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]

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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]

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.

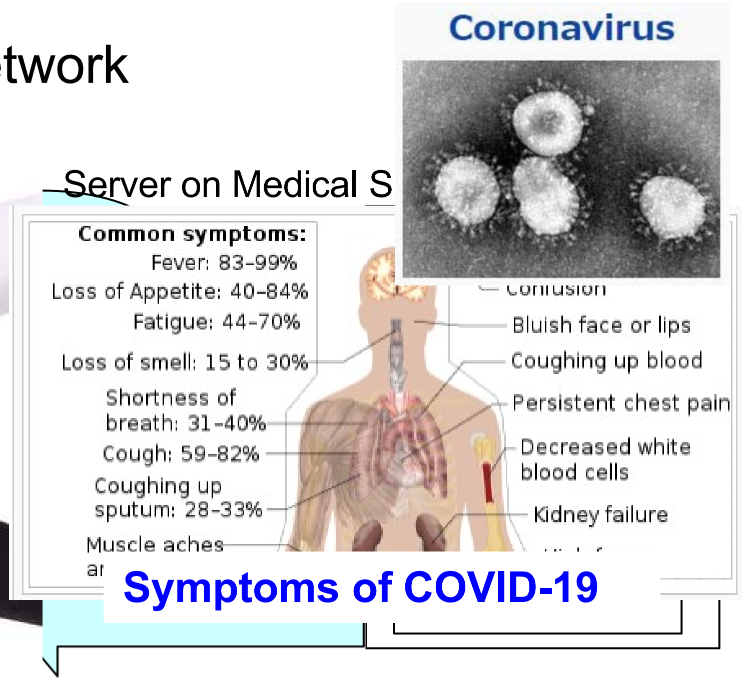
> Remote sensing vital sign and monitoring symptoms

> 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



1.3 Wireless BAN: Body Area Network

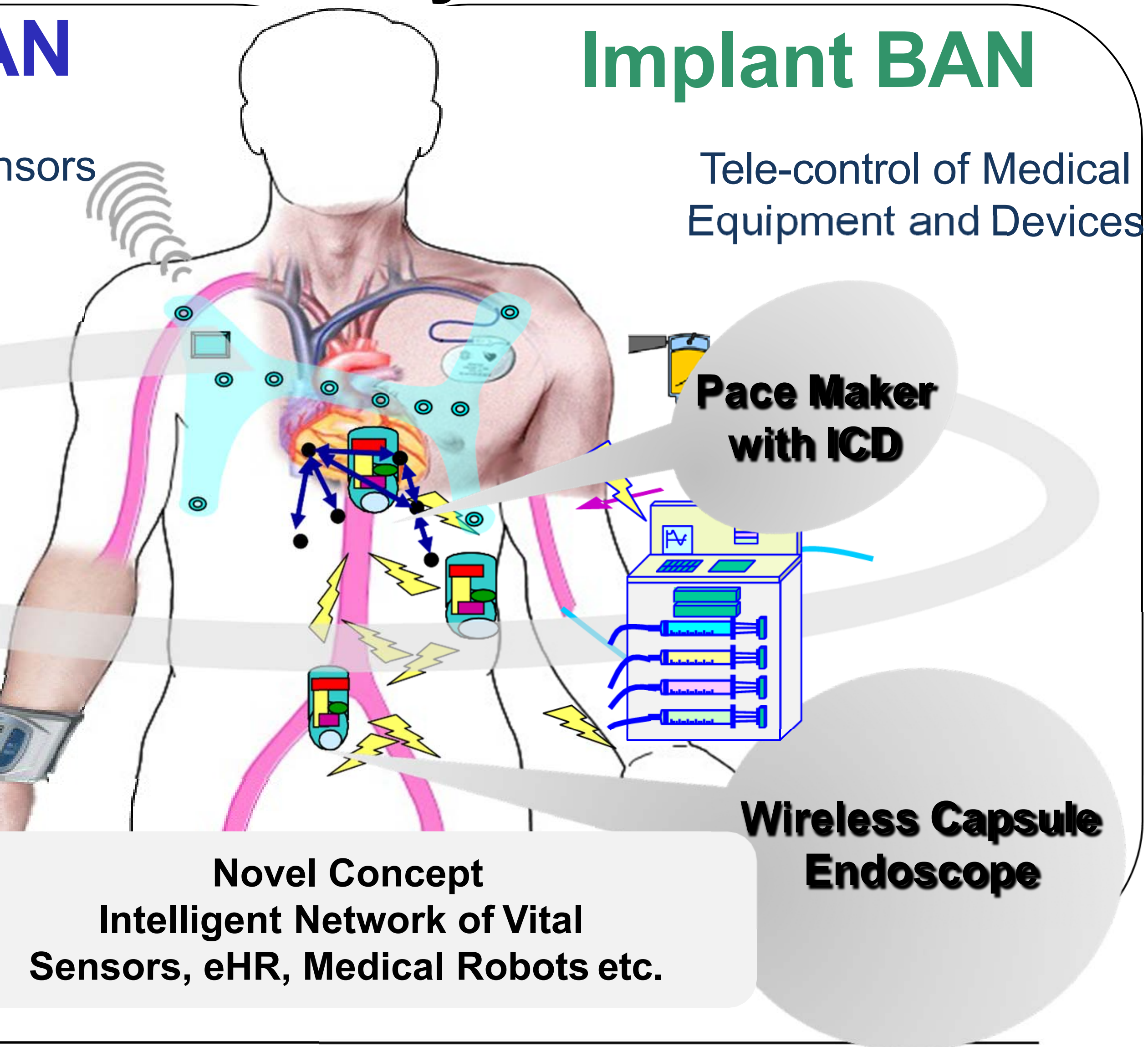
Wearable BAN

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

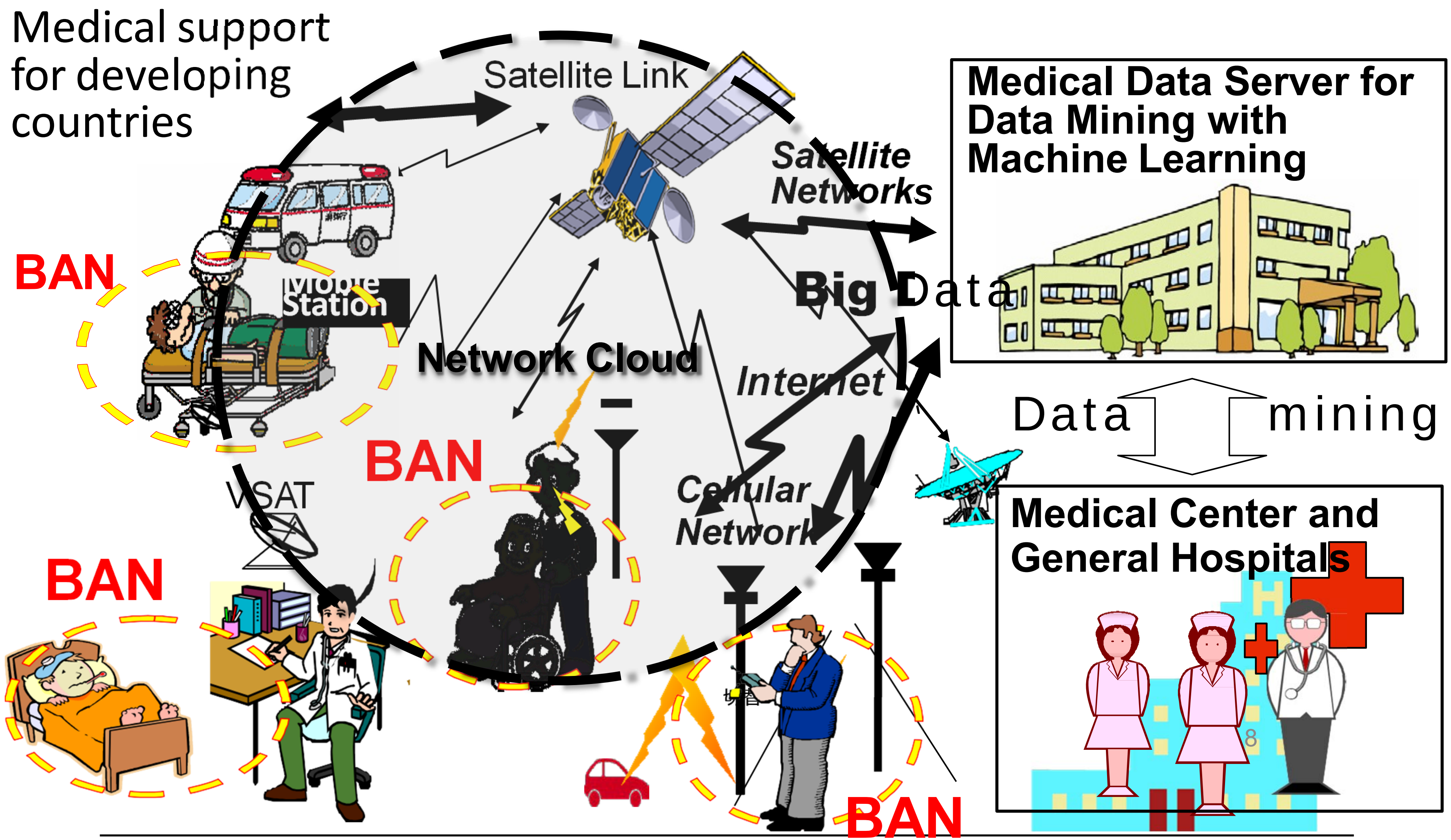
Implant BAN

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



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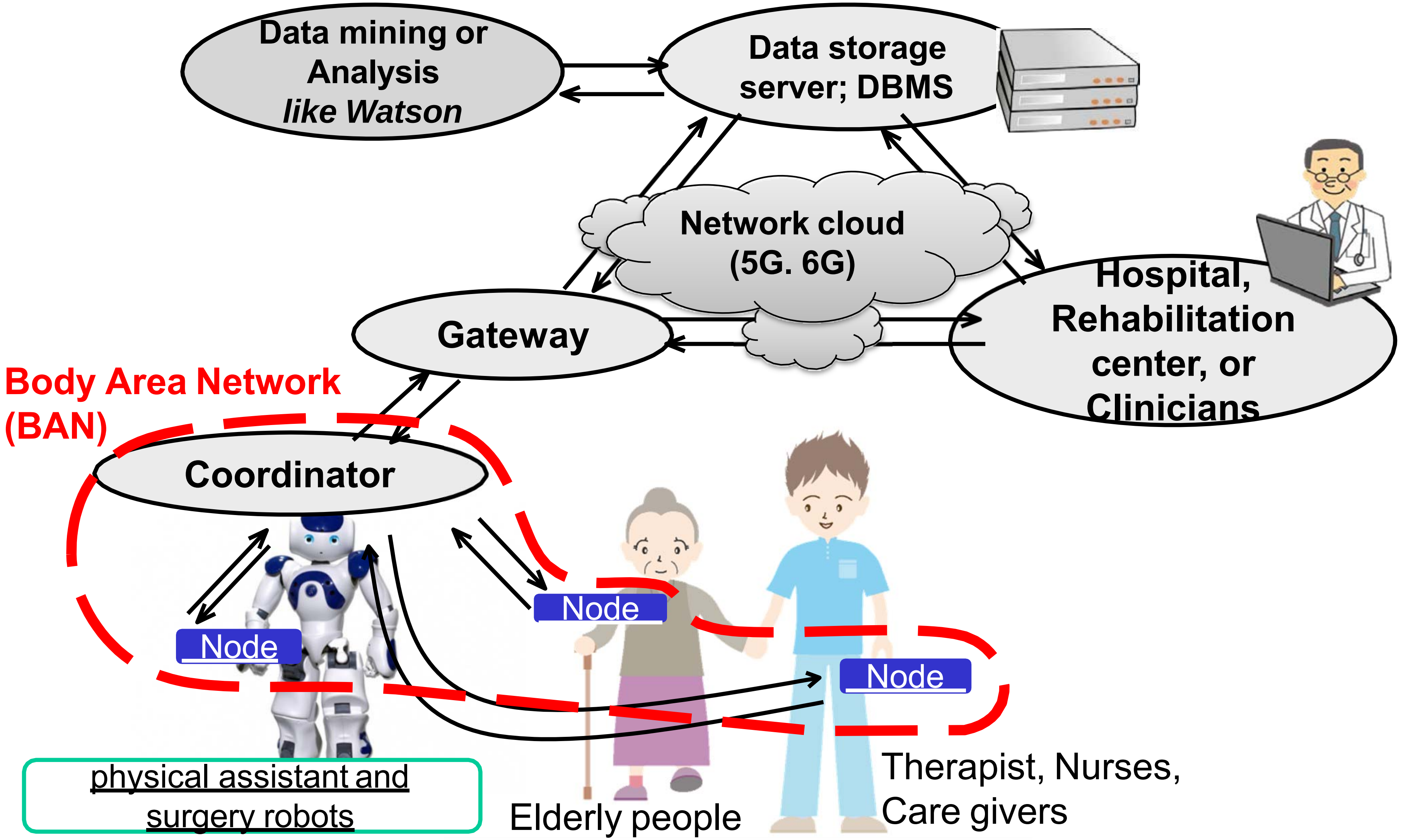
1.5 AN-base Universal Platform with Network Cloud, Data Mining Server for Medical Healthcare



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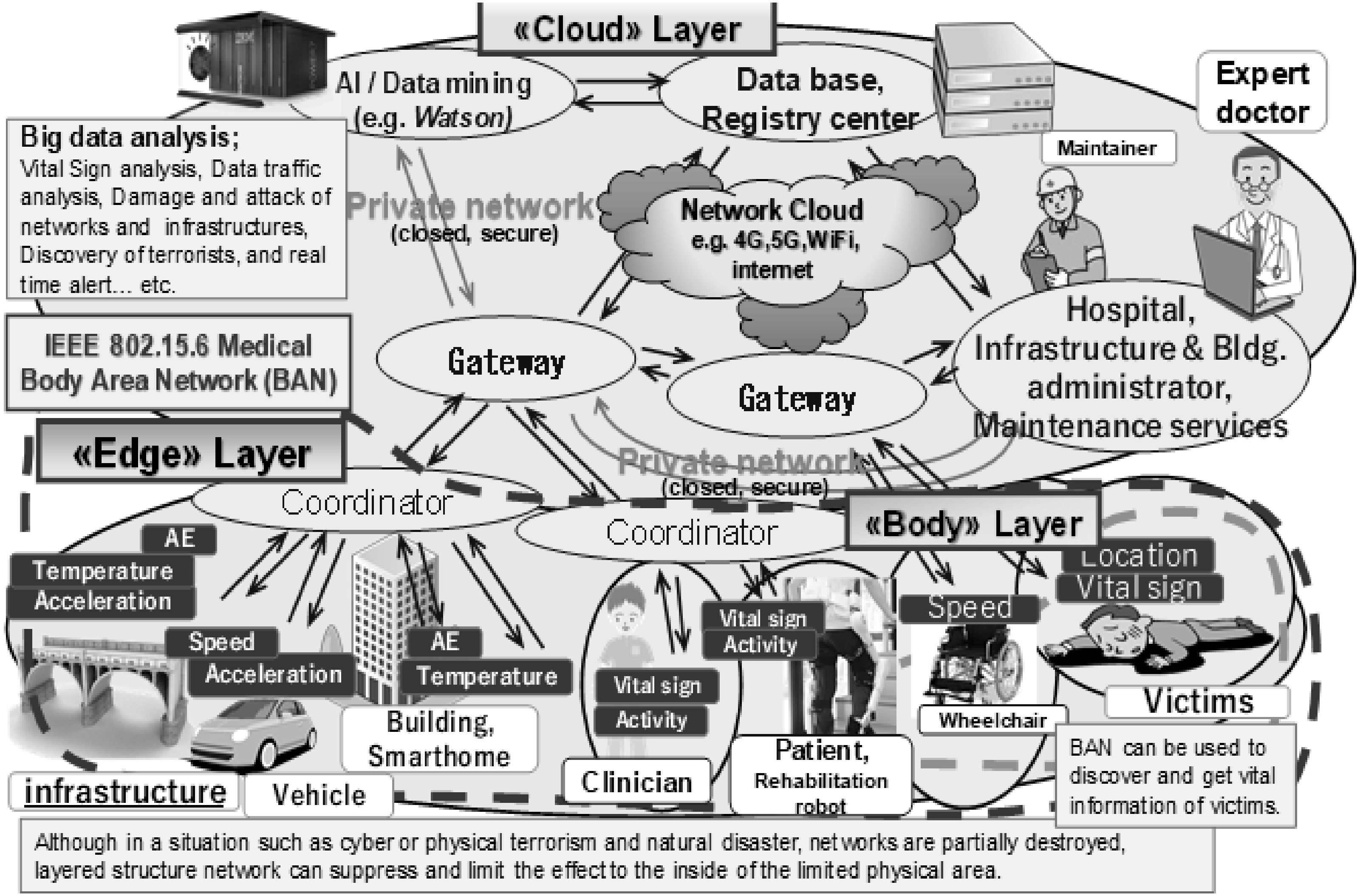
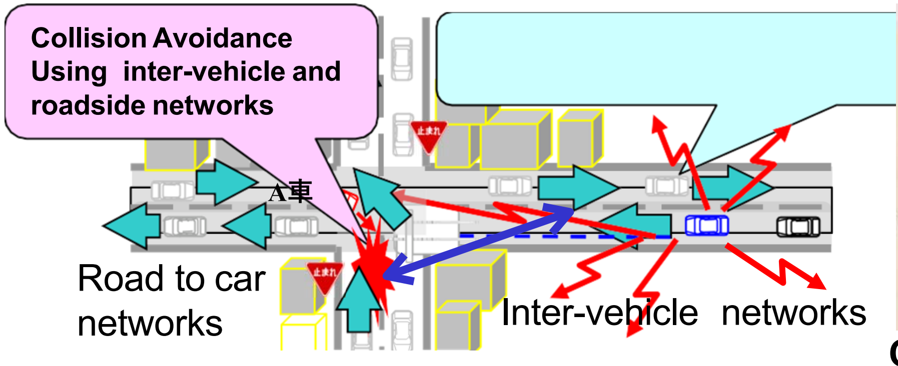
1.6 Universal Platform Based on BAN, Cloud Network, and AI Data Server for General Social Infrastructure beyond Medical Services

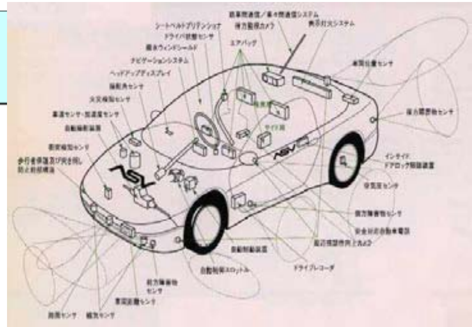


1.7 Extension of Use Cases of BAN beyond Medical Healthcare

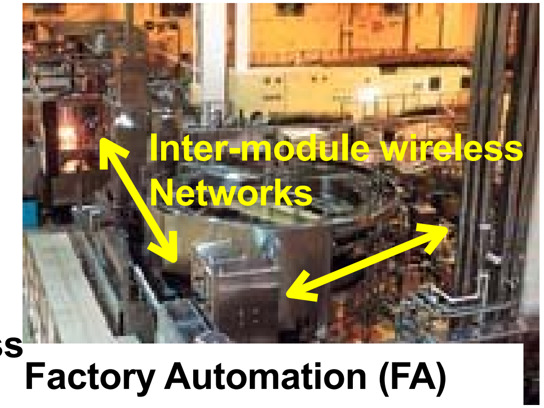


Car Navigation & Collision Avoidance Radar

Dependable Wireless Networks for Transportation

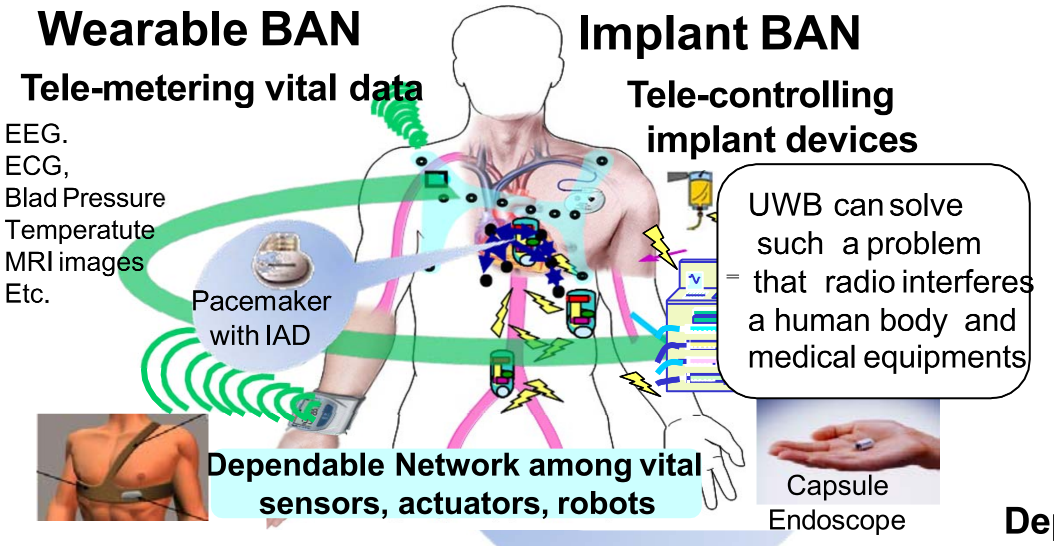


Car LAN & Wireless Harness

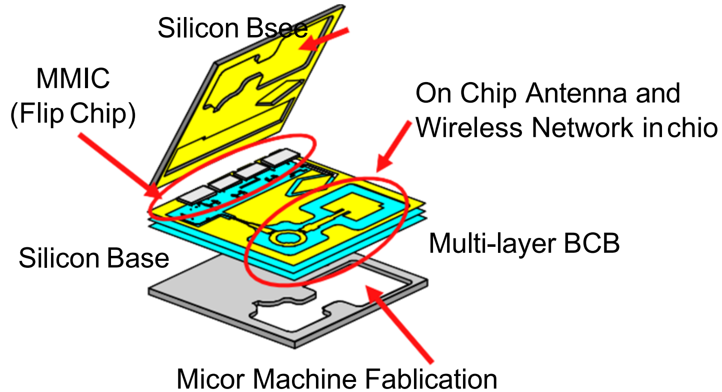


Factory Automation (FA)

Dependable Wireless Sensing & Controlling for Manufacturing (CIM)



Dependable BAN for Medical Healthcare



Dependable Wireless System Clock in Micro Circuit & Network in Devices

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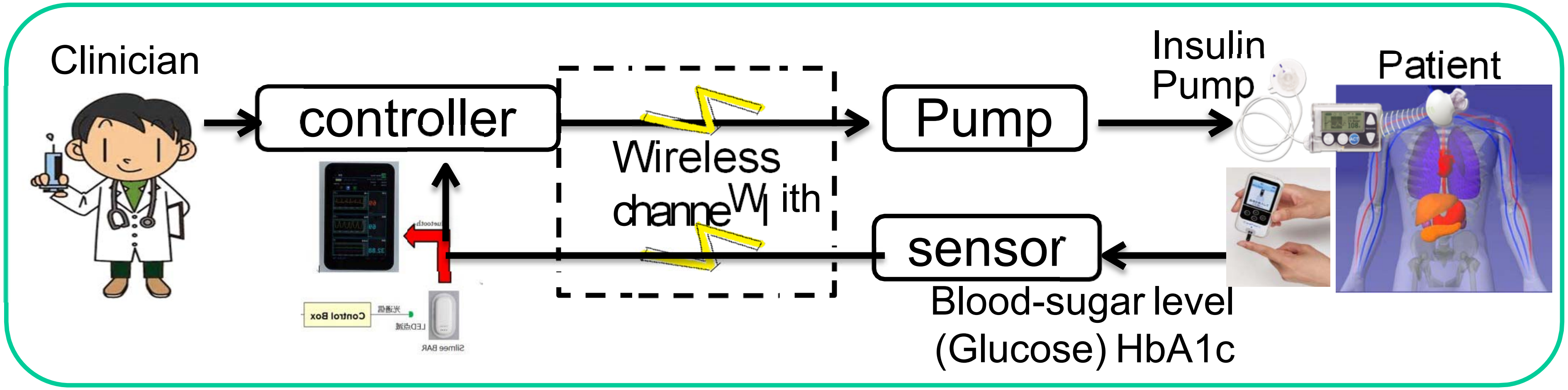
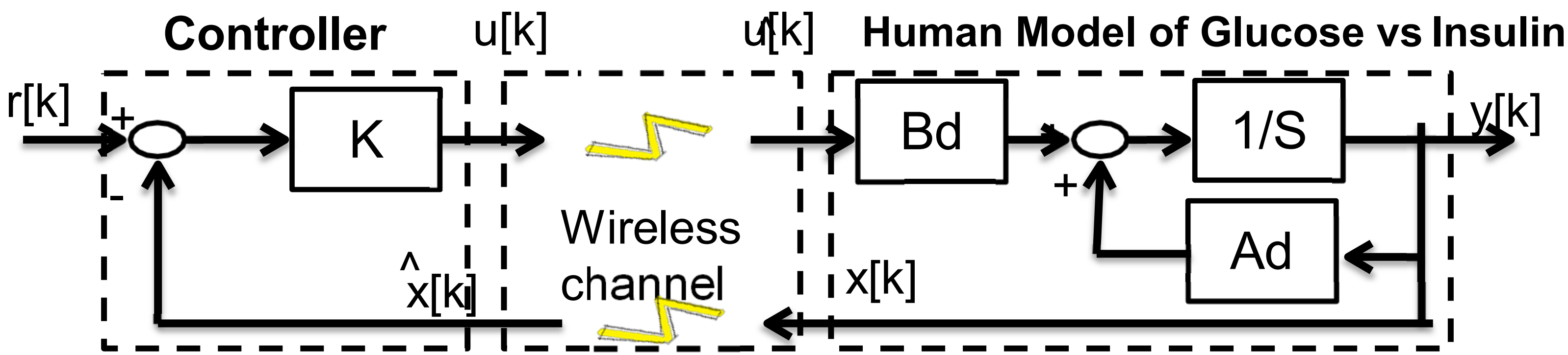
Automatic Remote Sensing Glucose and Controlling Insulin Pump for Diabetes Patients Using Wireless BAN



Wireless Feedback Sensing and Controlling Loop for Diabetes Patients



Feedback Delay Loop Model with Motion Equation

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

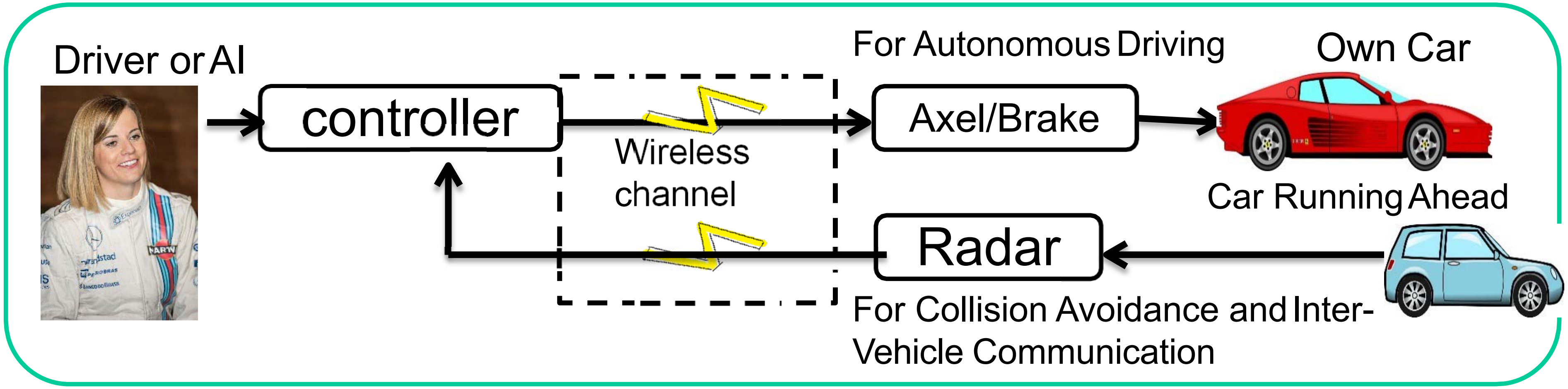
C. Approach:

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

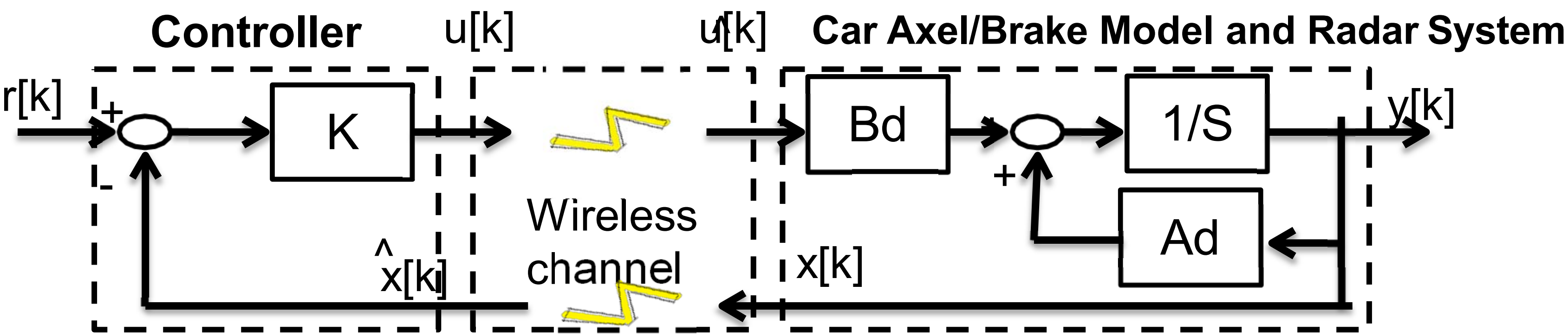
(2) Promote International Standard of Wireless Body Network (BAN) and Integrated Platform of BAN/5G/AI for Global Marketing for both Medical and Automotive uses

(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

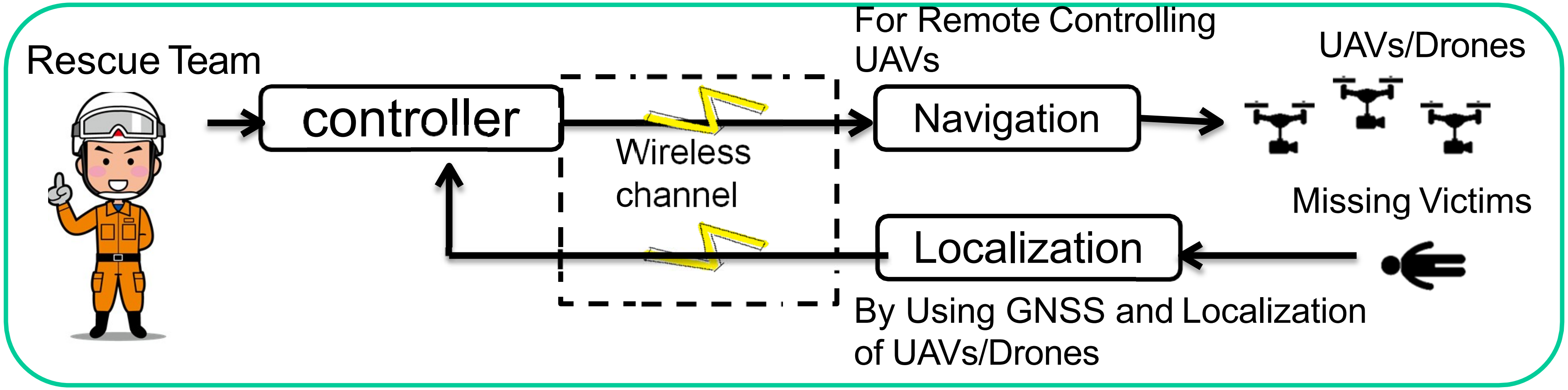


Wireless Feedback Sensing and Controlling Loop for Autonomous Driving

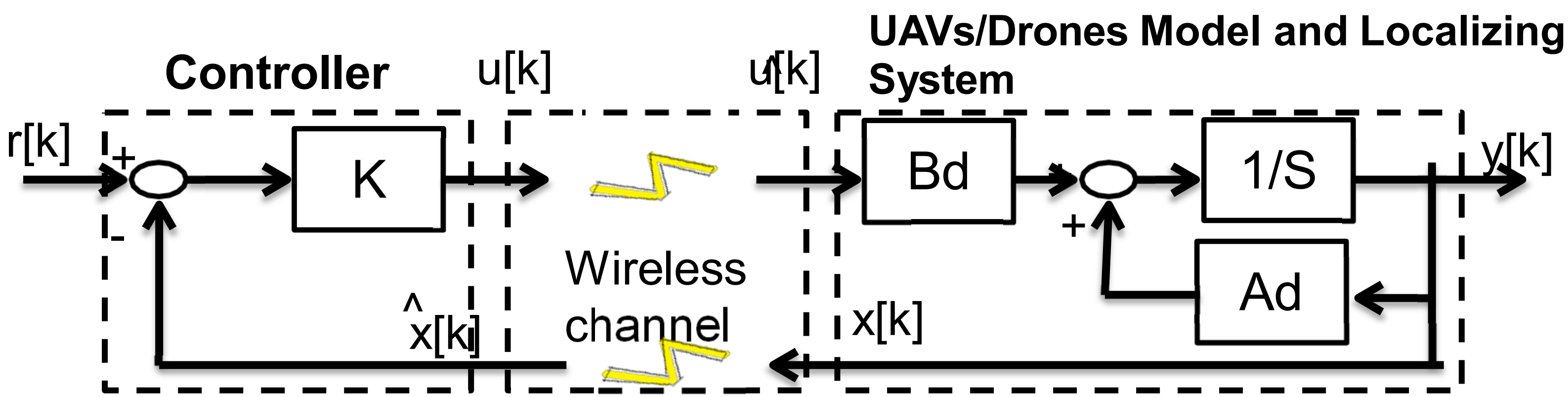


Feedback Delay Loop Model with Motion Equation

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

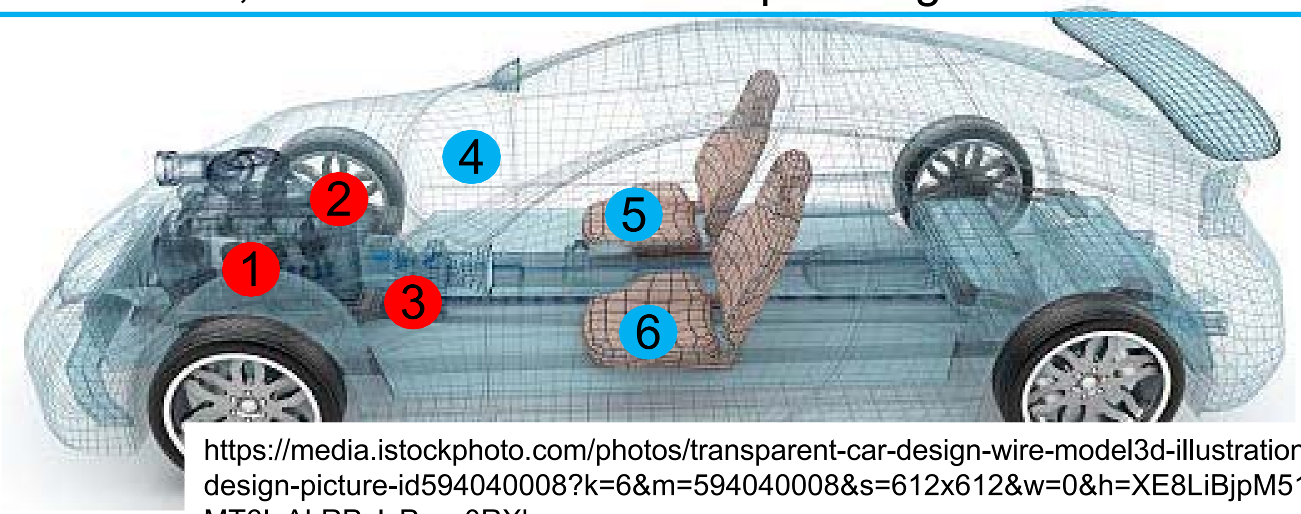
Motivation to extend human BAN(HBAN) to VBAN is to promote much dependable services by interaction between HBAN and VBAN.

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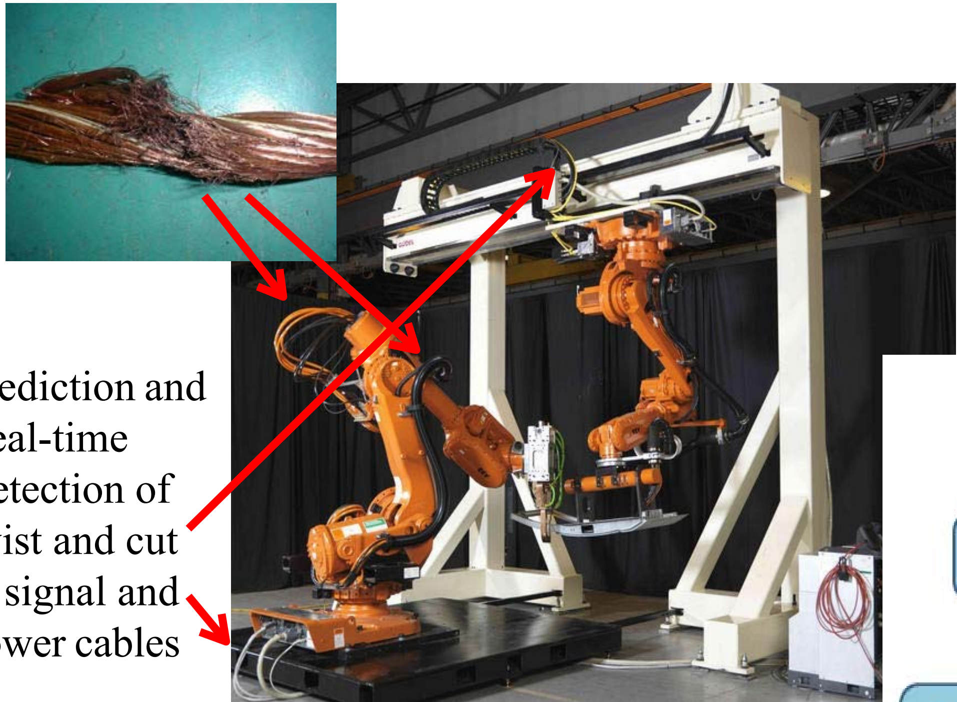
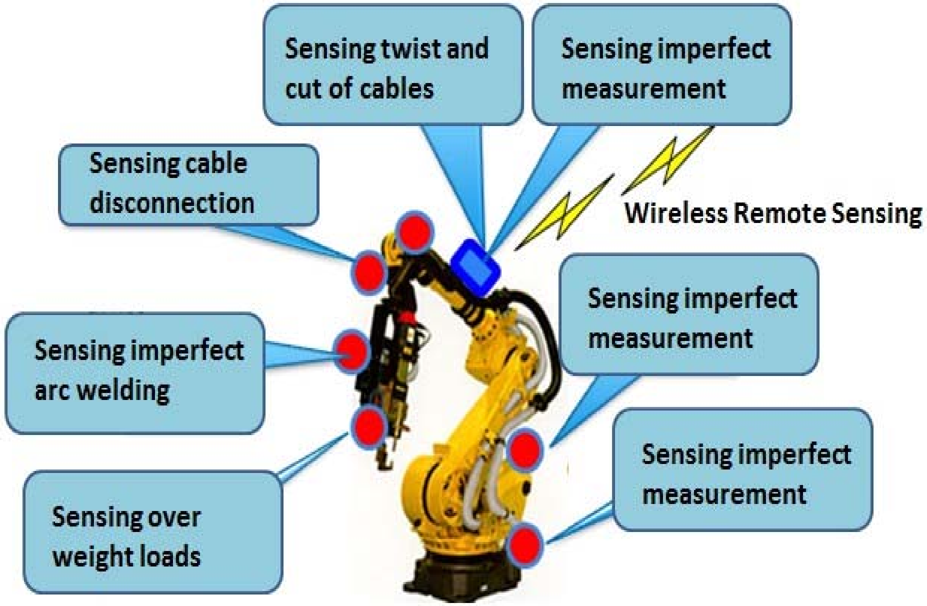
1.12 Use case in Factory Manufacturing Line; Detection of Twist and Cut of Cables



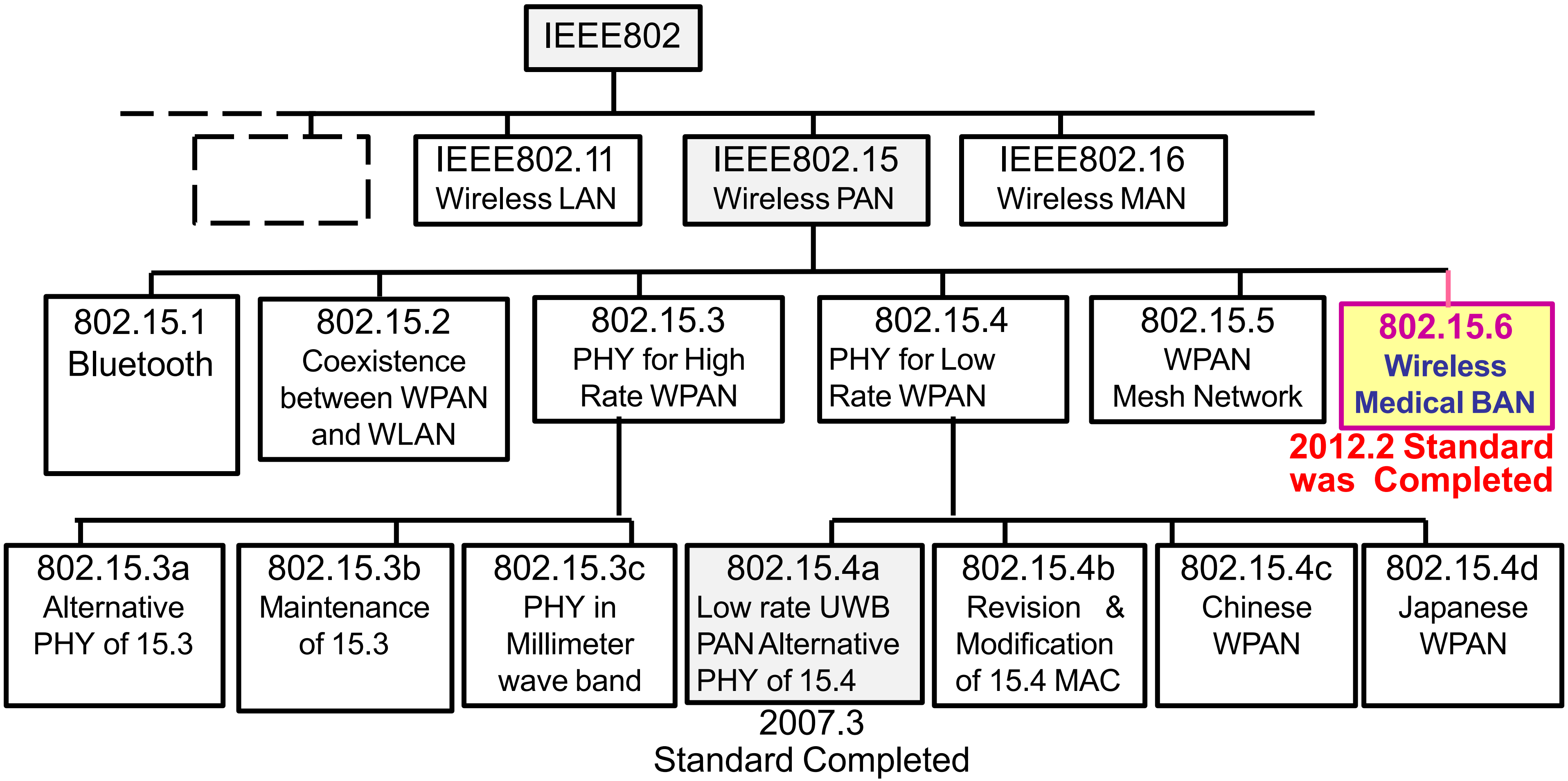
Prediction and Real-time Detection of twist and cut in signal and power cables

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



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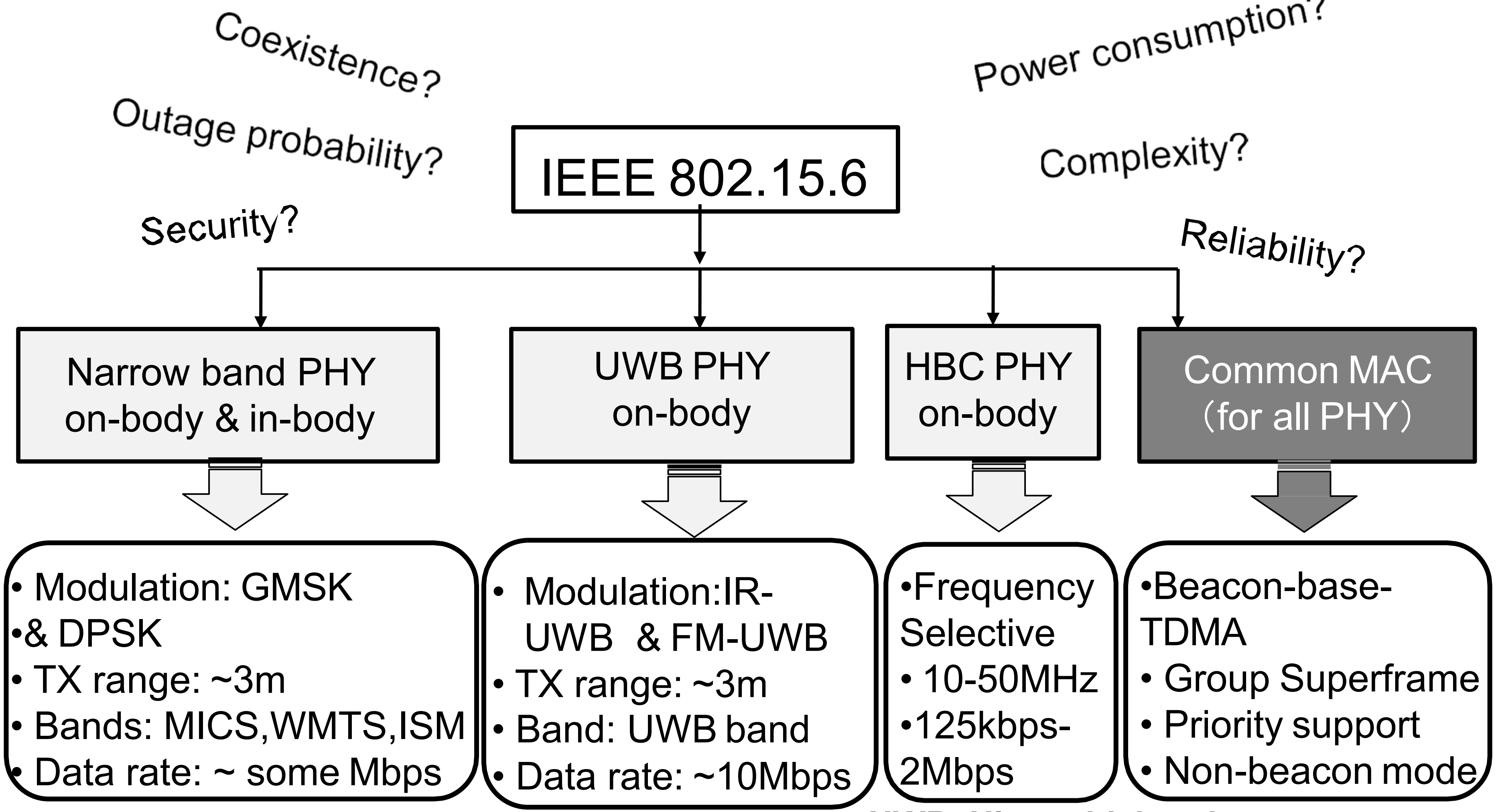
2.2 Top View of IEEE Std 802.15.6



UWB: Ultra-wideband
HBC: Human body communication

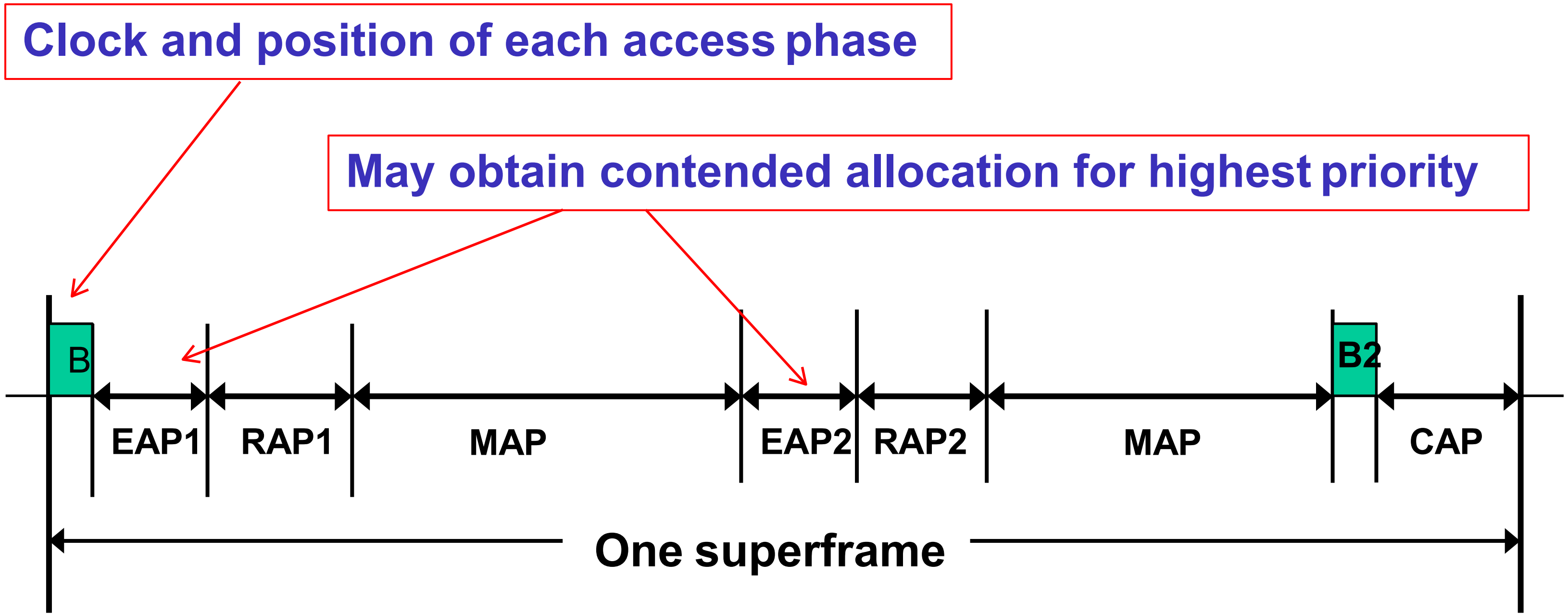
2.3 User Priority Mapping

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



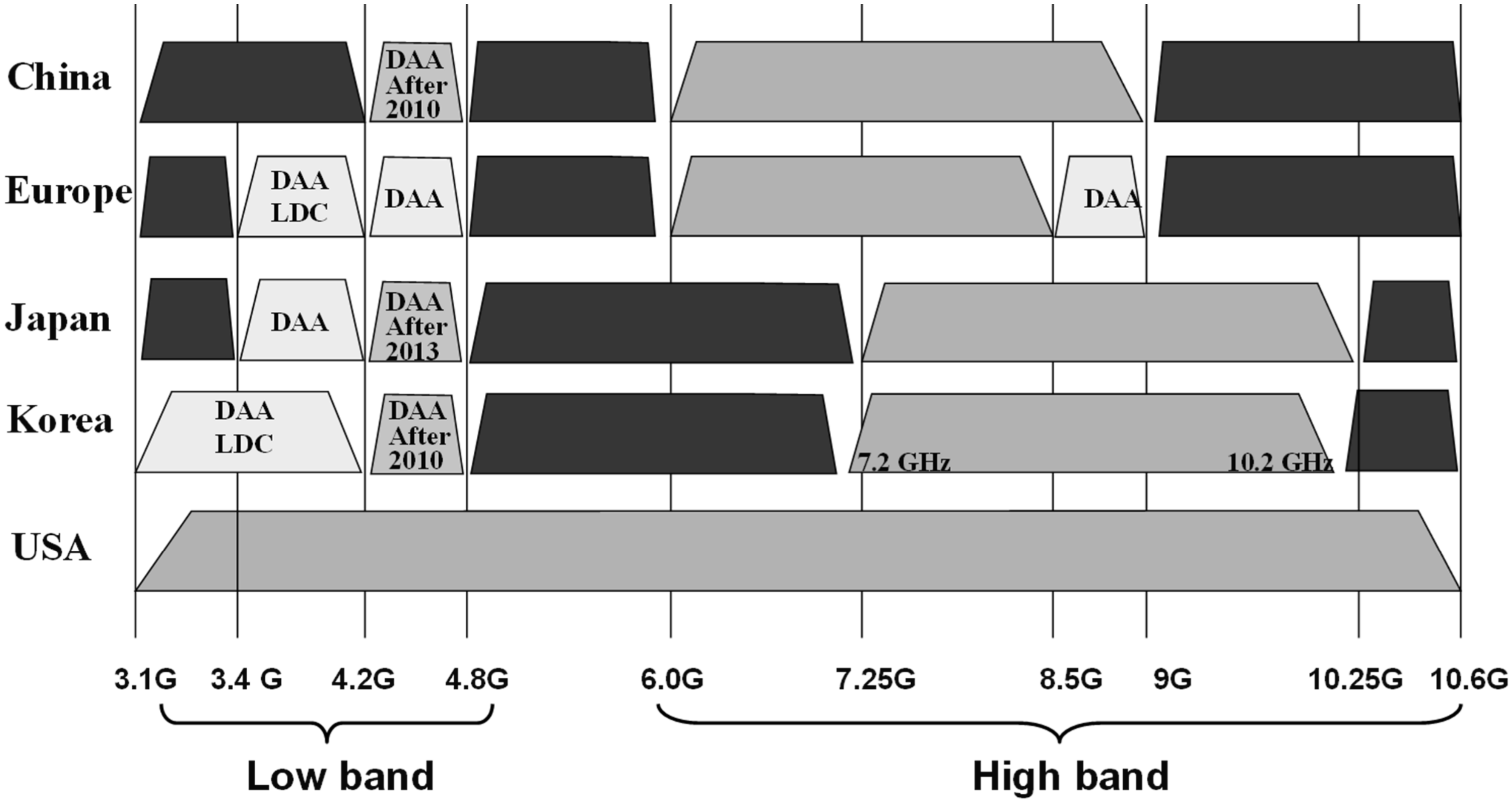
EAP: exclusive access phase

RAP: random access phase

MAP: managed access phase

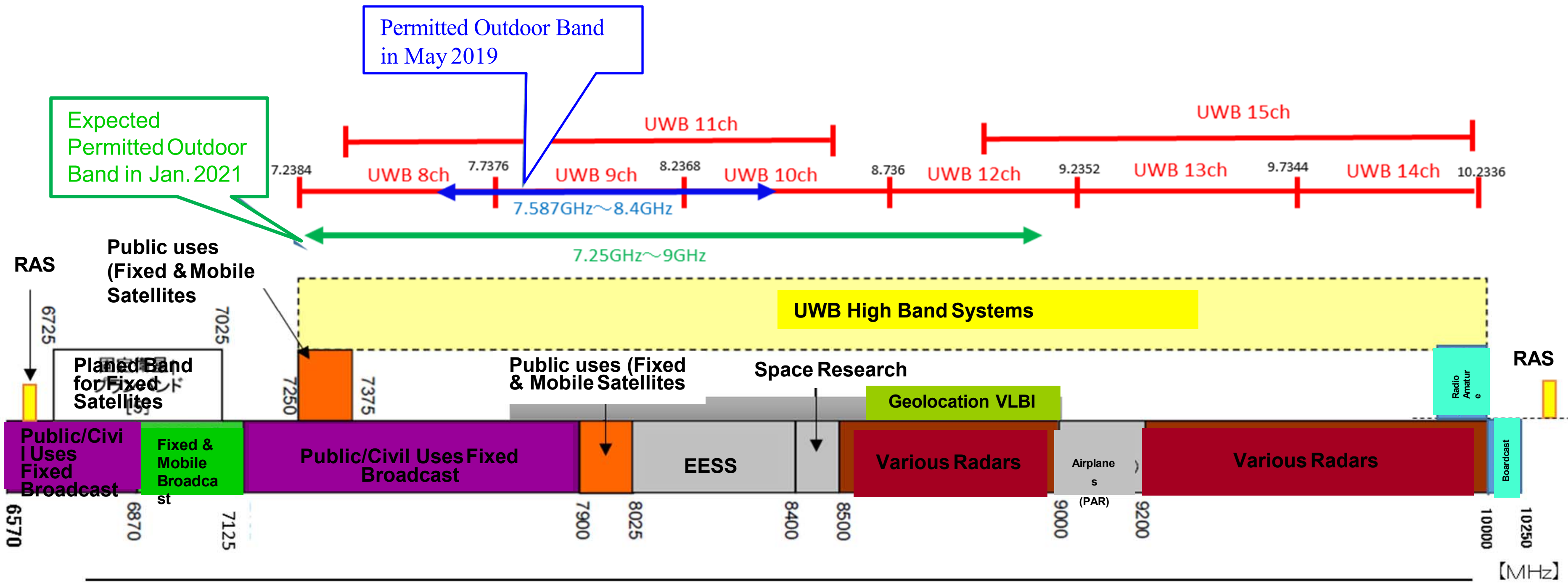
CAP: contention access phase

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 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.

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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

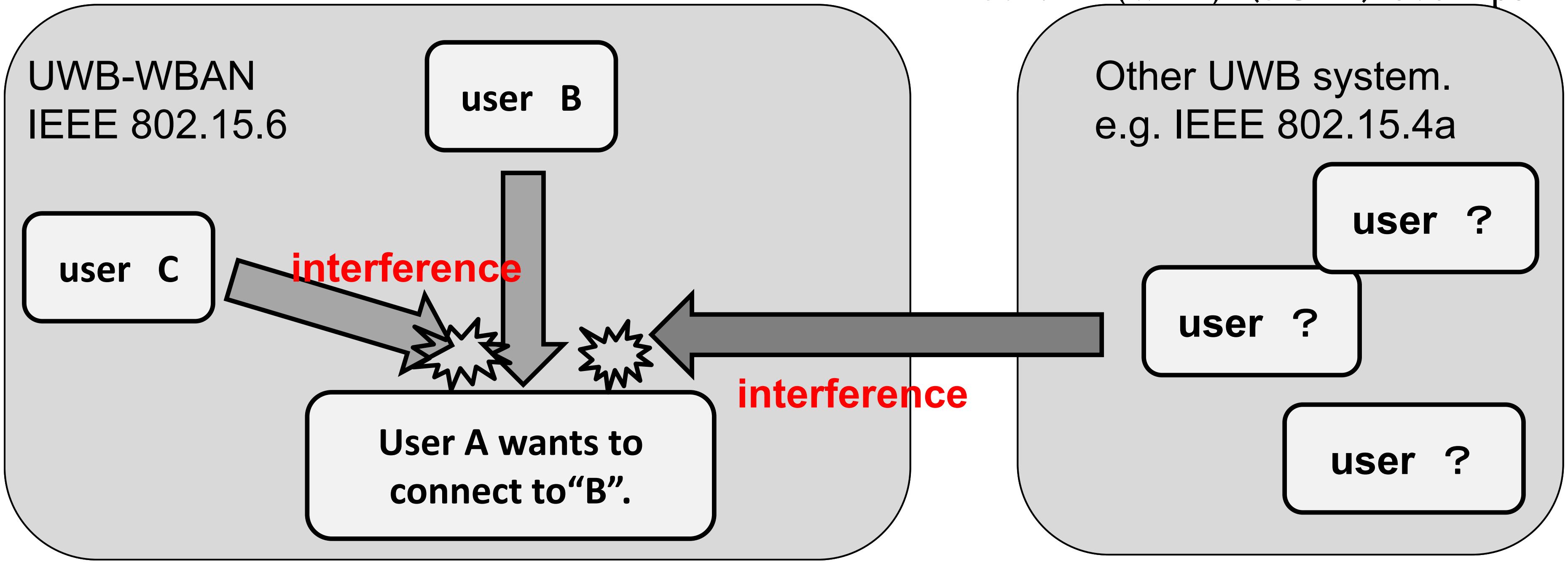
- Mobile nodes and coordinator of BAN need ranging and positioning of UWB-BAN

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 wireless 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

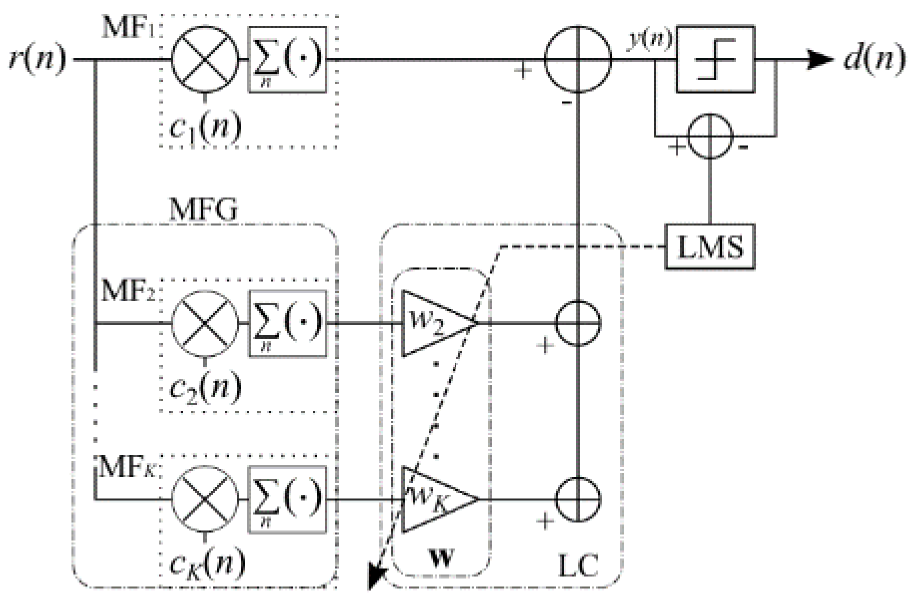
Interference canceller

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;θ and frequency; ω.

  $\Rightarrow$ has characteristics of both of spatial and time domain.

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

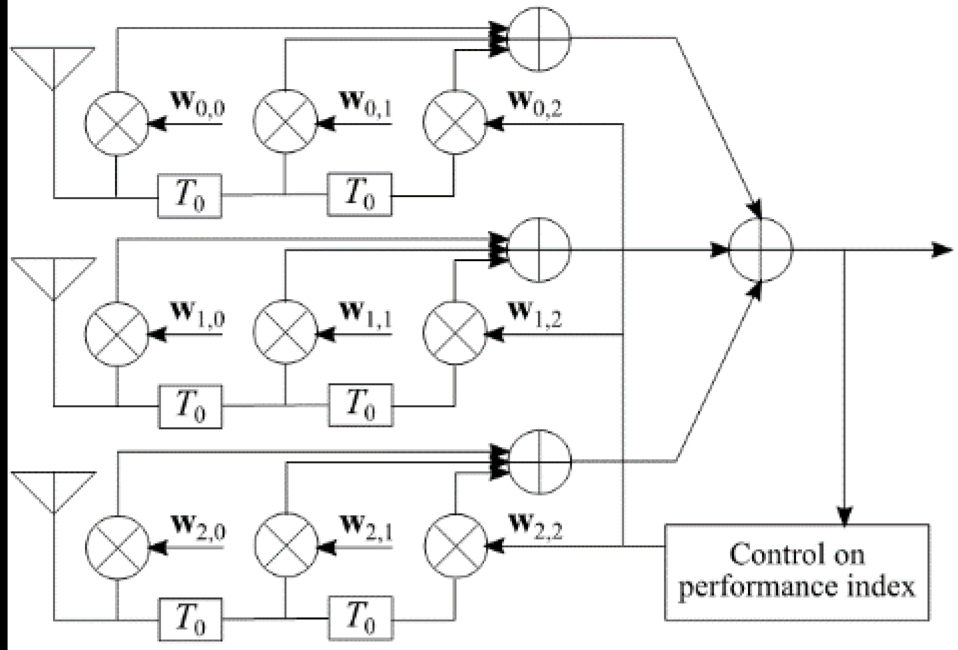
$$y(t) = \exp(j\omega t)\sum_{n=0}^{N-1}\sum_{m=0}^{M-1}\exp(-j\omega(\tau_n + mT_0))w_{n.m},$$

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

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

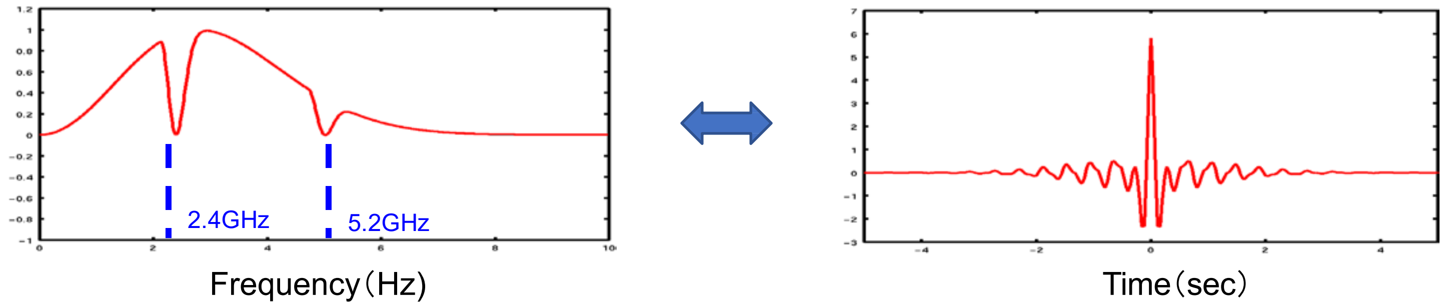
(Tapped delay line array antenna)

Principle of TDL-AA

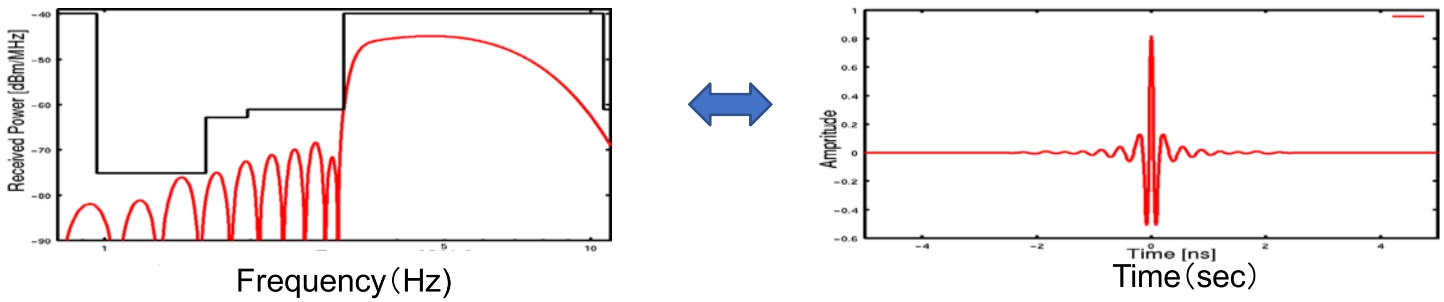


TDL-AA can work as interference canceller on both of time and space domains

4.5 Interference Mitigation among Other Radios



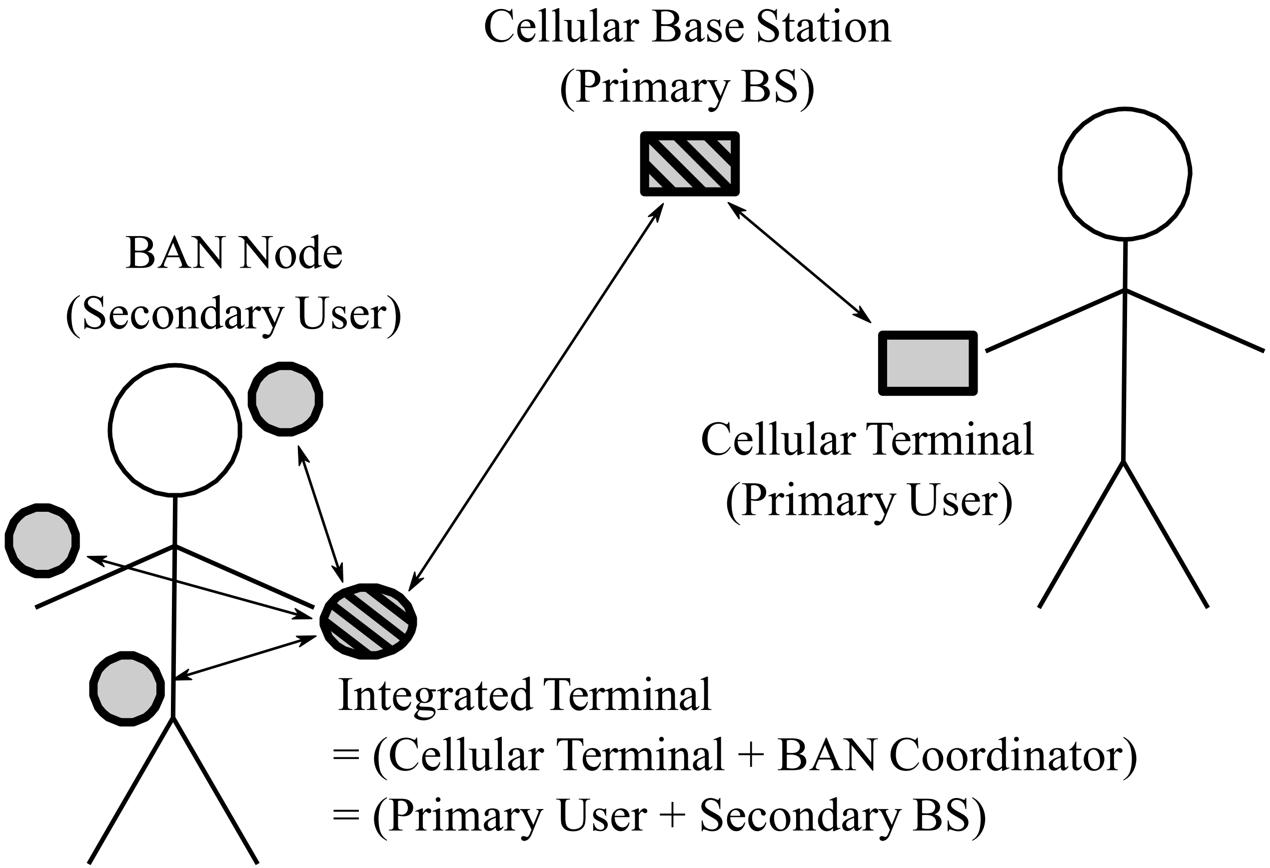
(a) Time Waveform of Pulse (right figure) and its Frequency Spectrum with notches in 2.4 and 5.2GHz for WLAN (left figure)



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

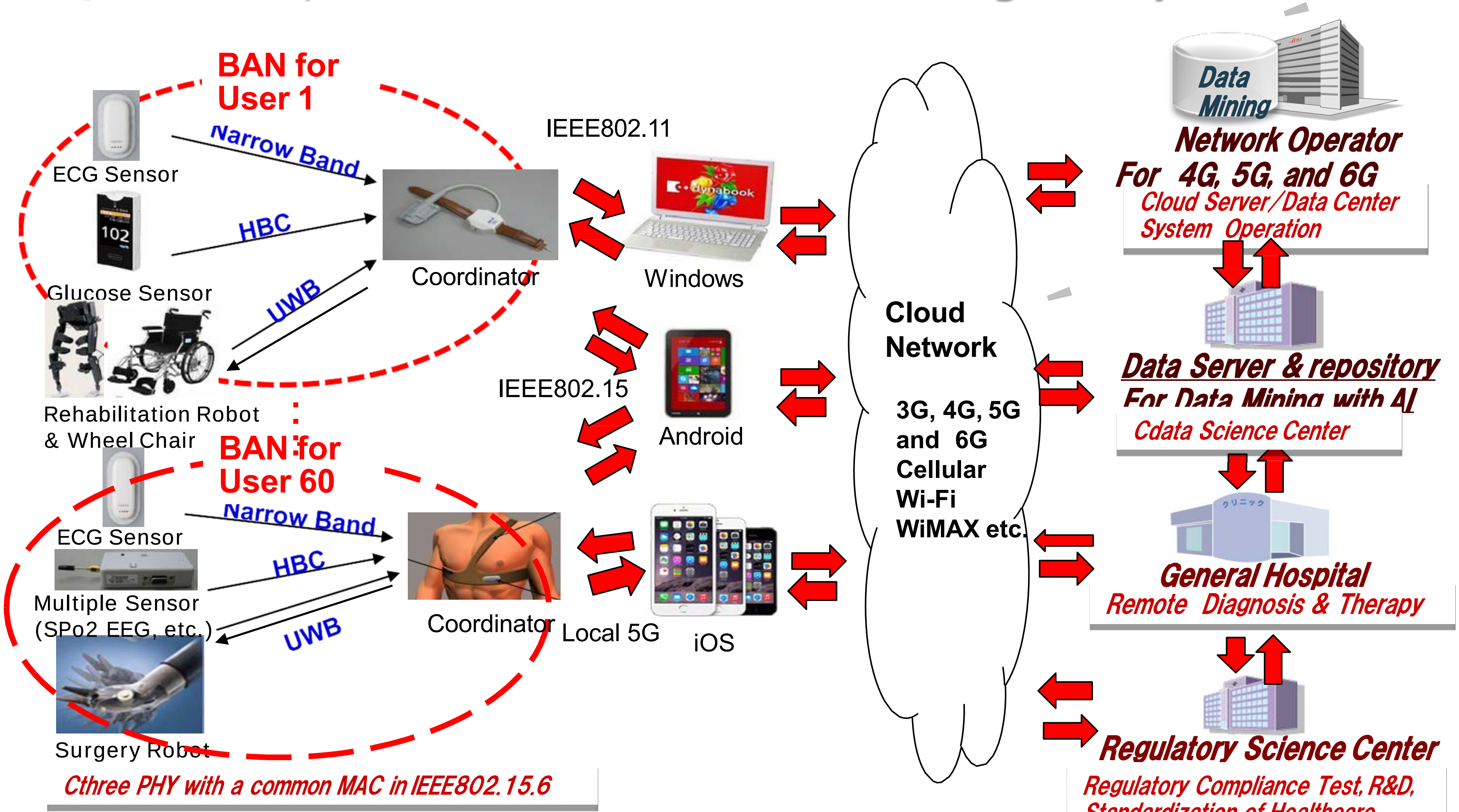
Ref. R.Kohno, H.Zhang, H.Nagasaka, "Ultra Wideband impulse radio using free-verse pulse waveform shaping , Soft-Spectrum adaptation, and local sine template receiving," doc.: IEEE 802.15-03/097r1, March 3, 2003.

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



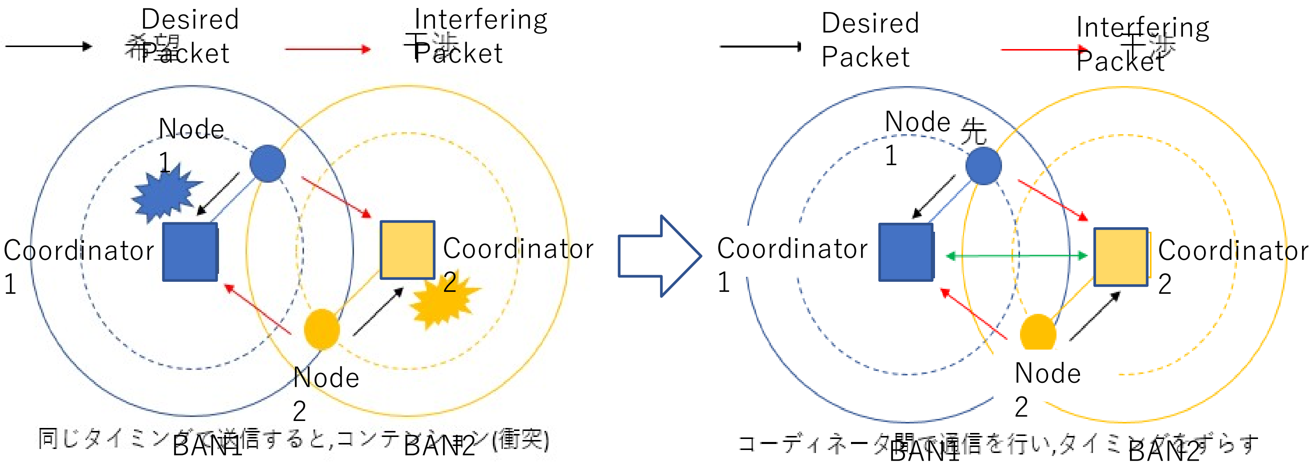
4.8 Contention among Overlaid BANs

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



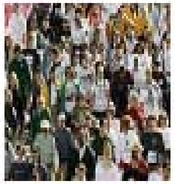
In case of no negotiation of Coordinators of overlapped BANs, contention happens among packets from nodes of f the BANs

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

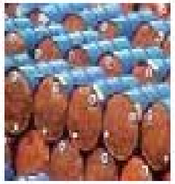
Ref. R.Kohno, S.Ogawa, "MAC Protocol with Interference Mitigation Using Negotiation among Coordinators in Multiple Wireless Body Area Networks (BANs)," IEEE802.15 doc.#15-19-0119-00-0dep-ig-dep, Vancouver, Canada, March 12, 2019

Demands of Dependable BAN of Things in IoT/M2M for Sustainable Social Services



Population Ageing & Medical crisis

Healthcare Service(Medical ICT)



Cost of energy ... fuel supply & demand

Energy Network(Smart Grid)

Increasing environmental requirements

CO_2 Reduction, Green Innovation

Escalating security concerns

Public Safety, National Defense

Heightened investor demands

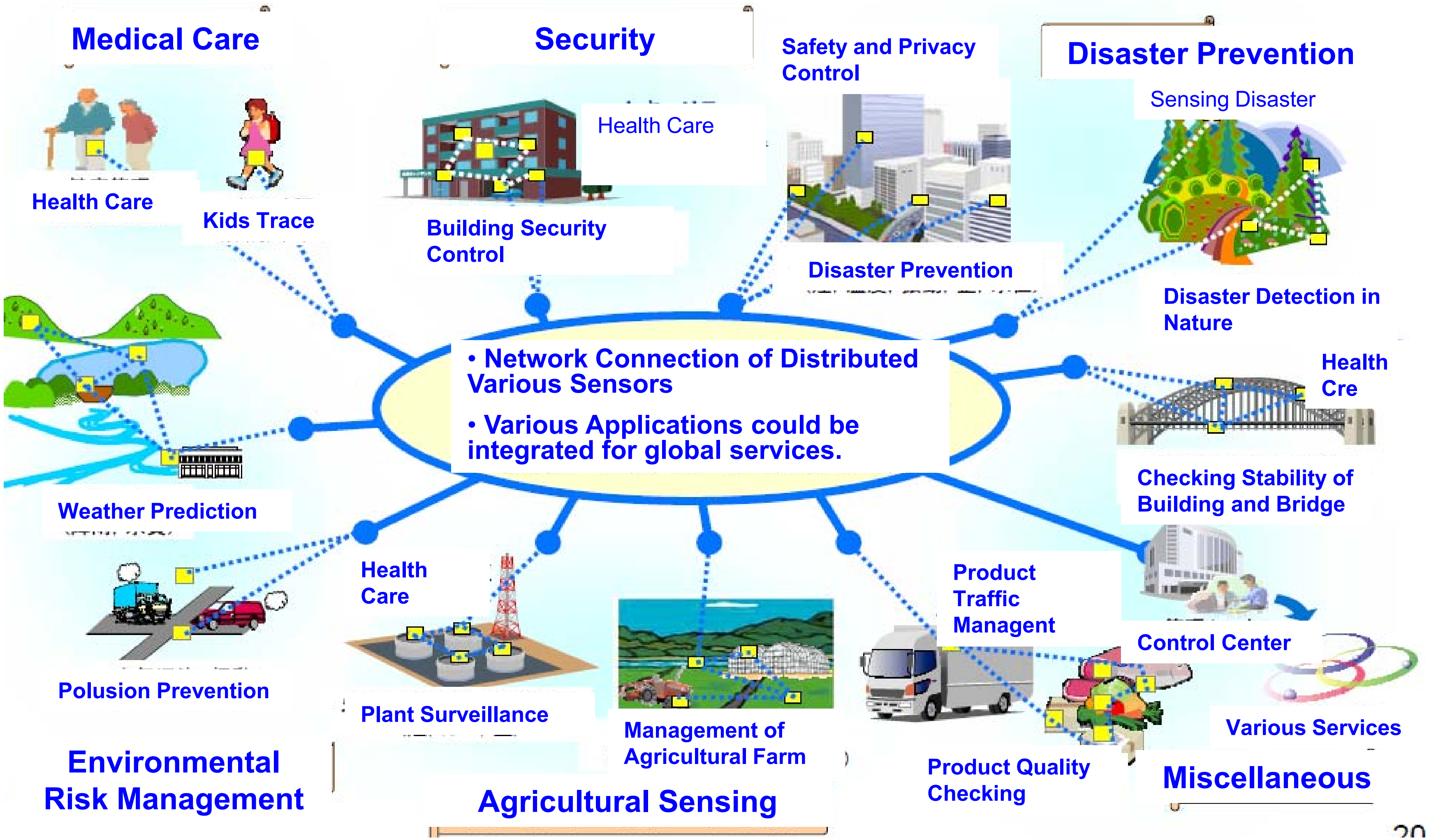
Global Borderless Economics

Driving Technology

Dependable BAN of Things for SDGs

Integrated BAN/Cloud/AI Platform of Beyond 5G

Application of Dependable BAN of Things to Social Infrastructure



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. In case of Human body,4 units can cover 256 nodes as the same as 15.6. In case of Car body, M>4 units can cover 64xM nodes in layer structure. Class A; node transmitting periodical packets Class B: node doing non-periodical ones.	256 For 2nd G ECoG BMI 128x32, 64x64 32x128, 16x256, 8x512 4x1024. 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. Other choices are 32 nodes/unit and max no. of units is 100 Ref. 64 sensors x 64 Units = 4,096 sensors that is sufficient for 2nd G ECoG BMI	0 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 Due to relationship with smart BAN and smart M2M 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 For low QoS packets, 2 Mbps or higher while permissible delay longer	1 Mbps for narrow Band 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

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 dependent
Jitter: critical max: 5% outliers acceptable	5 ms	5 ms	N/A	N/A	N/A	Dependent on Highest QoS	QoS dependent
Multi BAN Overlaid (A) Intra network interference	Driver/Passengers 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 2nd 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/Passengers 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 2nd G ECoG BMI	By a few use case models, worst interference can be defined.

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 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		

IG DEP & SG15.6a schedule in March & May 2021

	March 9th Tuesday	March 10th Wednesday	March 11th Thursday	March 15th Monday	March 17th Wednesday
EST 9:00AM-11:00AM JST 11PM-1AM	IEEE802.15 Opening Plenary		EST 5:00PM-7:00PM Joint Session of IG-DEP and IG-NG-UWB		IEEE802.15 Closing Plenary
EST 7:00PM-9:00PM JST 9:00AM-11:00AM +1 day		IG-DEP1 (March 11th JST)	IG-DEP2 (March 12th JST)	IG-DEP 3 (March 16th JST)	

	May 11th Tuesday	May 12th Wednesday	May 13th Thursday	May 18th Tuesday	March 20th Thursday
EST 9:00AM-11:00AM JST 11PM-1AM	IEEE802.15 Opening Plenary				IEEE802.15 Closing Plenary
EST 8:00AM-10:00AM JST 9:00PM-11:00PM		SG15.6a Session 1	SG15.6a Session 2	SG15.6a Session 3	

Actions to EC comments (March Plenary meeting)

According to doc.#15-21-0269-00-06a

Follow up to the EC comment on EMC/EMI in vehicles

We got comments from George Zimmerman about EMC/EMI in vehicles.

1. Email forwarded by Pat: “George Zimmerman, 802 Treasurer, responded to me with the following query: "I had not realized that the Body Area Networks combined automotive bodies as well as human bodies (I had thought they were human body networks). Having done a bit of work in automotive networking, I am somewhat familiar with the EM environment there, and it seems substantially different from what a human body would ordinarily deal with, including issues of compatibility, interference tolerance with high-levels of EM signals often due to interactions of the automotive body with EM fields. I would have thought that these (automotive and human networks) are two different problems, requiring different environmental expertise. Is the expertise present in the proposed SG from the automotive industry?”

Actions to EC comments (March Plenary meeting)

2. Email from G.Z.: “I very much appreciate your timely reply, and apologize for my un-timely response. (For some reason the email went into my junk folder, which is no good excuse) However, I have now found it, and will be interested to follow your progress. I have communicated the activity to other 802 participants whom I know through Steve Carlson's IEEE P802.3cy Multigigabit Automotive Electrical PHY Task Force, which includes individuals affiliated with major automotive OEMs and Tier-1 suppliers. I have worked with these individuals a number of years in previous automotive ethernet projects, and EMC has been a major concern. These individuals have been interested to learn what is being studied in the new project, and to lend their expertise as they can. It appears the web page for the activity is not yet set up, (https://www.ieee802.org/15/pub/default_page.html lists TG6a as a 'pending homepage'), but if this is not the right location to look and to point people to, please let me know where to find information.”

Actions to EC comments (March Plenary meeting)

2.1 Items to work out for the May meeting

1) We are planning to integrate Human BAN (HBAN) with vehicles, so-called Vehicle BAN (VBAN). Hence, careful consideration of the electromagnetic environment in vehicles should be considered. We start addressing EMC/EMI and channel models in document 21-0244-00-6a for further discussion.

A request from a Medical Consortium in Japan is related to the use case of senior/elderly car/truck/bus drivers due to the number of accidents at least in Japan. As the automotive industry is also involved, there must be an interaction between HBAN and VBAN for monitoring, warnings, alerts, emergency situations. This interaction HBAN and VBAN with enhanced dependability allows for more reliable and safe driving, including autonomous cars.

Actions to EC comments (March Plenary meeting)

2) During the March meeting, we met with the 802.1 Chair and Vice Chair for an introduction to Time sensitive Networks (TSN) activities.

For the May meeting, we have an initial discussion on how 802.1 TSN may be integrated into the amendment described in the document 21-0245-00-6a for further discussion.

3) Prof. Kohno will start addressing technology feasibilities for technical requirements.

4) Finishing PAR and CSD.

SG15.6a Session Schedule for 13–22, July 2021

	July 13th Tuesday	July 14th Wednesday	July 15th Thursday	July 19th Monday	July 20th Tuesday	July 21st Weneday
EST 9:00AM-11:00AM JST 10:00PM-12:00PM	IEEE802.15 Opening Plenary	AM1 SG15.6a Session 1	AM1 SG15.6a Session 2		AM1 SG15.6a Leadership Session	IEEE802.15 Closing Plenary
EST 11:00-13:00 JST 0:00AM-2:00AM+1 day				AM2 Joint Session SG15.6a, 4ab, &TG14		
EST 19:00-21:00 JST 8:00AM-10:00AM+1 day				EV2 SG15.6a Session 3		

1. SG 15.6a Session1, Wed AM1
   9:00 AM - 11:00 AM Wednesday, July 14th 2021 (UTC-04:00) Eastern Time,
   10:00 PM - 12:00 PM Wednesday, July 14th 2021 (UTC+9:00) Japan & Korean Time
   Meeting link: https://ieeesa.webex.com/ieeesa/j.php?MTID=mefa004064fd4ac5f6e28173f1bbc2bf4
   Meeting number: 173 279 7091 Password: 80215SG6a
2. SG 15.6a Session2 Thu AM1
   9:00 AM - 11:00 AM Thursday, July 15th 2021 (UTC-04:00) Eastern Time,
   10:00 PM - 12:00 PM Thursday, July 15th 2021 (UTC+9:00) Japan & Korean Time
   Meeting link: https://ieeesa.webex.com/ieeesa/j.php?MTID=mefa004064fd4ac5f6e28173f1bbc2bf4
   Meeting number: 173 279 7091 Password: 80215SG6a
3. Joint Session among SG 15.6a, 4ab and TG15.14. Mon AM2
   11:00 AM - 13:00 Monday, July 19th 2021 (UTC-04:00) Eastern Time,
   0:00 - 2:00 Tuesday July 120h 2021 (UTC+9:00) Japan & Korean Time
   Meeting link: https://ieeesa.webex.com/ieeesa/j.php?MTID=m42ff6a58444126fd311b751923d35977
   Meeting number: 173 009 8101 Password: 80215SG6a4ab14
4. SG 15.6a Session3 Mon EV2
   19:00 - 21:00 Monday, July 19th 2021 (UTC-04:00) Eastern Time,
   8:00 am - 110:00 am Tuesday, July 20th, 2021 (UTC+9:00) Japan & Korean Time
   Meeting link: https://ieeesa.webex.com/ieeesa/j.php?MTID=mb3c82b1a28c4c46e559c915a3dab109d
   Meeting number: 173 669 1256 Password: 80215SG6a

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

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