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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Source: [Ryuji Kohno, Takumi Kobayashi] [1; Yokohama National University (YNU), 2; YRP International Alliance Institute (YRP-IAI)]

Address [1; 79-5 Tokiwadai, Hodogaya-ku, Yokohama, Japan 240-8501
2; YRP1 Bldg., 3-4 HikarinoOka, Yokosuka-City, Kanagawa, Japan 239-0847]

Voice: [1; +81-90-5408-0611], FAX: [+81-45-383-5528],
Email: [1: kohno@ynu.ac.jp, kobayashi-takumi-ch@ynu.ac.jp, 2: kohno@yrp-iai.jp, kobayashi-takumi@yrp-iai.jp]

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

Ryuji Kohno, Takumi Kobayashi
Yokohama National University, Japan (YNU)
YRP International Alliance Institute, Japan (YRP-IAI)
Agenda

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

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

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

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

5. Technical Requirement for the Amendment of Std. 15.6 to Enhance Dependability
1. Demand for WBAN for Emergent Medical Healthcare Use and Huge Market of Automotive Use
1.1 Demand of BAN for Medical Uses

A. Emergent Problems over the world:
   ● 1-4% of total population in a world may be suffered by COVID-19, that is a global pandemic.
   ● Clinic are overloaded and many business are damaged seriously.

B. Challenging but Feasible Solutions:
   ◆ Provide Remote Vital Sensing and Therapy Using ICT and AI
     ➔ Prevent Epidemic and Maintain Safe and Efficient Diagnosis
   ◆ Promote Global Business of Medical ICT and Data Science

C. Approach:
   (1) R&D of Enable Technologies for Pandemic and Daily QoL
   (2) Promote International Standard of Wireless Body Network (BAN) and Integrated Platform of BAN/5G/AI for Global Marketing
   (3) Regulatory Compliance of Medical Devices & Services to Ensure Safety, Reliability, Security, i.e. Dependability by Regulatory Science
1.2 Medical Inspection and Treatment by BAN

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

WBAN can apply for preventing pandemic and supporting daily care by remote sensing and therapy in digital healthcare.

Symptoms of COVID-19

- Fever: 83-99%
- Loss of Appetite: 40-64%
- Fatigue: 44-70%
- Loss of smell: 15 to 30%
- Shortness of breath: 31-40%
- Cough: 59-82%
- Coughing up sputum: 28-33%
- Muscle aches

Coronavirus
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
- Glucose 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.
1.4 BAN- Use Cases for Remote Medical Services

Medical support for developing countries

Satellite Link

Medical Data Server for Data Mining with Machine Learning

Satellite Networks

Big Data

Internet

Cellular Network

Network Cloud

Data mining

Medical Center and General Hospitals

BAN

Mobile Station

VSAT

BAN

BAN

BAN

BAN

Ryuji Kohno, Takumi Kobayashi (YNU/FRP-IAI)
1.5 AN-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

physical assistant and surgery robots

Elderly people

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

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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

- Dependable Wireless Networks for Transportation
  - Road to car networks
  - Inter-vehicle networks

- Car Navigation & Collision Avoidance Radar

- Dependable Wireless BAN for Transportation
  - Tele-metering vital data
  - EEG, ECG, Blad Pressure, Temperature, MRI images Etc.

- Implant BAN
  - Tele-controlling implant devices
  - UWB can solve such a problem that radio interferes a human body and medical equipments

- Dependable BAN for Medical Healthcare
  - Dependable Network among vital sensors, actuators, robots
  - Capsule Endoscope
  - Pacemaker with IAD

- Dependable Wireless System Clock in Micro Circuit & Network in Devices
  - MMIC (Flip Chip)
  - On Chip Antenna and Wireless Network in chio
  - Multi-layer BCB

- Factory Automation (FA)
  - Dependable Wireless Sensing & Controlling for Manufacturing (CIM)
  - Collision Avoidance and safe driving by inter-vehicle networks
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

Controller: $u[k]$ (Insulin)

Human Model of Glucose vs Insulin: $y[k]$ (Blood-sugar level)

$K$: Controller

$r[k]$: Reference

$x[k]$: Sensor

$Bd$: Blood-sugar level (Glucose)

$Ad$: $1/S$

$u[k]$: Insulin Pump

Patient

Clinician

Wireless channel

July 2021
1.8 Demand of BAN for Automotive Uses

A. Increasing Demands in a world:
- New business promotion by applying wireless ICT to vehicle by huge alliance between automotive and telecom industries such as smart key, wireless harness
- Autonomous car driving and safety controlling of elderly drivers by ICT and data science

B. Challenging but Feasible Solutions:
- Provide Remote Sensing and Controlling Using ICT and AI
  - Prevent Traffic Accidents, Jam and CO2 Emission
- Promote a New Global Business of Automotive, ICT, and Electronics

C. Approach:
1. R&D of Enable Technologies for Smart Vehicle and City
2. Promote International Standard of Wireless Body Network (BAN) and Integrated Platform of BAN/5G/AI for Global Marketing for both Medical and Automotive uses
3. Regulatory Compliance of Devices & Services to Ensure Safety, Reliability, Security, i.e. Dependability by Regulatory Science
## 1.9 Use of BAN for Autonomous Car Driving

### Description:
- **Driver or AI**: Links to a controller via a wireless channel.
- **Controller**: Sends a signal to the Axel/Brake and Radar systems.
- **Axel/Brake**: Used for controlling the car's movement.
- **Radar**: For collision avoidance and inter-vehicle communication.
- **Own Car** and **Car Running Ahead**: Indicate the vehicles involved in the autonomous driving system.

### Feedback Loop Model:
- **Controller** sends a signal $u[k]$ to the **Car Axel/Brake Model and Radar System**.
- The **Radar** system sends a signal $x[k]$ to the **Controller** through a wireless channel.
- The **Feedback Delay Loop Model with Motion Equation** shows the interaction between the controller and the radar system, indicating the feedback delay.

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*Image and text content from Ryuji Kohno, Takumi Kobayashi (YNU/YRP-IAI)*
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
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.
2. Short Review of WBAN Standard
IEEE802.15.6-2012
2.1 Standard of Medical Wireless Body Area Network (BAN); IEEE 802.15.6

IEEE 802

IEEE 802.11
Wireless LAN

IEEE 802.15
Wireless PAN

IEEE 802.16
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

Ryuji Kohno, Takumi Kobayashi (YNU/YRP-IAI)
2.2 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
  - Band: UWB band
  - Data rate: 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?
- Power consumption?
- Complexity?
- Reliability?
- Outage probability?
- Security?
## 2.3 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>
## 2.4 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>
2.5 Time-referenced Superframe w/ Beacon

Clock and position of each access phase

May obtain contended allocation for highest priority

One superframe

EAP: exclusive access phase
RAP: random access phase
MAP: managed access phase
CAP: contention access phase
2.6 Worldwide UWB Regulations in 2012

- **China**
  - DAA LDC
  - DAA After 2010

- **Europe**
  - DAA LDC
  - DAA After 2010

- **Japan**
  - DAA After 2013

- **Korea**
  - DAA LDC
  - DAA After 2010

- **USA**
  - 7.2 GHz
  - 10.2 GHz

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

- **High band**
  - 6.0G
  - 7.25G
  - 8.5G
  - 9G
  - 10.25G
  - 10.6G
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 7.25-9.00GHz **Green line** and it is expected to allow it for outdoor use in January 2021.

![Diagram showing permitted outdoor band in May 2019 and expected permitted outdoor band in January 2021.](image-url)
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.
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

**Inter-system** interference
- “ISI” in this presentation
- Interference from a system using overlapped frequency

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

**Unknown**
- **Remove**
  - Interference canceller
OMF; orthogonal matched filter

- consists a matched filter ($\text{MF}_1$) 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$_{2~K-1}$ because orthogonality. →only interference can through.
- MFG makes replica of interference signal by linear combination with weight vector $w$ of linear combiner; LC.
- Subtract interference replica from the output of MF$_1$.

**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, \( \omega \).
  
  \[ \Rightarrow \] has characteristics of both spatial and time domain.

\[ \tau_n = \frac{n \cdot d}{c} \sin \theta, \]

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

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

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

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

Principle of TDL-AA
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)

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

Integrated Terminal
= (Cellular Terminal + BAN Coordinator)
= (Primary User + Secondary BS)

4.7 ICT & Data Science Platform for Infrastructure with BAN, 5G/6G 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**
  - Coordinator
  - Android

- **Local 5G**
  - iOS

- **Cloud Network**
  - 3G, 4G, 5G, and 6G Cellular
  - Wi-Fi
  - WiMAX etc.

- **Network Operator**
  - For 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

**Cdata Science Center**
- Three PHY with a common MAC in IEEE802.15.6
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

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
  - CO₂ Reduction, Green Innovation
- Escalating security concerns
  - Public Safety, National Defense
- Heightened investor demands
  - Global Borderless Economics

Dependable BAN of Things for SDGs

Integrated BAN/Cloud/AI Platform of Beyond 5G
Application of Dependable BAN of Things to Social Infrastructure

- Network Connection of Distributed Various Sensors
- Various Applications could be integrated for global services.

Medical Care
- Kids Trace
- Health Care
- Disaster Prevention
- Sensing Disaster
- Disaster Detection in Nature
- Checking Stability of Building and Bridge
- Control Center
- Various Services

Security
- Building Security Control
- Health Care

Agricultural Sensing
- Plant Surveillance
- Management of Agricultural Farm

Disaster Prevention
- Polusion Prevention
- Weather Prediction
- Health Care

Miscellaneous
- Network Connection of Distributed Various Sensors
- Various Applications could be integrated for global services.
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)

<table>
<thead>
<tr>
<th>Number of sensors</th>
<th>Car Factory automation</th>
<th>UAV(Drone)Sensing &amp;Control</th>
<th>High Data Rate BAN (HRP)</th>
<th>Low Data Rate BAN (LRP)</th>
<th>Dependable BAN including Car Body as well as Human and Robotic Body</th>
<th>Reference standard 802.15.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to ten per network</td>
<td>Up to ten per network</td>
<td>Up to ten (ex. camera, GPS etc.)</td>
<td>Up to 4096</td>
<td>Up to 256</td>
<td>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&gt;4 units can cover 64xM nodes in layer structure. Class A; node transmitting periodical packets Class B: node doing non-periodical ones.</td>
<td>256 For 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Less than 100</td>
<td>Up to 100</td>
<td>Up to ten (ex. at least 4 drones for relative localization)</td>
<td>Single</td>
<td>Up to 3 BANs</td>
<td>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</td>
<td>0 Not expected multiple BANs overlaid</td>
</tr>
<tr>
<td>Extended star</td>
<td>Star + bus</td>
<td>Star (dynamically allocation of coordinator)</td>
<td>Star (2pairs)</td>
<td>Star + multi hop</td>
<td>Star + multiple hop or Star + mesh Due to relationship with smart BAN and smart M2M Two layered cluster tree</td>
<td>(extended) star + one hop</td>
</tr>
<tr>
<td>Comparable to CAN, RIM</td>
<td>2 Mbps/se sensor</td>
<td>Up to several ten Mbps/camera/drone</td>
<td>Up to 1KHzx12 =12kbps/se sensor</td>
<td>Aggregate rate up to 2Mbps</td>
<td>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</td>
<td>1 Mbps for narrow Band 11 Mbps for UWB in max</td>
</tr>
</tbody>
</table>

**Reference**

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

**Slide 46**
<table>
<thead>
<tr>
<th></th>
<th>Car Factory automation</th>
<th>UAV(Drone) Sensing &amp; Controlling</th>
<th>High Data Rate BAN (HRP)</th>
<th>Low Data Rate BAN (LRP)</th>
<th>Dependable BAN for Car Body as well as Human Body</th>
<th>Reference standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate data rate over interooperating networks</td>
<td>Few hundred Mbps</td>
<td>Up to 1 Gbps</td>
<td>Up to several Mbps/drone</td>
<td>50 Mbps</td>
<td>2 Mbps</td>
<td>6 hundred Mbps in case of 4 nits x 64 nodes/unit Ref. Satisfying 49Mbps for 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Latency in normal operation</td>
<td>Comparable to CAN, RIM or Flex Ray</td>
<td>250 ms to 1s</td>
<td>250 ms to 500 ms</td>
<td>Frame length 10-20 ms Latency 10ms</td>
<td>10 ms to 20ms</td>
<td>250 ms to 1s Ref. to be considered use case of 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Latency in critical situation</td>
<td>Comparable to CAN, RIM or Flex Ray</td>
<td>Few ms to 15 ms *</td>
<td>Several 10 ms</td>
<td>5-10 ms</td>
<td>10 ms</td>
<td>100 ms Ref. to be considered use case of 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Association delay</td>
<td>N/A</td>
<td>&lt; 1 s</td>
<td>&lt; 100ms</td>
<td>Same direction &lt; 30ms</td>
<td>&lt; 60 ms</td>
<td>&lt; 1 s Ref. to be considered use case of 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Authenticatio n and security delay</td>
<td>N/A</td>
<td>&lt; 1 s</td>
<td>N/A</td>
<td>Same direction &lt; 50ms</td>
<td>&lt; 100 ms</td>
<td>&lt; 1 s Ref. to be considered use case of 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Delivery ratio requirement</td>
<td>&gt; 99.9%</td>
<td>&gt; 99%</td>
<td>&gt; 99.9%</td>
<td>&gt; 99.9%</td>
<td>&gt; 99%</td>
<td>&gt;95% Ref. to be considered use case of 2nd GBMI</td>
</tr>
</tbody>
</table>
### 5.2 Updated Technical Requirements (3/5)

<table>
<thead>
<tr>
<th></th>
<th>Car automation</th>
<th>UAV(Drone) Sensing &amp; Controlling</th>
<th>High Data Rate BAN (HRP)</th>
<th>Low Data Rate BAN (LRP)</th>
<th>Dependable BAN including Car Body as well as Human Body</th>
<th>Reference standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disconnection ratio (of time)</td>
<td>&lt; 0.01%</td>
<td>&lt; 0.1%</td>
<td>&lt; 0.001%</td>
<td>&lt; 0.01%</td>
<td>&lt; 2%</td>
<td>&lt; 1% to be considered use case of 2&lt;sup&gt;nd&lt;/sup&gt; G ECoG BMI</td>
</tr>
<tr>
<td>Synchronization recovery time</td>
<td>&lt; 100 ms</td>
<td>&lt; 100 ms</td>
<td>&lt; 70 ms</td>
<td>&lt; 10 ms</td>
<td>N/A</td>
<td>&lt; 50 ms to be considered use case of 2&lt;sup&gt;nd&lt;/sup&gt; G ECoG BMI</td>
</tr>
<tr>
<td>Coverage range</td>
<td>6 m</td>
<td>5 m</td>
<td>100m(among drones) some km(with controller)</td>
<td>10cm</td>
<td>50cm</td>
<td>&lt; 10 m Much less coverage for 2&lt;sup&gt;nd&lt;/sup&gt; G ECoG BMI</td>
</tr>
<tr>
<td>Feedback loop response time</td>
<td>&lt; 10 ms</td>
<td>&lt; 1 s</td>
<td>&lt; 10 ms</td>
<td>&lt; 10ms</td>
<td>&lt; 100ms</td>
<td>&lt; 50 ms Ref. to be considered use case of 2&lt;sup&gt;nd&lt;/sup&gt; G ECoG BMI</td>
</tr>
<tr>
<td>Handover capability</td>
<td>N/A</td>
<td>&lt; 2 s</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Data packet size</td>
<td>CAN &amp; RIM compatiblity</td>
<td>10 to 1000 bytes</td>
<td>802.11 compatible</td>
<td>802.11 compatible</td>
<td>802.11 compatible</td>
<td>Up to 255 octets</td>
</tr>
</tbody>
</table>

| Reference standard 802.15.6       |                |                                  |                          |                         |                                                       |                   |

- **Disconnection ratio (of time):**
  - Car: < 0.01%
  - UAV: < 0.1%
  - BAN: < 0.001%

- **Synchronization recovery time:**
  - Car: < 100 ms
  - UAV: < 100 ms
  - BAN: < 70 ms

- **Coverage range:**
  - Car: 6 m
  - UAV: 5 m
  - BAN: 100 m (among drones) some km (with controller)

- **Feedback loop response time:**
  - Car: < 10 ms
  - UAV: < 1 s
  - BAN: < 10 ms

- **Handover capability:**
  - Car: N/A
  - UAV: < 2 s

- **Data packet size:**
  - Car: 10 to 1000 bytes
  - UAV: 802.11 compatible
  - BAN: 802.11 compatible

- **Reference standard:**
  - 802.15.6

---

*July 2021 doc.: IEEE 802.15-21-0023-02-0dep
Ryuji Kohno, Takumi Kobayashi(YNU/YRP-IAI)*
5.2 Updated Technical Requirements (4/5)

<table>
<thead>
<tr>
<th>Car</th>
<th>Factory automation</th>
<th>UAV(Drone) Sensing &amp; Controlling</th>
<th>High Data Rate BAN (HRP)</th>
<th>Low Data Rate BAN (LRP)</th>
<th>Dependable BAN including Car Body as well as Human Body</th>
<th>Reference standard 802.15.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jitter: typical max</td>
<td>5 ms</td>
<td>50 ms</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>QoS dependent</td>
</tr>
<tr>
<td>Jitter: critical max: 5% outliers acceptable</td>
<td>5 ms</td>
<td>5 ms</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>QoS dependent</td>
</tr>
<tr>
<td>Multi BAN Overlaid (A) Intra network interference</td>
<td>Driver/Passengers room: &lt;10</td>
<td>&lt;50 according to coverage range</td>
<td>&lt;10 according to no. of drones cluster</td>
<td>Single(2pairs) according to spacing between BANs</td>
<td>Up to 3 BANs according to covering range</td>
<td>&lt;64 Ref. to be considered use case of 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Engine room: &lt;10</td>
<td></td>
<td></td>
<td></td>
<td>implant</td>
<td>wearable</td>
<td>By a few use case models, worst interference can be defined</td>
</tr>
<tr>
<td>Different PANs (B) Inter network interference (number of coexisting networks)</td>
<td>Driver/Passengers room: &lt;5</td>
<td>&lt;10 according to factory condition</td>
<td>&lt;5 according to no. of drones cluster</td>
<td>single Corresponding for interference mitigation technologies</td>
<td>Up to 3 PANS Corresponding to specification of coexisting PANs</td>
<td>&lt;10 Ref. to be considered use case of 2nd G ECoG BMI</td>
</tr>
</tbody>
</table>

Ryuji Kohno, Takumi Kobayashi (YNU/PRF/AI)
### 5.2 Updated Technical Requirements (5/5)

<table>
<thead>
<tr>
<th>Channel model resilience</th>
<th>Car</th>
<th>Factory automation</th>
<th>UAV(Drone) Remote Sensing and Controlling</th>
<th>High Data Rate BAN (HRP)</th>
<th>Low Data Rate BAN (LRP)</th>
<th>Dependable BAN</th>
<th>Reference standard 802.15.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver/Passengers room: Light multipath</td>
<td>Heavy multipath with shadowing</td>
<td>Line of sight (LOS)</td>
<td>Dedicated short distance (DSRC) with line of sight (LOS)</td>
<td>No Line of sight (NLOS) with shadowing and multipath</td>
<td>Dependent on Highest QoS Ref. to be</td>
<td>Dependable BAN</td>
<td>Reference standard 802.15.6</td>
</tr>
<tr>
<td>Engine room: Heavy multipath with shadowing</td>
<td>No Line of sight (NLOS) using camera</td>
<td>Compliance for safety guide line with SAR &amp; EMC</td>
<td>Compliance for safety guide line with SAR &amp; EMC</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

By a few use case models, worst interference can be defined.
<table>
<thead>
<tr>
<th></th>
<th>March 9&lt;sup&gt;th&lt;/sup&gt; Tuesday</th>
<th>March 10&lt;sup&gt;th&lt;/sup&gt; Wednesday</th>
<th>March 11&lt;sup&gt;th&lt;/sup&gt; Thursday</th>
<th>March 15&lt;sup&gt;th&lt;/sup&gt; Monday</th>
<th>March 17&lt;sup&gt;th&lt;/sup&gt; Wednesday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EST 9:00AM-11:00AM</strong></td>
<td>IEEE802.15 Opening Plenary</td>
<td>EST 5:00PM-7:00PM Joint Session of IG-DEP and IG-NG-UWB</td>
<td></td>
<td></td>
<td>IEEE802.15 Closing Plenary</td>
</tr>
<tr>
<td><strong>JST 11PM-1AM</strong></td>
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</tr>
<tr>
<td><strong>EST 7:00PM-9:00PM</strong></td>
<td>IG-DEP1 (March 11&lt;sup&gt;th&lt;/sup&gt; JST)</td>
<td>IG-DEP2 (March 12&lt;sup&gt;th&lt;/sup&gt; JST)</td>
<td>IG-DEP 3 (March 16&lt;sup&gt;th&lt;/sup&gt; JST)</td>
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<tr>
<td><strong>JST 9:00AM-11:00AM +1 day</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>May 11&lt;sup&gt;th&lt;/sup&gt; Tuesday</th>
<th>May 12&lt;sup&gt;th&lt;/sup&gt; Wednesday</th>
<th>May 13&lt;sup&gt;th&lt;/sup&gt; Thursday</th>
<th>May 18&lt;sup&gt;th&lt;/sup&gt; Tuesday</th>
<th>March 20&lt;sup&gt;th&lt;/sup&gt; Thursday</th>
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</thead>
<tbody>
<tr>
<td><strong>EST 9:00AM-11:00AM</strong></td>
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<td></td>
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<td></td>
<td>IEEE802.15 Closing Plenary</td>
</tr>
<tr>
<td><strong>JST 11PM-1AM</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>EST 8:00AM-10:00AM</strong></td>
<td>SG15.6a Session 1</td>
<td>SG15.6a Session 2</td>
<td>SG15.6a Session 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>JST 9:00PM-11:00PM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**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

<table>
<thead>
<tr>
<th>Date</th>
<th>AM1 SG15.6a</th>
<th>AM1 SG15.6a</th>
<th>AM1 SG15.6a</th>
<th>AM1 SG15.6a</th>
<th>AM1 SG15.6a</th>
<th>AM1 SG15.6a</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 13th</td>
<td>Tuesday</td>
<td>Wednesday</td>
<td>Thursday</td>
<td>Monday</td>
<td>Tuesday</td>
<td>Wednesday</td>
</tr>
</tbody>
</table>
| 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 Session 1, 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=mefa004064fd4ac5f6e28173f1bb2bf4](https://ieeesa.webex.com/ieeesa/j.php?MTID=mefa004064fd4ac5f6e28173f1bb2bf4)
   - Meeting number: 173 279 7091     Password: 80215SG6a

2. **SG 15.6a Session 2, 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=mefa004064fd4ac5f6e28173f1bb2bf4](https://ieeesa.webex.com/ieeesa/j.php?MTID=mefa004064fd4ac5f6e28173f1bb2bf4)
   - 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 20th, 2021 (UTC+9:00) Japan & Korean Time
   - Meeting link: [https://ieeesa.webex.com/ieeesa/j.php?MTID=m42ff6a58444126fd311b751923d35977](https://ieeesa.webex.com/ieeesa/j.php?MTID=m42ff6a58444126fd311b751923d35977)
   - Meeting number: 173 009 8101     Password: 80215SG6a4ab14

4. **SG 15.6a Session 3, Mon EV2**
   - 19:00 - 21:00 Monday, July 19th, 2021 (UTC-04:00) Eastern Time,
   - 8:00 am - 11:00 am Tuesday, July 20th, 2021 (UTC+9:00) Japan & Korean Time
   - Meeting link: [https://ieeesa.webex.com/ieeesa/j.php?MTID=mb3c82b1a28c4c46e559c915a3dab109d](https://ieeesa.webex.com/ieeesa/j.php?MTID=mb3c82b1a28c4c46e559c915a3dab109d)
   - Meeting number: 173 669 1256     Password: 80215SG6a

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**Submission**

Ryuji Kohno(YNU/CWC UofOulu), Takumi Kobayashi(YNU)
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 2\textsuperscript{nd} 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-takumich@ynu.ac.jp>.