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

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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.

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

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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 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.

4. Updated Technical Requirements(1/6)

	Car bus supplement	V2V	V2I	Factory automation	UAV(Drone) Sensing & Controlling	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 Few tens	Less than ten	Up to ten per network	Up to ten (ex. camera, GPS etc.)	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>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 Few tens	Less than 50	Up to 100	Up to ten (ex. at least 4 drones for relative localization)	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	mesh	Star	Star + bus	Star(dynamic allocation changing a coordinator)	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 or FlexRay	Up to 2 Mbps/vehicle	Up to 2 Mbps/sensor	2 Mbps/sensor	Up to several ten Mbps/camera/drone	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

4. Updated Technical Requirements(2/6)

	Car bus supplement	V2V	V2I	Factory automation	UAV(Drone) Sensing & Controlling	Dependable BAN including Car Body as well as Human Body	Reference standard 802.15.6
Aggregate data rate over interoperating networks	Few hundred Mbps	Few hundred Mbps	Few hundred Mbps	Up to 1 Gbps	Up to several Mbps/drone	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 1s	250 ms to 1s	250 ms to 500 ms	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	100 ms	100 ms	Few ms to 15 ms *	Several 10 ms	100 ms Ref. to be considered use case of 2nd G ECoG BMI	Less than typical case
Association delay	N/A	Same direction < 1 s	< 500 ms	< 1 s	< 100ms	< 1 s Ref. to be considered use case of 2nd G ECoG BMI	Less than 1s Optional requirement
Authentication and security delay	N/A	Same direction < 1 s	< 500 ms	< 1 s	N/A	< 1 s Ref. to be considered use case of 2nd G ECoG BMI	Seconds Optional requirement
Delivery ratio requirement	> 99.9%	> 99.9%	> 99%	> 99%	> 99.9%	>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

4. Updated Technical Requirements(3/6)

	Car bus supplement	V2V	V2I	Factory automation	UAV(Drone) Sensing & Controlling	Dependable BAN including Car Body as well as Human Body	Reference standard 802.15.6
Disconnection ratio (of time)	< 0.01%	< 1%	< 2%	< 0.01%	< 0.001%	< 1% Ref. to be considered use case of 2nd G ECoG BMI	?
Synchronization recovery time	< 100 ms	< 100 ms	N/A	< 100 ms	< 70 ms	< 100 ms Ref. to be considered use case of 2nd G ECoG BMI	Seconds
Coverage range	6 m	200 m (highway)	400 m (highway)	5 m	100m(among drones) Several km(with controller)	< 10 m Much less coverage for 2nd G ECoG BMI	< 10 m
Feedback loop response time	< 10 ms	< 1 s	N/A	< 1 s	< 10 ms	< 500 ms Ref. to be considered use case of 2nd G ECoG BMI	< 500 ms
Handover capability	N/A	N/A	N/A	< 2 s	N/A	N/A	Not defined
Data packet size	CAN & RIM compatibility	802.11 compatible	802.11 compatible	10 to 1000 bytes	802.11 compatible	Up to 255 octets	Up to 255 octets

4. Updated Technical Requirements(4/6)

	Car bus supplement	V2V	V2I	Factory automation	UAV(Drone) Sensing & Controlling	Dependable BAN including Car Body as well as Human Body	Reference standard 802.15.6
Jitter: typical max	5 ms	N/A	N/A	50 ms	N/A	Dependent on Highest QoS	QoS dependent
Jitter: critical max: 5% outliers acceptable	5 ms	N/A	N/A	5 ms	N/A	Dependent on Highest QoS	QoS dependent
Multiuser support (A) Intra network interference	Driver/Passengers room: <10	<50 according to car cluster	<20 according to car cluster	<50 according to coverage range	<10 according to no. of drones cluster	**<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						
(B) Inter network interference (number of coexisting networks)	Driver/Passengers room: < 5	<10 according to car cluster	<10 according to car cluster	<10 according to factory condition	<5 according to no. of drones cluster	**<10** Ref. to be considered use case of 2nd G ECoG BMI	By a few use case models, worst interference can be defined.

4. Updated Technical Requirements(6/6)

	Car bus supplement	V2V	V2I	Factory automation	UAV(Drone) Remote Sensing and Controlling	Dependable BAN	Reference standard 802.15.6
Channel model resilience	Driver/Passengers room: Light multipath	Mostly line of sight with some shadowing	Mostly line of sight with some shadowing	Heavy multipath with shadowing	Line of sight	Dependent on Highest QoS Ref. to be considered use case of 2nd G ECoG BMI	By a few use case models, worst interference can be defined
	Engine room: Heavy multipath with shadowing				No Line of sight 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.