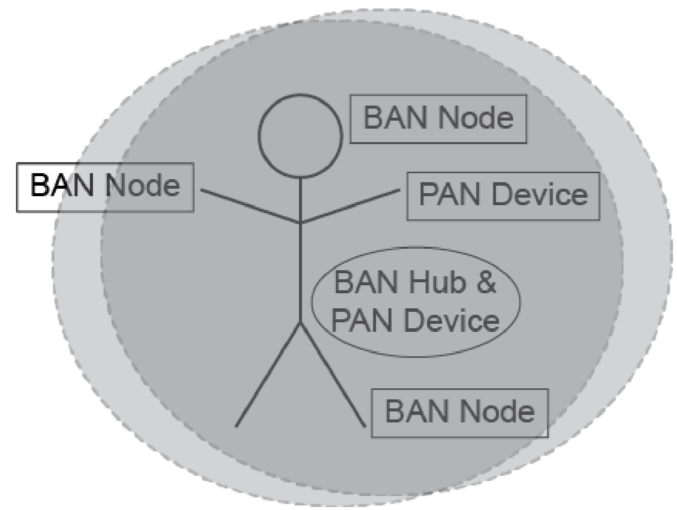
5. Requirement for Revision of 15.6 MAC for Human and Vehicle BANs with Enhanced Dependability TG15.6ma

5.1 Coexisting Models; Interference among BANs and other Networks

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

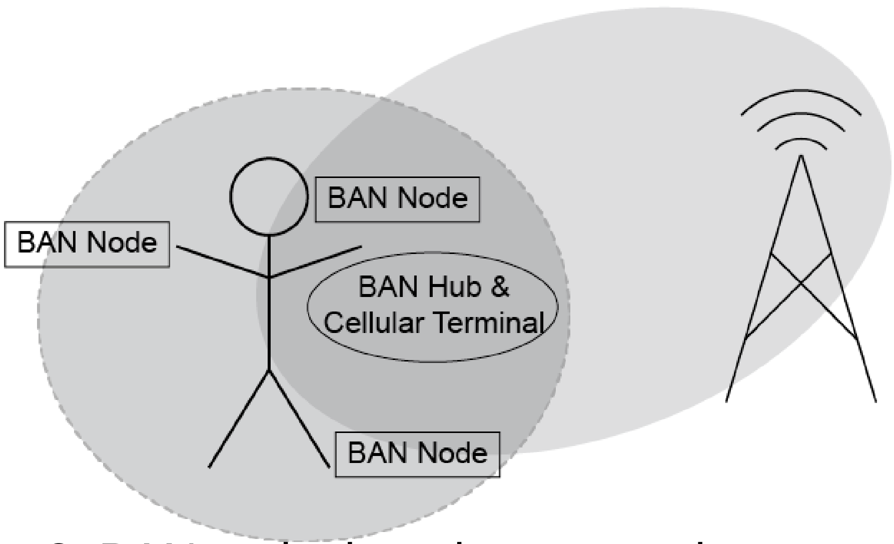


Case 1: BANs, using same frequency bands



Case 2: BAN and PAN, using same frequency bands

5.2 Coexisting Models; Interference among BANs and other Radio Systems



Space Exploration Ship, Earth Exploration Satellite（EESS)

Radio Astronomy(RAS)

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

Case 4: Coexisting Passive Radio Receiver Systems such as RAS, EESS etc.

・When introducing a new radio system, R&D of technologies to avoid interference among coexisting systems is mandatory by regulation and necessary in standard.

・Particularly, cognitive sensing, measuring, modelling, and interference mitigation technologies must be a common subject among URSI commissions.

5.3 Definition of Coexistence Environment Classes

Coexistence Class	Coexisting system(s)					Category
	802.15.6ma	802.15.6-2012	Non-UWB (ex. Wi-Fi / Unlicensed / 3GPP)	802.15 UWB (ex. 802.15.4)	Non-802.15 UWB (ex. ETSI SmartBAN)	
0	-	-	-	-	-	Single BAN
1 (1a)	✓	-	-	-	-	Multiple 15.6 BANs
2 (1b)	✓	✓	-	-	-	
3	✓	-	✓	-	-	Non-UWB
4 (2a)	✓	-	-	✓	-	Multiple UWB systems
5 (2b)	✓	-	-	-	✓	
6 (2c)	✓	-	-	✓	✓	
7	✓	✓	✓	✓	✓	Final Boss

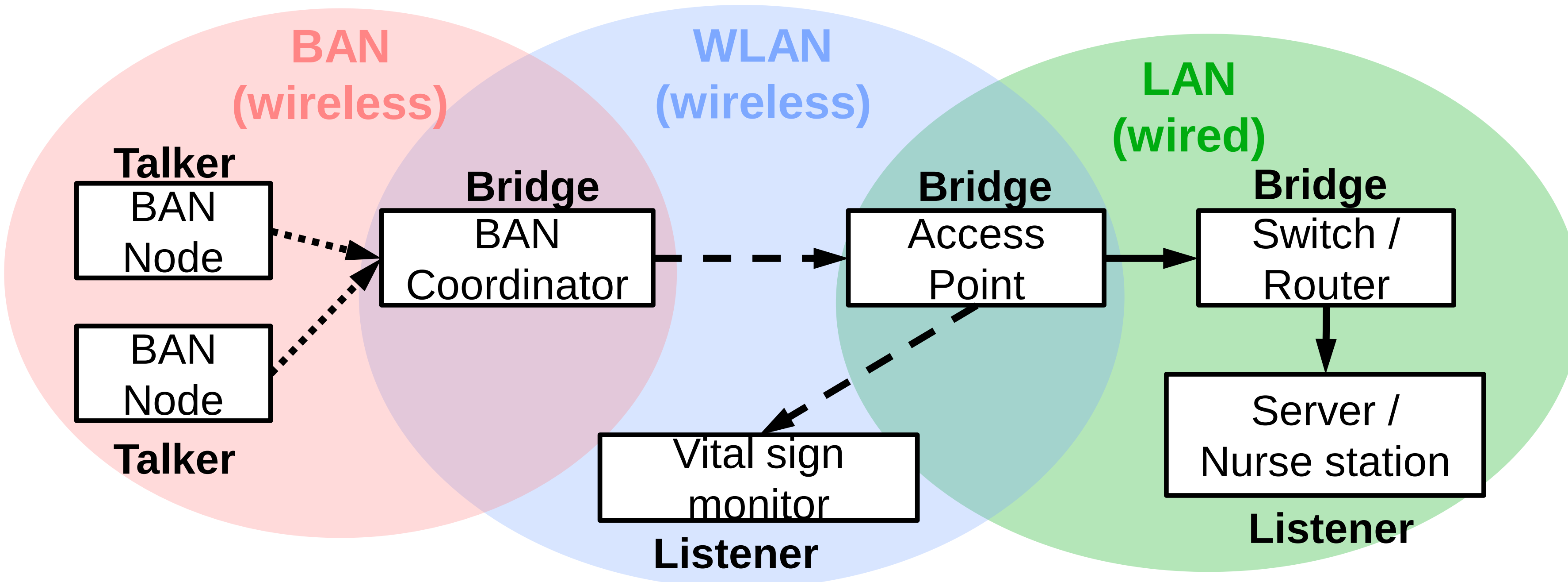
- The coexistence class has been redefied to 8 levels, which can be represented by 3 bits and would be suitable to include in PHY or MAC headers.

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.

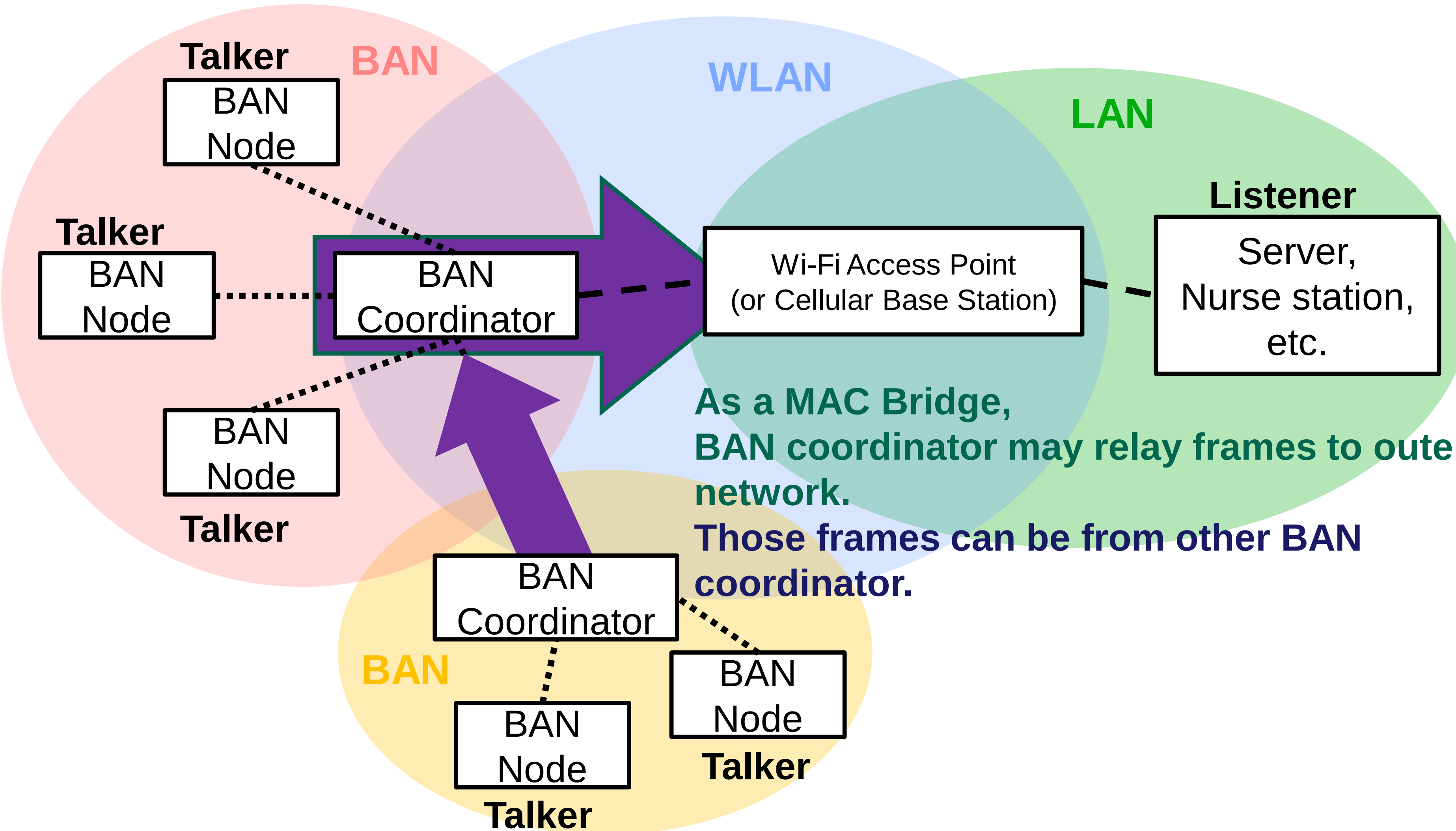
- The revision may enable a coordinator to connect to other coordinators, to avoid interference and enhance dependability.
  - Unlike wired network, wireless network shares same medium and collision occurs which plays significant role in dependability.

5.4 Possible bridging in 802.15.6ma



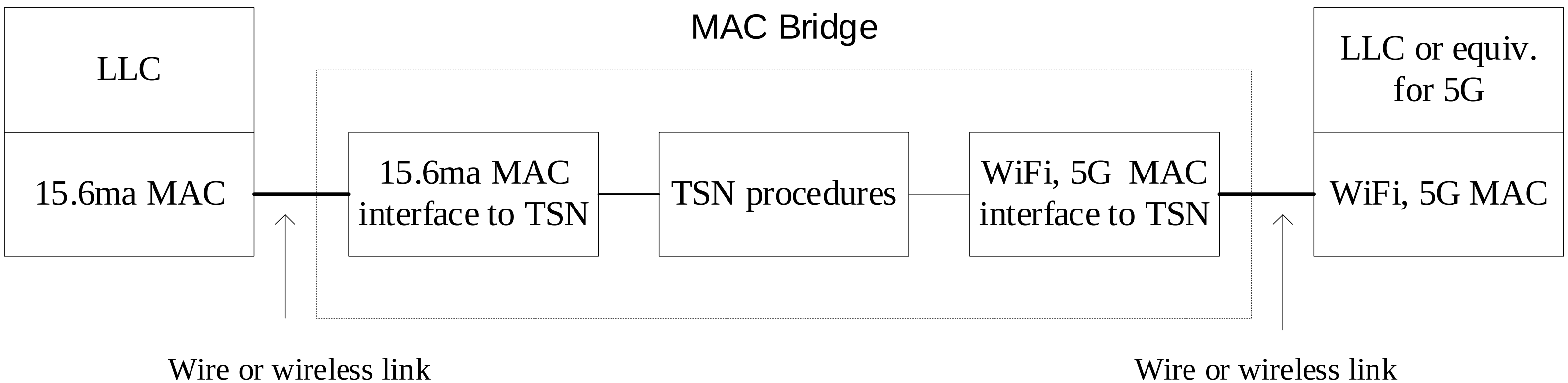
- BAN coordinator may relay frames to outer network as a MAC Bridge.

5.5 Coordinator to Coordinator Bridging

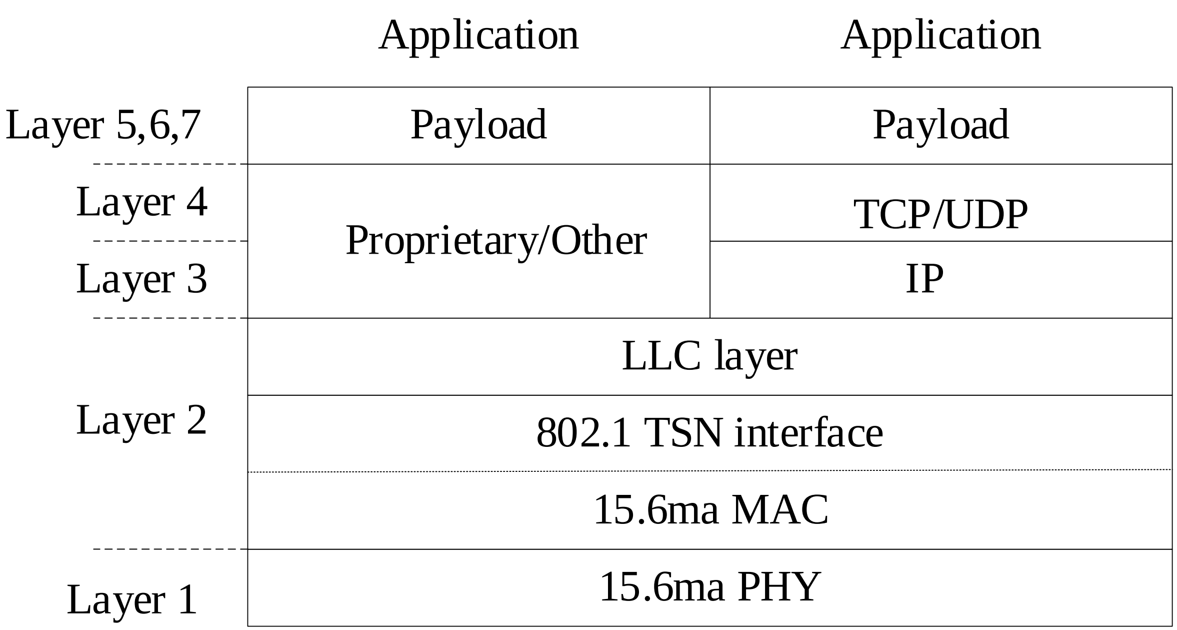


As a MAC Bridge,
BAN coordinator may relay frames to outer network.
Those frames can be from other BAN coordinator.

5.6 TSN equipment to infrastructure

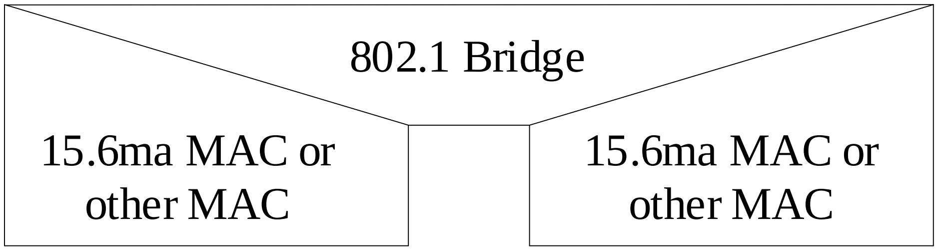


5.7 TSN in the 15.6ma protocol stack



5.7 TSN switch

15.6ma should focus on the MAC layer



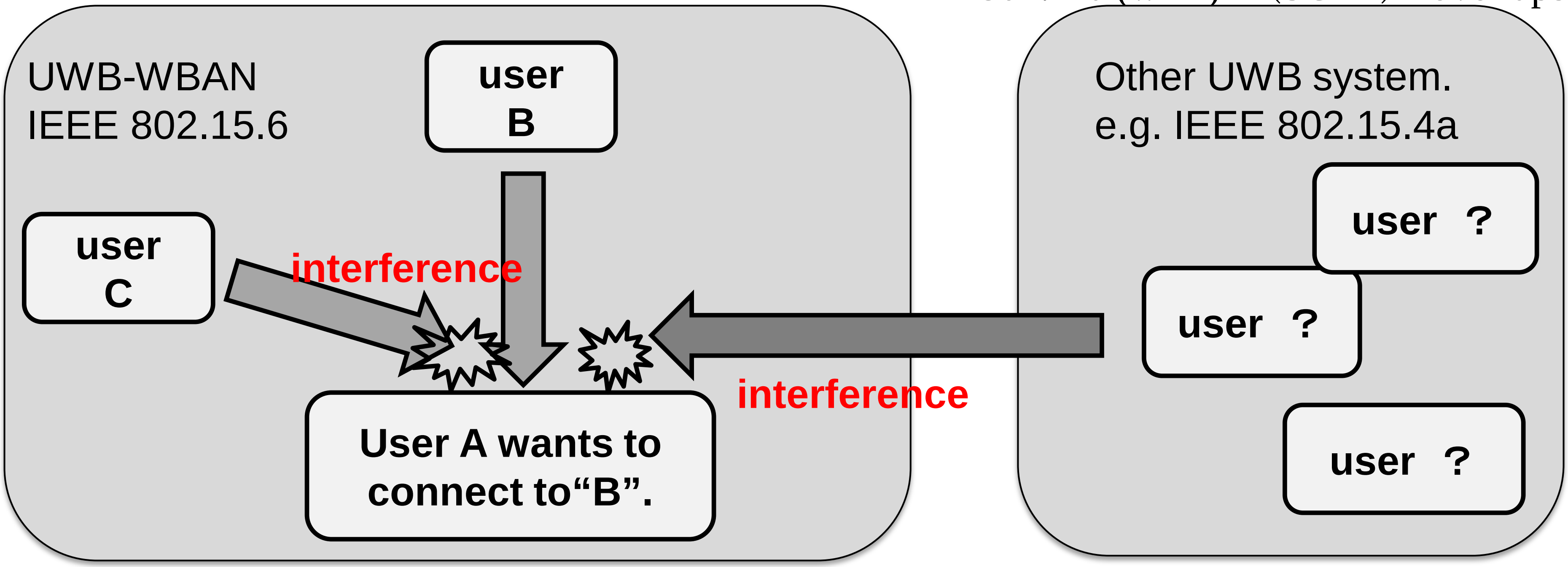
Fortunately, there is no conflict with 802.1 MAC addresses.

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

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

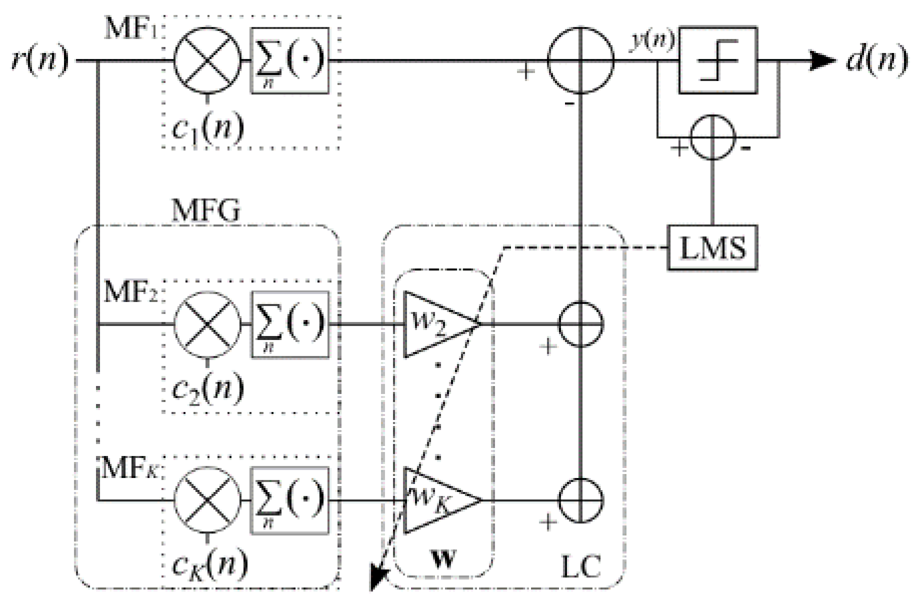
Interference canceller

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.

  ⇒ h a s characteristics of both of spatial and time domain.

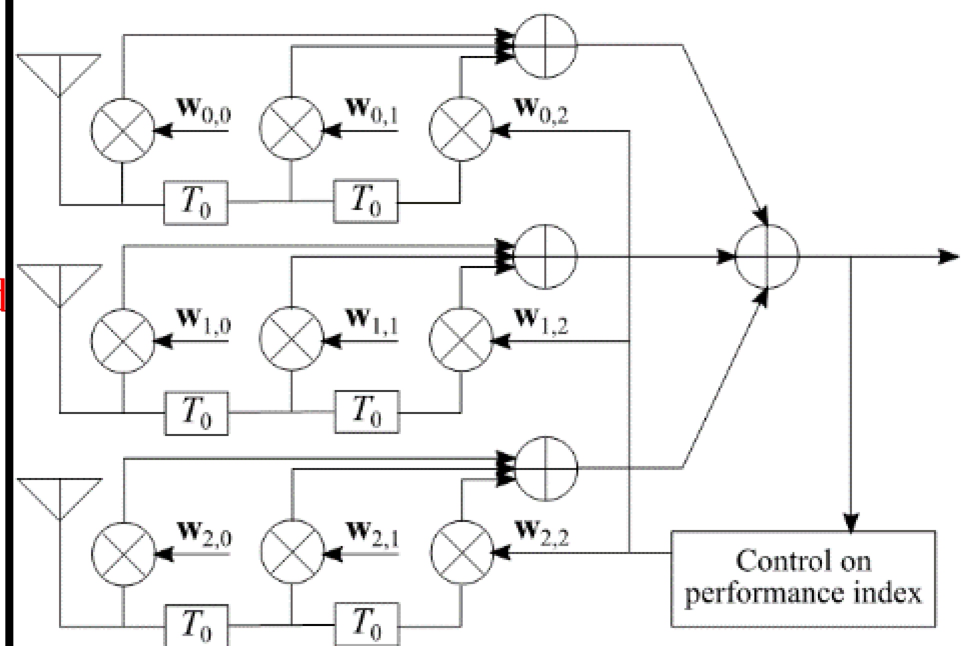
$$\tau_n = n\frac{d}{c}\sin\theta,$$

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

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

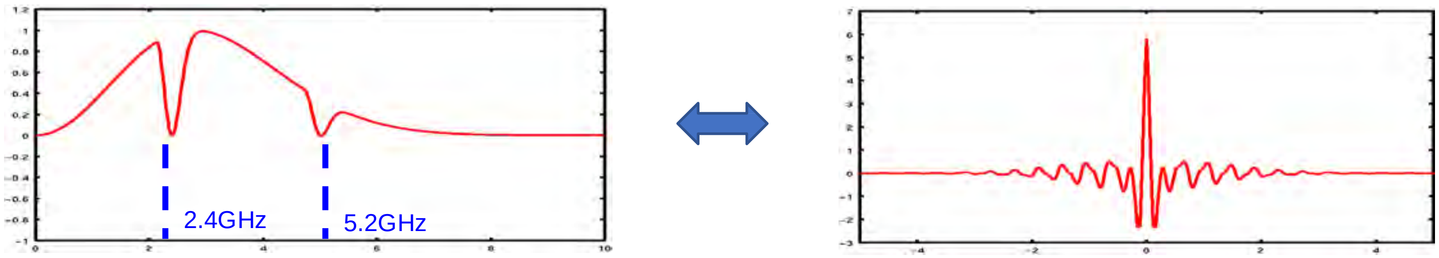
$$H(\theta,\omega) = \sum_{n=0}^{N-1}\sum_{m=0}^{M-1} w_{n,m}\exp(-jm\omega T_0)\exp(-jn\omega\frac{d}{c}\sin\theta).$$

Principle of TDL-AA



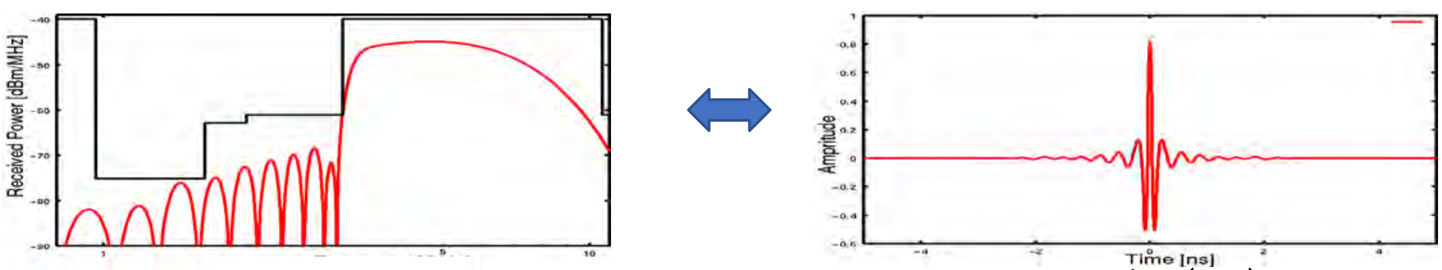
TDL-AA can work as interference canceller on both of time and space domains

6.5 Interference Mitigation among Other Radios



Frequency(Hz) Time(sec)

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

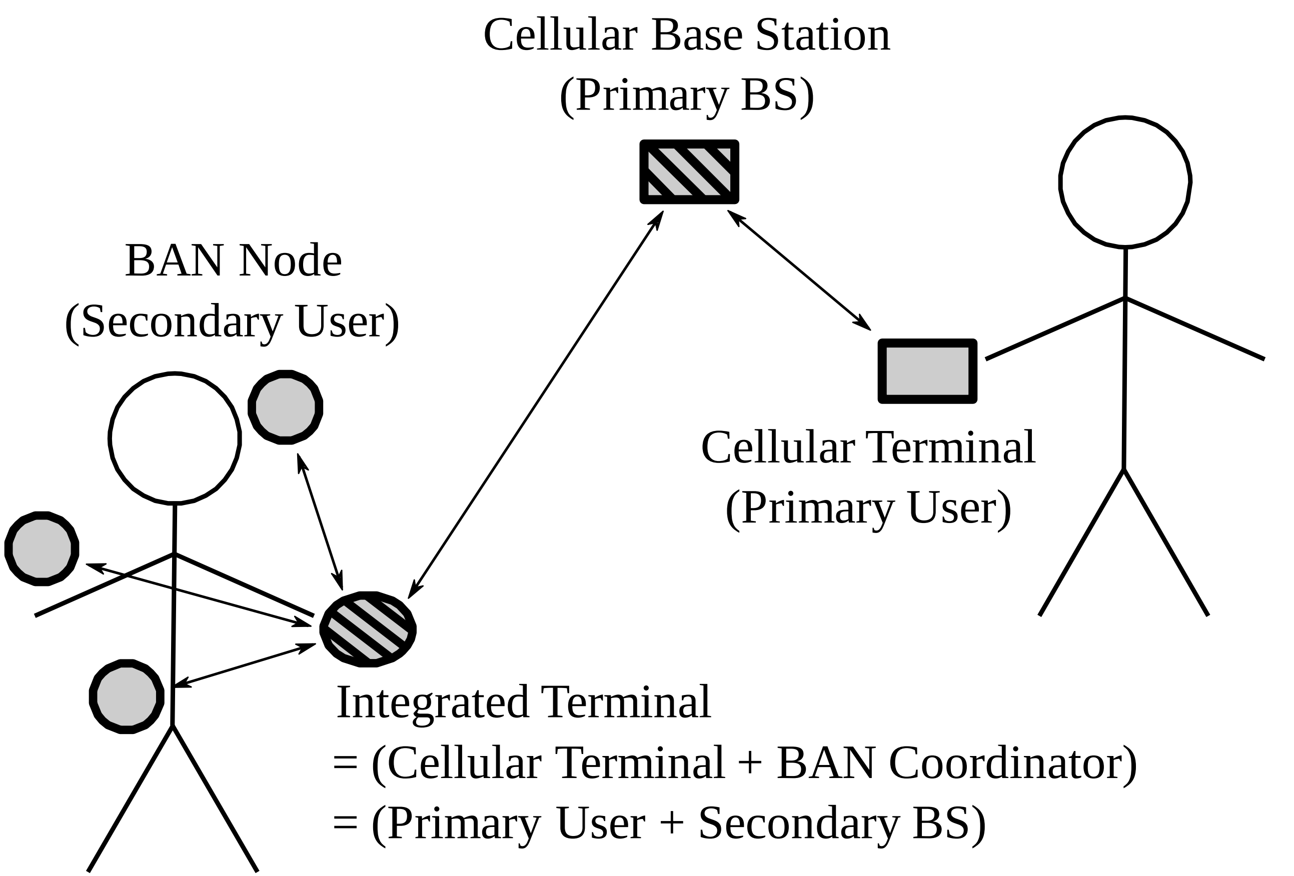


Frequency(Hz) Time(sec)

(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

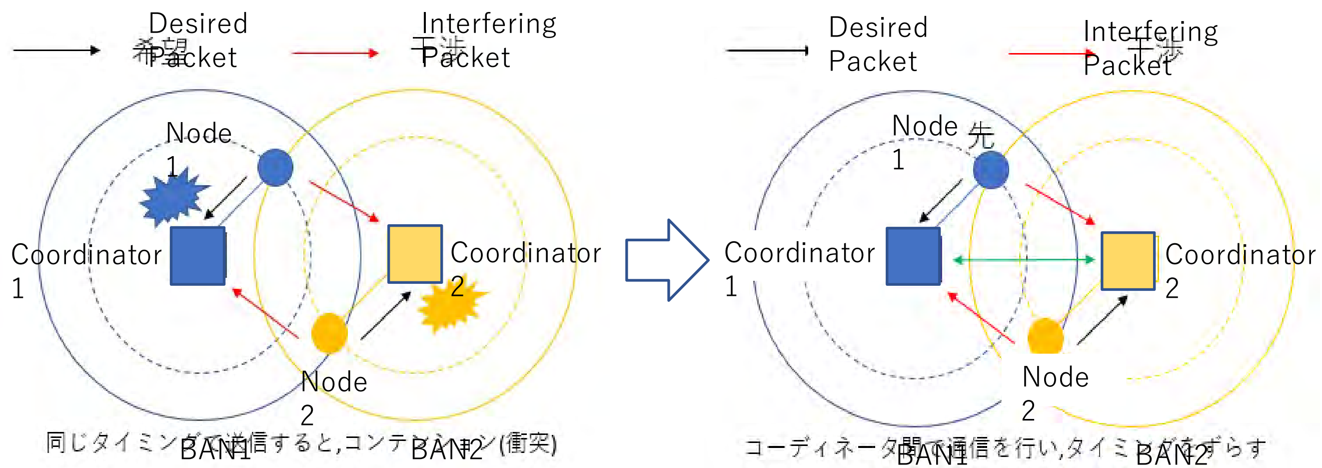
6.7 Contention among Overlaid BANs

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



In case of no negotiation of Coordinators of overlapped BANs, contention happens among packets from nodes of f the BANs

In case of negotiation of Coordinators of overlapped BANs, contention can be resolved

- 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

6.8 QoS Levels of Packets corresponding to User Priority in IEEE802.15.6

- In Std.15.6 WBAN systems, a various data such as vital signs, skin temperature, blood pressure, ECG, EEG, ECoG, and vehicle controlling commons have different QoS levels corresponding to user priority.
- In 15.6ma for dependable WBAN for human and vehicles, data packet transmission should be dependable according to QoS levels even in various classes of coexistence environment.
- Therefore, **appropriate sets of error controlling scheme with FEC and hybrid ARQ** corresponding to QoS levels have been standardized in 15.6ma,

User priority	Traffic designation	Frame type
0	Background (BK)	Data
1	Best effort (BE)	Data
2	Excellent effort (EE)	Data
3	Video (VI)	Data
4	Voice (VO)	Data
5	Medical data or network control	Data or management
6	High-priority medical data or network control	Data or management
7	Emergency or medical implant event report	Data

6.9 Channel Coding Table #1

Common with IEEE802.15.4ab

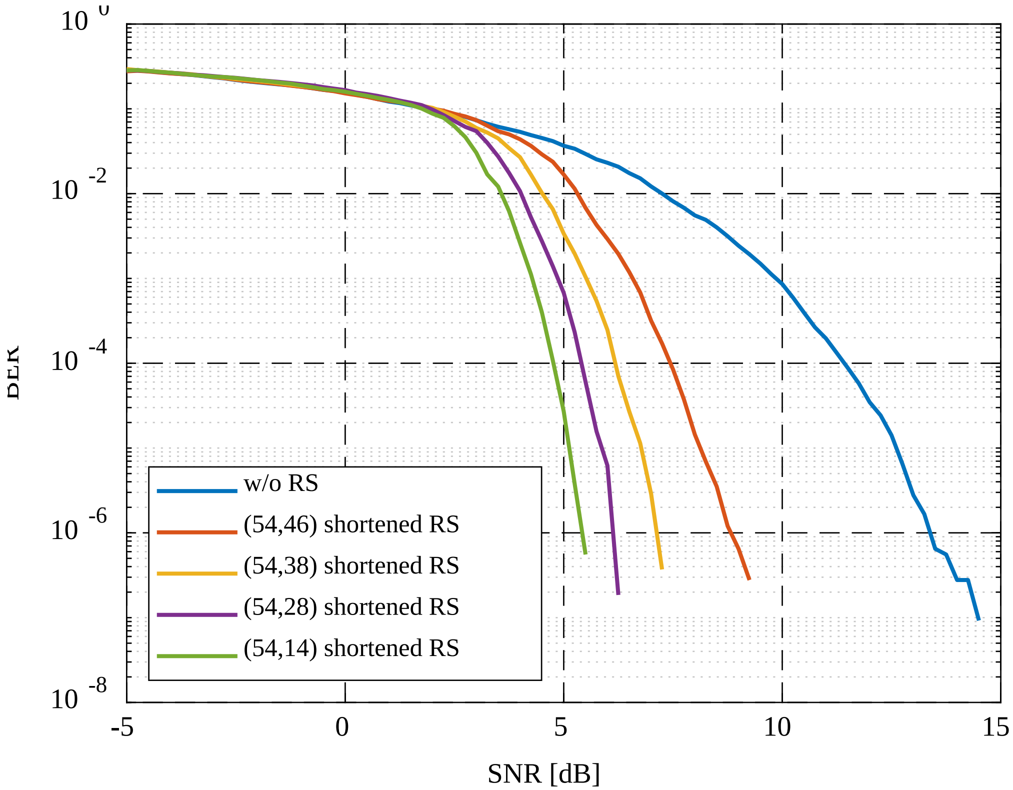
Error-correcting codes corresponding to QoS levels

User priority	Inner code	Outer code	HARQ
0	15.4ab LDPC code (R=1/2)		-
1	15.4ab LDPC code (R=1/2)		-
2	15.4ab LDPC code (R=1/2)		-
3	15.4ab LDPC code (R=1/2)		-
4	15.4ab LDPC code (R=1/2)	(54, 46) shortened RS code	-
5	15.4ab LDPC code (R=1/2)	(54, 38) shortened RS code	-
6	15.4ab LDPC code (R=1/2)	(54, 28) shortened RS code	-
7	15.4ab LDPC code (R=1/2)	(54, 14) shortened RS code	-

- As an outer code, shortened Reed-Solomon (RS) codes with N=54 (original code length N=63) will be selected to correct burst errors due to interference from other WBANs and the coding rates are changed according to each QoS and channel condition
- As an inner code, 15.4ab LDPC codes (K=324, 648, 972, R=1/2) will be selected for the coexistence of 15.6ma and 15.4ab
- This updated concept table is considered as the first priority

September 2023

Evaluation of Channel Codes Assigned Corresponding to Different QoS Priority Levels



Bit error ratio of (54,46), (54,38), (54,28), (54,14) shortened RS codes and no encoding were evaluated under an AWGN channel and BPSK modulation

Performances were improved as the coding rate decreased

LDPC simulator is currently checked and will be combined with the RS simulator

September 2023

Error-correcting codes corresponding to QoS levels

6.9 Channel Coding Table #2

Common with IEEE802.15.4ab

User priority	Inner code	Outer code	HARQ
0	-	15.4ab LDPC code (R=1/2)	-
1	-	15.4ab LDPC code (R=1/2)	-
2	-	15.4ab LDPC code (R=1/2)	-
3	-	15.4ab LDPC code (R=1/2)	-
4	15.4a/z based convolutional code, R=4/5	15.4ab LDPC code (R=1/2)	○
5	15.4a/z based convolutional code, R=2/3	15.4ab LDPC code (R=1/2)	○
6	15.4a/z convolutional code, R=1/2	15.4ab LDPC code (R=1/2)	○
7	15.4a/z based convolutional code, R=1/4	15.4ab LDPC code (R=1/2)	○

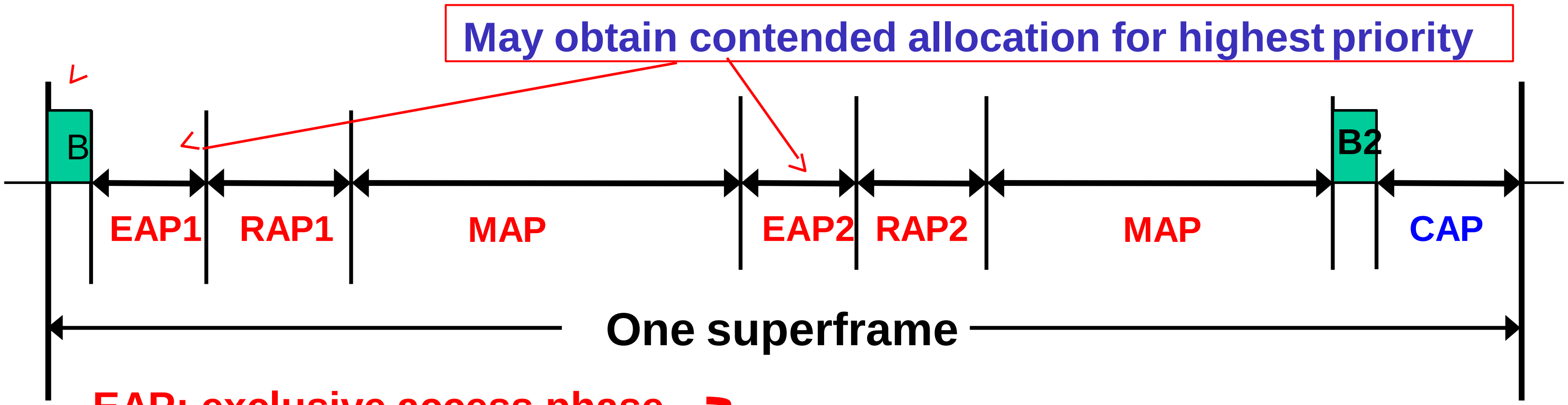
- As an outer code, 15.4ab LDPC (K=324, 648, 972, R=1/2) codes will be selected for the coexistence of 15.6ma and 15.4ab
- As an inner code, 15.4a/z based convolutional codes (which are almost the same of our proposed decomposable codes) will be selected, and the coding rates are changed according to each QoS and channel condition, which can be applied to hybrid ARQ
- This table is considered as the second choice

6.10 Specification of Error-Control Defined Corresponding Combination of 8 QoS Levels and 8 Coexistence Classes

Coexistence Class	0	1	2	3	4	5	6	7
QoS Level								
0	BCC	BCC+E	BCC+E	BCC+E			HARQ	HARQ
1	BCC	BCC+E	BCC+E	BCC+E			HARQ	HARQ
2	BCC	BCC+E	BCC+E	BCC+E			HARQ	HARQ
3	BCC	BCC+E	BCC+E	BCC+E			HARQ	HARQ
4	BCC	BCC+E	BCC+E	BCC+E			HARQ	HARQ
5	BCC	BCC+E	BCC+E	BCC+E			HARQ/IM	HARQ/IM
6	CFP/HARQ	CFP/HARQ	CFP/HARQ	CFP/HARQ	CFP/HARQ	CFP/HARQ	HARQ/IM	HARQ/IM
7	CFP/HARQ	CFP/HARQ	CFP/HARQ	CFP/HARQ	CFP/HARQ	CFP/HARQ	HARQ/IM	HARQ/IM

6.11 Dependable MAC for IEEE802.15.6ma

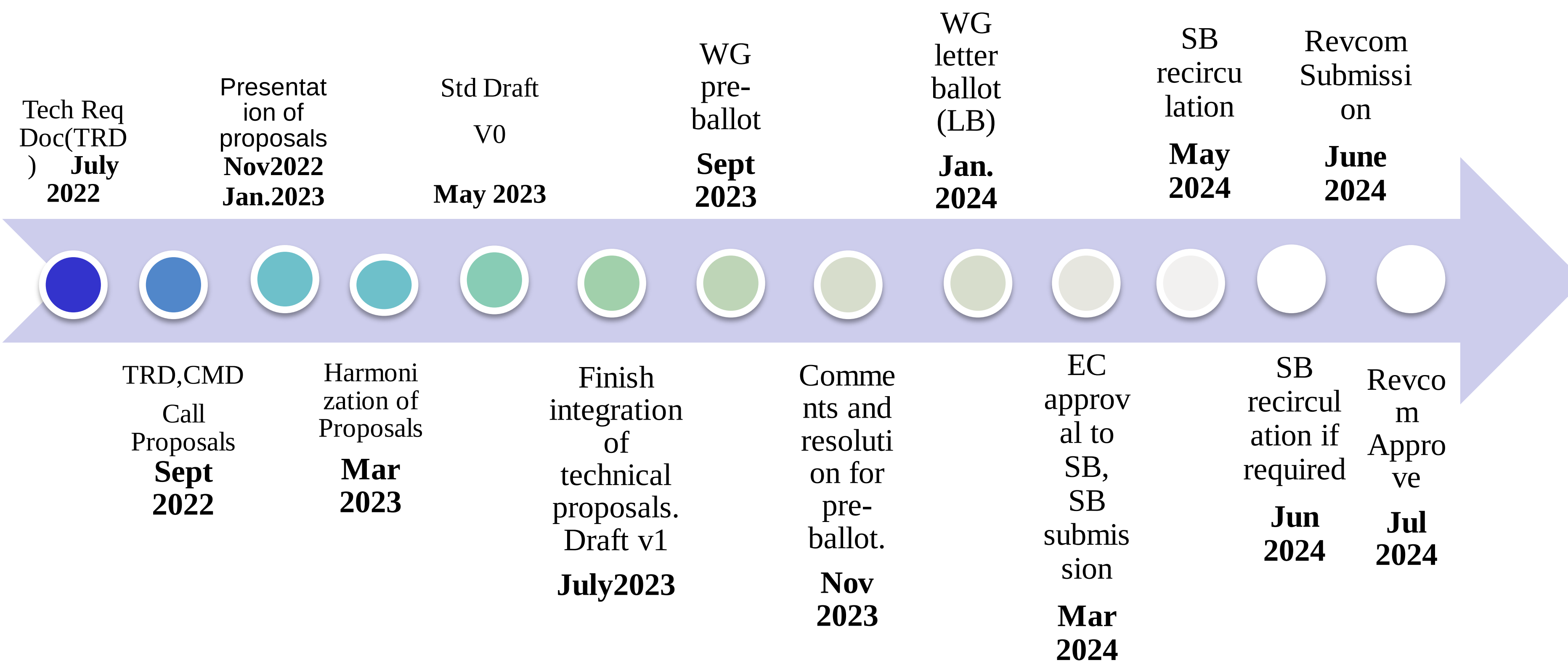
- To enhance dependability in MAC layer, IEEE802.15.6 has applied a **hybrid contention free and contention access MAC protocol** in which high QoS level of packets have transmit without delay in contention free period (CFP) while low QoS level of packets with permissible delay in contention access period (CAP).



EAP: exclusive access phase
RAP: random access phase
MAP: managed access phase
} **Contention Free Period (CFP), e.g. TDMA)**
CAP: contention access phase e,g. CSMA/CD, ALOHA

7. Timeline of TG15.6ma

TG 6ma Timeline



Notes: SASB/RevCom scheduled for 2024 a guess

Timeline details.

Topic	Deadline	Notes
Technical Requirements Document (TRD). Channel Model Document (CMD). Call for Proposals.	Sept. 2022	TRD describes the technical requirements baseline for the evaluation of proposals. The CMD contains the channel models for different use cases targeted by the Std. Announcement of call for proposals.
Due day for proposals	March 10th, 2023	Postponed from January 2023
Presentation of proposals	Nov. 2022, January, March 2023	Start of discussions for harmonization of proposals.
Harmonization of Proposals	March 2023	Agreements on key technologies.
Std Draft v.0	May 2023	Mostly editorial revisions and start integrating text of agreed proposals.
Std Draft v. 1	July 2023	Finish integration of technical proposals.
Std Draft v. 1 recirculation	August 2023	TG approval
WG pre-ballot	September 2023	WG pre-ballot submission.
Comments and resolution for pre-ballot.	November 2023	Finish resolutions to pre-ballot comments and recirculation.
WG letter ballot (LB)	January 2024	LB submission
LB recirculation	January 2024	Comment-resolutions to LB recirculation
Conditional approval for Sponsor Ballot (SB)	January 2024	Seek conditional approval
Final LB recirculation. EC approval	March 2024	Just before the March meeting.
EC approval to SB	March 2024	
SB submission	March 2024	
SB recirculation	May 2024	Resolutions to SB.
Conditional/unconditional approval to RevCom	May 2024	Submission to SASB agenda
SB recirculation if required	June 2024	
RevCom submission	June 2024	RevCom approval

Note: the deadlines are subject to change.

8. 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 a 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 a 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, 4f, 4z, 4ab 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 a revision of IEEE802.15.6 for enhanced dependability in PHY and MAC, established and will complete the revision IEEE802.15.6ma. About an year later. 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>

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