**IEEE P802.15**

**Wireless Personal Area Networks**

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| Re: | Technical Guidance for 802.15.8 Proposals | |
| Abstract | This is the clean version of 802.15.8 Technical Guidance Document. | |
| Purpose | To provide the technical guidance including functional and technical requirements to the P802.15 Working Group. | |
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# Overview

The 802.15.8 specification shall be developed according to the P802.15.8 Peer Aware Communications (PAC) project authorization request (PAR), document number 15-12-0063r2 and Five Criteria (5c), document number 15-12-0064r1, which were approved by the IEEE-SA in March of 2012.

# Definitions

Device ID:

. This is a unique identifier for a compliant PD.

. e.g., MAC address

Device group ID:

. This is a unique identifier for a group of compliant PDs.

Application type ID:

. This identifies a class of specific applications enabled in a PD.

. e.g., SNS, gaming, etc.

Application-specific ID:

. This identifies a specific application enabled in a PD.

. e.g., PACsocialnetwork, PACinvaders, etc.

Application-specific user ID:

. This is the user account ID linked to a specific application.

. e.g., account@PACsocialnetwork

Application-specific group ID:

. This identifies a group of selected Application-specific users.

Peer: this may be device or application specific user.

# Abbreviations and acronyms

PD: PAC Device

# General descriptions

This clause provides the basic framework of PDs. The framework serves as a guideline in developing the functionalities of PDs and their interactions specified in detail in the subsequent clauses.

## Concepts and architecture

IEEE 802.15.8 shall support a fully distributed, decentralized, and self-organized system composed of PDs.

Some of these devices may be able to connect on an opportunistic basis to infrastructure, which is out of scope for IEEE 802.15.8.

IEEE 802.15.8 shall support one-to-one and one-to-many communications.

IEEE 802.15.8 shall support scalable data rate to accommodate many applications such as listed in the Application Matrix (document number 15-12-0684-00-0008).

Possibly aided by higher layers, a PD shall support data transfers between itself and identified PDs or groups.

IEEE 802.15.8 shall support both one-way and two-way communications.

## Topology

Several topologies are considered to support various service interactions within PDs.

One-to-one and one-to-many topologies shall be supported.

IEEE 802.15.8 shall support a PD participation in at least two independent one-to-many communications with different peers at the same time.

IEEE 802.15.8 shall support a PD having simultaneous communication sessions for same or different applications.

Mesh topology may be supported.



## Reference model

All PDs are internally partitioned into a physical (PHY) layer and a medium access control (MAC) sublayer of the data link layer, in accordance with the ISO/OSI-IEEE Std 802-2001 reference model. Direct communications between PDs are to transpire at the PHY layer and MAC sublayer as specified in this standard. Message security services are to occur at the MAC sublayer, and security operations are to take place inside and/or outside the MAC sublayer.

Within a PD, the MAC provides its service to the higher layer through the MAC service access point (SAP) located immediately above the MAC sublayer, while the PHY provides its service to the MAC through the PHY SAP located between them. On transmission, the higher layer passes MAC service data units (MSDUs) to the MAC sublayer via the MAC SAP, and the MAC sublayer passes MAC frames (also known as MAC protocol data units or MPDUs) to the PHY layer via the PHY SAP. On reception, the PHY layer passes MAC frames to the MAC sublayer via the PHY SAP, and the MAC sublayer passes MSDUs to the higher layer via the MAC SAP.

MAC and PHY SAPs also pass control information between the layers.



There may be a logical PD management entity (PDME) that exchanges network management information with the PHY and MAC as well as with other layers.

# General requirements

## Operating frequencies

All PDs shall operate in selected globally available unlicensed/licensed bands, below 11 GHz.

There are 4 candidate bands;

* Unlicensed Sub 1 GHz band
* Unlicensed 2.4 GHz, 5 GHz ISM band
* Unlicensed 6 ~ 10 GHz UWB band
* Licensed bands

## Common communication mode

Common mode (e.g., for discovery and communication) shall be supported for interoperability. Common mode used in different frequency bands needs not necessarily be the same.

# Functional requirements

The functional requirements described in this document shall be met by IEEE 802.15.8 compliant PDs.

## Multiple access

Multiple access schemes shall be supported.

## Synchronization

IEEE802.15.8 may operate in synchronous or asynchronous mode.

When IEEE802.15.8 is operating in synchronous mode, a PD shall maintain synchronization among synchronized PDs.

## Discovery

Possibly with higher layer support, an IEEE 802.15.8 device shall support peer discovery and group discovery.

Discovery is defined as uni-directional. Mutual discovery is therefore two uni-directional discoveries.

The following properties are desirable for discovery process.

* Expedited discovery
* Energy-efficient discovery(e.g. low duty cycle)
* Support high PD density and high discovery traffic
* Efficient spectrum utilization
* Prioritized access to discovery

For the purpose of discovery of PAC peers, the discovery signal conveys information that may reflect one or more of the following IDs such as Device ID, Device Group ID, Application type ID, Application-specific ID, Application-specific user ID, Application-specific group ID.

Note that it is up to the proposers how to use these IDs or to use part of them.

IEEE 802.15.8 may support that a peer discovers only other peers who are in the same application-specific ID/application-specific user ID/group ID or the designated application-specific ID/application-specific user ID/group ID.

IEEE 802.15.8 shall support mechanisms to ensure privacy that a PD is not tracked.

IEEE 802.15.8shall support protection of identity from impersonation.

IEEE 802.15.8 may provide support proximity-based presence functionality that a PD shall recognizes another peer entering in the proximity as well as the peer going out of the proximity.

## Peering

IEEE 802.15.8 shall support peering. Peering is equivalent to link establishment; link establishment is the process at the end of which two or multiple PDs are ready to exchange data.

IEEE 802.15.8shall support re-peering. In the re-peering procedure, discovery may be simplified or omitted.

## Scheduling

IEEE 802.15.8 shall provide a fully distributed scheduling mechanism.

## QoS

IEEE 802.15.8 shall support prioritized services including emergency services with highest priority, various QoS classes, enabling an optimal matching of service, application and protocol requirements to resources and radio characteristics.

## Interference management

IEEE 802.15.8 shall provide the functionality to mitigate interference from other PDs.

## Transmit power control

IEEE 802.15.8 shall support the functionality for PDs to control the transmit power to minimize interference and power consumption.

## Multicast

IEEE 802.15.8 may support a reliable multicast transmission including both one-hop and multi-hop cases.

## Broadcast

IEEE 802.15.8 shall support a broadcast transmission including both one-hop and multi-hop cases.

## Multi-hop support

IEEE 802.15.8 shall provide at least 2-hop relaying function.

Only relay-enabled PD shall relay discovery messages and/or traffic data from PDs in the proximity.

## Relative positioning

IEEE 802.15.8 shall support relative positioning. Relative positioning parameters shall include presence or distance, and may include orientation as well.

## Power management

IEEE 802.15.8 shall support a power management functionality to reduce power consumption in PDs for all services as listed in the Application Matrix (document number 15-12-0684-00-0008).

## Security

The impact of security procedures on the performance of other system procedures, such as discovery and peering procedures should be minimized.

IEEE 802.15.8 shall make no assumption regarding security protection offered by applications.

The IEEE 802.15.8 may include the following security features:

* Security functions that provide necessary means to achieve authentication, authorization, and encryption against passive and active attacks.
* A key management protocol that provides efficient means to derive secret keys by a user, or establish private keys or group keys among the devices.
* Multiple levels of security modes depending on security requirements of services.
* Support of various security algorithms on the basis of the security and efficiency requirements of the services.

## Scalability

IEEE 802.15.8 shall support scalability according to the number of PDs and data rates.

### Network scalability

* IEEE 802.15.8 shall support discovery and communications for at least a hundred of PDs.

### Data rate scalability

* IEEE802.15.8 PAC shall support scalable data rate to accommodate many applications such as listed in the Application Matrix (document number 15-12-0684-00-0008).

## Coexistence

IEEE 802.15.8 shall coexist with other specifications or systems (radio interface technology) at the same frequency band.

IEEE 802.15.8 shall support the coexistence of PDs used for different applications.

## Requirements for high layer and infrastructure interaction

IEEE 802.15.8 may be able to interact with higher layers to access suitable infrastructure, if it exists, e.g. to facilitate the set up and maintenance of communication.

IEEE 802.15.8 shall support the report to higher layers with updated discovery and association information.

IEEE 802.15.8 shall perform measurements at the request of and report the results to higher layers. These measurements may include received signal strength and interference levels.

How to handle discovery and peering in the absence of higher layers, infrastructure access or sufficient pre-configuration information is out of scope for 802.15.8.

# Performance requirements

The performance requirements described in this document shall be met by IEEE 802.15.8 compliant PDs.

## Areal spectral efficiency

The areal spectral efficiency means that the summation of link spectral efficiency (e.g. point-to-point link) in the certain dimension. IEEE 802.15.8 shall maximize the areal spectral efficiency (*[bps/Hz/km2])* without sacrificing other requirements.

## Data rate

IEEE 802.15.8 shall support data rate up to typically 10 Mbps.

## Error rate

### Packet error rate (PHY)

The packet error rate (PER)without retransmission shall be less than or equal to 10% for a 256 octet packet size with a link success probability of 95% over all channel conditions as specified in the channel model document per frequency band.

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, i.e., the PER performance due to the worst 5% channels at a given Eb/N0 should not be included in the average PER calculation.

## Latency

### Discovery latency

Discovery latency is the time from moment when PD first transmits or receives the discovery signal to moment before the PD establishes a communication link.

IEEE802.15.8 shall support the minimum latency but there is a trade-off between the latency and power consumption.

### Data latency

IEEE 802.15.8 shall support differentiated data latency requirements of the supported QoS classes.

## Fairness

IEEE 802.15.8 may meet fairness constraints.

## Mobility

IEEE 802.15.8 shall support PDs with various mobility scenarios.

|  |  |
| --- | --- |
| Walking speed (up to 3km/h) | Best performance |
| Running speed (up to 10 km/h) | Graceful degradation |
| Vehicular (up to 60 km/h) | Best effort |

## System overhead

Overhead, including overhead for control signalling as well as overhead related to data communications shall be reduced as far as feasible without compromising overall performance and ensuring proper support of systems features.

## Complexity

Complexity should be minimal to enable mass commercial adoption for a variety of cost sensitive products.

# Regulations

The contents related to regulations are referred to the latest version of DCN15-12-0477-0x-0008.

# Evaluation methodology

## Antenna Configuration

PDs shall be equipped with antenna array configurations from one to four antennas.

## Channel models

The contents related to channel models are referred to the latest version of DCN15-12-0459-0x-0008.

## Simulation scenarios and parameters

### Link budget analysis (PHY)

Parameter:

* Average transmitter power  x [dBm]
* Distance  [m]
* Transmitter antenna gain x [dBi]
* Receiver antenna gain x [dBi]
* Central frequency x [Hz]
* Average received power  [dBm]

Parameter:

* Data rate  x [bps]
* Receiver’s noise figure x [dB]
* Receiver’s implementation losses  x [dB]
* x [dB] required for a PER10% over a random packet of 256 bytes.
* Thermal noise 174 dBm/Hz for room temperature 293 °K.
* Receiver sensitivity  [dBm]

Parameter:

* Fade margin[dB]
* Link margin  [dB]
* The amount by which the received signal level can be reduced without causing the PER is larger than 10%.

\*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 liner frequency scale.

### Link-level simulation (PHY)

The channel model document specifies the following channel model conditions (path-loss, small scale fading and scenarios):

- Indoor office, outdoor to indoor and pedestrian, vehicular for the 900 MHz band

- Outdoor to indoor and pedestrian, vehicular, typical urban for 2.4 GHz band

- Model A, B, C, D, E for 5 GHz band.

802.15.4a UWB channel models for UWB band.

## System-level simulation (MAC)

### General simulation parameters

|  |  |
| --- | --- |
| **Large-scale fading** | \* Path-loss value depends on frequency band, refer to TG8 Channel Model Document  \* 2.4 GHz band: 2.2.6. “Path loss between terminals located below roof-top for 900 MHz and 2.4 GHz bands” scenario with percentage location p as 50% and Lurban as 6.8 dB is mandatory for comparison. |
| **Small-scale fading** | \* Not considered for common scenario.  \* It may be modelled up to proposers for additional scenario. (e.g. MIMO) |
| **Maximum TX. power** | 20 dBm |
| **Tx/Rx antenna gain** | 2.5 dB |
| **Rx noise figure** | 7 dB |
| **Receiver sensitivity** | -82 dBm (for channel sensing) |
| **Reference time duration for data transmission** | \* [x] μsec to transmit [y] bytes (up to proposers).  \* 256 μsec to transmit 16bytes at BPSK 1/2 (for common scenario). |

#### Es/N0 calculation

The *Es/N0* is obtained as follows:

From the simulation scenario layout, the received *Es/N0* between a receiver and a transmitter with distance *ds* [m] is computed as:

,

where and the cardinality of constellation of modulation. For instance *M=2* (BPSK), *M=4* (QPSK), *M=16* (16QAM), etc.

,

where ****

* *NT* is the thermal noise density which is -204 [dBW/Hz] (-174 [dBm/Hz]).
* is the number of interferers collided in the same resource such as frequency or time. *R* is the bit rate, which is the same as the inverse of symbol period multiplied by , and *R* is determined as Mbps when 1 sec symbol period is assumed.
* dB (fade margin plus implementation losses)
* dB (receiver’s noise figure)
* Ps and Pi are the transmission power of desired signal and the transmission power of interferers, respectively.
* dBW (20 dBm, transmission power)
* dB (transmitter’s antenna gain)
* dB (receiver’s antenna gain)
*  [dB] is the path loss at distance *d* m taken from clause 2.2.6 “Path loss between terminals located below roof-top for 900 MHz and 2.4 GHz bands” of channel model document with parameters *f*=2.4 GHz, *p*=50% (see Table 2) and =6.8 dB. The value d is regarded as the distance dS between the desired transmitter and the receiver, and is the distance di between the ith interfering transmitter and the receiver.
* An apostrophe at the specific parameter denotes in linear scale to avoid confusion, if the parameter is generally denoted as dB-scale.

You can refer the following procedure to lead the Es/N0 equation which is copied from DCN15-13-0407-00-0008:

1. The SNR measured after the receiving filter in linear scale is given by

 1

where ‘ denotes value in linear scale, for instance power in W.

1. Add interference as aggregate noise

 2

where  is the total interference power after the receiving filter assuming the interference bandwidth .  is the channel’s gain, but assume 1 as the channel’s gain effect is counted in the fade margin *M*.

The key point to observe is the addition/subtraction of powers needs to be done in the linear domain as log(a+b)≠log(a)+log(b) .

1. Noise power plus interference power is model as *PN’* (interference as aggregate noise) such that

 3

1. Noise density is and energy per bit is , where *R* is bit rate such that

 4

 5

At room temperature, .

1. Multiplying and diving by 1/B and substituting in the right hand term:

 6

If (no interference), the equation is the usual link budget formula, only given in the linear domain.

Finally: , where and  the cardinality of constellation of modulation. For instance *M=2* (BPSK), *M=4* (QPSK), *M=16* (16QAM), etc.

### Scenarios & parameters for just PDs

This sub-clause is described for discovery phase.

#### Simulation parameters for discovery

|  |  |
| --- | --- |
| **PD deployment** | \* Uniform random drop or clustered random drop in 500×500 m2 area. The number of PDs: 100, 500, 1000, 5000, 10000. |
| **Simulation time** | At least10 sec |
| **Iteration** | Until smooth curve is obtained |
| **PHY interface abstraction** | \* Common PHY mode:  The received *Es/N0* can be used in the PER (Packet Error Rate) curves provided in DCN13-0058 to know the value of PER of discovery signal sent by BPSK and 1/2 coding rate. Such PER curves were obtained assuming using convolution code and a packet length of 150 bytes at AWGN channel. Assuming bit errors in a packet are independent and uniformly distributed, the PER curves for a packet length of 16 bytes are obtained as    . Optionally and in addition, proposers may provide results with their own PHY interface abstraction |
| **Discovery ID length** | 16 bytes and any other sizes are up to proposers |
| **Discovery transmission interval** | It depends on proposers. |

#### Performance metric for discovery

* Average number of discovered PDs over the simulation time.  
  (Note that PDs already discovered are not counted when those are re-discovered again.)
* CDF of the discovery latency according to the number of PDs
* Average power consumption [mW]  
  \* Power consumption : for Tx 11.3mA, for Rx 13.5mA, for standby 26 A with 3.6 V power supply

### Scenarios & parameters for PD links

This sub-clause is described for communication phase (including unicast, multicast, groupcast).

Unicast with 1 hop is mandatory with optional multicast, group-cast, multi-hop scenarios.

#### Simulation parameters for communication

|  |  |
| --- | --- |
| **PD deployment** | Two step uniform random drop model |
| **Traffic** | \* Full buffer (for high data rate)  . Latency is not measured at this parameter.  \* Poisson(for low and mid date rate)  . Inter arrival time : mean 10msec |
| **Simulation time** | at least 100 sec |
| **Iteration** | until getting smooth curve |
| **PHY interface abstraction** | Perfect rate adaptation with target PER 0.1  \* Common PHY mode:  The received *Es/N0* can be used in the PER(Packet Error Rate) curves provided in DCN13-0058 to know the value of PER of different coding and modulation schemes. Such PER curves were obtained assuming using convolution code and a packet length of 150 bytes at AWGN channel. Assuming bit errors in a packet are independent and uniformly distributed, the PER curves for a packet length of M bytes are obtained as    \* Optionally and in addition, proposers may provide results with their own PHY interface abstraction |
| **Packet (MPDU) length**  **for Poisson** | \* 64bytes (for low data rate)  \* 512bytes (for mid data rate) |

#### Simulation scenario for communication

Two step uniform random drop model is assumed as follows:

* a) A PD transmitter is dropped in the area of 500×500 m2 with uniform distribution. The action of dropping PDs is to create different deployments or topologies, upon which different simulations can be performed.
* b) A certain number of PD receivers, one in the case of a unicast scenario, are dropped with uniform random distribution within a distance d<50 m from the PD transmitter. A unicast scenario is mandatory, and additional scenarios such as multicast, group-cast or multi-hop are up to proposers. For a multicast case, proposers need to show the number of receivers in one-hop area.
* c) The process described in a) and b) is repeated until a total number of PD transmitters reaches to Nt.

Test scenarios are defined as follows:

* Density test (for common scenario)
* The number of transmitter PDs Nt is increasing as1, 2, 4, …, up to 512.
* MPDU length test (for additional scenario)
* The MPDU length is increasing as 64, 128, …, up to 4096 bytes.
* MPDU arrival test (for additional scenario)
* Mean of inter arrival time is decreasing as 100, 10, 1 msec.

These testing values are recommended to be presented as x-axis.

#### Performance metric for communication.

* Areal sum goodput\* [bps/km2]
* In packets, the average amount of received packets in the area
* Data packet reception efficiency [ratio]
* The total number of successfully received packet to the total number of transmitted packet including retransmission procedure
* Jain’s fairness index



* Latency [sec]
* Time until success per message, is the average time a node needs to transmit successfully a complete message.

These performance metrics are recommended to be presented as y-axis.

\* Goodput is the number of bits in the payload delivered by the network to a certain destination per unit of time.

#### Reference system model

This model is optional, for calibration and comparison.

The reference system model is simplified based on IEEE802.11g-2003. (Refer to the [link](http://standards.ieee.org/getieee802/download/802.11g-2003.pdf).)

The following conditions and parameters are recommended.

|  |  |  |
| --- | --- | --- |
|  | **Discovery, Multicast, Groupcast** | **Unicast** |
| **RTS/CTS** | Disable | Enable |
| **NAV** | Disable | Disable |
| **ACK/NACK** | Disable | Enable |
| **CSMA/CA** | No increase of CW\* | Exponential increase of CW\* |
| **Carrier Sensing** | Enable | Enable |
| **CWmin** | 24 | 24 |
| **CWmax** | - | 210 |
| **Retry Count** | Disable | Disable |

\* CW: Contention Window

**Annex A. Clustered Random Drop**

(Informative)

In a realistic network scenario, the PDs are distributed clustered around the area of attractions, and thus uniform distribution of PDs may lead to inaccurate performance evaluation in system simulations. In this annex, realistic distribution model of PDs for performance evaluation is provided.

***A.1 Clustered Random Drop Procedure***

1. Choose an area, where device will be randomly dropped.
2. The first PD is dropped according to uniform distribution.
3. Update the probability distribution of PDs.
4. Drop a PD according to the current probability distribution of PDs.
5. Repeat Step 3 – 4 until the target number of PDs are dropped.

***A.2 Probability Distribution of PDs***

Let be the probability distribution of the devices after dropping n devices, then

where

|  |  |
| --- | --- |
|  | a uniform distribution function |
|  | a scalar, |
|  | a scalar, |
|  | drop location of i-th device |
|  | pdf representing gravity or pull by *i*-th device |
| , where *A* is the area of the network | |

Note that

* can be a fixed number, which means the attraction by all PDs are identical. Alternatively, can be a number drawn from a probability distribution function. For example, a number drawn from a uniform random distribution between 0 and 1.
* is a probability distribution function representing the attraction, that is, the probabilistic “pull” exerted by the already dropped *i*-th PD on the PD being dropped. For example, normal distribution can be used as follows:
* When , clustered random drop becomes identical to uniform random drop. Smaller represents stronger attraction by existing PDs. A typical for clustered random drop is 0.2.
* A typical value for is 50 m.

***A.3 Matlab code for Clustered Random Drop***

