**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title |  | |
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| Re: | Task Group 15.4k Technical Guidance for Proposals | |
| Abstract | TG4k - technical guidance for PHY proposals. | |
| Purpose | To capture essential PHY requirements derived from the CFA responses, parameterized into a set of PHY characteristics that technical proposals can address. Guide discussion within task group, help proposers and provide a framework for evaluation of proposals by the TG. | |
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TG4k Technical Guidance Document

# Introduction

## Purpose

This document provides technical guidance based summarizing parametrically the key PHY characteristics identified in consideration of LECIM application requirements, as presented in the responses to the TG4k Call for Applications. We present PHY parameters and criteria to guide the preparation and selection of PHY proposals for task group 802.15.4k: it defines the PHY characteristics 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 provides sufficient descriptions of the technical requirements to enable relevant responses, with efficiency of effort while meeting the critical need for a timely standard.

## 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;
* Application/performance descriptions which characterizes the types of LECIM applications and the derived performance characteristics;

The 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 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

## High Level Requirements Overview

The PAR states some overall goals and requirements:

* Operation in any of the regionally available licensed, license exempt, and special purpose frequency bands
* Simultaneous operation for at least 8 co-located orthogonal networks
* Application data rate of less than 40 kbits per second
* Propagation path loss of at least 120 dB
* >1000 endpoints per mains powered infrastructure
* Asymmetric application data flow
* Extreme difference in capabilities and performance between endpoint devices and coordinating devices (collectors)
  + coordinator may support all standardized modulations (MCS) and data rates
  + coordinator may be required to support antenna diversity or antenna beam steering
  + end point must be able to conserve energy
* Reliable operation in dramatically changing environments (no control over environment)
* Mechanisms that enable coexistence with other systems in the same band

The PAR as approved can be found on the document server: (<https://mentor.ieee.org/802.15/dcn/11/15-11-0061-00-004k-tg4k-par-as-approved-by-nescom.docx>)

## Application Requirements Matrix (copied from 15-11-0245 Application Requirements Worksheet)

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Application | No-mains power | very low infrastructure (large number of endpoints) | many to one information flow | large link budget (widely dispersed or challenging environment) | very reliable (probability of success on single tx) | simple to deploy and maintain | intrinsic safety | low duty cycle | small payload (under normal conditions) | mobility | global regulatory | OTA Upgrade | time synchronization/stamp | Low Latency (system delay) | Application IP connectivity |
| Urban WSN | 3 (up to 10 yr) | 3 (up to 10000) | 3 | 2 | 2 | 3 | 3(gas meter) | 3 | 2(50-200 octets) | 3 (bike rental); 1 | 1 | 2 | 3 (1 S) | 2 (10's of s) |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Faulted circuit indicators | 3 (10-20yr) | 2 | 3 | 3 | 3 | 2 |  | 3 | 3(<100 octets) |  | 1 | 1 | 2 (small µs) | x (10's of s) | 3 |
| transformer | 3 | 3 | 3 | 3 | 1 | 3 |  | 3 | 3 |  |  |  |  |  | 3 |
| water leak detection | 3 (5 yr) | 3 | 3 | 3 | 1 | 3 |  | 3 | 3?(1Kb) |  | 1 | ? | 3 (small ms) |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| bridges, levees | 3 | 1 | 3 | 2 | 3 | x |  | 3 | 3 |  | 1 | 2 |  |  |  |
| gas meter | 3 (20yr) | 3 | 3 | 3 (sub surface or in building) | 1 (98.5%) | 3 | 3 | 3 | 3 |  | 1 | 2? | 3 (1s) |  | 3 |
| water meter | 3 (20yr) | 3 | 3 | 3 (sub surface or in building) | 2 (98.5%) | 3 |  | 3 | 3 |  | 1 | 2? | 3 (1s) |  | 3 |
| chemical processing | x |  | x | x | x | x | x |  |  |  |  |  |  |  |  |
| container monitoring | x | x | x | x | x | x |  | x | x | 3 | x |  |  |  |  |
| first responder monitoring/personal tracking | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |  |  |  |  |
| agriculture/soil monitoring | 3 (2yr) | 3 | 3 | 3 | 2 | 3 | x | 3 | 3? | 2 | 3 | 2? |  |  |  |
| secure harbor/buoy | 3 | 3 | 3 | 2 | 2 | 3 | x | 3 | 3 | 1 | 3 | 2 |  |  |  |
| machine room/server monitoring | 3 | 3 | 3 | 2 | 3 | 3 | x | 3 |  | x | 2 | 3 |  |  |  |
| River restoration, monitoring | 3 (5yr) | 2 | 3 | 3 (0.5-2km, surface) | 2 (95%) | 3 | x | 3 | 3(<100 octet) | x | 1 | 1 | 2 (1s) | x (?) |  |
| electric grid (china) | 3 (4-6yr) | ? | 3 | 3 (metal box) | ? | ? | x | ? | 3(50 octet) | x | 1? | ? | ? | x (30s) |  |
| Building monitoring | 3 (3 yr) | 1 (50% battery) | 1 (10:1 sensor/collector) | x | x | 3 | x | 3 (hour) | 1 10's of kbits (biggest picture 300kb) | x (may be re-deployed) | 1 | 2 | 2(ms) | 2(ms) |  |
| mine | 2 (1 yr) | 2 (30% battery) | 1 (20:1 sensor/collector) | 2 | 3 | 3 | 3 | 3 (10 Min) | 1 10's of kbits (biggest picture 300kb) | 3 (may be re-deployed) | 1 | 2 | 2(ms) | 3(ms) |  |
| note: keep alive message (periodic), primary messaging is by exception |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

## Performance characteristics Summary

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

* Link conditions (RF environment) are challenging and varying over time:
  + Primarily outdoor environment
  + Widely dispersed devices (high link loss)
  + Not static over time:
    - Long term, slow varying change due to long (>20year) deployed lifetime, building and geographic changes
    - Transient impairments due to changing interference sources, moving objects, variations in noise, may affect conditions during packet transmission.
    - Must have means to adapt to both kinds of variation
    - Need means to inform MAC and upper layers (measurements, metrics)
  + Asymmetric local link
    - End point and concentrator may see very different noise floor, multipath, and other impairments
    - May need mechanisms to ‘share’ link metrics
  + Hidden nodes likely (self-interference)
  + Optimize for connectivity over data rate.
  + Band considerations (interference, propagation)
* Information flow characteristics
  + Small, infrequent messages
  + Tolerant of data latency
  + Low bit-rates compatible with high loss links
  + Asymmetric data flow:
    - More data from end-point to concentrator
    - Many to one information flow from end-points to concentrator
  + Endpoints don’t communicate directly with each other
  + Addressing should support thousands of connected end points
* Asymmetric complexity and energy consumption between concentrator and sensor nodes
  + Concentrators typically mains powered,
  + end point nodes typically no mains power, must be very low energy (>20 year battery)
* Low infrastructure costs
  + Large number of end points per concentrator [?? Hundreds, thousands ??]
  + Efficient access method for RF link with high path loss (capacity, energy efficiency)
* Interference mitigation
  + Co-located systems
  + Susceptibility to/from other systems
* Data integrity critical in many applications
  + Error detection
  + Energy efficient means to enhance medium reliability in harsh, high loss environment
* Device mobility (vs. portability --- as per 802.15 norms) -dah
  + Devices move slowly or not at all:
    - Infrastructure doesn’t move, but things crop up
    - Containers move infrequently relative to collector
* Deployment considerations and constraints
  + Provisioned installation
  + Very long deployment life w/o human contact

[Could elaborate on expected data volume and update frequency, device density (endpoint/concentrator), RF loss dynamics]

**Put data models from presentations on document server e.g. water, gas, fci, transformer, etc.**

**-S.R.Dey**

State vs. stateless (resources on device vs. over the link) tradeoffs.

**-B. Rolffe**

LECIM networks should coexist with other services in the same band. Effective mitigation of interference and an ability to adapt to actual conditions is essential. Coexistence scenarios are discussed in **[TBD].**

**Show how LECIM minimizes impact on other PHY’s, and how LECIM is robust to other PHY’s interference.**

**-S. Kato**

# PHY Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| PHY Parameter | | Performance Criteria, Constraints, Comments | Regional Regulatory |
| Parameter: | Example: |
| Operating band  (band/channel plan) | * Target band(s) * Channel bandwidth used * Channelization methods | Band characteristic considerations impacts and mitigation, such as expected interference, propagation loss, etc, and how proposal addresses these. | Type of band: License exempt, user licensed, specified use (dedicated, application constrained)  Proposer should specify intended regions targeted. |
| Environmental Considerations | * Assumed channel conditions and dynamics of channel conditions | Identify intended environment and how proposal is addresses them. | Constraints such as TX power, BW, other restrictions, Listen Before Talk, Duty Cycle |
| Modulation and Coding Scheme(s) | * Modulation method * Methods for adaptability (knobs) | Suitable for application constraints  Meet regulator domain constraints | Potential restrictions by region and band. |
| Data rate(s) | * Range of rates * How achieved * Dynamic vs. Static | Should be <= 40kbps per PAR |  |
| 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 | Permit the maximum TX power allowed by regulations | Regionally dependent. The transmit spectrum mask shall comply with necessary regional regulations. |
| PSD | * In band * Out of band |  |  |
| Chan availability (interference detection) | * Spectrum scanning * CCA | Specify suitable mechanisms if specific to a proposed PHY | Some regulations may require LBT or DAA methods based on band, duty cycle, TX power. |
| 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 | * Baseline mode * Channels |  |  |
| Co-existence features | * Interference rejection methods * Channel sensing, scanning, assessment * Coordination/cooperation mechanisms for different radios in close proximity | Key parameters unique to the proposed PHY which impact coexistence (if any) should be described;  See also Coexistence Scenarios document [TBD] |  |
| MAC dependencies / support required | * Channelization * Channel access * Scanning * Synchronization | MAC features required to support the PHY, if unique to the proposed PHY and methods that enhance PHY performance, or fit PHY to existing MAC more seamlessly.  (please use 15.4i/.4e as the baseline MAC) |  |
| Energy consumption | * Rx/Tx ontime * Tx power control * Reliable delivery efficiency * Heart beat * Synchronization | Joules per bit? |  |

# Background and Supporting Discussion

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

* **Add paragraphs defining Interference, reliability (FER, PER, etc).**
* **T. Meyers, D. Howard, P Kinney**

## Channel Characteristics

## Reference presentations, Dey, etc.

*Channel Model*

**Paragraph needed (Kato, Dey, Wilbur)**

## Complexity and Cost considerations

**[TBD] simple paragraph, statement, etc.**

**L. Li**

# Definitions

The following provides definition of specific terms in the context of discussion with respect to TG4k applications and PHY proposals**. [TBD] coding, spreading, channel, etc…**

|  |  |
| --- | --- |
| Term: | Definition |
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# References

1. 15-11-0061-00-004k TG4k PAR as approved by NESCOM