Abstract: [This document summarizes necessity and request for amendment of IEEE802.15.6-2012 Medical Body Area Networks corresponding to increasing wide variety of use cases and satisfying dependability of BAN in PHY and MAC layers.]

Purpose: [information]

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Necessity for Amendment of IEEE 802.15.6 Medical BAN with Enhanced Dependability

Ryuji Kohno (YNU/CWC UofOulu)
Takumi Kobayashi (YNU)
Agenda

1. Review of WBAN Standard IEEE802.15.6
2. Extension and Amendment of BAN with Enhanced Dependability
3. Technical Challenges for Enhanced Dependability
4. Focused Amendment of std 15.6 BAN with Enhanced Dependability
1. Review of WBAN Standard IEEE802.15.6
1.1 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
- Pace Maker with ICD
- Wireless Capsule Endoscope

**Novel Concept**
Intelligent Network of Vital Sensors, eHR, Medical Robots etc.
1.2 Standard of Medical Wireless Body Area Network (BAN); IEEE 802.15.6

IEEE802

IEEE802.11 Wireless LAN
IEEE802.15 Wireless PAN
IEEE802.16 Wireless MAN

802.15.1 Bluetooth
802.15.2 Coexistence between WPAN and WLAN
802.15.3 PHY for High Rate WPAN
802.15.4 PHY for Low Rate WPAN
802.15.5 WPAN Mesh Network

802.15.3a Alternative PHY of 15.3
802.15.3b Maintenance of 15.3
802.15.3c PHY in Millimeter wave band
802.15.4a Low rate UWB PAN Alternative PHY of 15.4
802.15.4b Revision & Modification of 15.4 MAC
802.15.4c Chinese WPAN
802.15.4d Japanese WPAN

2007.3 Standard Completed

2012.2 Standard was Completed
1.3 Main Contributors at TG6

- Casuh
- CEA-LETI
- CNU
- CSEM
- CUNY
- ETRI
- France Telecom
- Fujitsu Lab. Europe
- Fujitsu Lab.
- GE Global Research
- GE Healthcare
- IMEC
- Inha University
- KETI
- Korpa
- LG Electronics
- Meiji University

- Mitsubishi Electric Research Labs, USA
- NICT
- NICTA
- NIST
- Olympus, USA
- Philips, USA
- Philips, EU
- Samsung
- Tensorcom
- Texas Instrument
- Thales
- Toumaz Technologies
- Yokohama National University
- Zarlink Semiconductor

Asia
Europe
USA
1.4 Top View of IEEE Std 802.15.6

IEEE 802.15.6

Narrow band PHY on-body & in-body
  - Modulation: GMSK & DPSK
  - TX range: ~3m
  - Bands: MICS, WMTS, ISM
  - Data rate: ~some Mbps

UWB PHY on-body
  - Modulation: IR-UWB & FM-UWB
  - TX range: ~3m
  - Band: UWB band
  - Data rate: ~10Mbps

HBC PHY on-body
  - Frequency Selective
  - 10-50MHz
  - 125kbps-2Mbps

Common MAC (for all PHY)
  - Beacon-base-TDMA
  - Group Superframe
  - Priority support
  - Non-beacon mode

UWB: Ultra-wideband
HBC: Human body communication

Coexistence?
Outage probability?
Security?
Power consumption?
Complexity?
Reliability?
### 1.5 User Priority Mapping

<table>
<thead>
<tr>
<th>Priority level</th>
<th>Traffic designation</th>
<th>Data type</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Emergency or medical event report</td>
<td>Data</td>
</tr>
<tr>
<td>6</td>
<td>High priority medical data or network control</td>
<td>Data or management</td>
</tr>
<tr>
<td>5</td>
<td>Medical data or network control</td>
<td>Data or management</td>
</tr>
<tr>
<td>4</td>
<td>Voice</td>
<td>Data</td>
</tr>
<tr>
<td>3</td>
<td>Video</td>
<td>Data</td>
</tr>
<tr>
<td>2</td>
<td>Excellent effort</td>
<td>Data</td>
</tr>
<tr>
<td>1</td>
<td>Best effort</td>
<td>Data</td>
</tr>
<tr>
<td>0</td>
<td>Background</td>
<td>Data</td>
</tr>
</tbody>
</table>
### 1.6 Three Channel Access Modes

<table>
<thead>
<tr>
<th>Channel access mode</th>
<th>Time reference-based (superframe structure)</th>
<th>Beacon</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Yes</td>
<td>Yes</td>
<td>Coordinator sends beacon in each superframe except for inactive superframes.</td>
</tr>
<tr>
<td>II</td>
<td>Yes</td>
<td>No</td>
<td>Coordinator establishes time reference but doesn’t send beacon.</td>
</tr>
<tr>
<td>III</td>
<td>No</td>
<td>No</td>
<td>There is not time reference.</td>
</tr>
</tbody>
</table>
1.7 Time-referenced Superframe w/ Beacon

- EAP: exclusive access phase
- RAP: random access phase
- MAP: managed access phase
- CAP: contention access phase

Clock and position of each access phase
May obtain contended allocation for highest priority

One superframe
1.8 Main Features of the Three PHYs

<table>
<thead>
<tr>
<th></th>
<th>Frequency band (MHz)</th>
<th>Data rate (kbps)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW-PHY</td>
<td>400, 600, 800, 900, 2400</td>
<td>75.9 --- 971.4</td>
<td>Interference with other systems operate at the same bands</td>
</tr>
<tr>
<td>UWB-PHY</td>
<td>6000-10600, 3100-4800</td>
<td>390 --- 12600</td>
<td>Worldwide common band is 7.25 – 8.5 GHz</td>
</tr>
<tr>
<td>HBC-PHY</td>
<td>21</td>
<td>164 --- 1312.5</td>
<td>Strong concern on the effect to implant devices</td>
</tr>
</tbody>
</table>
# 1.9 Main Specifications of NB-PHY

<table>
<thead>
<tr>
<th>Frequency bands (MHz)</th>
<th>Modulations</th>
<th>Data rates (kbps)</th>
<th>Number of channel</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PLCP header</td>
<td>PSDU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>402-405</td>
<td>(\pi/2)-DBPSK</td>
<td>(\pi/2)-DBPSK, (\pi/4)-DQPSK, (\pi/8)-D8PSK</td>
<td>75.9/151.8/303.6/455.4</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>GMSK</td>
<td>GMSK</td>
<td>75.9/151.8/187.5</td>
<td>12</td>
</tr>
<tr>
<td>863-870</td>
<td>(\pi/2)-DBPSK</td>
<td>(\pi/2)-DBPSK, (\pi/4)-DQPSK, (\pi/8)-D8PSK</td>
<td>101.2/202.4/404.8/607.1</td>
<td>14</td>
</tr>
<tr>
<td>902-928</td>
<td>(\pi/2)-DBPSK</td>
<td>(\pi/2)-DBPSK, (\pi/4)-DQPSK, (\pi/8)-D8PSK</td>
<td>101.2/202.4/404.8/607.1</td>
<td>60</td>
</tr>
<tr>
<td>950-958</td>
<td>(\pi/2)-DBPSK</td>
<td>(\pi/2)-DBPSK, (\pi/4)-DQPSK, (\pi/8)-D8PSK</td>
<td>101.2/202.4/404.8/607.1</td>
<td>16</td>
</tr>
<tr>
<td>2360-2400</td>
<td>(\pi/2)-DBPSK</td>
<td>(\pi/2)-DBPSK, (\pi/4)-DQPSK</td>
<td>121.4/242.9/485.7/971.4</td>
<td>39</td>
</tr>
<tr>
<td>2400-2483.5</td>
<td>(\pi/2)-DBPSK</td>
<td>(\pi/2)-DBPSK, (\pi/4)-DQPSK</td>
<td>121.4/242.9/485.7/971.4</td>
<td>79</td>
</tr>
</tbody>
</table>
# 1.10 Main Specifications of UWB-PHY

<table>
<thead>
<tr>
<th>Mode</th>
<th>Modulation</th>
<th>Data rate (Mbps)</th>
<th>Waveform</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR-UWB (I)</td>
<td>OOK</td>
<td>0.49 – 15.6</td>
<td>Chirp pulse, chaotic pulse, SRRC-like pulse, or others.</td>
</tr>
<tr>
<td>IR-UWB (II)</td>
<td>DBPSK/DQPSK</td>
<td>0.49 – 15.6</td>
<td></td>
</tr>
<tr>
<td>FM-UWB</td>
<td>Continuous-phase 2FSK (sub carrier) combined with FM</td>
<td>≤0.25</td>
<td>Gaussian (default)</td>
</tr>
</tbody>
</table>

- **FM-UWB** is an optional mode
- **High QoS mode**
  - Hybrid Type II ARQ
1.11 Main Specifications of HBC PHY

- **HBC frequency band**
  - center frequency: **21MHz (3dB_BW=5.25MHz)**

- **Transmission method**
  - Frequency Selective Digital Transmission

- **Data rate**
  - 164, 328, 656, 1312.5 kbps

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The electrode in contact with the body is used for transmitting or receiving an electrical signal through the body to a device
1.12 Worldwide UWB Regulations in 2012

- **China**: DAA After 2010
- **Europe**: DAA LDC, DAA
- **Japan**: DAA After 2013
- **Korea**: DAA LDC, DAA After 2010
- **USA**: 3.1G, 3.4G, 4.2G, 4.8G, 6.0G, 7.25G, 8.5G, 9G, 10.25G, 10.6G

**Low band**:
- 3.1G, 3.4G, 4.2G, 4.8G

**High band**:
- 6.0G, 7.25G, 8.5G, 9G, 10.25G, 10.6G
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 and it is expected to allow it for outdoor use in January 2021.
1.13 Specifications of High Band UWB

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency band</td>
<td>7.25 – 10.25 GHz</td>
</tr>
<tr>
<td>Average e.i.r.p.</td>
<td>≤ -41.3 dBm/MHz</td>
</tr>
<tr>
<td>Peak e.i.r.p.</td>
<td>≤ 0 dBm/50MHz</td>
</tr>
<tr>
<td>Average unwanted radiation</td>
<td>≤ -70 dBm/MHz</td>
</tr>
<tr>
<td>Peak unwanted radiation</td>
<td>≤ -64 dBm/MHz</td>
</tr>
<tr>
<td>Pulse rate</td>
<td>~ 50 Mpps</td>
</tr>
<tr>
<td>Communication range</td>
<td>~ 3m</td>
</tr>
</tbody>
</table>
1.14 Summary of IEEE802.15.6

- 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 Body area network (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 QoS levels of packets but its implementation complexity is too high for its complete protocol.
2. Extension and Amendment of BAN with Enhanced Dependability
2.1 Demands for BAN Extension

1. BAN for Car and Other Bodies beyond Human Body
   - Reliable performance of medical BAN for human body could be widely applicable for remote maintenance of car body and other bodies in IoT/M2M use cases.
   - Demands for More flexible and widely applicable BAN in cars, robotics, UAVs and others are increasing for autonomous remote sensing and controlling.

   current IEEE802.15 IG-Dependability

2. BAN-base Infrastructure Platform for Medical Healthcare
   - BANs in end users are connected through Cloud Network and Edge Computer with AI Data Mining Server and Repository for medical healthcare platform by integration between ICT and data science.
   - Enhanced dependability is required for end-to-end reliability and security.

3. BAN-base Universal Platform for Medical and beyond Medical Infrastructures
   - Emergency for natural disasters and terrorism, smart city with reliable maintenance of cars, buildings etc. need common dependable platform,
BAN-base Universal Platform for Medical and beyond Medical Infrastructures

Medical support for developing countries

Medical Data Server for Data Mining with Machine Learning

Data mining

Medical Center and General Hospitals

BAN Mobile Station

VSAT

Satellite Link

Big Data

Network Cloud

Cellular Network

Internet

Network Cloud

November 2020

Ryuji Kohno (YNU/CWC UofOulu), Takumi Kobayashi (YNU)
BAN-base Universal Platform with Network Cloud, Data Mining Server for Medical Healthcare

Data mining or Analysis like Watson

Data storage server; DBMS

Network cloud (5G. 6G)

Gateway

Hospital, Rehabilitation center, or Clinicians

Body Area Network (BAN)

Coordinator

Node

Node

Node

physical assistant and surgery robots

Elderly people

Therapist, Nurses, Care givers
Medical Healthcare Data Mining and Networking Based on Universal Platform by Wireless BAN, Network Cloud, Data Server with AI Data Mining

Body Area Network; (BAN)
Universal Platform Based on BAN, Cloud Network, and AI Data Server for General Social Infrastructure

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.
Scalable Applications of WBAN with Enhanced Dependability

1. Remote healthcare monitoring and therapy
2. Remote sensing and controlling robots and UAVs for disasters
3. Recovering infrastructure networks after disasters
4. Resilient, reliable and robust IoT network against disasters
5. Vehicle internal sensing and controlling
6. Collision avoidance radar
7. Inter-vehicle communications and ranging
8. Wearable and implant wireless medical sensing and controlling
9. Wearable healthcare sensing
10. Dependable Brain-Machine Interface (BMI)
11. Wireless sensing system for Factory with feedback control
12. Dependable multi-hop inter-vehicle communications
13. Inter-navigation and inter-vehicle information sharing in normal and emergency conditions
14. Single wireless communication network solution that functions both in normal and in disaster environments
15. Disaster prevention, emergency rescue and recovery
Visualizing Portfolio of Focused Use Cases
Highly Life Critical Uses (High QoS)

QoS 1; Highest Priority of Demand of Dependability

Home & Consumer Uses
- Fitness, Massage & Sauna
- Sports: Walking, Jogging, Bicycling, Hiking, Skiing etc
- Home Medical Therapy
- Remote Wellness & Well-being
- Hospital Clinical Service

QoS 2; Middle Priority of Dependability

Industrial & Governmental Uses
- Remote Sensing and Recovering for Disasters
- Government Infrastructure
- Life Line (Water/Gas/Electricity Supply)
- Remote Sensing & Controlling Mobile Robots
- Remote Triage in Disasters
- Disaster Analysis & Prevention

QoS 3; Relatively Lower Priority of Dependability

Home & Consumer Uses
- Remote Sensing
- Entertainment business

Less Life Critical Uses (Low QoS)

Ryuji Kohno (YNU/CWC UofOulu), Takumi Kobayashi (YNU)
Three Classes of Focused Potential Use Cases

We have classified focused potential applications into three classes according to demands of dependability.

Class 1 QoS: Highest Priority Level for Demand of Dependability
1.1 Remote Sensing and Control of Implanted and Wearable Medical Devices (ex. BMI etc.)
1.2 Remote Medical Diagnosis and Therapy
1.3 Vehicle Autonomous Driving
1.4 Remote Monitoring Infrastructure for Rescue in Disaster

QoS 2 Class: Meddle Priority Level for Demand of Dependability
2.1 Personal Healthcare
2.2 Vehicle Wireless Harness
2.3 Lifeline Maintenance (Water/Gas/Electricity Supply)
2.4 Remote Maintenance of Infra(bridge/bldg./train)

QoS 3 Class: Low Priority Level for Demand of Dependability
3.1 Wellness, Wellbeing
3.2 Public Safety
3.3 Remote Sensing and Controlling Mobile Robots
3.4 Disaster Analysis and Prevention
2.2 Needs 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.
2.3 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

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
2.4 Interference Mitigation among Other Radios (1/2)

(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)

2.4 Interference Mitigation among Other Radios(2/2)

Synthesized Pulse Waveform

\[ f(t) = \sum_{k=1}^{N} f_k(t) \]

Component Pulse Waveform Corresponding to Each Frequency Sub Band

\[ f_k(t) = \cos[2\pi(f_L + \frac{(1+2k)B}{2N})t] \times \frac{\sin(B\pi t)}{N\pi t} \]

- **B**: bandwidth \([f_H \sim f_L]\)

(c) Principle of Soft Spectrum Adaptation which can design any pulse waveform corresponding a desired spectral shape
2.5 Feedback Sensing and Controlling Loop for Remote Diagnosis and Therapy

Remote Sensing Polyp and Controlling Capsule Endoscopy in Intestine

Wireless Feedback Sensing and Controlling Loop for Endoscope

Feedback Delay Loop Model with Motion Equation
Remote Medicine of Types I & II of Diabetes Patients Using Wireless BAN with Glucose Sensor & Insulin Pump

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

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

Wireless Feedback Sensing and Controlling Loop for Diabetes Patients

Controller

Human Model of Glucose vs Insulin

Feedback Delay Loop Model with Motion Equation

Wireless Feedback Controlling based on Cognitive Sensing with Dependable BAN must be necessary for life critical applications.
Collision Avoidance Radar and Automatic Brake Using Wireless Dependable BAN of Things/M2M

Wireless Feedback Sensing and Controlling Loop for Autonomous Driving

Feedback Delay Loop Model with Motion Equation

Driver 

Controller 

u[k] 

Car Axel/Brake Model and Radar System 

u[k] 

For Autonomous Driving 

Axel/Brake 

Own Car 

For Collision Avoidance and Inter-Vehicle Communication 

Wireless channel 

Controller Car Axel/Brake Model and Radar System 

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

Wireless Feedback Sensing and Controlling Loop for Autonomous Driving

Feedback Delay Loop Model with Motion Equation
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

Controller: $u[k]$

UAVs/Drones Model and Localizing System: $x[k]$

For Remote Controlling UAVs

Navigation

Localization

By Using GNSS and Localization of UAVs/Drones

Rescue Team

Controller

$K$

$1/S$

$Bd$
3.1 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.
3.2 Discussion on 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
3.2 Discussion on Uniqueness different from existing standards(2/2)

2. PHY technologies to satisfy technical requirement for enhanced dependability in the focused applications of in automotive industry.

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.
6G (Beyond 5G) ICT & Data Science Platform for Infrastructure with BAN, Cloud, and Data Servers Based on Regulatory Science

BAN for User 1
- ECG Sensor
- Glucose Sensor
- Rehabilitation Robot & Wheel Chair

BAN for User 60
- ECG Sensor
- Multiple Sensor (SpO2, EEG, etc.)
- Surgery Robot

IEEE802.11
Coordinator
Windows

IEEE802.15
Android
Local 5G
iOS

Cloud Network
- 3G, 4G, 5G and 6G Celluarls
- Wi-Fi
- WiMax etc.

Network Operator
- For 3G, 4G, 5G, and 6G
- Cloud Server/Data Center System Operation

Data Server & repository
- For Data Mining with AI
- Cdata Science Center

General Hospital
- Remote Diagnosis & Therapy

Regulatory Science Center
- Regulatory Compliance Test, R&D, Standardization of Healthcare

Coordination
- 3G, 4G, 5G
- and 6G Celluarls
- Wi-Fi
- WiMax etc.

Data Mining

ECG Sensor

Glucose Sensor

Rehabilitation Robot & Wheel Chair

Multiple Sensor (SpO2, EEG, etc.)

Surgery Robot

Cthree PHY with a common MAC in IEEE802.15.6
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
Contributions

• We focus on amendment of IEEE802.15.6 for enhanced dependability in PHY and MAC.
• We move on SG/TG/WG to complete the amendment.
• If you have any question and comment, you are welcome to discussion in IG-DEP or TG6a.
• Send content contributions to Ryuji Kohno <kohno@ynu.ac.jp> and Takumi Kobayashi <Kobayashi-takumi-ch@ynu.ac.jp>