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IEEE 802.16t System Requirements Document

R8

December 3, 2020

## Introduction

This document is to summarize the performance requirements for IEEE 802.16 operation in channel bandwidths greater than or equal to 5 kHz and less than 100 kHz. This SRD will act as a guide for the development of an amendment to IEEE Std 802.16-2017. This amendment builds on the 802.16s Amendment completed in 2017 and incorporated in the revision IEEE Std 802.16-2017

The following terminology is used in this document:

SHALL: This word, or the terms "REQUIRED" or "MUST", mean an absolute requirement of the specification.

SHALL NOT: This phrase means an absolute prohibition of the specification.

SHOULD: This word, or the adjective "RECOMMENDED", mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.

SHOULD NOT: This phrase, or the phrase "NOT RECOMMENDED" mean that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.

MAY: This word, or the adjective "OPTIONAL", mean that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein an implementation which does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.)

# Markets and Use Cases

The following markets and use cases were identified in [IEEE 802.15-20-0108r0](https://mentor.ieee.org/802.15/dcn/20/15-20-0111-00-016t-april-9-2020-teleconference-presentation.pptx)

|  |  |  |
| --- | --- | --- |
| **Market** | **Use Case/Application** | **Sub-Application** |
| Drone | UAS CNPC RADIO LINK |  |
| Oil/Gas | Pump Off Controller |  |
| Oil/Gas | PtP IP Backhaul | LoRa WAN Gateway |
| Electric | PtP Analog Data Circuit replacement | Transfer Trip/EMS SCADA |
| Electric | Advanced Metering Infrastructure (AMI) |  |
| Electric | Volt/VAR Control (Capacitor banks) |  |
| Electric | Distribution Feeder Automation |  |
| Electric | Circuit Sensors |  |
| Electric | Advanced Solar Inverters |  |
| Electric | Remote Fault Indicators |  |
| Water | SCADA |  |
| Electric | Substation Monitoring Devices |  |
| Electric | Field Devices | Reclosers, Fault Circuit Indicators (FCIs), Switches, Access Points |
| Electric | AMI Collector |  |
| Electric | Substation |  |
| Electric | Distribution Sub SCADA |  |
| Electric | Distribution Sub Metering |  |
| Electric | AMI |  |
| Electric | Distribution Substation SCADA |  |
| Electric | Downline Distribution Automation | Cap bank controller |
|  |  |  |
| Rail | I-ETMS Positive Train Control | Periodic wayside status |
| Rail | I-ETMS Positive Train Control | Back office to loco |
| Rail | Locomotive Distributed Power |  |
| Rail | End-of-Train Communication |  |
| Rail | Wayside Maintenance |  |
| Rail | Central Traffic Controller Communication |  |
| Rail | Fault detector communication |  |
| Rail | Grade Crossing Communication | Activation |
| Rail | Grade Crossing Communication | Monitoring |
| Rail | Hy-rail Limits Compliance |  |
| Rail | Employee-in-charge |  |
| Rail | Worksite protection |  |
| Rail | On-board Sensor Network |  |
| Rail | Remote Control Locomotive |  |
| Rail | Drone Communication |  |
| Rail | Differential GPS |  |
| Rail | Wayside signaling | Wayside to Office |
| Rail | Wayside signaling | Wayside to Wayside (main/remote) |
| Rail | PTC-enabled crossing |  |
| Rail | Remote monitoring and systems mgmt | w/o video |
| Rail | Remote monitoring and systems mgmt | w/video |
| Rail | ACSES Train control | Loco to Office and Wayside |
| Rail | End-of-train (EOT)/Head-of-Train (HOT) |  |
| Rail | Local DTMF crossing activation |  |
| Rail | Defect detectors | Voice and data |

The standard should support this set of use cases for field area networks, and similar critical infrastructure industry applications, that require high reliability and availability.

## 802.16t Amendment Requirements

Amendment Requirements that must be specified in the amendment in order to meet the operational requirements. These requirements identify the gaps in the existing standard that must be addressed by the amendment in order to attain those capabilities.

**Topology:**

The point to multipoint modes and repeater functionality defined in 802.16-2017 are retained and supported in this amendment. These capabilities can be used for both TDD and FDD spectrum.

**Frequency Range**

See [IEEE 802.15-20-0055-04-016t-frequency-band-layout.xls](https://mentor.ieee.org/802.15/dcn/20/15-20-0055-03-016t-frequency-band-layout.xlsx)

(Proposed in 802.15-20-0050r0)

Operation in paired or unpaired continuous licensed bands available for private networks (e.g., AMTS, IVDS, 454 A2G, 700 MHz A-Block, RR 900 MHz, 1.4 GHz).

* Support for partition of these bands into multiple channels is required for frequency reuse and link budget/coverage considerations.

Operation in Private Land Mobile Radio (PLMR) bands (e.g., RR160 MHz).

* PLMR channels in the VHF band are available worldwide.
* Common PLMR channel bandwidth: 6.25, 12.5, 25 and 50 kHz
* Special PLMR channel bandwidth: 5, 7.5 and 15 kHz
* Multiple adjacent or non-adjacent PLMR channels in the same band will be combined to support higher throughput services.

**Channel BW Range**

From PAR: “The amendment defines operation for channel bandwidths greater than or equal to 5 kHz and less than 100 kHz.”

Operation above 100 kHz is already supported and will not be changed in this amendment.

**UL/DL Ratio for TDD operation**

The standard shall support configurable TDD UL/DL frame timing ratio. The range of configuration should support ratios up to 10:1 to 1:10, consistent with frame size and latency requirements defined elsewhere.

Potentially other modes of remote device operation could allow larger ratios by operating on superframe timing of one out of N frames.

**Duplexing Requirements TDD or FDD**

(Proposed in 802.15-20-0050r0)

TDD will be used in unpaired spectrum and in paired spectrum if allowed by the applicable regulation authority. A highly asymmetrical or reverse asymmetrical DL:UL ratio (e.g., 1:10 to 10:1) should be supported.

Typical IoT application is highly reverse asymmetrical.

HD-FDD or FDD will be used in paired spectrum if TDD is not allowed

FDD will be used in paired spectrum if the latency requirements cannot be satisfied by TDD

**Mobility:**

Rail use cases require mobility. (similar capabilities to GSMR, but tailored for <100 kHz channels) Maximum velocity 220 mph.

Unmanned Aircraft Systems require mobility. Maximum velocity of 614 MPH

Some reduction in mobility performance in the base standard may be acceptable to improve efficiency in MAC overhead. Reliability remains a primary consideration, but higher latency in handover is acceptable as a means to improve overall efficiency and throughput.

**BS to BS Handoff:**

Handover between BS required for mobility and reliability of fixed devices

**One-way Latency and Operational throughput:**

(Proposed in 802.15-20-0050r0)

Throughput and latency requirements per endpoint:

* Many endpoints run low throughput non-critical latency applications. They should be served by low-end remote stations.
* Some endpoints run substantial throughput and sometimes also low latency applications. They should be served by high-end remote stations.

The air interface protocol will support concurrent operation of both low-end and high-end remotes on the same sector / base station

Low-end remote station specific requirements

* Limited throughput, Limited total bandwidth, Low power consumption, Low cost

High-end remote station specific requirements

* Support high throughput over relatively high total bandwidth. Supports low latency for time critical applications.

Need a table for throughput requirements:

Rows for use cases, including # users (grouped into base station capacity)

Columns for channel width

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Railroad Use Case** | **Max. # of users per base []** | **Data bandwidth per user [bps]** | **Aggregate base goodput [bps]** | **Base channel bandwidth target [Hz]** | **Required spectral efficiency [bps/Hz]** |
| Central Traffic Controller Communication | 150 | 100 | 15000 | 12500 | 1.20 |
| Differential GPS (broadcast) | 1 | 400 | 400 | 12500 | 0.03 |
| Drone Communication |  |  | 4800 | 12500 | 0.38 |
| Employee-in-Charge | 50 | 100 | 5000 | 12500 | 0.40 |
| End-of-Train (no video) | 1 | 100 | 100 | 12500 | 0.01 |
| Fault Detector | 10 | 50 | 500 | 12500 | 0.04 |
| Grade Crossing Activation | 1 | 250 | 250 | 12500 | 0.02 |
| Grade Crossing Monitoring | 150 | 100 | 15000 | 12500 | 1.20 |
| Hy-rail Limits Compliance | 150 | 100 | 15000 | 12500 | 1.20 |
| I-ETMS | 150 | 200 | 30000 | 12500 | 2.40 |
| Locomotive Distributed Power | 5 | 400 | 2000 | 12500 | 0.16 |
| On-board Sensor Network |  | 56000 | 0 | 12500 |  |
| Remote Control Locomotive |  |  | 4800 | 12500 | 0.38 |
| Wayside Maintenance | 150 |  | 0 | 12500 |  |
| Worksite Protection | 20 | 50 | 1000 | 12500 | 0.08 |

**Predictable Performance:**

(Proposed in 802.15-20-0050r0)

Licensed band (mandated by the PAR)

Central scheduling

QOS

**Range (DL or UL) and Coverage Requirements:**

(Proposed in 802.15-20-0050r0)

Long range single hop coverage (e.g., up to 50+ miles cell radius):

Some railroad use cases currently experience signal coverage up to 100 miles .

Unmanned Aviation Use Case has a maximum cell radius of 200+ miles

Receiver sensitivity requirement

TDD frame structure requirements (related to efficiency and time for TDD guard interval?)

**Endpoints:**

(Proposed in 802.15-20-0050r0)

Support for 1000’s of endpoint devices per sector (known as “massive connectivity”) in a Point to Multi-Point architecture

An example of massive connectivity requirement includes rapid reconnection of all remotes in a sector after a base station failure has occurred. Reconnection time depends on use case.

**Throughput maximization, reduction of overhead:**

Stated in terms of system level and spectral efficiency? Kbps/hz of “goodput” at the MAC SAP

Proposal – 4X of 802.16-2017

There should be options to trade throughput for link margin (robustness)

**Advanced Antenna Systems:**

Unmanned Aviation use case intends to utilize Beam Steering antennas (would apply aviation spectrum and C-band - 5031-5090 ) Support for Beam Steering is a requirement for the standard.

Practicality depends on operational band. There should be no impact if the feature is not used.

**Coexistence with PLMR channels operating with other standards**

Support of analog voice/data coexistence in low utilization voice channels. Voice will have priority over data. The voice may carried as analog, NXDN, P.25, etc.

**Cyber Security**

High Security is a requirement.

Example requirements coming from

* + IEC-62443, CR 1.2
  + CIP 005-5, R-1.2
  + DO-377 SER-08, SER-16, SER-17