**IEEE P802.15**

**Wireless Personal Area Networks**

|  |  |
| --- | --- |
| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title |  |
| Date Submitted | November 6, 2011 |
| Source | Soo-Young Chang [CSUS], Mi-Kyung Oh, Cheolho Shin, Sangsung Choi [ETRI], Alina Lu, SUM Chin Sean, Hiroshi Harada, F. Kojima [NICT], Kunal Shah, Jay Ramasastry, Cristina Seibert, George Flammer, Steve Shearer [Silver Spring Networks] | E-Mail: [sychang@ecs.csus.edu] |
| Re: | Task Group 15.4m Technical Guidance for Proposals |
| Abstract | [TG4m - technical guidance for PHY proposals.] |
| Purpose | [Working document for the PAR to the P802.15 Working Group.] |
| 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. |

Table of Contents

1.Introduction

Purpose

Methodology

# 2.Requirements Discussion

Summary of PAR

## High Level Requirements Overview

Application Requirements Matrix

## Performance characteristics Summary

Data models

Coexistence

Interoperability

PHY parameters

# Background and Supporting Discussion

Channel characteristics

## Complexity and Cost considerations

Definitions

References

TG4m Technical Guidance Document

1. **Introduction**

**Purpose**

This document provides technical guidance by summarizing parametrically the key PHY characteristics and MAC amendment requirements identified in consideration of WPAN-WS (WPAN white space) application and regulatory requirements. PHY parameters and criteria to guide the preparation and selection of ~~PHY~~ proposals for Task Group 802.15.4m are presented. This document defines the PHY characteristics and MAC amendment requirements with guidance on how proposals might address them, and provides a framework for evaluating proposals.

The intent of the task group is to use a flexible and efficient process ~~which~~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 TG4m task group will use this document to help qualify MAC and PHY protocol proposals.

## Methodology

The methodology provides a consensus approach 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~~ ~~which~~that characterizes the types of WPAN-WS applications and the derived performance characteristics.

The PHY parameters table provides guidance on developing complete technical proposals. This represents a subset of parameters, and the absence of a parameter should not be seen as a constraint. The PHY parameter column consists of two sub-columns. The first identifies the parameter, which should be addressed in some way in the proposal; the second provides some examples of how this might be addressed in a proposal; there will be alternatives appropriate to specifying the characteristic depending on the specifics of the proposal. The performance criteria column includes potential requirements, constraints, and/or explanations that may help in consideration during the proposal preparation. The “regulatory” column is intended to identify where regional differences in regulations (present and anticipated) may affect the PHY 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

**2.1 Title:**

IEEE Standard for Local and Metropolitan Area Networks Part 15.4: Low Rate Wireless Personal Area Networks (LR-WPANs) Amendment: TV White Space between 54 MHz and 862 MHz Physical Layer

**5.2 Scope:**

This amendment specifies a physical layer for 802.15.4 meeting TV white space regulatory requirements in as many regulatory domains as practical and also any necessary Media Access Control (MAC) changes needed to support this physical layer. The amendment enables operation in the VHF/UHF TV broadcast bands between 54 MHz and 862 MHz, supporting typical data rates in the 40 kbits per second to 2000 kbits per second range, to realize optimal and power efficientdevice command and control applications.

**5.5 Need for the Project:**

There are many instances in large area device command and control applications where infrastructure requirements need to be minimized for effective deployment. These needs are effectively served by the ability to operate 802.15.4 class networks in the TV white space spectrum.

## High Level Requirements Overview

The PAR states some overall goals and requirements:

* Operation in any of the regionally available TV white space frequency bands between 54 MHz and 862 MHz on a license-exempt basis;
* Fixed devices and personal/portable devices operated;
* Typical data rates in the 40 kbits per second to 2000 kbits per second range;
* Protection of all incumbent user services such as over-the-air TV broadcasting services and low power licensed devices operated in the above specified bands;
* Dynamic use of frequency bands applied, such as dynamic frequency assignment and dynamic spectrum access techniques for seamless frequency band and channel switching ~~for improved spectrum sharing~~;
* Simultaneous operation for at least 5 co-located piconet networks;
* At least one operation mode that supports up to at least 1000 direct neighboring devices;
* Operating range: ~~up to several~~ at least 1 km; and
* Coexistence with other 802 systems operating in the TV white space.

The PAR can be found on the IEEE802 web site: (https://mentor.ieee.org/802.15/dcn/11/15-11-0643-00-004m-tg4m-par.pdf).

**Application Requirements Matrix**

~~Weight 0 - don't care, 1 - desirable, 2 - very desirable, 3 - must have, x – unknown~~

|  |  |  |  |
| --- | --- | --- | --- |
| **Application** | **Description**  | **Key Parameters** | **Reference** |
| super Wi-Fi hot spots  | Access to this spectrum could enable more powerful public Internet connections with extended range, fewer dead spots, and improved individual speeds as a result of reduced congestion on existing networks  |  | 15-11-0039-00 |
| campus networks  | better able to keep pace with user’s increasing demands for bandwidth  |  | 15-11-0039-00 |
| home networks  | better able to support real time streaming video applications  |  | 15-11-0039-00 |
| remote sensing  | water supplies by municipalities and support for the smart grid  |  | 15-11-0039-00 |
| Smart utility networks (SUN) | TV White space application is a good candidate for SUN* + There is no special interference source except TV signal.
	+ Use the similar TV Channel frequencies all over the world
 | * Environment: Indoor/outdoor, Urban/suburban/rural
* Data rate: up to 1 Mbps
* PER<1%
* Operating range: up to several km
* User capacity: up to several thousands
* Mobility: fixed
* Security features: required
* Reliability: high
* Device category (WPAN): FFD (network controller, device), RFD (device)
* Device category (regulations): high power device, low power device and very low power device
 | 15-09-0275-0215-11-0171-00 |
| Intelligent Transportation System | TV bands make signal travel long distance and less vulnerable in rural areas, which can enable multiple applications between cars in the highways.* Inter-car video call
* Inter-car gaming
* Inter-car social networking
 | * two-way, 100 end devices (mobile) to 1 controller (fixed)
* PER: < 10%
* One controller covers up to 1 square km
 | 15-11-0194-0015-11-0279-01 |
| Surveillance, control and monitoring network |  |  | 15-11-0215-02 |
| Infrastructure moditoring network |  |  | 15-11-0215-02 |
| Local network in machine-to-machine (M2M) |  |  | 15-11-0215-02 |

## Summary of Regulations – An Overview

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Region****/Country** | **TVWS Channel Band** | **Device Type** | **Transmitted Power Requirements** | **GDB \* Requirements** | **Sensing Requirement** |
| **US (FCC)**Related document: FCC 10-174Final order: almost finalized | 6MHz channel allocationFD only: TV channel 2 (54-60MHz); TV channel 5 to 20 (76-512MHz)FD and PPD: TV channel 21 to 35 (512 to 602MHz) and TV channel 39 to 52(620-704MHz) | Fixed Device (FD): capable of geolocation and TV bands database accessPersonal Portable Device (PPD): Mode I:list of available channels through fixed or Mode II devices; Mode II: capable of geolocation and TV bands database access;Sensing-only PPD: with no geolocation and TV bands database access. | FD:30dBm (1W) delivered to antenna, 4W EIRP; Mode I and II PPD: 16dBm (40mW) EIRP if the adjacent channel separation requirement is not met; 20dBm (100mW) EIRP if the adjacent channel separation requirement is met; Sensing-only PPD:17dBm (50mW) EIRPTransmit power control required | Must be supported in both Fixed and Portable Mode II devices | Optional for Fixed and Mode I and II PPD devices,Mandatory for sensing-only PPDs |
| **UK (OFCOM)**Related document: 9 Nov 2010 ConsultationFinal rules pending | 8MHz channel allocationPossibly 470-550 and 614-790MHz and FM radio bands and other bands to be identified | Master device (direct connect to database)Slave device (no need to contacct database, managed by master device) | Determined by the database with information in-block power limit, out of block limit and bandwidth and incumbent signal level The database provides frequency bands and power levels to be used by the white space devices based on its location.Transmit power control required | Required to provide a WSD with information on the availablefrequencies and the associated maximum e.i.r.p. values | Not to be used in the UK but included to aidinternational harmonisation |
| **Europe (CEPT (ECC))**Related document: ECC Report 159Still in progress | 8MHz channel allocation470-790 MHz | Not defined as devices with specific roles/features. Personal/portable; Home/office devices; and Private and public Access points. | Determined by the database with information in-block power limit, out of block limit and bandwidth and incumbent signal level The database provides frequency bands and power levels to be used by the white space devices based on its location.Transmit power control required | Required to provide a WSD with information on the availablefrequencies and the associated maximum e.i.r.p. values Requied  | Optional  |
| **Canada (Industry Canada(CRTC))**Related document: SMSE-012-11Still in progress | 6MHz channel allocation54-72, 76-88, 174-216, 470-608, 614-698MHz, these bands are already shared with LTA and RRBS  | Fixed;Mobile:Mode I (slave device- no direct access to database); Mode II (master device- direct access to database) | Fixed: Max EIRP 6dBW;Mobile: Max EIRP 16dBm for Mode I and 20dBm for Mode II | Required one or more database support is compulsory | To be considered in the future when technology is matured |
| **Singapore (IDA)**Related document: IDA White Space Technology Information Package 7 April 2010Still in progress | VHF 7MHz and UHF 8MHz channel allocationVHF: between 174 to 230 MHz and UHF: between 494 to 790 MHz | Will be developed in future | For sensing only devices, 4dBm, adjacent channel 17dBm, N+2 channel, 100mW per channel ; With only geolocation, up to 100mw;Out-of-band-performance:<-48dBm  | Required | Mandatory to detect both analogue and digital broadcast services and optional to detect both analogue and digital wireless microphones services  |

 GDB - Geolocation Database

## Performance Requirements Summary

From the use cases we can identify a set of common requirements derived from the type of communications performed:

Frequency bands:

* Operation in any of the regionally available VHF-UHF ~~TV~~ white space frequency bands between 54 MHz and 862 MHz on a license-exempt basis:
	+ Personal/portable white space devices may be limited to operating (transmit or receive) only on available channels above 512 MHz (TV channels 21-36 and 38-51 in the U. S.) and operation of fixed white space devices may not be permitted on TV channels 3 and 4 (60-72 MHz).

Transmit power:

* Fixed devices and personal/portable devices operated in the frequency bands specified above on an unlicensed basis.
	+ Fixed devices with maximum 4W EIRP transmit power for assurance of incumbent uses while the maximum power delivered to transmit antenna is 1W regardless of the number of TV channels on which the device operates and the maximum height of their directional antennas is 30 m above ground.
		- with geolocation/database access features
	+ Personal/portable devices with maximum 100mW EIRP transmit power for assurance of incumbent uses with permanently attached transmit and receive antennas.
		- with geolocation/database access features (Mode II device) or
		- without geolocation/database access (Mode I device)
			* Under the control of fixed device or
			* Under the control of personal/portable device with geolocaion/database access
	+ Personal/portable devices with maximum 50mW EIRP transmit power for assurance of incumbent uses
		- with spectrum sensing only
	+ All devices shall incoporate transmit power control to limit their operating power to the minimum necessary for successful communication.
	+ In the television channels immediately adjacent to the channel in which a device is operating, emissions from the device shall be at least 72.8 dB below the highest average power in the TV channel in which the device is operating.
	+ At frequencies beyond the television channels immediately adjacent to the channel in which the device is operating, the radiated emissions from devices shall meet the following limit requirements:
		- 54-88MHz: 100 μV/m @ 3 m;
		- 88-174MHz: 150 μV/m @ 3 m;
		- 174-216MHz: 1500 μV/m @ 3 m;
		- 216-470MHz, 512-566 MHz, 608-614 MHz, 806-862 MHz : 200 μV/m @ 3 m;
		- 470-512MHz, 566-608 MHz, 614-806 MHz: 5000 μV/m @ 3 m.

Geolocation requirements:

* Fixed devices
	+ The geographic coordinates with an accuracy of +/- 50 meters by either an incorporated geo-location capability or a professional installer.
	+ If the fixed device is moved to another location or if its stored coordinates become altered, the operator shall re-establish the device’s by re-registering with the data base.
* Mode II personal/portable devices
	+ Accuracy of a geo-location capability to determine its geographic coordinates is +/- 50 meters.
	+ Re-establishment of its position by using its geo-location capability
		- each time it is activated from a power-off condition and
		- at least once every 60 seconds while in operation, except while in sleep mode, i.e., in a modein which the device is inactive but is not powered-down.

White space bands database access and frequency bands operated:

* Dynamic use of frequency bands applied, such as dynamic frequency assignment and dynamic spectrum access techniques for improved spectrum sharing:
	+ Fixed and Mode II devices must be able to access a TV bands database over the Internet to determine the TV channels that are available
		- at their geographic coordinates,
		- taking into consideration the fixed device’s antenna height for fixed devices,
		- at least once a day to verify that the operating channels continue to remain available.
	+ Mode II devices must access the database:
		- each time it is activated from a power-off condition and re-check its location, and
		- if it changes location during operation by more than 100 meters from the location at which it last accessed the database.
	+ A Mode II device that has been in a powered state shall re-check its location and access the database daily to verify that the operating channel(s) continue to be available.
* A fixed device needing initialization and registration without a direct connection to the internet may transmit to another fixed device on either a channel that that other device has transmitted on or on a channel which that other device indicates is available for use to access the database to register its location and receive a list of channels that are available for its own use.A Mode I personal/portable TVBD may only transmit upon receiving a list of available channels from a fixed or Mode II TVBD that has contacted a database and verified that the FCC identifier (FCC ID) of the Mode I device is valid.
* To initiate contact with a fixed or Mode II device, a Mode I device may transmit on an available channel used by the fixed or Mode II TVBD or on a channel the fixed or Mode II TVBD indicates is available for use by a Mode I device on a signal seeking such contacts.
* At least once every 60 seconds, except when in sleep mode, a Mode I device must either receive a **contact verification signal** from the Mode II or fixed device that provided its current list of available channels or contact a Mode II or fixed device to re-verify/re-establish channel availability.
	+ A Mode I device may respond only to a contact verification signal from the fixed or Mode II device that provided the list of available channels on which it operates.
	+ A fixed or Mode II device shall provide the information needed by a Mode I device to decode the contact verification signal. At the same time it provides the list of available channels.A Mode I device must cease operation immediately if it does not receive a contact verification signal or is not able to re-establish a list of available channels through contact with a fixed or Mode II device on this schedule.
* Periodic reconfirmation of spectrum availability with databases on an on-going basis as well as in the stage of establishment of infrastructure
* Operation on a channel must cease immediately if the database indicates that the channel is no longer available.

Sensing requirements for sensing only devices:

* Detection threshold: referenced to an omnidirectional receive antenna with a gain of 0 dBi
	+ ATSC digital TV signals: -114 dBm, averaged over a 6 MHz bandwidth;
	+ NTSC analog TV signals: -114 dBm, averaged over a 100 kHz bandwidth;
	+ Low power auxiliary, including wireless microphone, signals: -107 dBm, averaged over a 200 kHz bandwidth.
* Channel availability check time
	+ A TVBD may start operating on a TV channel if no TV, wireless microphone or other low power auxiliary device signals above the detection threshold are detected within a minimum time interval of 30 seconds.
* In-service monitoring
	+ In-service monitoring of an operating channel at least once every 60 seconds
* Channel move time
	+ After a TV, wireless microphone or other low power auxiliary device signal is detected on a TVBD operating channel, all transmissions by the TVBD must cease within 2 seconds.

Other requirements:

* Support different classes of fixed devices with different conditions of operation such as transmit power levels, etc. where permitted by regulatory domains.
* Simultaneous operation for at least 5 co-located piconet networks
* Application data rates of 40 kbits per second to at least 2000 kbits per second range supported
* Environment: Indoor/outdoor. Urban/suburban/rural.
* BER/PER requirement: PER <= 10%
* Operating range: Up to several km
* User capacity: Up to several thousands devices
* Security features: required
* Reliability: high
* Device category with respect to WPAN: FFD (network controller, device) and RFD (device)

**Data Model(s)**

**To be filled.**

|  |  |
| --- | --- |
| SUN applications | xxx bytes/day ULxx bytes/day DL (Intermittent Command)  |
|  |   |
|  |  |
|  |   |
|  |   |

**Coexistence**

WPAN-WS networks should coexist with other services in the same band. Effective mitigation of interference and an ability to adapt to actual conditions is essential. Although the coexistence scenarios will be discussed in-depth in Atlanta meeting in November 2011, here is a guideline for preliminary proposals should consider:

All proposals must refer to the intra-system coexistence and inter-system coexistence. The intra-system coexistence will ensure the proposed system can survive in the environments where similar systems are in operation in the same band. The inter-system coexistence will ensure the proposed system can survive in the environments where other systems including the ones defined by IEEE standardization or others not defined by IEEE standardization in operation in the same band.

**Interoperability**

Proposals should discuss levels of interoperability. Support for previously deployed systems is not a consideration.

# PHY Parameters:

# To be filled

|  |  |  |
| --- | --- | --- |
| PHY Parameter | Performance Criteria, Constraints, Comments | Regional Regulatory |
| Parameter: | Example: |
| Operating band (band/channel plan) | * Target band(s)
* Channel bandwidth used
* Channelization methods
 |  |  |
| Environmental Considerations | * Assumed channel conditions and dynamics of channel conditions
 |  |  |
| Modulation and Coding Scheme(s) | * Modulation method
* Methods for adaptability (knobs)
 |  |  |
| Data rate(s) | * Range of rates
* How achieved
* Dynamic vs. Static
 |  |  |
| Symbol / chip rate(s) | * As appropriate to the proposed technique
 |  |  |
| Synchronization and Timing  | * might come from specific sync mechanisms or may be dependent on other PHY features
* clock accuracy / stability required
 |  |  |
| PHY frame structure  | * Pre-amble
* Sync Header, SFD
* codes and/or patterns
* (as appropriate to proposal)
 |  |  |
| Transmit Power | * MAX
* MIN
* Peak to Average
* Management, control
 |  |  |
| PSD | * In band
* Out of band
 |  |  |
| Channel availability (interference detection) | * Spectrum scanning
* CCA
 |  |  |
| Link Quality Indication | * Technique used
* Frequency of assessment
* Accuracy and resolution
* Bi-directional (cooperative)?
 |  |  |
| Reliability enhancing features/methods | * Error Detection
* Error Correction and recovery
* Interference mitigation/avoidance
* Collision avoidance
 |  |  |
| Interoperability |  |  |  |
| Co-existence features |  |   |  |
| MAC dependencies / support required |  |  |  |
| Energy consumption |  |  |  |

# Background and Supporting Discussion

This section identifies performance considerations, constraints and requirements. This section provides background for the requirements captured in the prior section.

To be filled.

## Channel Characteristics

*Channel Model*

1). Path loss model (for link budget calculation)

**a. LOS (**The Friis free space equation)



Where , *c* is the speed of light. Additionally, *d*, *f*, *G*B and *G*T specify the transmitter-receiver-distance in meters, the frequency in Hertz and the base and terminal station antenna gain values in dBi, respectively. This model does not take the contributions from additional reflected and scattered signal paths into account.

**b. NLOS (**Hata model)

Indoor propagation model: 

Where *R*: transmitter-receiver separation (m)

*n*: number of floors in the path



Where f=carrier frequency (MHz)

d=separation between base station and mobile unit (km)

hb=height of the base station antenna (m)

hmu=height of the mobile unit antenna (m)

a(hmu)=correction factor for mobile unit antenna height

For Large cities,



For small and medium cities,



2). Channel Impulse Response model (for PHY simulations)

a). For indoor scenario (to be included)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Path 1  | Path 2  | Path 3  | Path 4  | Path 5  | Path 6  |
| Indoor-B as defined in ITU-R M.1225  |
| Path Delay (us)  | 0  | 0.1  | 0.2  | 0.3  | 0.5 | 0.7 |
| Avg PathGain  | 0  | -3.6 | -7.2 | -10.8 | -18.0 | -25.2 |

b). For Outdoor scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Path 1  | Path 2  | Path 3  | Path 4  | Path 5  | Path 6  |
| d=1.5 km Profile A  |
| Path Delay (us)  | 0  | 0.7  | 1.2  | 3.2  | 5.5  | 6.8  |
| Avg PathGain  | 0  | -34.9  | -25.9  | -22.7  | -24.8  | -34.6  |
| d=2.7 km Profile B  |
| Path Delay  | 0  | 0.9  | 1.7  | 3.1  | 3.8  | 7.5  |
| Avg PathGain  | 0  | -18.2  | -20.6  | -25  | -26.5  | -19.6  |
| d=6.1 km Profile C  |
| Path Delay  | 0  | 0.6  | 5.3  | 6.2  | 7.5  | 19.5  |
| Avg PathGain  | 0  | -12.1  | -25.2  | -22.2  | -18.5  | -21.8  |
| COST 207 Profile D  |
| Path Delay  | 0  | 0.2 | 0.5 | 1.6 | 2.3 | 5 |
| Avg PathGain  | -3 | 0 | -2 | -6 | -8 | -10 |

## Complexity and Cost considerations

**To be filled**

# Definitions

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

**To be filled**

|  |  |
| --- | --- |
| Term: | Definition |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# References

1. 15-11-0039-00-04tv-introduction-of-tv-white-space
2. 15-09-0275-02-004g-phy-proposal-for-802-15-4g-based-on-ofdm-technology-using-tv-white-space
3. 15-11-0000-00-04tv-possible-PHYs-for-upcoming-TG4m
4. 15-11-0394-00-04tv-tv-white-space-operation-for-wpan
5. 15-11-0171-00-04tv-usage-model-and-system-design-considerations-for-low-rate-wpan-operating-in-tv-white-space
6. 15-11-0194-00-04tv-tv-white-space-used-for-intelligent-transportation-system
7. 15-11-0215-02-04tv-wpan-applications-operating-in-tv-white-space
8. 15-11-0279-01-04tv-tv-white-space-for-vehicle-application
9. 15-11-0543-00-04tv-possible-phys-for-upcoming-tg4m
10. 15-11-0546-00-04tv-TV-white-space-issues-for-15.4