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

Submission Title: IG DEP Updated Technical Requirements for Focused Use Cases on WBAN for Human, Robotic and Car Bodies

Date Submitted: July 15, 2019

Source: Ryuji Kohno (YNU/CWC-Nippon), Jussi Haapola (CWC),
Contact: Ryuji Kohno (YNU/CWC-Nippon), Jussi Haapola (CWC),
Voice: +358-8-553-2849, E-Mail: kohno@ynu.ac.jp, jhaapola@ee.oulu.fi
Re: IG DEP Selected applications technical requirements

Abstract: Core applications are summarized to be focused use cases for WBAN for human, robotics and car bodies different from applications covering inter-vehicle, vehicle to roadside and car manufacturing line. Moreover, requirement for high capacity and reliability in 2nd Generation of ECoG for BMI could be focused in medical BAN is new trend for amendment of IEEE802.15.6 for dependable BAN while to collaborate with ETSI smart BAN and smart M2M, commonality and difference are discussed.

Notice: This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release: The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15.
IG DEP  Updated Technical Requirements for Focused Use Cases on WBAN for Human, Robotic and Car Bodies

Vienna, Austria
July 15th, 2019

Ryuji Kohno; Yokohama National University(YNU), University of Oulu Research Institute Japan - CWC-Nippon, Jussi Haapola; CWC, University of Oulu
1. Original Selected applications for IG-DEP

1. Remote healthcare monitoring
2. Remote sensing and controlling
3. Vehicle internal sensing and controlling
4. Collision avoidance radar
5. Inter-vehicle communications and ranging
6. Wearable and implant wireless medical sensing and controlling
7. Applications for ultra wideband radio
8. Reliable and robust radio control
9. Wearable healthcare sensing
10. Secure remote healthcare and medicine
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
2. Original and New Focused Use Cases

2.1 Original Focused Use Cases; Automotive Use Case

- Wireless intra-vehicle communications (car bus supplement)
- Wireless inter-vehicle (V2V) and vehicle to infrastructure communications (V2I)
- Remote sensing and control in factory

2.2 New Focused Use Cases; Car, Robotic and Human Bodies

- Internal car network for sensing and controlling including UAV and robotics in factory is focused for enhanced dependability as an amendment of medical BAN IEEE802.15.6.
3. Summary of Requirements for Previous Focused Use Cases

- Number of sensors: few tens to hundreds per network
- Support for multiple network co-existence & interoperability: few tens of networks
- Types of topologies: star, mesh, inter-connected networks
- Data rate requirement: up to 2 Mbps per sensor
- Latency in normal operation: 250 ms to 1 s
- Latency in critical situation: few ms to 15 ms
- Aggregate data rate per network: up to 1 Gbps (in some applications) / few Mbps (in others)
- Delivery ratio requirement: >99.9 % (in some applications) / > 99 % (in others)
- Disconnection ratio < 0.01 % (of time)
- Synchronization recovery time: < 100 ms
- Coverage range: up to 1000 m (in some applications) / 20 m (in others)
- Feedback loop response time: less than 1 s (10 ms In collision avoidance radar)
3. Summary of Requirements for Previous Focused Use Cases (cont.)

- Handover capability: seamless between BANs and/or PANs, walking speed, 2 seconds
- Transceiver power consumption: SotA acceptable
- Module size: wearable for hospital use, maximum size 5 cm x 2 cm x 1 cm for automotive
- Module weight: < 50 g for hospital, < 10 g for automotive & body
- Data packet sizes (typical, maximum):
  - Hospital: 100 bytes, 1000 bytes
  - Automotive: 10 bytes, 1000 bytes
  - Compatibility with CAN and RIM buses for intra-vehicle
- Security considerations: Handover peers need to have trust relationship. High confidentiality and privacy requirements in hospital environment. Lifecycle management.
- Sensor lifetime: minimum 1 year, up to equipment lifetime
- Jitter: < 50 ms in regular case, < 5 ms in critical situations. 5 % outliers acceptable.
3. Summary of Requirements for Previous Focused Use Cases (cont.)

- Interference models:
  - Intra network interference (MAC&PHY specification dependent)
  - Inter-network interference (take a look at literature, coexistence statements)
- Channel models:
  - in intra-vehicle (needs to be measured),
  - inter-vehicle (exists in literature),
  - in factory (partially exists in literature),
  - in hospital (exist in literature),
  - in emergency rescue field (exists?)
- Any other?
4. Update of Technical Requirements for New Medical 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 2\textsuperscript{nd} 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.
## 4. Updated Technical Requirements (1/6)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Car bus supplement</th>
<th>V2V</th>
<th>V2I</th>
<th>Factory automation</th>
<th>UAV(Drone) Sensing &amp; Controlling</th>
<th>Dependable BAN including Car Body as well as Human and Robotic Body</th>
<th>Reference standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of sensors</strong></td>
<td>Up to ten per network</td>
<td>Up to Few tens</td>
<td>Less than ten</td>
<td>Up to ten per network</td>
<td>Up to ten (ex. camera, GPS etc.)</td>
<td>64 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 128x32 64x64 32x128 16x256 8x512 4x1024 2x2048</td>
</tr>
<tr>
<td><strong>Support for multiple network co-existence &amp; interoperability</strong></td>
<td>Less than 100</td>
<td>Up to Few tens</td>
<td>Less than 50</td>
<td>Up to 100</td>
<td>Up to ten (ex. at least 4 drones for relative localization)</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><strong>Topology</strong></td>
<td>Extended star mesh Star Star + bus</td>
<td>Star</td>
<td>Star (dynamic allocation changing a coordinator)</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>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data rate</strong></td>
<td>Comparable to CAN, RIM or FlexRay</td>
<td>Up to 2 Mbps/vehicle</td>
<td>Up to 2 Mbps/sensor</td>
<td>2 Mbps/se sensor</td>
<td>Up to several ten Mbps/camera/drone</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>

*Slide 9*
# 4. Updated Technical Requirements (2/6)

<table>
<thead>
<tr>
<th></th>
<th>Car bus supplement</th>
<th>V2V</th>
<th>V2I</th>
<th>Factory automation</th>
<th>UAV(Drone) Sensing &amp; Controlling</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>Aggregate data rate over interoperating networks</td>
<td>Few hundred Mbps</td>
<td>Few hundred Mbps</td>
<td>Few hundred Mbps</td>
<td>Up to 1 Gbps</td>
<td>Up to several Mbps/drone</td>
<td>6 hundred Mbps in case of 4 nits x 64 nodes/unit</td>
<td>N/A</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 1s</td>
<td>250 ms to 1s</td>
<td>250 ms to 500 ms</td>
<td>250 ms to 1s</td>
<td>Typical 50 to 100 ms</td>
</tr>
<tr>
<td>Latency in critical situation</td>
<td>Comparable to CAN, RIM or Flex Ray</td>
<td>100 ms</td>
<td>100 ms</td>
<td>Few ms to 15 ms *</td>
<td>Several 10 ms</td>
<td>100 ms</td>
<td>Less than typical case</td>
</tr>
<tr>
<td>Association delay</td>
<td>N/A</td>
<td>Same direction &lt; 1 s</td>
<td>&lt; 500 ms</td>
<td>&lt; 1 s</td>
<td>&lt; 100 ms</td>
<td>&lt; 1 s</td>
<td>Less than 1s</td>
</tr>
<tr>
<td>Authentication and security delay</td>
<td>N/A</td>
<td>Same direction &lt; 1 s</td>
<td>&lt; 500 ms</td>
<td>&lt; 1 s</td>
<td>N/A</td>
<td>&lt; 1 s</td>
<td>Seconds</td>
</tr>
<tr>
<td>Delivery ratio requirement</td>
<td>&gt; 99.9%</td>
<td>&gt; 99.9%</td>
<td>&gt; 99%</td>
<td>&gt; 99%</td>
<td>&gt; 99.9%</td>
<td>&gt;95%</td>
<td>95%</td>
</tr>
</tbody>
</table>

## 4. Updated Technical Requirements (3/6)

<table>
<thead>
<tr>
<th></th>
<th>Car bus supplement</th>
<th>V2V</th>
<th>V2I</th>
<th>Factory automation</th>
<th>UAV(Drone) Sensing &amp; Controlling</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>Disconnection ratio (of time)</td>
<td>&lt; 0.01%</td>
<td>&lt; 1%</td>
<td>&lt; 2%</td>
<td>&lt; 0.01%</td>
<td>&lt; 0.001%</td>
<td>&lt; 1%</td>
<td></td>
</tr>
<tr>
<td>Synchronization recovery time</td>
<td>&lt; 100 ms</td>
<td>&lt; 100 ms</td>
<td>N/A</td>
<td>&lt; 100 ms</td>
<td>&lt; 70 ms</td>
<td>&lt; 100 ms</td>
<td></td>
</tr>
<tr>
<td>Coverage range</td>
<td>6 m</td>
<td>200 m (highway)</td>
<td>400 m (highway)</td>
<td>5 m</td>
<td>100 m (among drones)</td>
<td>&lt; 10 m</td>
<td>Much less coverage for 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Feedback loop response time</td>
<td>&lt; 10 ms</td>
<td>&lt; 1 s</td>
<td>N/A</td>
<td>&lt; 1 s</td>
<td>&lt; 10 ms</td>
<td>&lt; 500 ms</td>
<td></td>
</tr>
<tr>
<td>Handover capability</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>&lt; 2 s</td>
<td>N/A</td>
<td>N/A</td>
<td>Not defined</td>
</tr>
<tr>
<td>Data packet size</td>
<td>CAN &amp; RIM compatible</td>
<td>802.11 compatible</td>
<td>802.11 compatible</td>
<td>10 to 1000 bytes</td>
<td>802.11 compatible</td>
<td>Up to 255 octets</td>
<td>Up to 255 octets</td>
</tr>
</tbody>
</table>
### 4. Updated Technical Requirements (4/6)

<table>
<thead>
<tr>
<th></th>
<th>Car bus supplemental</th>
<th>V2V</th>
<th>V2I</th>
<th>Factory automation</th>
<th>UAV(Drone) Sensing &amp; Controlling</th>
<th>Dependable BAN including Car Body as well as Human Body</th>
<th>Reference standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jitter: typical max</strong></td>
<td></td>
<td>5 ms</td>
<td>N/A</td>
<td>N/A</td>
<td>50 ms</td>
<td>N/A</td>
<td>QoS dependent</td>
</tr>
<tr>
<td><strong>Jitter: critical max:</strong></td>
<td>&lt;5 ms</td>
<td>N/A</td>
<td>N/A</td>
<td>5 ms</td>
<td>N/A</td>
<td>Dependent on Highest QoS</td>
<td>QoS dependent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Multiuser support</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>(A) Intra network interference</strong></td>
<td>Driver/Passengers room: &lt;10</td>
<td>&lt;50 according to car cluster</td>
<td>&lt;20 according to car cluster</td>
<td>&lt;50 according to coverage range</td>
<td>&lt;10 according to no. of drones cluster</td>
<td>By a few use case models, worst interference can be defined</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engine room:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>(B) Inter network interference</strong></td>
<td>Driver/Passengers room: &lt; 5</td>
<td>&lt;10 according to car cluster</td>
<td>&lt;10 according to car cluster</td>
<td>&lt;10 according to factory condition</td>
<td>&lt;5 according to no. of drones cluster</td>
<td>By a few use case models, worst interference can be defined</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 4. Updated Technical Requirements (6/6)

<table>
<thead>
<tr>
<th>Car bus supplement</th>
<th>V2V</th>
<th>V2I</th>
<th>Factory automation</th>
<th>UAV(Drone) Remote Sensing and Controlling</th>
<th>Dependable BAN</th>
<th>Reference standard 802.15.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel model resilience</td>
<td>Driver/Passengers room: Light multipath</td>
<td>Mostly line of sight with some shadowing</td>
<td>Mostly line of sight with some shadowing</td>
<td>Heavy multipath with shadowing</td>
<td>Line of sight</td>
<td>Dependent on Highest QoS Ref. to be considered use case of 2nd G ECoG BMI</td>
</tr>
<tr>
<td>Engine room: Heavy multipath with shadowing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>By a few use case models, worst interference can be defined</td>
</tr>
</tbody>
</table>

Driver/Passengers room:
- Light multipath
- Mostly line of sight with some shadowing
- Mostly line of sight with some shadowing

Engine room:
- Heavy multipath with shadowing
- No line of sight using camera
5. Concluding Remark

• Corresponding request from ETSI smart BAN associating with smart M2M, IG-DEP has discussed to focus on internal car network for IoT/M2M connections that is called Car BAN as well as BAN for human and robotic bodies.

• As amendment of IEEE802.15.6, MAC for multiple BANs coexistence can be guaranteed to satisfy permissible delay or back-off time and throughput of high QoS packets for all car, robotic and human BANs while maintaining overall 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 another use case of 2nd Generation of ECoG for Brain-Machine-Interface(BMI), technical requirement has been updated to cover 4,096 units of ECoG sensors with appropriate combination of no. of units x no. of sensors in a unit such as 64x64, 32x128, 16x256, 8x512, 4x1024 etc.