**IEEE P802.15**

**Wireless Personal Area Networks**

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| Abstract | [TG4r - technical guidance for PHY proposals.] |
| Purpose | [Working document for the PAR to the P802.15 Working Group.] |
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**Abbreviations**

The following abbreviations are used in this document.

ATSC Advanced Television Systems Committee

CEPT European Conference of Postal and Telecommunications Administrations

CRTC Canadian Radio-Television and Telecommunications Commission

dB Decibels

DVB-T Digital Video Broadcasting — Terrestrial

ECC Electronic Communications Committee in Europe

EIRP Equivalent Isotropically Radiated Power

ERC European Radiocommunications Committee in Europe

ERP Effective Radiated Power

FCC Us Federal Communications Commission

FD Fixed Device

GDB Geo-Location Database

GSM Global System for Mobile Communications, originally Groupe Spécial Mobile

GHz Gigahertz (1 GHz = 109 Hertz or a frequency of one billion cycles per second)

IDA Info-Communications Development Authority in Singapore

ITU International Telecommunication Union

LOS Line-Of-Sight

M2M Machine To Machine

MAC Media Access Control Layer

MHz Megahertz (1 MHz = 106 Hertz or a frequency of one million cycles per second)

NLOS Non-Line-Of-Sight

NTSC National Television System Committee

PAR Project Authorization Request

PDP Power Delay Profile

PHY Physical Layer

PICS Protocol Implementation Conformance Statement

PPD Personal/Portable Device

TG4m Ieee802 Working Group 15 Task Group m

TGD Technical Guidance Document

TVBD TV Band Device

TVWS TV White Space

UHF Ultra High Frequency

VHF Very High Frequency

WPAN Wireless Personal Area Network

WPAN-WS Wireless Personal Area Network – White Space

WSD White Spaces Device

TG4r Technical Guidance Document (TGD)

# Introduction

## Purpose

This document provides technical guidance by summarizing parametrically the key PHY characteristics and any necessary MAC changes identified in consideration of WPAN application and regulatory requirements. The technical summary on PHY and MAC parameters are intended to provide guidelines to the proposals for Task Group 802.15.4r. It should be noted that the main objective of this document is to provide technical recommendations for designing and evaluating potential proposals, and should not be understood as mandatory requirements for the system design.

The intent of the task group is to use a flexible and efficient process that provides sufficient descriptions of the technical requirements to enable relevant responses, with efficiency of effort while meeting the critical need for a timely standard. The TG4r task group will use this document to help qualify MAC and PHY protocol related proposals.

The responsibility of the TG4r is to produce a quality and timely standard specification. To achieve this goal, TG4r will consider the technical recommendations in this document to assist the preparation and evaluation of technical proposals.

## Methodology

The methodology provides recommendations to defining a minimal set of features, characteristics, performance and constraints to be considered. This document provides:

* A functional view of the PHY characteristics, in the form of specific parameters which define externally verifiable performance and interoperability characteristics; and
* Application/performance description~~s~~ that characterizes the types of WPAN applications and the derived performance characteristics.

In preparing proposals, this can be used as a framework to produce a concise summary of the characteristics of each given proposal, and will allow the group to see the similarities and differences in submitted proposals.

# Requirements Discussion

## Summary of PAR

### Title:

IEEE Standard for Local and Metropolitan Area Networks Part 15.4: Low Rate Wireless Personal Area Networks (LR-WPANs) Amendment: Distance Measurement Techniques

### Scope:

This amendment integrates wireless ranging techniques and technologies, including those existing within IEEE 802.15.4 and new to IEEE 802.15.4, into a consistent, standardized method addressing the needs of a wide range of applications and PHYs and enabling the interoperability of devices by different vendors using this method. Additionally, the amendment defines necessary MAC and PHY extensions which enable common radio based distance measurements.

### Need for the Project:

The IEEE 802.15.4 standard addresses many markets where there is a substantial need for both communications and determination of distances between two devices, i.e. ranging. The following is a representative set of application examples: covering a variety of accuracies, from centimeters to many 10s of meters:

* a retailer needs to determine the proximity of a shopper to specific points/displays and then send the appropriate data
* a medical environment needs to determine the proximity of a staff person to a desired item and inform that staff as to specific data for that item
* lighting control networks need to determine the range between devices to facilitate binding for control, e.g. a specific switch to a specific light fixture
* TV whitespace networks require location awareness via accurate ranging from multiple devices to determine available frequency bands
* Railroad services desire the ability for a locomotive to determine the distance to various devices for identification, etc.

Given that various regions and applications are served by numerous frequency bands following different regulatory rules, modulations, and data rates; complexity and confusion can only be avoided if ranging data is made available to higher layers in a consistent manner for location

determination mechanisms. Hence there is a need for a Real Time Locating System (RTLS) which works with the diverse PHYs of IEEE 802.15.4.

The PAR can be found on the IEEE802 web site: (<https://development.standards.ieee.org/P866200033/par>).

## High Level Requirements Overview

The following table summarizes the key componets of the proposal:

|  |  |  |
| --- | --- | --- |
| **Propsal element** | **Must/Should Provide** | **Description of element (question to answer)** |
| Recurring Acquisition Speed  | Should | State supported update rate and/or time required for one measurement. |
| Initial Acquisition Time | Must | State the time required for initial operation. |
| Application  | Must | Identify which applications from the application matrix the proposal addresses. |
| Classes of devices | Must | Describe the types of devices that can be supported, such as fixed, mobile stationary and non-stationary. |
| Collateral support (applications) | Should | Describe support and/or requirement for external information. Examples would be support for synthesis with additional external measurement sources, such as accelerometer, barometric pressure, attitude sensors, angular rate sensors, magnetometers, other sensors. Another example would be dependence on a geolocation database. |
| Dimensions  | Must | Decribe the dimensions resovled by the proposal (x,y,z,t). |
| Environment  | Must | Describe the environment (indoor, outdoor), speed variances. |
| Flexibility and Tradeoff options | Should | Describe features with possible tradeoffs, such as different distributions of complexity to achieve low power, tradeoffs between complexity, energy and accuracy; tradeoffs between infrastructure devices and mobile objects; tradeoffs associated with operation modes such as unidirectional vs bi-directional vs blink; tradeoffs related to topology such as dependence on infrastructure, global synchronization (network time). |
| Measurement Specifics | Must | Depending on the type proposal: For proposals of ranging measurement techniques, describe the specific measurement(s) provided by the technique, e.g. one way or round trip time of flight, phase difference, arrival angle. For proposals including higher level processing, describe what is provided, e.g. derived parameters such as distance and/or position, and if it is dependent or independent of the low level measurement technique?  |
| Mobility Rate | Must | State support for mobility and maximum (and minimum?) supported velocity. |
| Position Accuracy | Must | Describe factors or characterstics of the proposal that affect the accuracy of range measurement and position derived from the range. |
| Positioning method supported  | Should | Describe the position derivation techniques supported, i.e. support for triangulation, trilateration or other position determination method.  |
| Resolution  | Should | State the achievable resolution for values involved in the measurement process, e.g. distance, RSSI, phase, angle, time. |
| Supported bands | Must | State the frequency bands intended/expected to be used. |
| Type of operation | Must | Describe the type(s) of operation(s) supported by the proposal. Examples would be:Does the technique require cooperation of multiple devices, can it operate in a “listen only” mode (i.e. not requiring cooperation/response of other devices); If depending on cooperation of multiple devices, how many cooperating devices are required to operate? Are infrastructure devices required? |
| Use of the band | Must | Describe how the band (spectrum) is used (i.e. narrow band, wide band approaches, multi-band approach) in compliance with local regulatory requirements. |

From the PAR and general procedural rules, key overall goals and requirements of this project can be summarized as follows:

* [Look at TG 4m]
* The amendment complies with the P802.15.4r PAR and 5 Criteria.
* The amendment will include a PICS proforma.
* The amendment should provide technical mechanisms to enable direct device-to-device communications in both star and peer-to-peer networks.

### Application Requirements Matrix

|  |  |  |
| --- | --- | --- |
| **Application** | **Key Parameters** | **Reference** |
|  | Resolution | Acq.Speed | Range | Dimensions | Mobility | TBC |
| Lighting | <1m | 1/s | <50m | 1-4 (x,y,z,t) | None |  |
| TWS(min. Req. by regulatory | +/-50m min.  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Applications using TVWS | DMT and TBC | TBC |
| Medical | TBC | TBC |
| Lighting |  |  |
| Smart Energy |  |  |
|  |  |  |

## Frequency Band Related Regulations

### Summary of Regulations

Incorporate TWS

Enable DMT as widely as possible

### Regulatory Requirements

State regulatory considerations, such as is the technique globally applicable or depending on specific regional regulations. For example:

* Does the proposal support world wide operation?
* If not which regions and or rule sets allow operation?
* If not what rules prevent operation?

Example, for a proposal targeting TVWS bands, might describe regulatory considerations:

There are several regulatory bodies including the Federal Communications Commission (FCC) in the U. S, Electronic Communications Committee (ECC) under the European Conference of Postal and Telecommunications Administrations (CEPT) in EU, Ofcom in the U. K., and Industry Canada in Canada. Based on the rules from the FCC (refer to FCC 12-36, Third Memorandum Opinion and Order, September 2012) and ECC (refer to ECC Report 159, January 2011), a set of regulatory requirements for white space communications is identified. Therefore whenever new rules are established or future changes of rules from any regulatory bodies are made, they should be considered for the proposals.

Requirements identified from FCC rules:

A set of common regulatory requirements for white space communications from the rules of FCC are listed as follows:

Frequency bands: Defined in above referenced regulations

Types of devices:

* Fixed devices
* Mode II personal/portable devices
* Mode I personal/portable devices

Transmit power: Radiated transmit power up to 4W in U.S, varies by TVWS channel and other conditions.

Transmit power related requirements:

* All devices may incorporate transmit power control to limit their operating power to the minimum necessary for successful communication.

Geolocation requirements:

* 2D geo-position with 50m accuracy
	+ Update rates measured in hours not seconds depending on application
	+ Some devices may have higher mobility rates
	+ Some devices may have very slow mobility rates (fixed)

Security: Proposal should state if the proposal cryptographically secure by design

***Requirements from ECC rules not identified in or different from the rules of FCC***

## Coexistence

Proposals should identify coexistence impacts of the proposed approach. Impact may be positive (makes for better coexistence), negative (either makes the 15.4 device more vulnerable, or increases the interference footprint of the device), or neutral.

Coexistence among systems within the same band should be addressed fulfilling the requirements of the coexistence assurance document.

Thoughts:

* The drafters should make a reasonable attempt to establish coexistence with the majority of currently deployed systems.
* The proposers shall provide information relative to coexistence with existing systems

## Interoperability

Proposals should discuss levels of interoperability. Support for previously deployed systems is encouraged but not required.

As guidance to the drafters of the standard, the standard should be written such that there may be behavior that will facilitate interoperability and coexistence with existing devices in the field.

Thoughts:

* Investigate need for clarification relative to interoperability for existing PHY’s assuring independent implementations to achieve results of a certain minimum quality.

## Complexity and Cost considerations

The PHY(s) supporting DMT following TG4r should be realizable by low complexity implementations to minimize cost and to enable mass adoption of the standard. The cost considerations are not only for low capital expenditure, but also low operational expenditure. One of this proposed amendment’s objectives includes low cost installation with minimal to no operator intervention.

Cost effective communication and simple modulation techniques are potential mechanisms that help meet the low complexity, low cost requirements.

Examples of cost/complexity considerations to discuss:

* Complexity of calculations required
* Accuracy of timebase required
* Tradeoffs possible with the approach

## Power and Energy consumption

Proposals should discuss power and energy consumption. With most ranging systems being battery powered, these considerations may play an important role.

Power consumption is mainly dependent on PHY related parameters such as desired range, type of modulation and on implementation approaches.

While implementation is not part of the standard, different approaches might enable different implementations.

Energy consumption also takes into account higher layer behavior. This may include the rate at which frames have to be sent to achieve the desired ranging results. Overhead in headers and synchronization, as well as network management contribute to energy consumption amongst others.

Proposals are encouraged to show which of their mechanisms consume more or less power and energy than comparable approaches. If power and energy consumption scales with different possible settings within a proposal, rough estimates should be given of the expected influence on power and energy consumption.

Examples of parameter that may be used to characterize energy consumption:

* Overhead added for ranging
	+ Number of packets needed for a range measurement (might be a trade-off)
	+ Ranging information exchange
* Size of packet (including SHR, PHR, etc.)
* Transmit power/SNR requirements
* Timing and duration considerations
	+ Channel time required (channel blocked time, TX, RX, dead time)
* Receiver on time required
* Calculation/processing complexity

## Channel Characteristics

To evaluate the proposed systems, channel models are needed which represent target environments given for applications considered for TG4r.

[Recommendation from discussion is to examine channels modes used in previous TGs and adopt on or more of the existing documents by reference]

### Path Los Channel Models (for link budget calculation)

1. *Line-of-Sight (LOS) Propagation Model*

***b.*** *Non-Line-of-Sight (NLOS) Propagation Model*

### Channel Impulse Response Model (for PHY simulations)

1. For indoor scenarios

1. For Outdoor scenarios

Note: Some good channel models developed for past 802.15.4 projects can be applied to the proposals likely in TG4r; could provide list of document references for proposers to use.

Review for existing (published) amendments the methods/models used for channel characterisation)

# Definitions

The following provides definition of specific terms in the context of discussion with respect to TG4m applications and PHY proposals**.**

Available Channel:

Fixed device:

Geo-location capability:

# References