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

**Submission Title:** [IG DEP & SG15.6a Activity for Amendment of 15.6 BAN with Enhanced Dependability]
**Date Submitted:** [12 May 2021]
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**Abstract:** [This document summarizes IG-DEP and SG15.6a activity for amendment of IEEE802.15.6 -2012 Medical Body Area Network(BAN) corresponding to increasing demand 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]

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# IG-DEP & SG15.6a Activity for Amendment of IEEE 802.15.6 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.

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

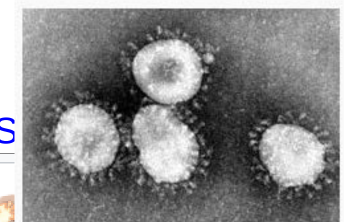
# 1.2 Medical Inspection and Treatment by BAN

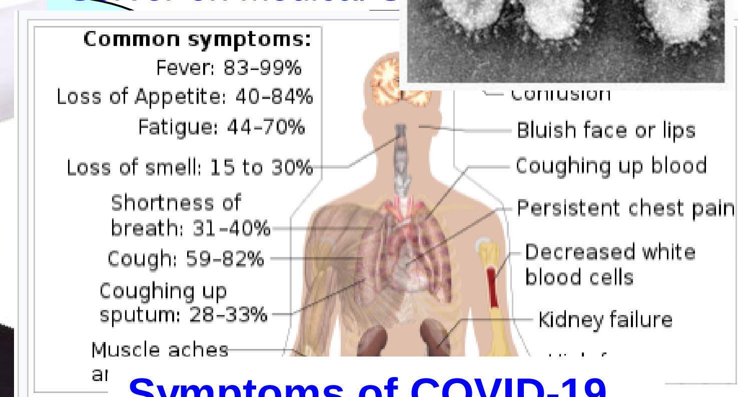
Medical Healthcare Using BAN can perform remote real-time medical diagnosis and therapy

- 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


Server on Medical S

Coronavirus






**Symptoms of COVID-19**

**6**

# 1.3 Wireless BAN: Body Area Network

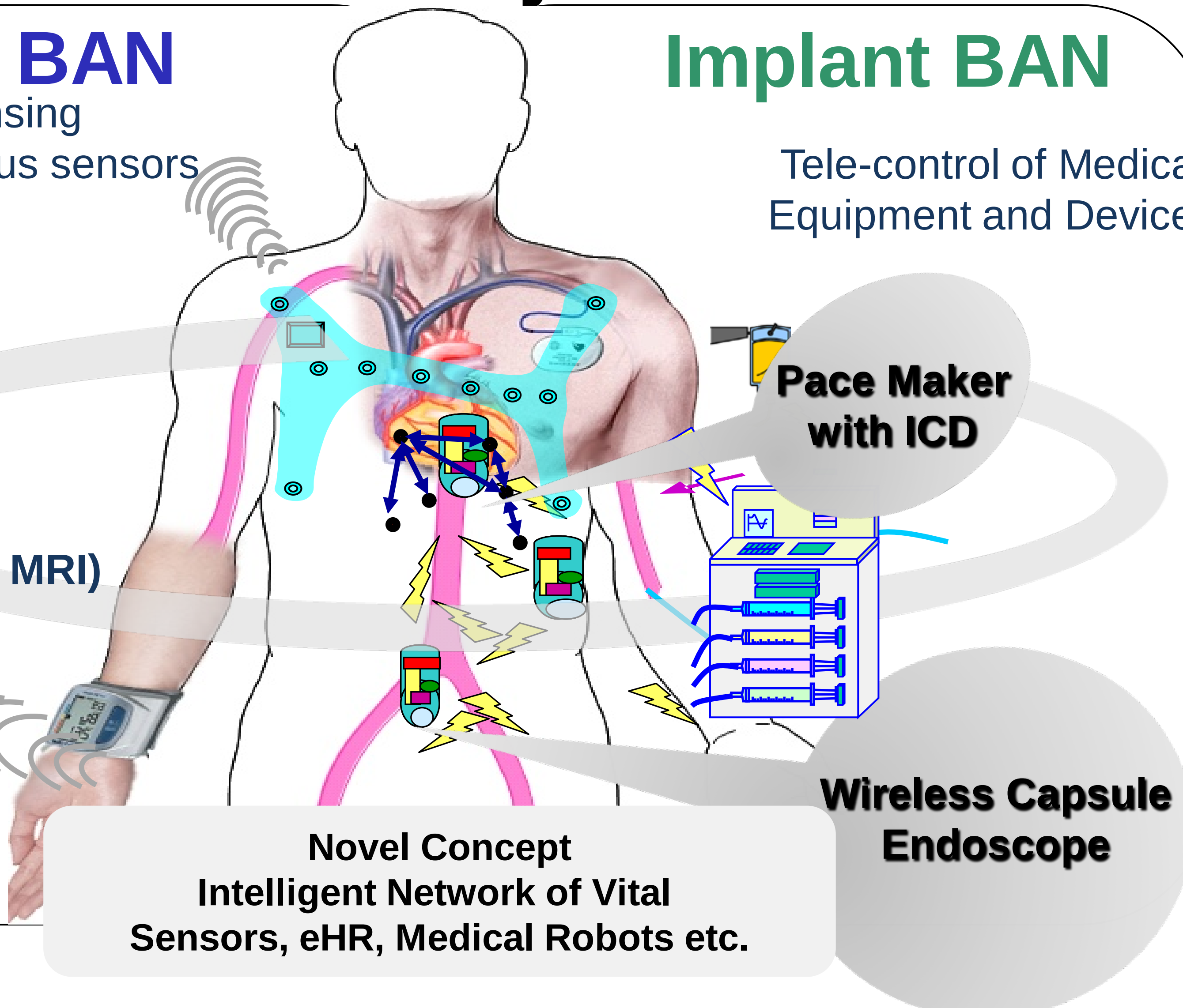
## Wearable BAN

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**

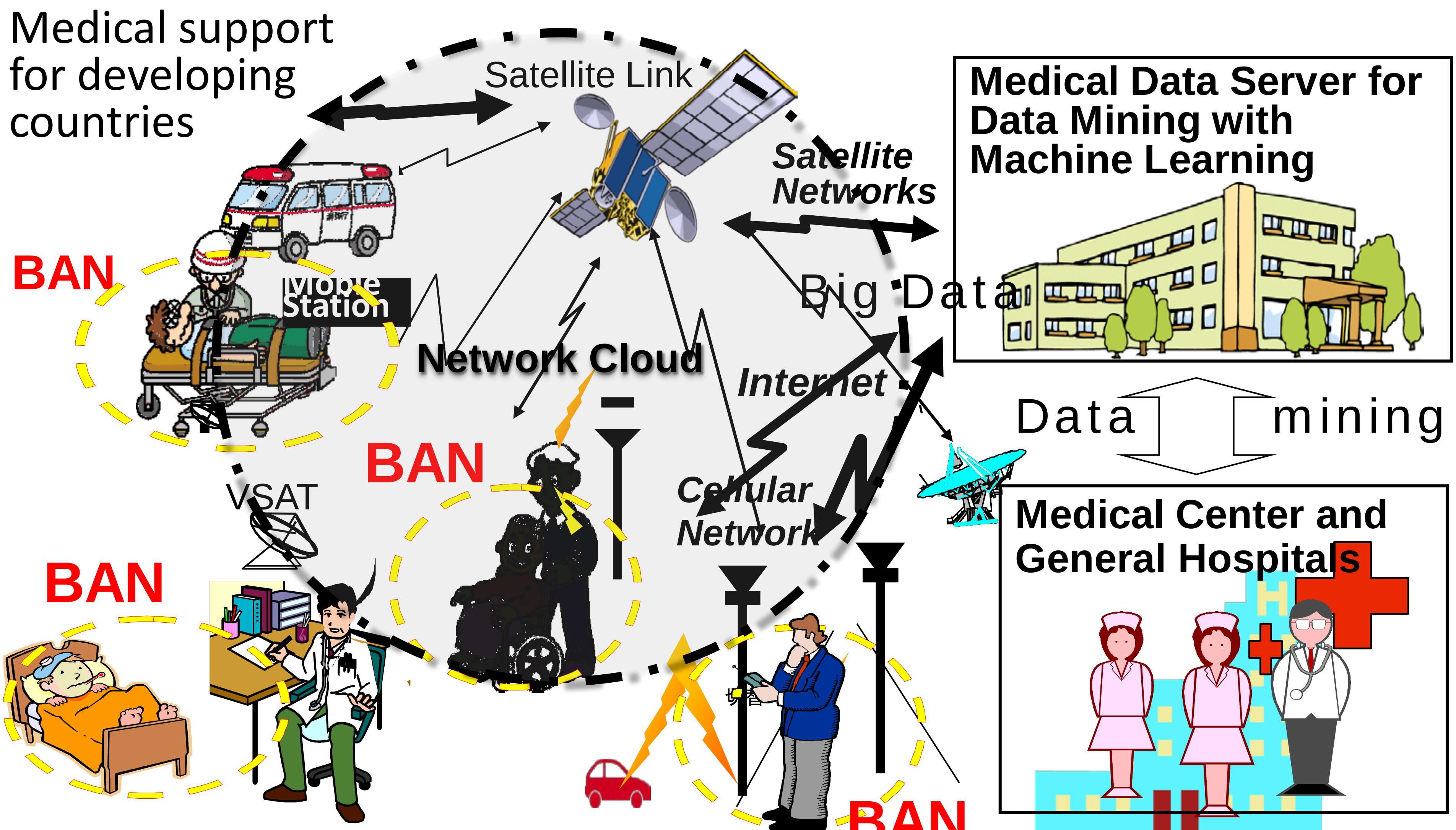

## Implant BAN

Tele-control of Medical
Equipment and Devices

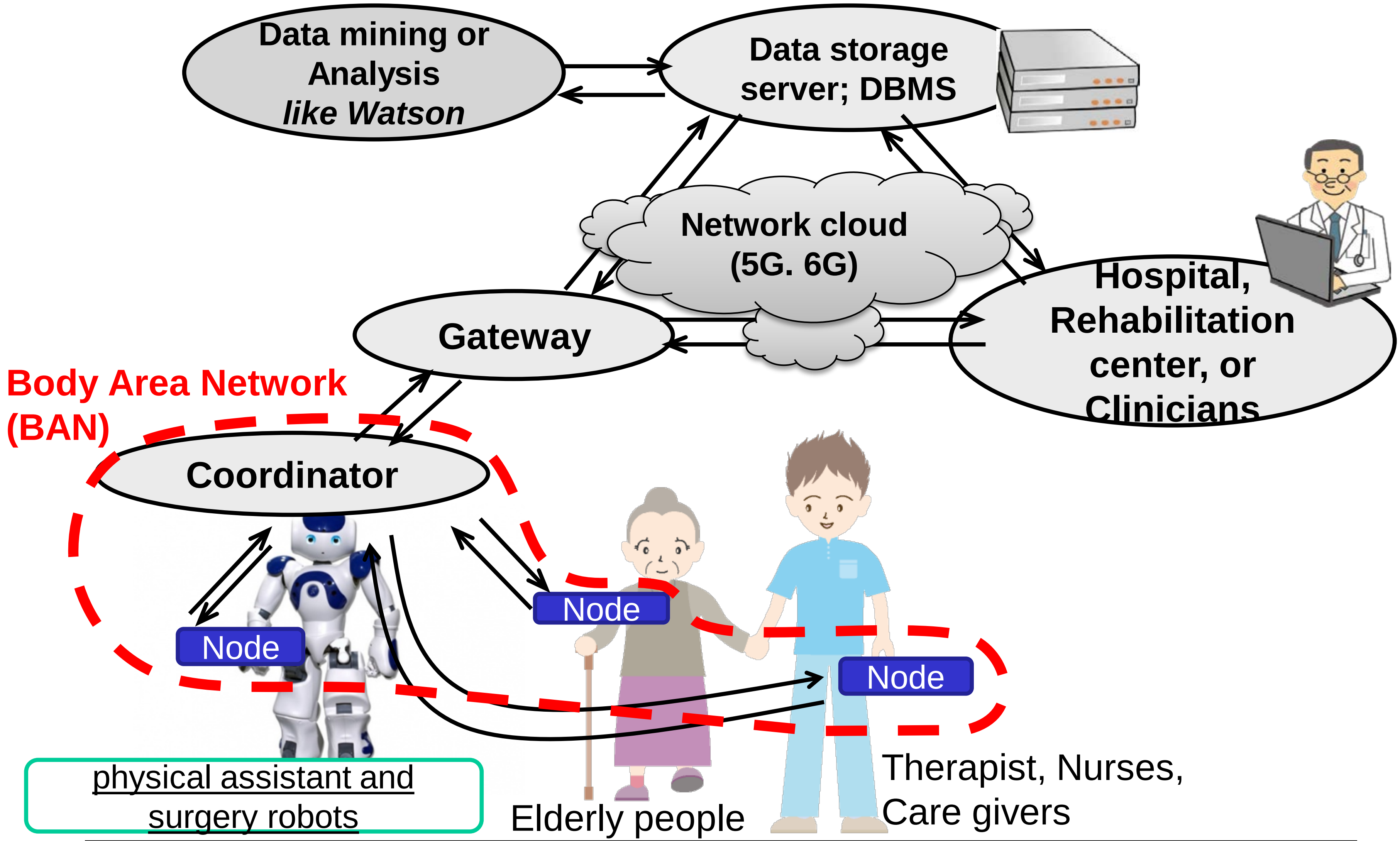



**Novel Concept**
**Intelligent Network of Vital**
**Sensors, eHR, Medical Robots etc.**

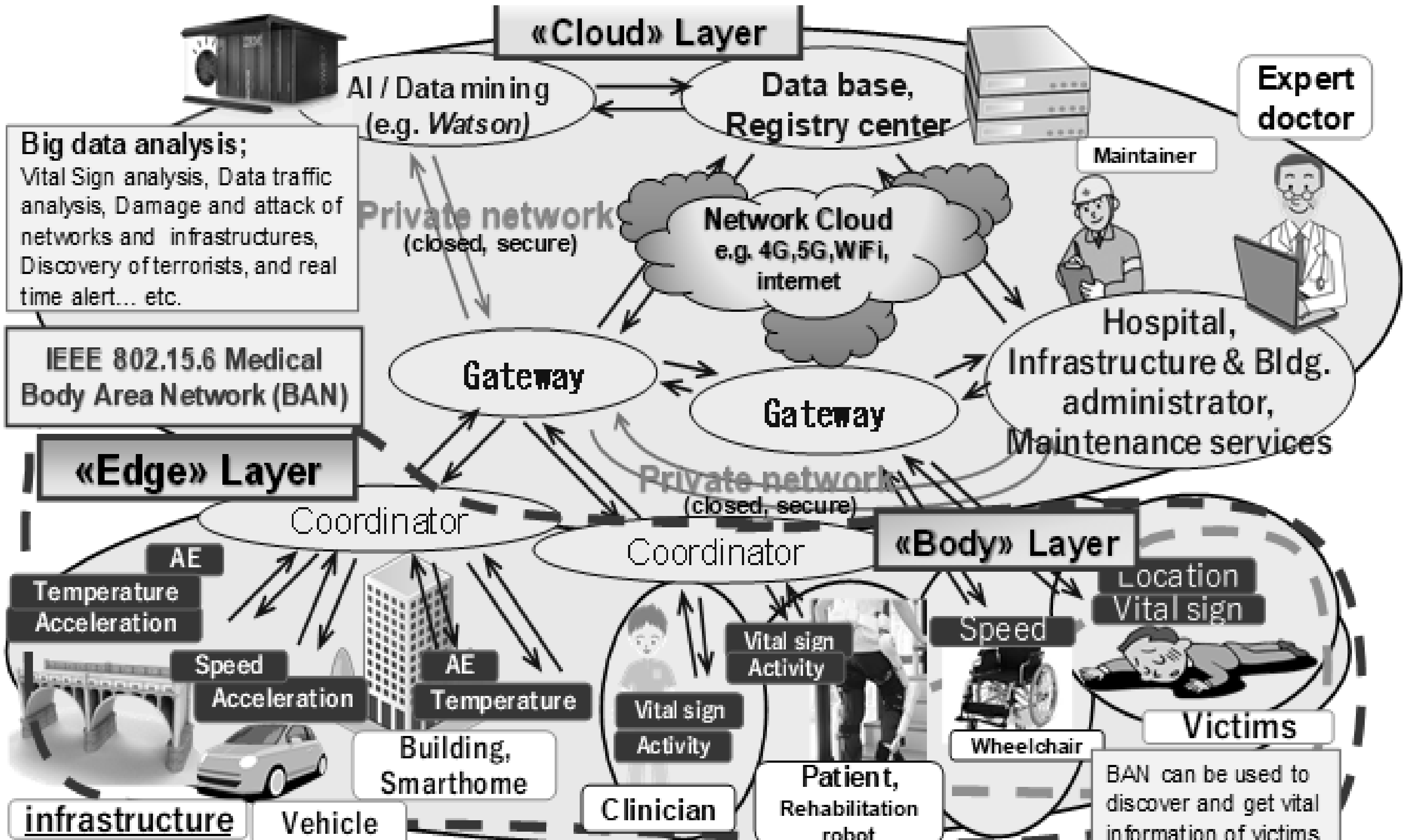
# 1.4 BAN- Use Cases for Remote Medical Services



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

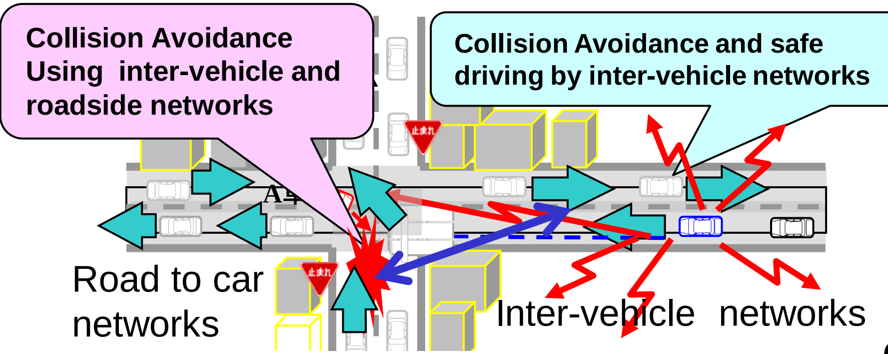


# 1.6 Universal Platform Based on BAN, Cloud Network, and AI Data Server for General Social Infrastructure beyond Medical Services

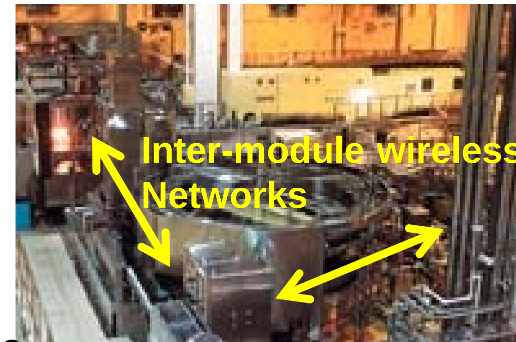



Although in a situation such as cyber or physical terrorism and natural disaster, networks are partially destroyed, layered structure network can suppress and limit the effect to the inside of the limited physical area.

# 1.7 Extension of Use Cases of BAN beyond Medical Healthcare




Car LAN & Wireless Harness

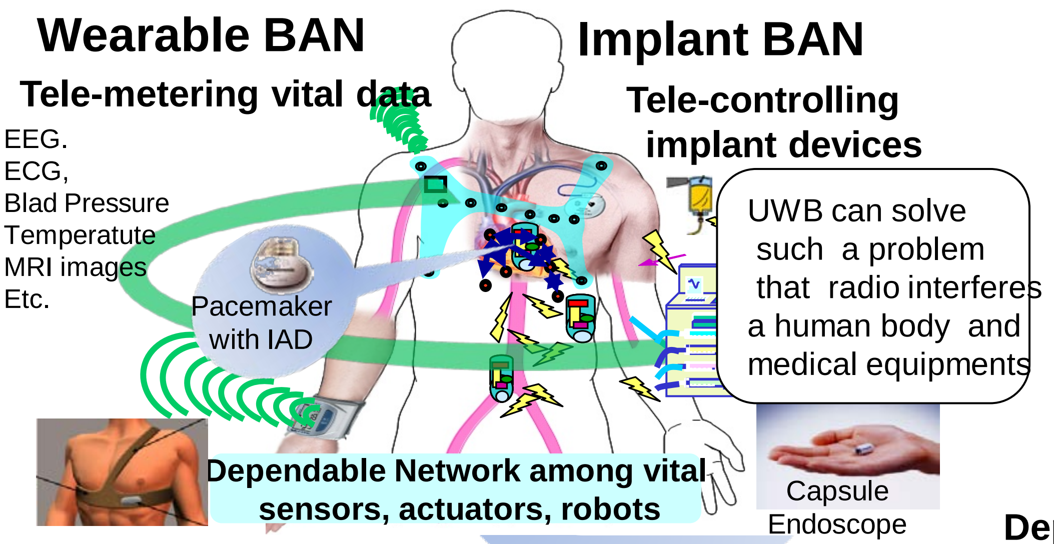


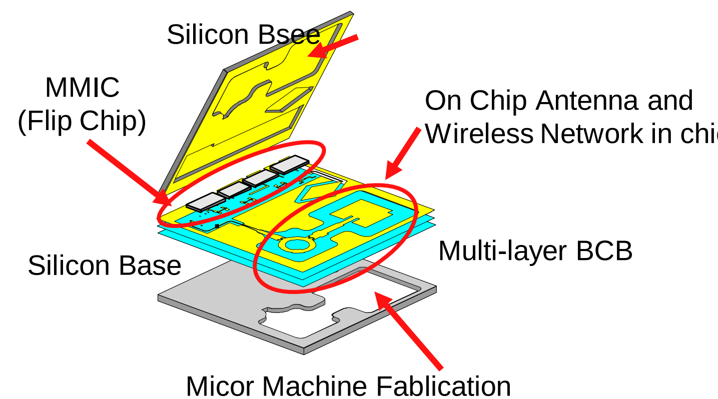

Car Navigation & Collision Avoidance Radar

Factory Automation (FA)

**Dependable Wireless Networks for Transportation**

**Dependable Wireless Sensing & Controlling for Manufacturing (CIM)**

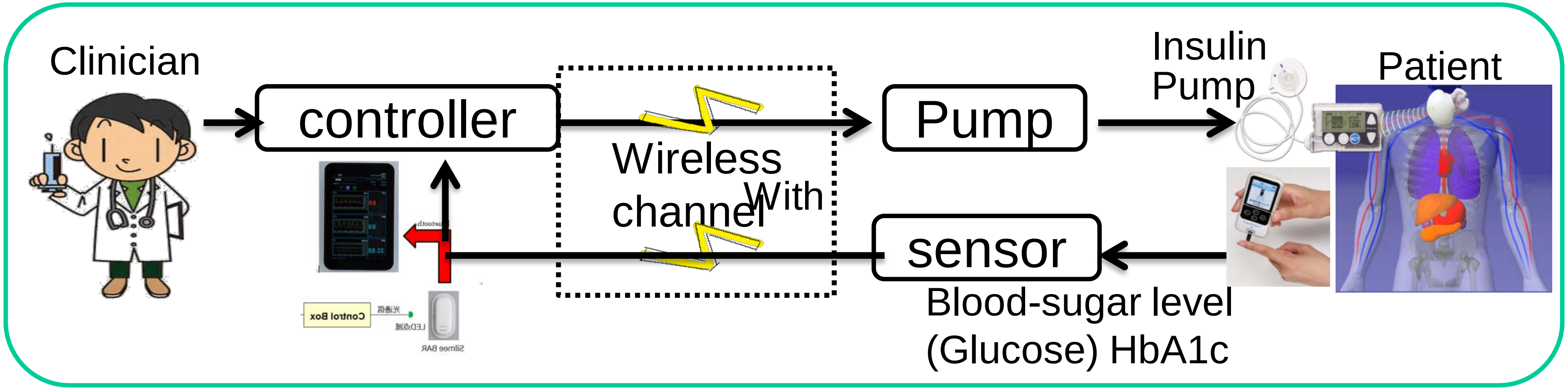


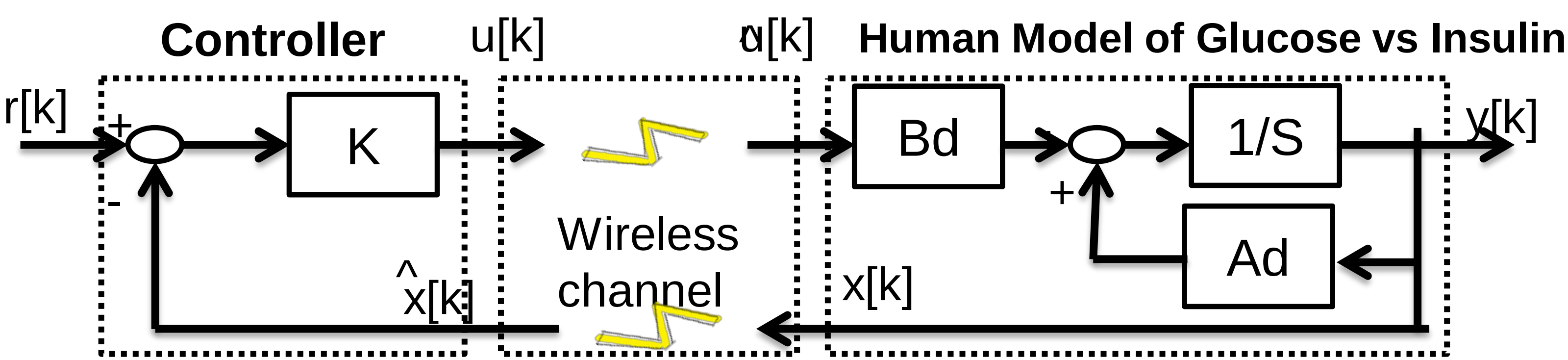

**Dependable BAN for Medical Healthcare**

**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**

# 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

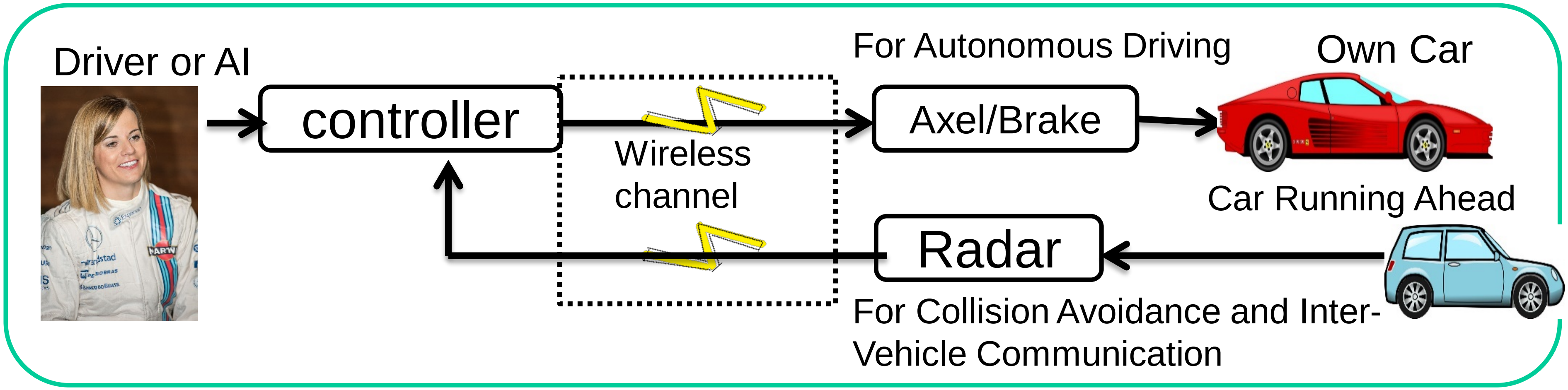
**C. Approach:**

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

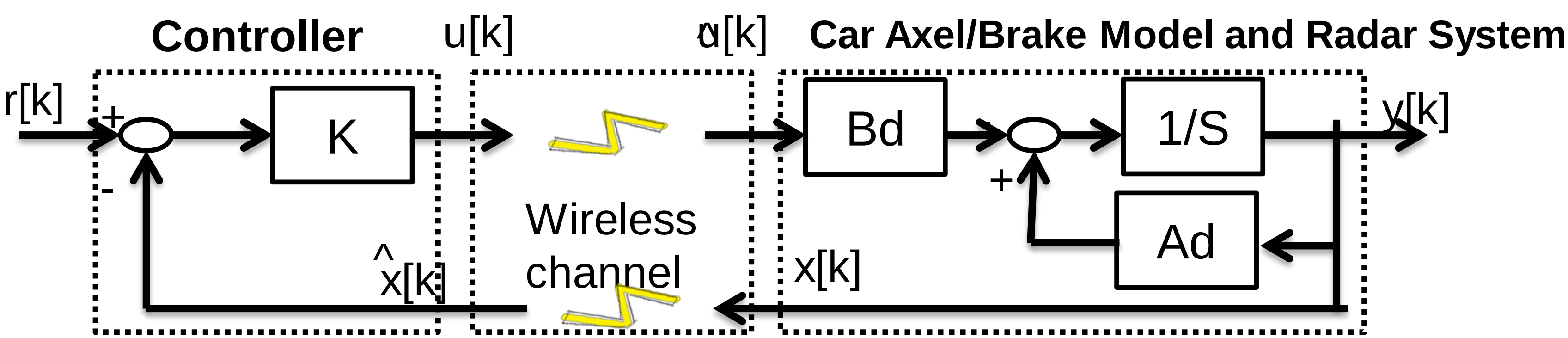
(2) Promote International Standard of Wireless Body Network（BAN) and Integrated Platform of BAN/5G/AI for Global Marketing for both Medical and Automotive uses

(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

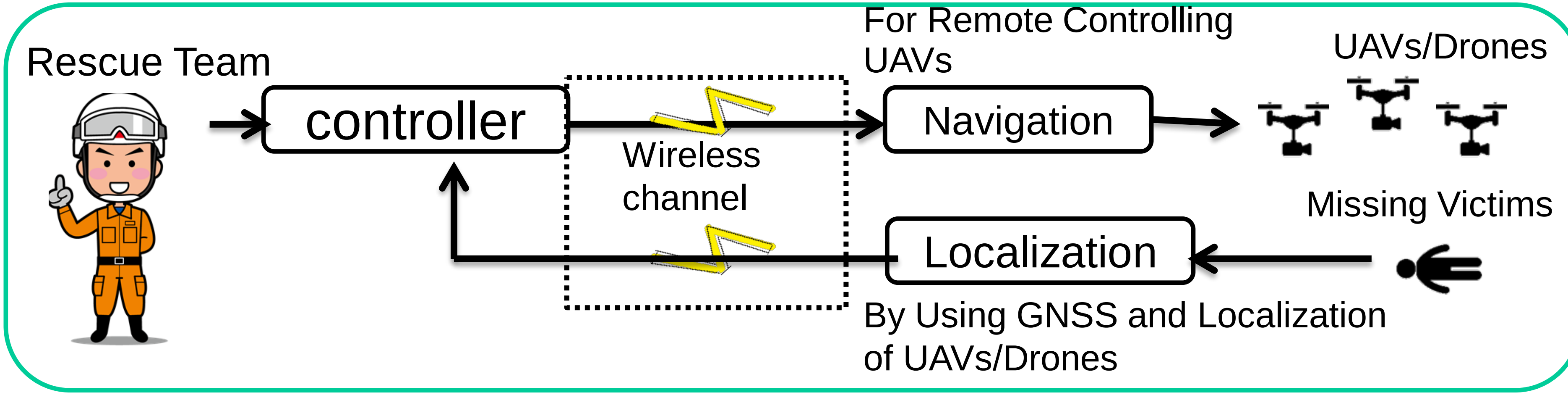



**Wireless Feedback Sensing and Controlling Loop for Autonomous Driving**

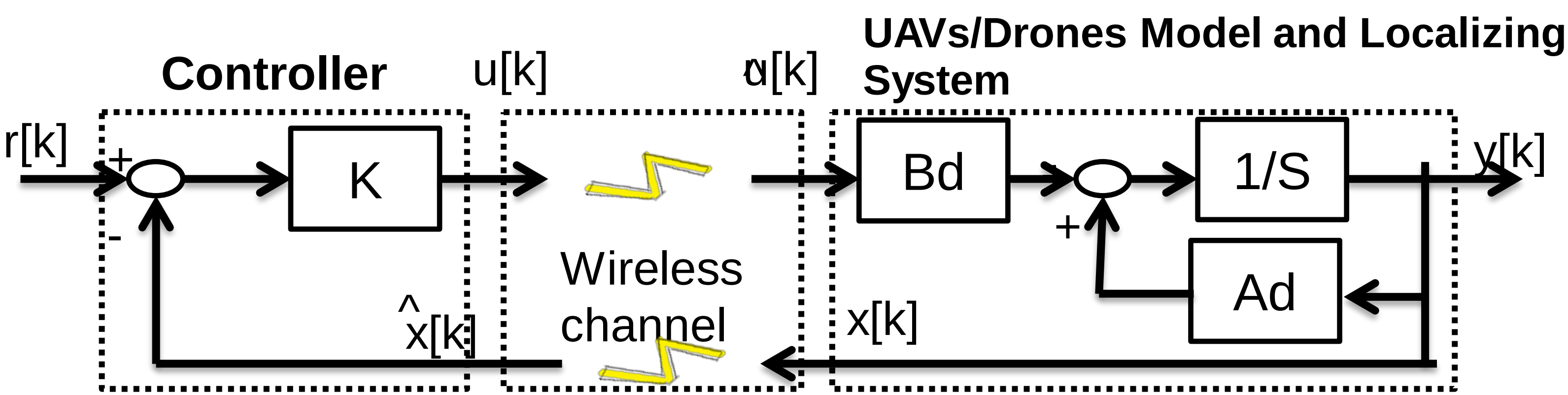



**Feedback Delay Loop Model with Motion Equation**

# 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

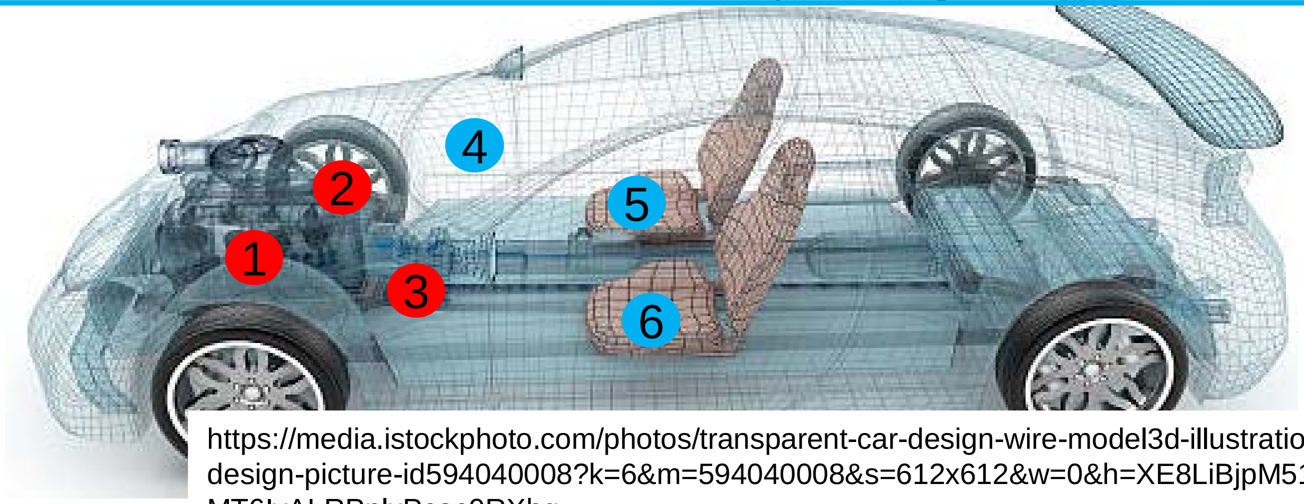
Motivation to extend human BAN(HBAN) to VBAN is to promote much dependable services by interaction between HBAN and VBAN.

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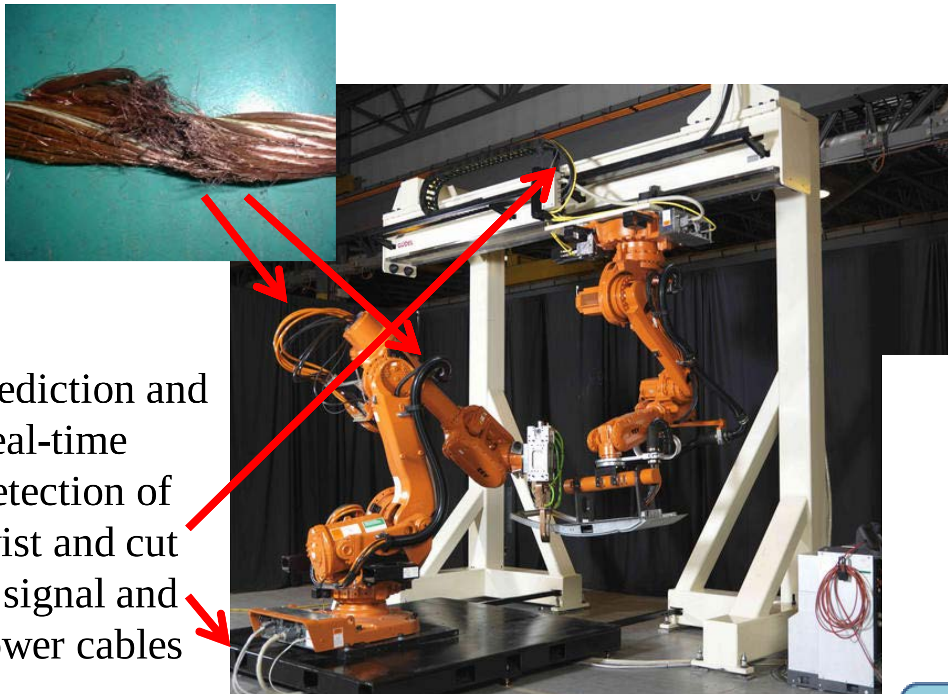
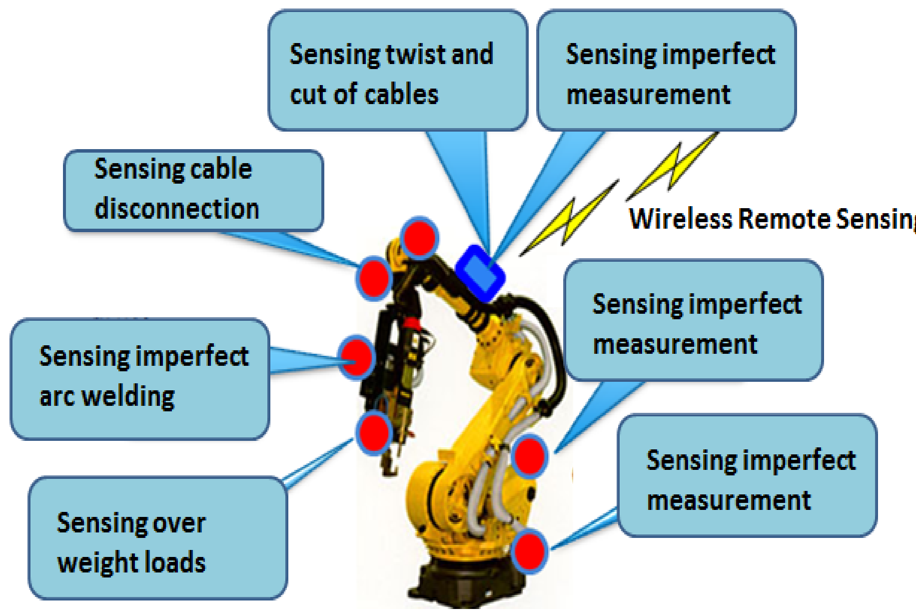
# 1.12 Use case in Factory Manufacturing Line; Detection of Twist and Cut of Cables

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

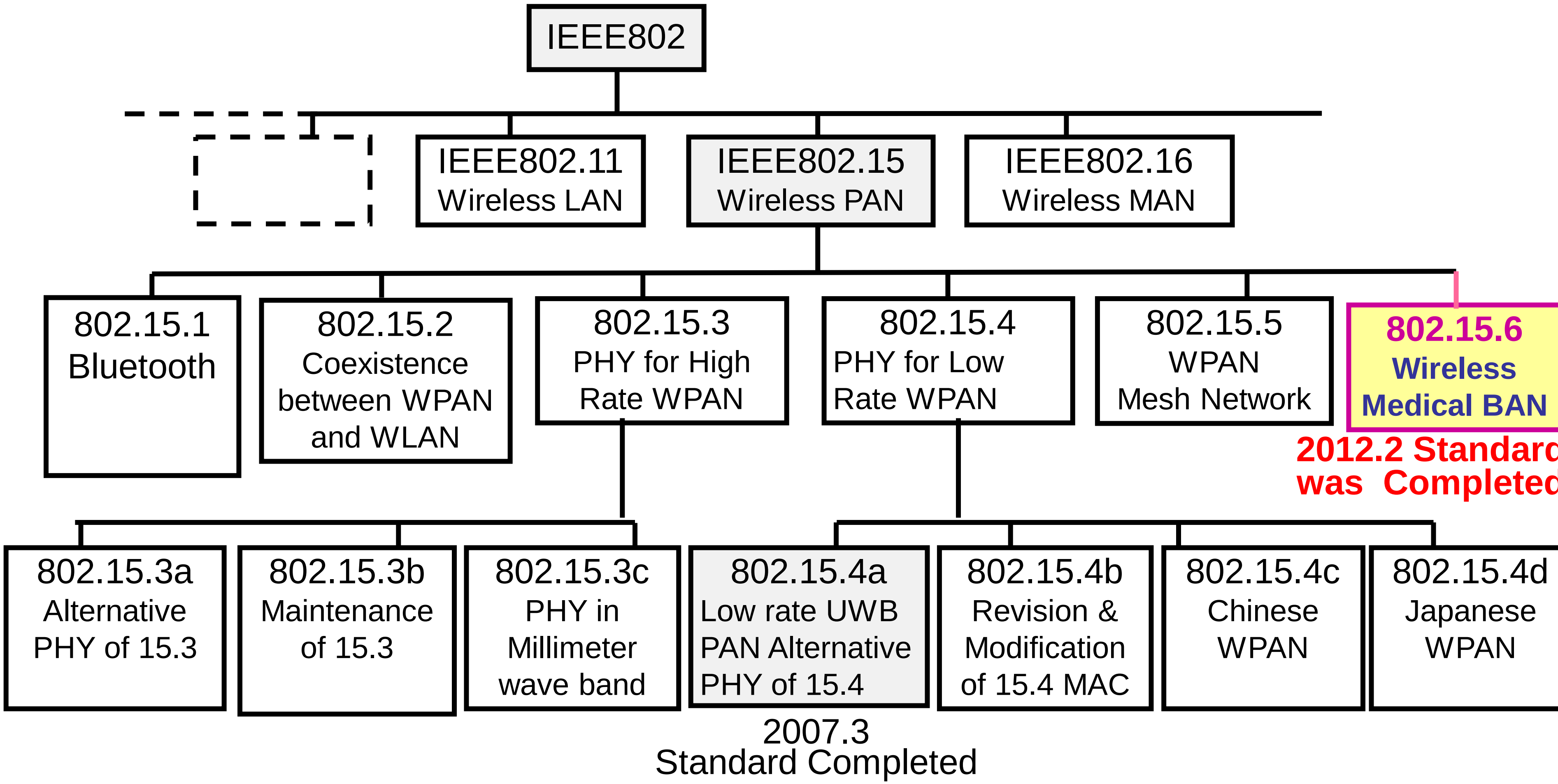
Prediction and Real-time Detection of twist and cut in signal and power cables



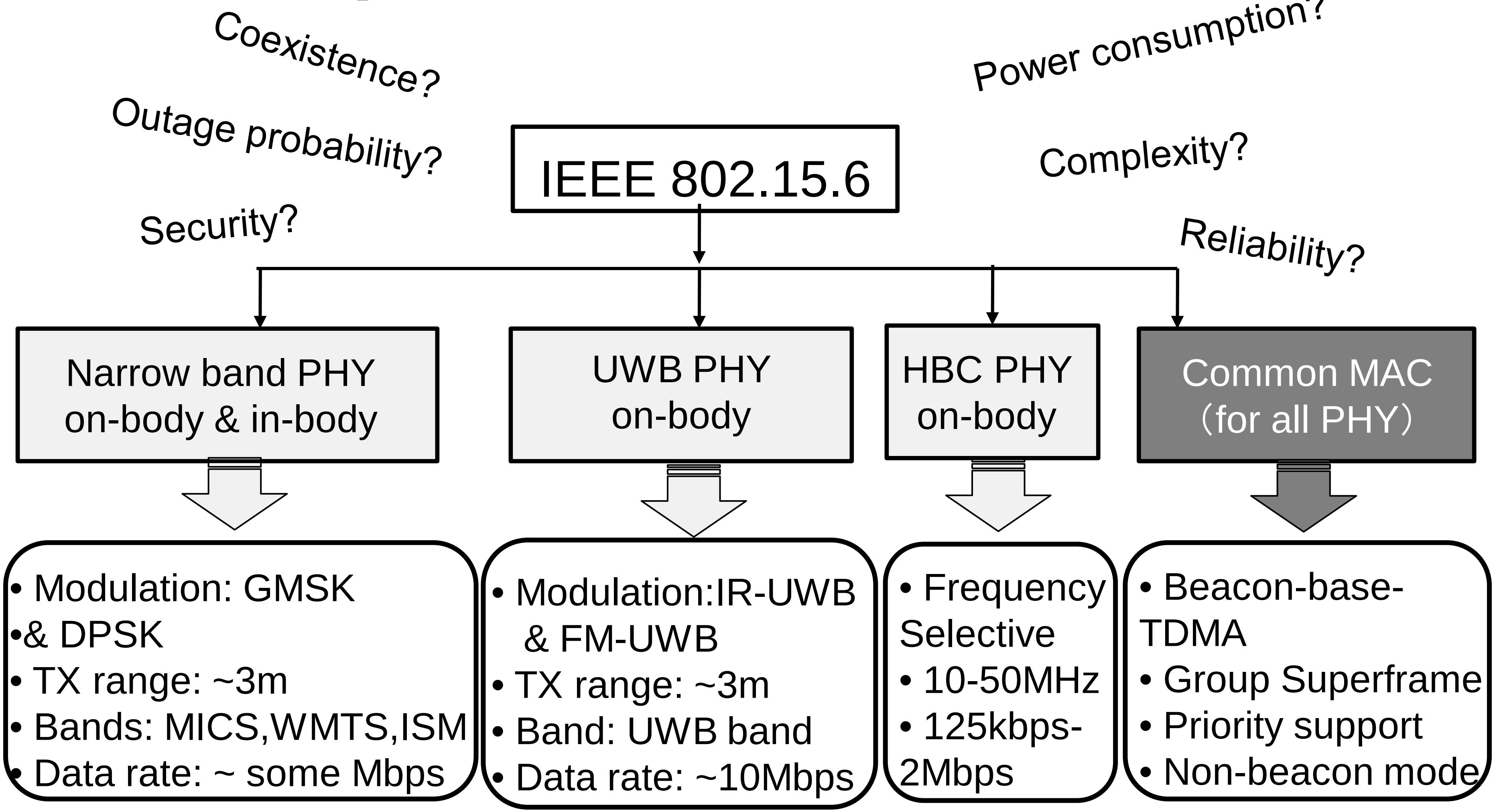


# 2. Short Review of WBAN Standard IEEE802.15.6-2012

# 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**

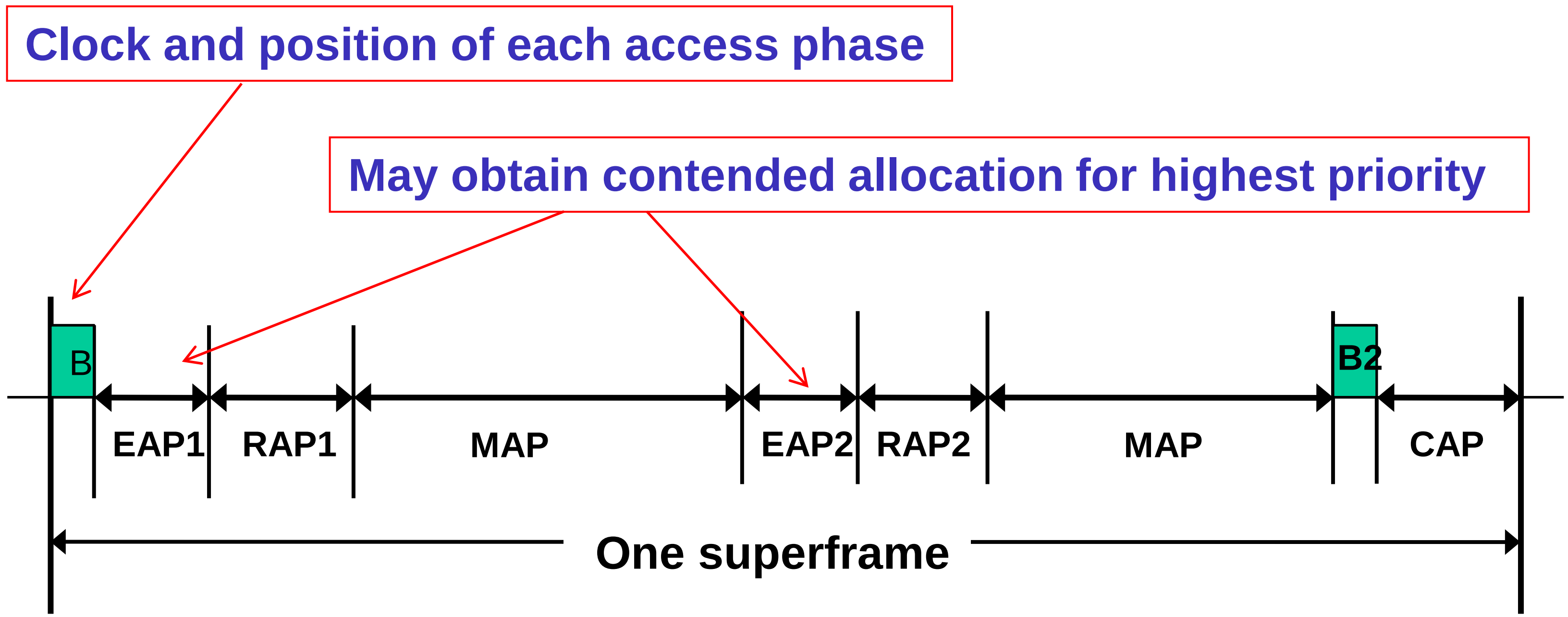
# 2.3 User Priority Mapping

| 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



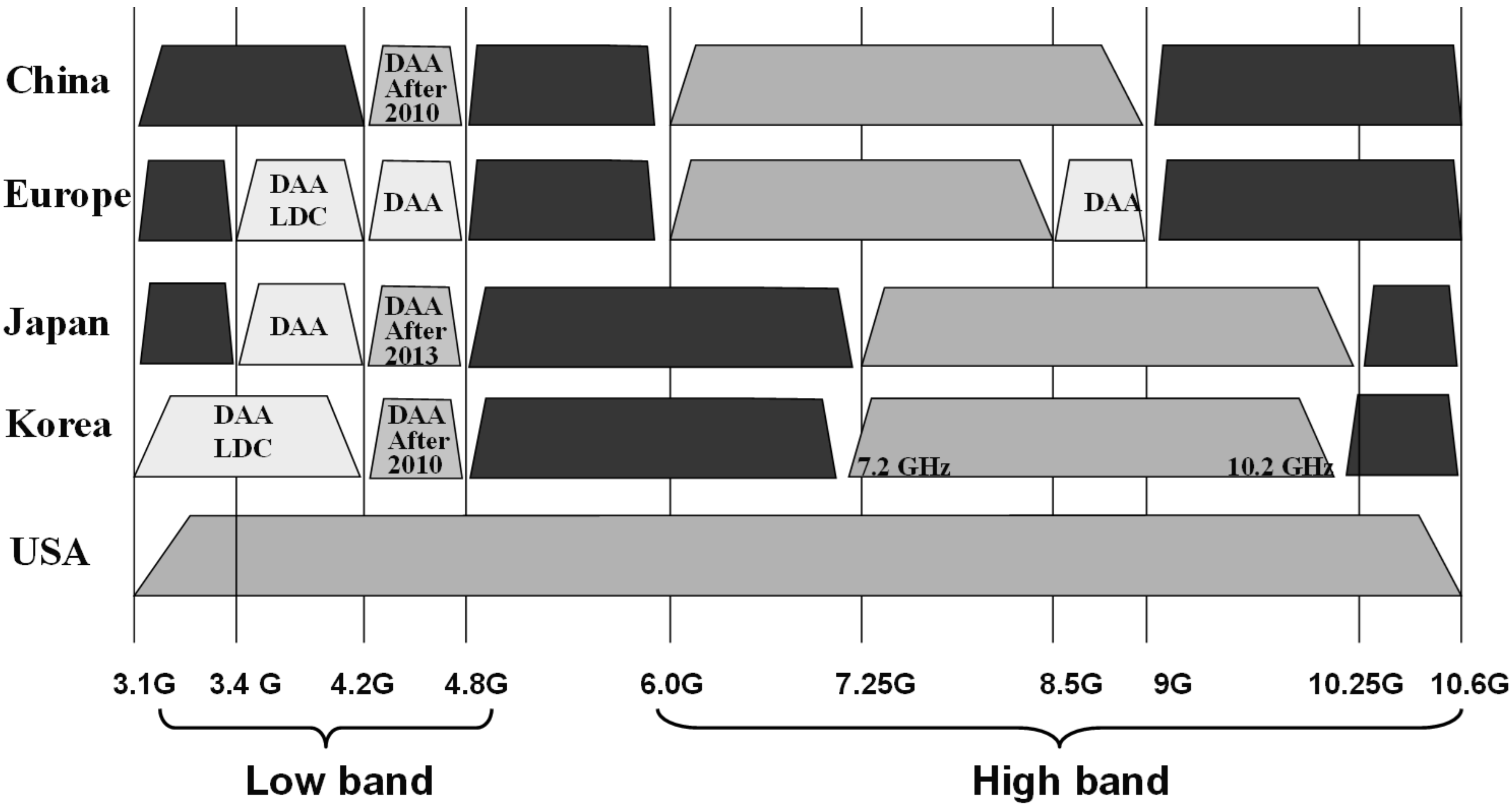

**EAP: exclusive access phase**

**RAP: random access phase**

**MAP: managed access phase**

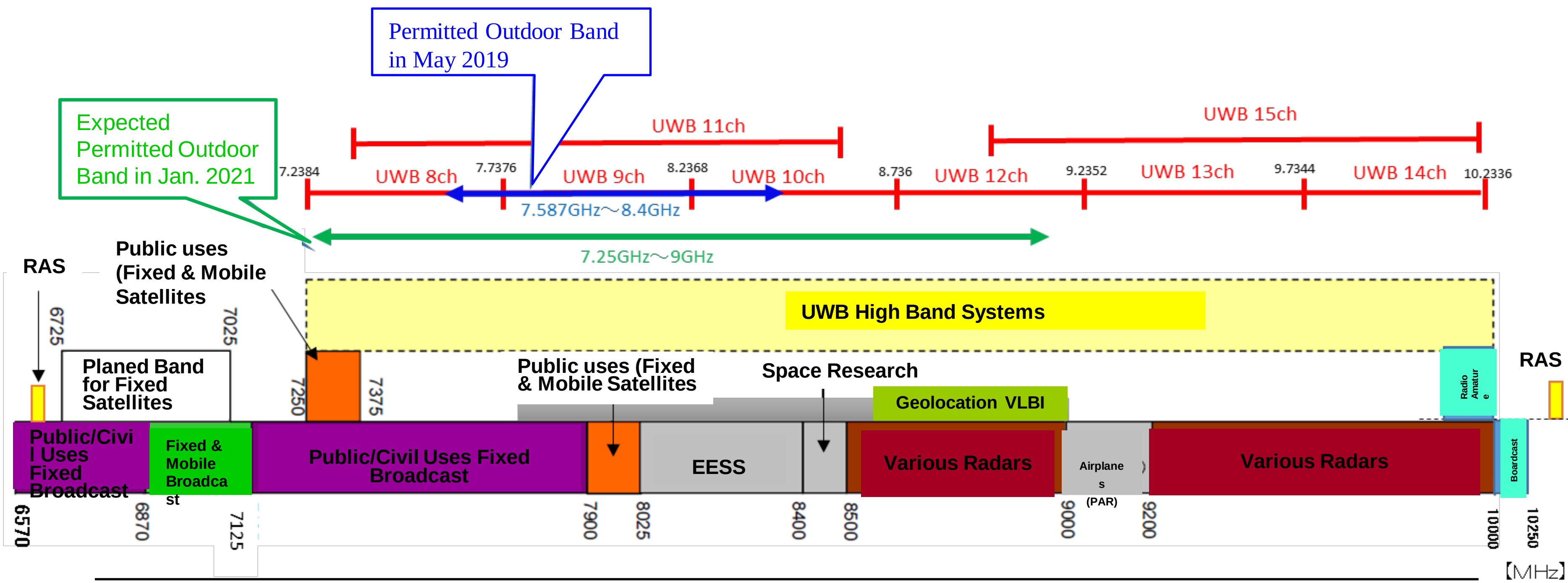
**CAP: contention access phase**

# 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$^{TM}$ 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 std 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

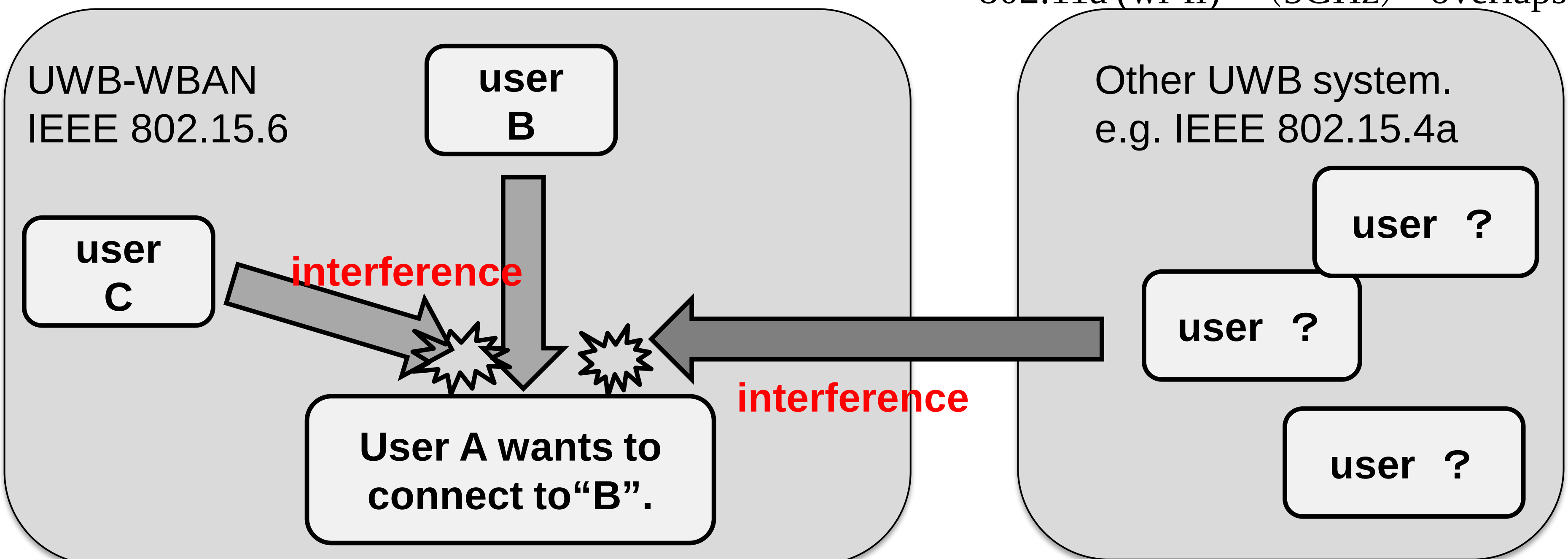
- Mobile nodes and coordinator of BAN need ranging and positioning of UWB-BAN

# 4. Available Technologies in PHY and MAC Layers for the Focused Amendment of std 15.6 BAN with Enhanced Dependability

# 4.1 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



# 4.2 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**

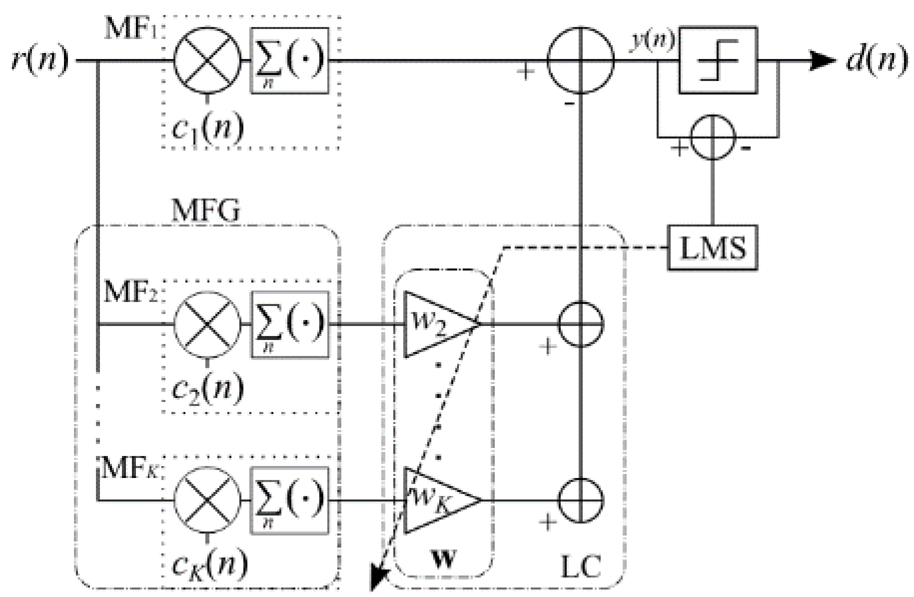
*Interference canceller*

# 4.3 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.*

# 4.4 Space Domain Interference Mitigation

## TDL-AA ; 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;$\theta$ and frequency; $\omega$.

⇒has characteristics of both of spatial and time domain.

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

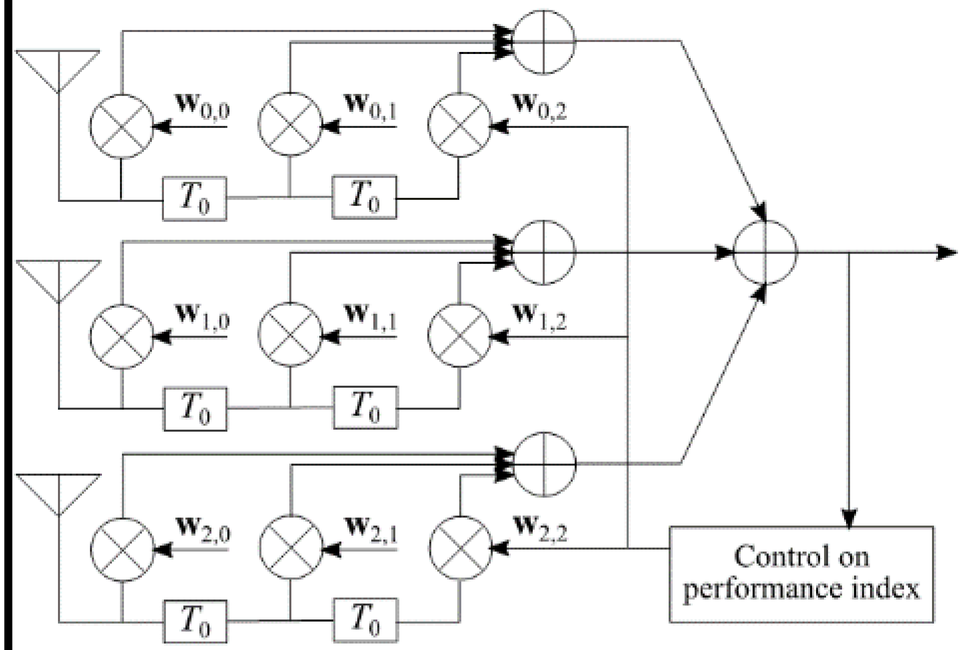
$$y(t) = \exp(j\omega t)\sum_{n=0}^{N-1}\sum_{m=0}^{M-1}\exp(-j\omega(\tau_n + mT_0))w_{n.m},$$

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

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

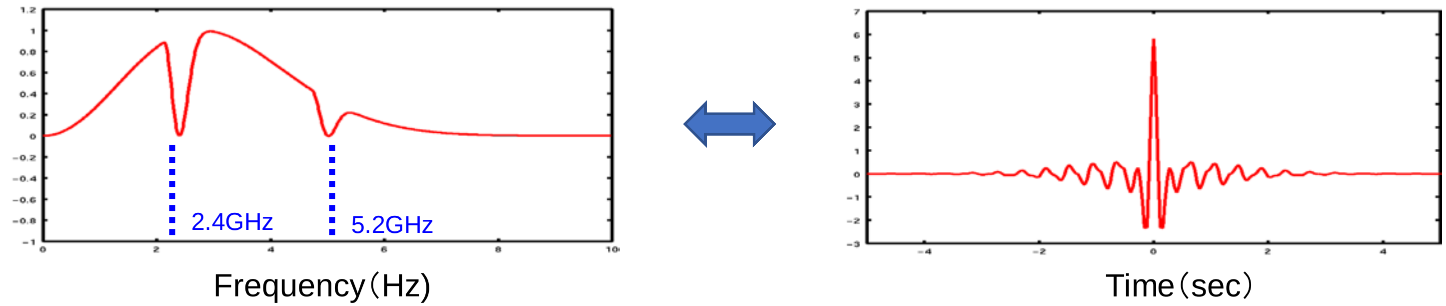
（Tapped delay line array antenna）

Principle of TDL-AA

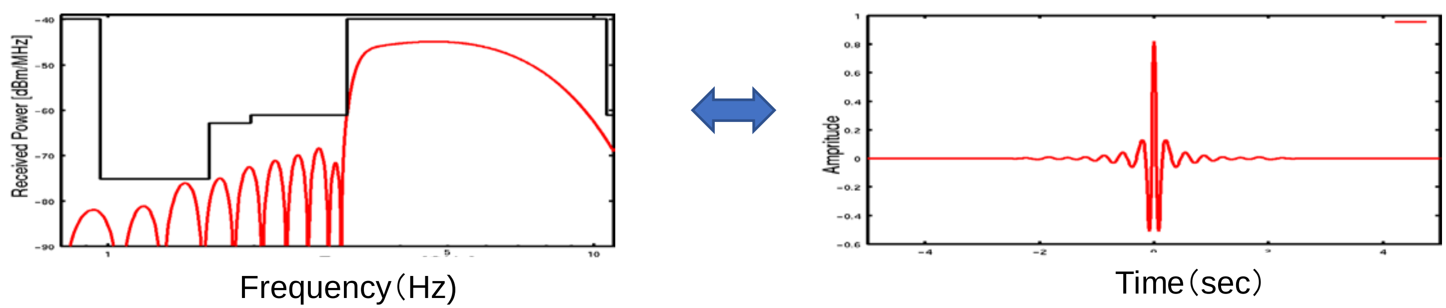



*TDL-AA can work as interference canceller on both of time and space domains*

# 4.5 Interference Mitigation among Other Radios



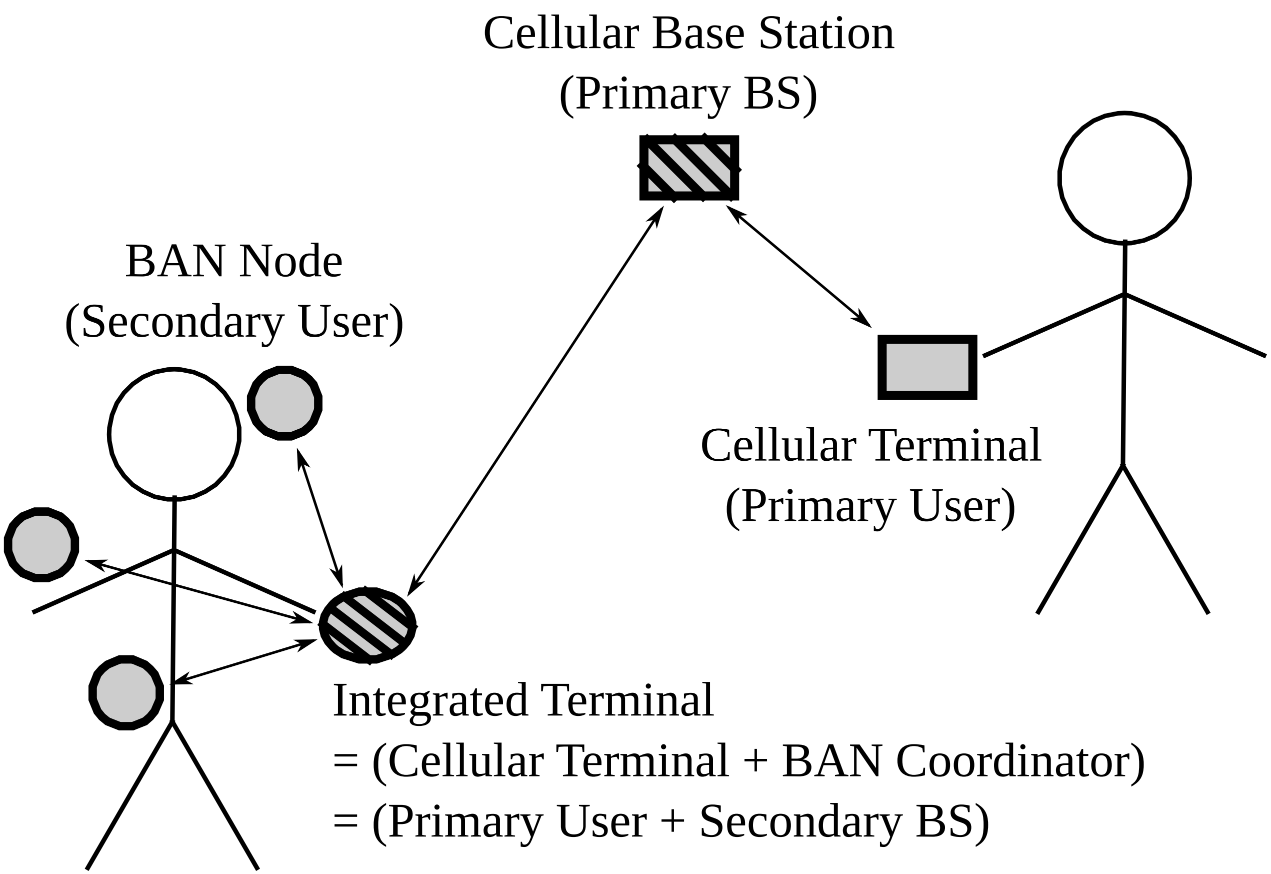

(a) Time Waveform of Pulse (right figure) and its Frequency Spectrum with notches in 2.4 and 5.2GHz for WLAN (left figure)




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

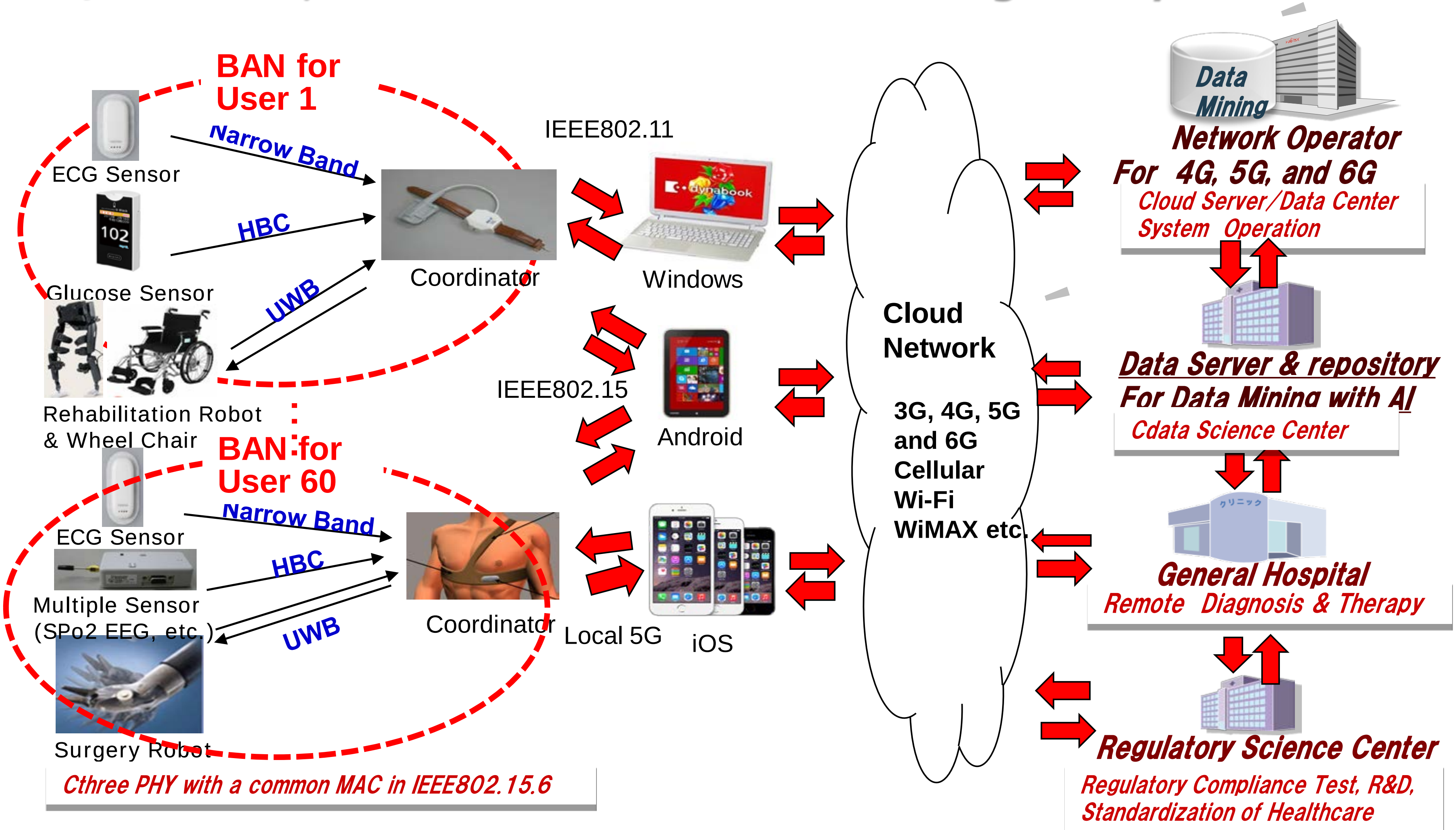
Ref. R.Kohno, H.Zhang, H.Nagasaka, "Ultra Wideband impulse radio using free-verse pulse waveform shaping , Soft-Spectrum adaptation, and local sine template receiving," doc.: IEEE 802.15-03/097r1, March 3, 2003.

# 4.6 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

# 4.7 ICT & Data Science Platform for Infrastructure with BAN, 5G/6G Cloud, and Data Servers Based on Regulatory Science



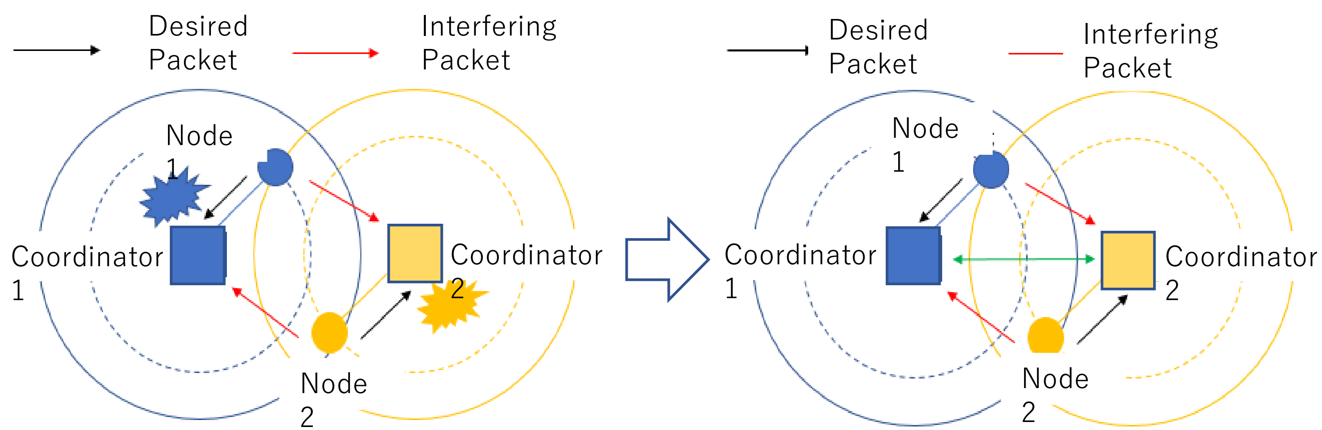
# 4.8 Contention among Overlaid BANs

**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

# 5. Technical Requirement for the Amendment of Std. 15.6 to Enhance Dependability

# 5.1 Update of Technical Requirements for Amendment of BAN

- IEEE802.15.6 for Medical BAN was established in Feb. 2012 and has not been updated for successive applications.
- IG-DEP has been discussing with ETSI Smart BAN for digital healthcare and further medical applications.
- NICT Brain Machine Interface; BMI labs with medical community requests amendment of IEEE802.15.6 for much higher capacity and reliability in IG-DEP, particularly 2nd Generation of ECoG with much more electrodes beyond EEG using UWB technologies.
- IG-DEP has decided to include dependable medical BAN with higher capacity and reliability in focused applications.
- Then updated technical requirement has been discussed.
- The updated requirement will be summarized in next pages.

# 5.2 Updated Technical Requirements(1/5)

| | Car | Factory automation | UAV(Drone)Sensing &Control | High Data Rate BAN (HRP) | Low Data Rate BAN (LRP) | Dependable BAN including Car Body as well as Human and Robotic Body | Reference standard 802.15.6 |
|---|---|---|---|---|---|---|---|
| Number of sensors | Up to ten per network | Up to ten per network | Up to ten (ex. camera, GPS etc.) | Up to 4096 | Up to 256 | 128, 64, 32, 16, 8, 4, 2 nodes for each unit.<br>In case of Human body,4 units can cover 256 nodes as the same as 15.6.<br>In case of Car body, M>4 units can cover 64xM nodes in layer structure.<br>Class A; node transmitting periodical packets<br>Class B: node doing non-periodical ones. | 256<br>For 2nd G ECoG BMI<br>128x32, 64x64<br>32x128,<br>16x256, 8x512<br>4x1024.<br>2x2048 |
| Support for multiple network co-existence & interoperability | Less than 100 | Up to 100 | Up to ten (ex. at least 4 drones for relative localization) | Single | Up to 3 BANs | Less than 64 units. 1 unit contains 64 sensors. Includes multiple BANs overlaid.<br>Other choices are 32 nodes/unit and max no. of units is 100<br>Ref. 64 sensors x 64 Units = 4,096 sensors that is sufficient for 2nd G ECoG BMI | 0<br>Not expected multiple BANs overlaid |
| Topology | Extended star | Star + bus | Star(dynamic allocation of coordinator) | Star(2pairs) | Star+multi hop | Star +multiple hop or Star + mesh<br>Due to relationship with smart BAN and smart M2M<br>Two layered cluster tree | (extended) star+one hop |
| Data rate | Comparable to CAN, RIM | 2 Mbps/sensor | Up to several ten Mbps/camera/drone | Up to 1KHzx12 =12kbps/sensor | Aggregate rate up to 2Mbps | 2 Mbps For high QoS(priority) packets, 1Mbps while shorter back-off time or delay<br>For low QoS packets, 2 Mbps or higher while permissible delay longer | 1 Mbps for narrow Band<br>11 Mbps for UWB in max |

# 5.2 Updated Technical Requirements(2/5)

| | Car | Factory automation | UAV(Drone) Sensing & Controlling | High Data Rate BAN (HRP) | Low Data Rate BAN (LRP) | Dependable BAN for Car Body as well as Human Body | Reference standard 802.15.6 |
|---|---|---|---|---|---|---|---|
| Aggregate data rate over interoperating networks | Few hundred Mbps | Up to 1 Gbps | Up to several Mbps/drone | 50 Mbps | 2 Mbps | 6 hundred Mbps in case of 4 nits x 64 nodes/unit Ref. Satisfying 49Mbps for 2nd G ECoG BMI | N/A |
| Latency in normal operation | Comparable to CAN, RIM or Flex Ray | 250 ms to 1s | 250 ms to 500 ms | Frame length 10-20 ms Latency 10ms | 10 ms to 20ms | 250 ms to 1s Ref. to be considered use case of 2nd G ECoG BMI | Typical 50 to 100 ms Ref. 15.4e |
| Latency in critical situation | Comparable to CAN, RIM or Flex Ray | Few ms to 15 ms * | Several 10 ms | 5-10 ms | 10 ms | 100 ms Ref. to be considered use case of 2nd G ECoG BMI | Less than typical case |
| Association delay | N/A | < 1 s | < 100ms | Same direction < 30ms | < 60 ms | < 1 s Ref. to be considered use case of 2nd G ECoG BMI | Less than 1s Optional requirement |
| Authentication and security delay | N/A | < 1 s | N/A | Same direction < 50ms | < 100 ms | < 1 s Ref. to be considered use case of 2nd G ECoG BMI | Seconds Optional requirement |
| Delivery ratio requirement | > 99.9% | > 99% | > 99.9% | > 99.9% | > 99% | >95% Ref. to be considered use case of 2nd G BMI | 95% |

*Reference: Factory Automation critical latency: FFPJ docs new-maruhashi-general-industrial-usage-part1-0317-v00.pdf & new-itaya-general-industrial-usage-part2-0317-v00.pdf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# 5.2 Updated Technical Requirements(3/5)

| | Car | Factory automation | UAV(Drone) Sensing & Controlling | High Data Rate BAN (HRP) | Low Data Rate BAN (LRP) | Dependable BAN including Car Body as well as Human Body | Reference standard 802.15.6 |
|---|---|---|---|---|---|---|---|
| Disconnection ratio (of time) | < 0.01% | < 0.01% | < 0.001% | < 0.01% | < 2% | < 1% to be considered use case of 2nd G ECoG BMI | ? |
| Synchronization recovery time | < 100 ms | < 100 ms | < 70 ms | < 10 ms | N/A | < 50 ms to be considered use case of 2nd G ECoG BMI | Seconds |
| Coverage range | 6 m | 5 m | 100m(among drones) some km(with controller) | 10cm | 50cm | < 10 m Much less coverage for 2nd G ECoG BMI | < 10 m |
| Feedback loop response time | < 10 ms | < 1 s | < 10 ms | < 10ms | < 100ms | < 50 ms Ref. to be considered use case of 2nd G ECoG BMI | < 500 ms |
| Handover capability | N/A | < 2 s | N/A | N/A | N/A | N/A | Not defined |
| Data packet size | CAN & RIM compatibility | 10 to 1000 bytes | 802.11 compatible | 802.11 compatible | 802.11 compatible | Up to 255 octets | Up to 255 octets |

# 5.2 Updated Technical Requirements(4/5)

| | Car | Factory automation | UAV(Drone) Sensing & Controlling | High Data Rate BAN (HRP) | Low Data Rate BAN (LRP) | Dependable BAN including Car Body as well as Human Body | Reference standard 802.15.6 |
|---|---|---|---|---|---|---|---|
| Jitter: typical max | 5 ms | 50 ms | N/A | N/A | N/A | Dependent on Highest QoS | QoS dependen t |
| Jitter: critical max: 5% outliers acceptable | 5 ms | 5 ms | N/A | N/A | N/A | Dependent on Highest QoS | QoS dependen t |
| Multi BAN Overlaid (A) Intra network interference | Driver/P asseng ers room: <10 | <50 according to coverage range | <10 according to no. of drones cluster | Single(2pairs) according to spacing between BANs | Up to 3 BANs according to covering range | **<64** Ref. to be considered use case of $2^{nd}$ G ECoG BMI | By a few use case models, worst interference can be defined |
| | Engine room: <10 | | | implant | wearable | | |
| Different PANs (B) Inter network interference (number of coexisting networks) | Driver/P asseng ers room: < 5 | <10 according to factory condition | <5 according to no. of drones cluster | single Corresponding for interference mitigation technologies | Up to 3 PANS Corresponding to specification of coexisting PANs | **<10** Ref. to be considered use case of $2^{nd}$ G ECoG BMI | By a few use case models, worst interference can be defined. |


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# 5.2 Updated Technical Requirements(5/5)

| | Car | Factory automation | UAV(Drone) Remote Sensing and Controlling | High Data Rate BAN (HRP) | Low Data Rate BAN (LRP) | Dependable BAN | Reference standard 802.15.6 |
|---|---|---|---|---|---|---|---|
| Channel model resilience | Driver/Passengers room: Light multipath | Heavy multipath with shadowing | Line of sight (LOS) | Dedicated short distance (DSRC) with line of sight (LOS) | No Line of sight (NLOS) with shadowing and multipath | Dependent on Highest QoS Ref. to be considered use case of 2nd G ECoG BMI | By a few use case models, worst interference can be defined |
| | Engine room: Heavy multipath with shadowing | | No Line of sight (NLOS) using camera | Compliance for safety guide line with SAR & EMC | Compliance for safety guide line with SAR & EMC | | |

# 5. 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 amendment 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 amendment 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 amendment of IEEE802.15.6 for enhanced dependability in PHY and MAC and move on TG to complete the amendment.
- If you have any question and comment, you are welcome to discussion in SG15.6a and send content contributions to

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