IEEE 802.15

Wireless Specialty Networks

Project	IEEE 802.15 Working Group for Wireless Specialty Networks	
Title	Technical Requirements Document	
Date Submitted	November 10th, 2021	
Source	Marco Hernandez[1], Ryuji Kohno[1,2], Takumi Kobayashi[1,2], Minsoo Kim[2] [1]YRP-IAI, [2]YNU, Japan	Marco.Hernandez@ieee.org Kohno@ynu.ac.jp Kobayashi-Takumi-ch@ynu.ac.jp Minsoo@minsookim.com
Response	To call for contributions	
Abstract	This document contains the technical requirements document (TRD) as a guide for technical proposals to form the P802.15.6a specification.	
Purpose	For contributions to P802.15.6a	
Notice	This document has been prepared to assist the IEEE P802.15.6a. 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.	

Contributors

Name & affiliation	Email
Marco Hernandez, YRP-IAI Japan	Marco.Hernandez@ieee.org
Ryuji Kohno, YRP-IAI, YNU, Japan	Kohno@ynu.ac.jp
Takumi Kobayashi, YRP-IAI, YNU, Japan	Kobayashi-Takumi-ch@ynu.ac.jp
Minsoo Kim, YRP-IAI Japan	Minsoo@minsookim.com
Kamran Sayrafian, NIST USA	Kamran.Sayrafian@nist.gov

Revision history

Revision	Date	Notes
0	11/10/2021	
1	11/10/2021	Include implant use case.
2	11/20/2021	Include agreements reached during the November meeting.

Contents

1. Definitions, abbreviations and acronyms

Data rate:	denotes the number of bits per second (b/s) transmitted at the PHY SAP.
Throughput:	denotes the effective data information rate in b/s measured at the MAC SAP. It involves overhead and losses in the radio link due to congestion, interference, and protocol communication exchanges.
Decode:	is the ability to process MAC frames at the receiving side.
Detect:	is the ability to be aware of the transmission of PHY frames but cannot decode.
Interoperability:	is the ability of IEEE 802.15.6a devices to decode at least one mode of transmission of IEEE 802.15.4ab devices and vice versa.
Intraoperability:	is the ability of IEEE 802.15.6a devices to decode IEEE 802.15.6 transmissions.
Coexistence:	is the ability of IEEE 802.15.6a devices to detect IEEE 802.15.6, IEEE 802.14.4ab transmissions and therefore to defer to transmit or mitigate interference during IEEE 802.15.6, IEEE 802.15.4ab transmissions causing collisions, and vice versa.
Fairness:	is the ability of IEEE 802.15.6, IEEE 802.15.4ab devices to have the same opportunity as IEEE 802.15.6a devices to access the channel.
15.6a device	denotes the entity with the implementation of PHY and MAC as specified by P802.15.6a.
Packet Error Rate (PER)	is the ratio of packets unsuccessfully received to the total number of packets sent measured at the MAC-SAP.
Bit Error Rate (BER)	is the ratio of bits unsuccessfully received to the total number of bits sent.
Packet Delivery Ratio (PDR)	is the ratio of packets successfully received to the total number of packets sent measured at the MAC-SAP.
Sensitivity level	is defined as the power level measured at the receiver input when the bit error rate (BER) is equal to 10^{-6}.
Node	is the entity with PHY and MAC implementation as specified by 802.15.6a without coordination functions.
Coordinator	is the entity with PHY and MAC implementation as specified by 802.15.6a with coordination functions.

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CCA:	Clear Channel Assessment
SAP:	Service Access Point
HBAN:	Human Body Area Network.
VBAN:	Vehicle Body Area Network.

PAN: Personal Area Network

MLDE: MAC Layer Data Entity

MLME: MAC Layer Management Entity

PLDE: PHY Layer Data Entity

PLME: PHY Layer Management Entity

SINR Signal to Interference plus Noise Ratio

TSN: Time-Sensitive Networking

2. Purpose

The document establishes the technical requirements, agreed by the Task Group (TG), for solutions addressing functionalities provided by the 802.15.6a amendment.

2.1 Scope

The scope for deriving functional technical requirements is based on the 802.15.6a PAR [B1], CSD [B2], and the Draft Technical Requirement of IEEE 802.15.6a [B3]. Additional requirements may be added if agreed by the TG.

2.2 Notation

Technical requirements are identified by the label **TG15.6a Rn**, where **n** represents the ID number of the technical requirement.

3. Functional technical requirements

3.1 System Performance

3.1.1 Throughput measured at MAC SAP

TG15.6a.R1. The 802.15.6a amendment shall provide at least one mode of operation capable of achieving a throughput of at least 40 Mb/s, operating at a maximum mandatory data rate of 50 Mb/s in the high band of UWB (500 MHz channel) under a PDR of 99% [B1].

3.1.2 Transmission range

TG15.6a.R2. The 802.15.6a amendment shall provide at least one mode of operation that achieves the same transmission range for HBAN as the one provided by IEEE Std 802.15.6-2012 of 3m at the lowest data rate and operating in the high band of UWB band [B1].

TG15.6a.R3. The 802.15.6a amendment shall provide at least one mode of operation that achieves the transmission range for VBAN of *proposal-specific* for cars, utility vehicles *and proposal-specific* for passenger bus [B1].

TG15.6a.R4. The 802.15.6a amendment shall provide at least one mode of operation that achieves the transmission range between HBAN and VBAN of *proposal-specific* [B1].

3.1.3 Transmission reliability

TG15.6a.R5. The 802.15.6a amendment shall improve transmission reliability under congested communication environment compared to IEEE Std 802.15.6-2012 operating in UWB band, including interference from other wireless systems [B1].

3.1.4 Latency

TG15.6a.R6. The 802.15.6a amendment shall improve latency under congested communication environment compared to IEEE Std 802.15.6-2012 operating in UWB band [B1].

3.1.5 Power saving

TG15.6a.R7. 802.15.6a shall consider mechanisms for power saving [B2].

3.1.6 Connection to infrastructure

TG15.6a.R8. 802.15.6a shall consider mechanisms for connecting to infrastructure (TSN domain) [B1].

3.2 Bands of Operation

TG15.6a.R9. The 802.15.6a amendment shall define operations for the UWB band as specified in clause 4.

3.3 Positioning

TG15.6a.R10. The 802.15.6a amendment shall define procedures for at least one form of positioning [B1].

3.4 Coexistence and interoperability

TG15.6a.R11. The 802.15.6a amendment shall provide coexistence and fairness with devices operating in the UWB band as specified in IEEE Std 802.15.6-2012, IEEE Std 802.15.4-2020, IEEE 802.15.8-2017, and ETSI Smart Band [B1], [B2].

3.5 Privacy and security

TG15.6a.R12. 802.15.6a shall consider mechanisms to enhance security and privacy at the MAC layer [B1].

3.6 Compliance to PAR

TG15.6a.R13. The 802.15.6a amendment shall comply with the P802.15.6a PAR [B1] and the CSD [B2].

4. Operating frequency bands

Current state of the UWB band regulations.

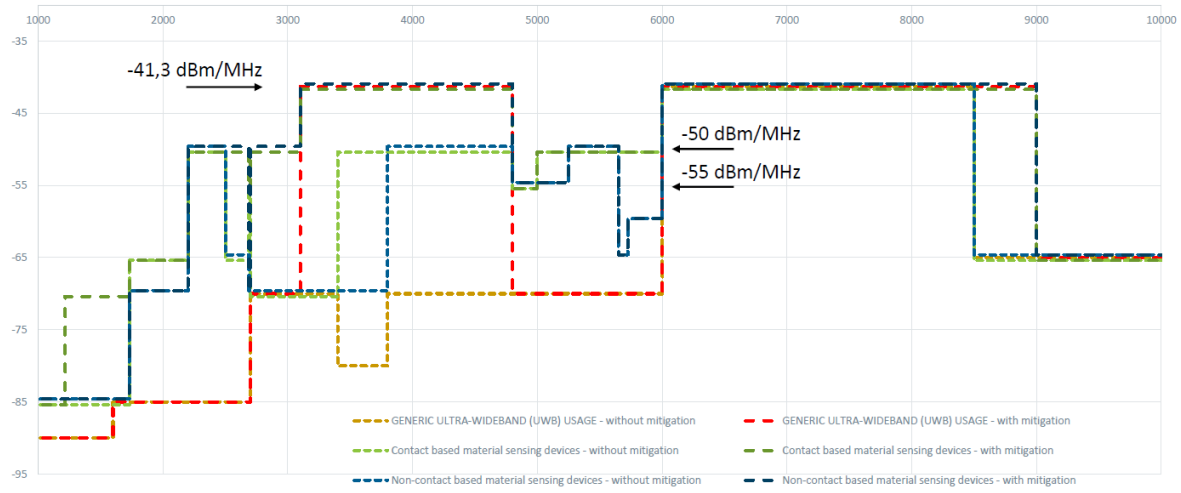

Figure 1—UWB band regulation (example for illustration).

5. Reference model

Figure 2 illustrates the user plane and control plane protocol stack for P802.15.6a.

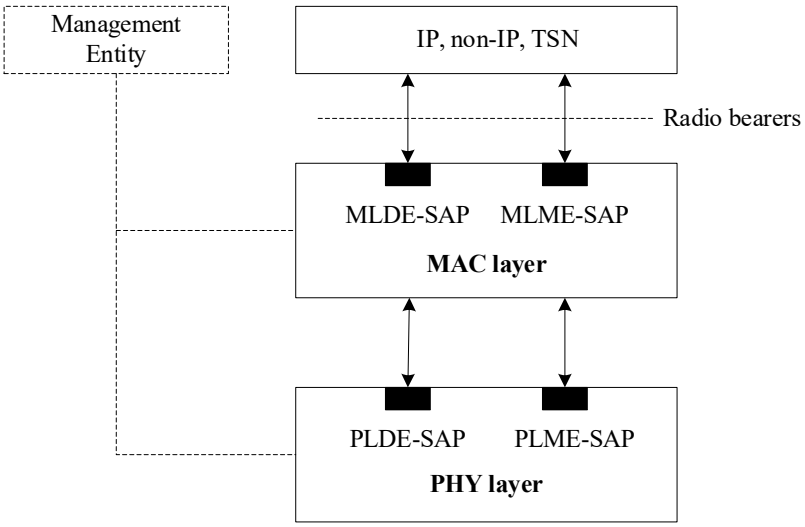

Figure 2—P802.15.6a protocol stack.

5.1.1 PHY layer

The PHY layer includes, but not be limited to, mechanisms for synchronization, channel estimation, modulation, FEC, ranging, Clear Channel Assessment (CCA), interference mitigation.

5.1.2 MAC layer

The MAC layer includes, but not be limited to, mechanisms for QoS flow handling, security services included key management, privacy protection, segmentation, Automatic Repeat Request (ARQ), scheduling & priority handling, interference mitigation, Hybrid ARQ (HARQ).

The MAC frame shall include an Ethertype field that indicates the network protocol encapsulated in the payload of the MAC frame.

6. Topology

6.1 Single BAN

Individually, HBAN and VBAN shall support the star topology with one coordinator suitable for 100 nodes. Nodes may support 1, 2, 3 relaying hops. Coordinator and nodes may be on the human body or vehicle's cabin. In the case of HBAN, nodes may include implant devices. In the case of HBAN, nodes may include implant devices.

6.2 Coordinator to coordinator topology

1. A VBAN coordinator shall support a star topology with 5 HBAN coordinators for a passenger vehicle, i.e., sedan, pickup, SUV, utility vehicle.

2. One or two VBAN coordinators shall support a star topology with 15 HBAN coordinators for a passenger bus.

3. Coordinators of HBANs operating within the transmission range of one another may support Peer-to-Peer (P2P) topology.

7. Multiple access

HBAN and VBAN shall support contention access, contention-free access or a hybrid form of contention access and contention-free access.

8. Handover

1. In the passenger bus use case with one or two VBAN coordinators, HBAN coordinators may support handover to alleviate congestion.

2. A given device associated with an HBAN approaching a VBAN may be disassociated from the HBAN and immediately associated with the VBAN via handover.

9. Priority traffic

Priority traffic shall be compatible with IEEE 802.15.6-2012 with eight possible levels of priority. Proposals may include their classification of priority traffic, indicating justification and traffic discriminator.

10. Mobility

HBAN walking speed 3 miles/h or 4.8 km/h.

11. Antenna configuration

A 15.6a device may be equipped with multiple antennas configuration to support a higher data rate.

12. Interference management

Interference is defined as unwanted emissions from coordinated or uncoordinated wireless systems operating in the UWB band.

1. 802.15.6a devices shall support the functionality to control the transmit power to minimize interference to other systems and power consumption.

2. 802.15.6a devices shall support the functionality to mitigate interference from other wireless systems operating in the UWB band.

3. VBAN operating in coordination with other HBANs shall support the functionality to control and mitigate interference.

12.1 EMC and EMI

Electromagnetic Interference (EMI) is defined as unwanted emissions from electromagnetic sources such as electric systems, alternators, fast digital switches unproperly shield.

13. Positioning and ranging

TBD

14. Infrastructure interaction

802.15.6a coordinator shall interact with suitable infrastructure, if it exists, to facilitate the setup, operation, and maintenance with such infrastructure. For example, a TSN domain.

15. Security and privacy

Enhancements for security and privacy protection at the MAC layer.

Identification of 15.6a nodes based on location.

16. Performance metrics

16.1 Packet delivery ratio

Packet Delivery Ratio (PDR) is computed as the ratio of packets successfully received at the MAC-SAP of the receiver (*receivedPackets*) to the total number of packets sent to the PHY-SAP of the transmitter. It indicates the efficiency and reliability of the proposal to successfully deliver packets to its destination under given conditions.

$$PDR = \frac{receivedPackets}{receivedPackets + lostPackets} \quad (1)$$

The variable *lostPackets* indicates the number of lost packets due to collisions or insufficient SINR at the receiver's input connector during a communication flow.

There may be packets dropped from the transmit queue when the CCA procedure could not detect that the medium was clear for transmitting the next packet in the queue.

16.1.1 Packet error rate

The Packet Error Rate (PER) is the complement:

$$PER = 1 - PRD \tag{2}$$

— For PHY-only proposals, the PER may be obtained by assuming an ideal MAC layer.

— For MAC-only proposals, the PER may be obtained from a look-up table.

16.1.2 Requirement

Proposals shall provide 99% of PRD under congested communication environment.

16.2 Throughput

Throughput denotes the effective transfer of information data rate (without overhead) in b/s measured at the MAC-SAP during a communication flow. It involves losses in the radio link due to congestion, transmission range, interference, and protocol communication exchanges.

16.2.1 Data rate

Data rate denotes the number of bits per second (b/s) transmitted at the PHY output connector.

16.2.2 Requirement

Proposals shall provide at least one mode of operation capable of achieving a throughput of at least 40 Mb/s, operating at a maximum mandatory data rate of 50 Mb/s in the high band of UWB (500 MHz channel) in a low mobility channel environment (3 miles/h or 4.8 Km/h) under congested communication environment and under a PDR of 99%.

Other data rates are proposal-specific.

16.3 End-to-end latency

End-to-end latency represents the time interval between the time instant the transmitter's MAC delivers the first bit of a MAC packet to the PHY-SAP for transmission to the time instant of the last bit of such MAC packet received by the MAC-SAP at the receiver.

End-to-end latency involves processing delay at the transmitter, propagation delay, and processing delay at the receiver. It includes all mechanisms at the PHY and MAC levels, like scheduling to access the medium, retransmissions, signal processing, etc.

16.3.1 Association latency

Association latency represents the time interval from the time instant a 15.6a device transmits the 15.6a signal requesting association to time instant such 15.6a device establishes a communication link. It involves all processing and messages exchanges.

16.3.2 Requirement

Proposals should include end-to-end latency in the interval [250 msec, 1 sec]. Association latency bounded to 1 sec.

Proposals for critical use cases should include end-to-end latency bounded to 100 msec.

16.4 Inter-Packet Reception Gap

Inter-Packet Reception Gap (IPRG) is the time in msec between successive and successful packet receptions from a particular transmitter calculated at the receiver.

The IPRG indicates the effect of increasing BANs and other wireless systems density on timely information exchanges.

The IPRG evaluates the reliability of the proposals in delivering packets to the destination relative to consecutive beacon transmissions when subjected to higher wireless devices densities.

16.4.1 Requirement

Proposals may include IPRG graphs as a function of the density of BANs.

17. Evaluation methodology for proposals

To compare proposals, we provide a set of parameters and scenarios for link-level simulations and system-level simulations. Proposers may choose the appropriate parameters or may provide parameters instead.

Table 1—Configuration parameters

Parameter	Value
Power spectral density	Generic UWB usage without mitigation
Tx/Rx antenna gain	3 dB
Rx noise figure	5 dB
Implementation losses	5 dB
Fading losses	6 dB
Data rate	Proposal specific
Transmission distance	Proposal specific
Packet size for comparison of simulations	127, 300, 2047 bytes
Channel models	Latest version of 15-21-0XXX-0x-006a
BER (for receiver reference sensitivity level)	10^{-6}
BAN density	5, 10, 20
Other systems operating in the UWB band at the maximum transmit power according to regulations	5, 10, 20
Congestion control	On

Interference control	On
Deployment	Two step uniform random drop model in 20x20 m^2 area
Traffic	* Full buffer. * Poisson (mean inter-arrival time of 10 msec).
Simulation time	at least 100 sec
Iteration	until getting smooth curve

17.1 Simulation scenarios

1. HBAN only, VBAN only, see Table 1.
2. One VBAN and 1, 5, 15 coordinated HBANs, see 6.2.
3. Random drop of coordinator and nodes over a human body and vehicle's cabin.
4. Classification of vehicle: passenger vehicle (car, SUV, pickup, bus), utility vehicle.
5. Random drop of uncoordinated BANs for interference scenarios.
6. Random drop of collocated UWB-based or other wireless systems operating in the UWB band for interference scenarios.

17.1.1 Intra-BAN operation

A VBAN operating in coordination with other HBANs via their coordinators shall support the functionality to control interference and maximize the area spectral efficiency.

17.1.2 Inter-PAN interference

Either VBAN or HBAN devices operate in the surroundings of other wireless systems in the UWB band without coordination. See Annex B for interference modeling.

17.1.3 Intra-BAN interference

Either VBAN or HBAN devices operate in the surroundings of other HBANs, VBANs without coordination. See Annex B for interference modeling.

Annex A

Link level simulations

A.1 Link budget

Parameter:

Average transmitter power $Pt =$ x [dBm]

Distance $d =$ [m]

Transmitter antenna gain $G_t =$ x [dBi]

Receiver antenna gain $G_r =$ x [dBi]

Central frequency $f_c =$ x [Hz]

The central frequency between the 10 dB upper and lower cut-off frequencies of a band-pass filter. Such filter is not necessarily symmetric but treated on a linear frequency scale.

Average received power at the input connector:

$$P_r = P_t + G_t + G_r - 20\log_{10}\left(\frac{4\pi f_c d}{3\text{x}10^8}\right) \text{ [dBm]}$$

Parameter:

Data rate $R =$ x [b/s]

Receiver's noise figure $NF =$ x [dB]

Receiver's implementation losses $I_L =$ x [dB]

SNR required for a PER = 10% over a random packet of 300 bytes $\frac{E_b}{N_0} =$ x [dB]

Thermal noise at room temperature $kT_0 = -$ 174 dBm/Hz

Receiver sensitivity:

$$S_r = -174 + NF + \frac{E_b}{N_0} + 10\log_{10}(R) + I_L \text{ [dBm]}$$

Parameter:

Fading losses $F_M =$ x [dB]

Link margin:

$$M = P_r - (S_r - 30) - F_M \quad \text{[dB]}$$

The link margin is the amount by which the received signal level may decrease while maintaining a target PER ≤ 10%.

A.2 Receiver reference sensitivity level

The reference sensitivity level is the minimum mean power received at the 802.15.6a receiver input connector, at which the PER shall not exceed a specific target value.

For the AWGN channel, the target PER obtained from the packet length in bits (*N*) and the requirement of BER=10^{-6} under the assumption of independent errors event after decoding given by

$$\mathrm{PER} = 1 - \left(1 - \mathrm{BER}\right)^N \tag{3}$$

For fading channels, the target PER is 10% without retransmission.

The packet length is 127, 300, 2047 bytes.

A.3 PER vs Eb/N0 measured at the receiver input connector

For PHY proposals, the PER without retransmission shall be less than or equal to 10% for a 300-octet packet at the PHY level with a link success probability of 95% overall channel conditions as specified in the channel model document.

A link success probability of 95% is defined as the PER averaged over the channels that result in the 95% best performance at a given Eb/N0 for a channel model. The average PER calculation does not include the PER performance due to the worst 5% channels at a given Eb/N0.

Annex B

Interference modeling

15.6a devices operate in the surroundings of other wireless systems in the UWB band. The produced interference models as aggregated noise.

Annex C

Bibliography

[B1] Project Authorization Request P802.15.6a. Online: 15-21-0259-04-006a

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[B3] Draft Technical Requirement of P802.15.6a. Online: 15-21-0493-01-006a