|  |  |  |
| --- | --- | --- |
| Project | **IEEE 802.15 Wireless Specialty Networks Working Group <**<http://ieee802.org/15>**>** | |
| Title | **IEEE 802.15.16t System Requirements Document** | |
| Date Submitted | **2021-03 11** | |
| Source(s) | 16t Task Group | Voice:  E-mail: |
| Re: | 16t Task Group: Licensed Narrowband Amendment | |
| Abstract | System Requirements Document | |
| Purpose | To develop System Requirements for 802.16t | |
| Notice | *This document does not represent the agreed views of the IEEE 802.16 Working Group or any of its subgroups*. It represents only the views of the participants listed in the “Source(s)” field above. It is offered as a basis for discussion. It is not binding on the contributor(s), who reserve(s) the right to add, amend or withdraw material contained herein. | |
| Copyright Policy | The contributor is familiar with the IEEE-SA Copyright Policy <http://standards.ieee.org/IPR/copyrightpolicy.html>. | |
| Patent Policy | The contributor is familiar with the IEEE-SA Patent Policy and Procedures:  <<http://standards.ieee.org/guides/bylaws/sect6-7.html#6>> and <rmation is located at <<http://standards.ieee.org/board/pat/pat-material.html>> and <<http://standards.ieee.org/board/pat>>. | |

IEEE 802.16t System Requirements Document

802.15-21-0097r5

March 11, 2021

## 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 [802.15-20-0213r5](https://mentor.ieee.org/802.15/dcn/20/15-20-0213-05-016t-ieee-802-16t-use-cases.xlsx)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Market** | **Use Case/Application** | | **Sub-Application** | |
| Agri-culture | Environmental Monitoring | | rain, temperture, sunlight, wind | |
| Drone | UAS Control and Non Payload Communications (CNPC) | |  | |
| Electric | Point-to-Point Analog Data Circuit replacement | | Transfer Trip/EMS SCADA | |
| Electric | Advanced Metering Infrastructure (AMI) | |  | |
| Electric | Advanced Solar Inverters | |  | |
| Electric | AMI | |  | |
| Electric | AMI Collector | |  | |
| Electric | Circuit Sensors | |  | |
| Electric | Distribution Feeder Automation | |  | |
| Electric | Distribution Sub Metering | |  | |
| Electric | Distribution Sub SCADA | |  | |
| Electric | Distribution Substation SCADA | |  | |
| Electric | Downline Distribution Automation | | Cap bank controller | |
| Electric | Field Devices | | Reclosers, Fault Circuit Indicators (FCIs), Switches, Access Points | |
| Electric | Remote Fault Indicators | |  | |
| Electric | Substation | |  | |
| Electric | Substation Monitoring Devices | |  | |
| Electric | Volt/VAR Control (Capacitor banks) | |  | |
| Electric, Gas, Water | Outage Restoration Management | |  | |
| Electric | Demand Response to Optimally Distribute Power | |  | |
| Fleet Mgmnt | Vehicle Tracking and Monitoring | | Transportation and Construction | |
| Fleet Mgmnt | Fuel Consumption Monitoring | | Tranportation | |
| Oil/Gas | Point-to-Point IP Backhaul | | LoRa WAN Gateway | |
| Oil/Gas | Pump Off Controller | |  | |
| Gas | Methane detection | |  | |
| Gas & Water utilities | Pressure Sensing | |  | |
| Manu-facturing | Machinery Condition Monitoring | | Vibration sensing | |
| Rail | Central Traffic Controller Communication | |  | |
| Rail | Differential GPS | |  | |
| Rail | Drone Communication | |  | |
| Rail | Employee-in-charge | |  | |
| Rail | End-of-Train Communication | |  | |
| Rail | Fault detector communication | |  | |
| Rail | Grade Crossing Communication | | Activation | |
| Rail | Grade Crossing Communication | | Monitoring | |
| Rail | Hy-rail Limits Compliance | |  | |
| Rail | Interoperable Electronic Train Management System (I-ETMS) Positive Train Control | | Back office to locomotive | |
| Rail | Interoperable Electronic Train Management System (I-ETMS) Positive Train Control | | Periodic wayside status | |
| Rail | Locomotive Distributed Power | |  | |
| Rail | On-board Sensor Network | |  | |
| Rail | Remote Control Locomotive | |  | |
| Rail | Wayside Maintenance | |  | |
| Rail | Worksite protection | |  | |
| Rail | Advanced Civil Speed Enforcement System (ACSES) Train control | | Locomotive to Office and Wayside | |
| Rail | Defect detectors | | Voice and data | |
| Rail | End-of-train (EOT)/Head-of-Train (HOT) | |  | |
| Rail | Local DTMF crossing activation | |  | |
| Rail | Positive Train Control (PTC)-enabled crossing | |  | |
| Rail | Remote monitoring and systems mgmt | | w/o video | |
| Rail | Remote monitoring and systems mgmt | | w/video | |
| Rail | Wayside signaling | | Wayside to Office | |
| Rail | Wayside signaling | | Wayside to Wayside (main/remote) | |
| Rail/DOT | Bridge and infrastructure monitoring | |  | |
| Smart City | Smart Street Lights | |  | |
| Smart City | Parking management | |  | |
| Smart City | Security Systems (Excludes video monitoring) | | motion detectors, door open sensors, proximity | |
| Smart City | HVAC monitoring and control | | Smart Building | |
| Waste-water & flood control | Level and Overflow | | Private Septic Systems | |
| Water | SCADA | |  | |
| Water | Leak Detection | |  | |

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:**

Support of the following topologies is required:

Network topology: Multicell and multisector

Sector topology: Point to Multipoint Point to Point topology will be supported as a private case of Point to Multipoint

Repeater for range extension:

S&F on the same carrier frequency/carrier frequency pair

Use of distinct carrier frequency/carrier frequency pair.

Base Station Controller (BSC) for:

Seamless handover

Coordination of base station operation to minimize self-interference.

A Base Station to Base Station Controller communication protocol to support the above functions will be standardized.

Consider impact of PTT one-way LMR on topology.

**Frequency Range**

While the IEEE 802.16t amendment does not require or exclude support for any specific frequency, the majority of bands used for the IEEEE 802.16t air interface protocol will be in the sub 1 GHz frequency range.

**Band Support Requirements**

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)

* Support operation in paired and unpaired continuous licensed bands available for private networks is required (e.g., AMTS, IVDS, 454 A2G, 700 MHz A-Block, RR 900 MHz, 1.4 GHz).
* Support for partition of continuous licensed bands into multiple channels is required for frequency reuse and link budget/coverage considerations.
* Support operation in Private Land Mobile Radio (PLMR) bands (e.g., RR160 MHz) is required. This includes:
* Support of common PLMR channel bandwidth: 6.25, 12.5, 25 and 50 kHz
* Support special PLMR channel bandwidth: 5, 7.5 and 15 kHz
* Support aggregation of multiple adjacent and non-adjacent PLMR channels to enable 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.

* The specification will support simultaneous remote operation over one or more aggregated (adjacent or non-adjacent) subchannels of bandwidth as low as 5 kHz.
* The specification will support base station operation over any one or more sub-channels. The base station may support aggregation of multiple subchannels such that the total bandwidth in the sector is is not limited to 100 KHz.
* . TDD may be used

The standard will support hybrid duplexing, where a remote may operate in half duplex while connected to a base station operating FDD, for the purpose of reducing complexity in remotes due to small duplexer gap.

**TDD Frame Configuration**

The standard shall support configurable TDD frame configuration including:

* Configuration of the downlink subframe duration
* The Configuration of the uplink subframe duration
* The duration of the transmit to receive and the receive to transmit gap durations.

The standard shall support a range of TDD frame durations consistent with throughput, latency, frequency utilization and overhead requirements defined in this document.

The standard shall support a range of downlink to uplink subframe duration ratios between 10:1 to 1:10. The ratio will be constrained by the frame duration and the minimum capacity of the downlink/uplink subframe.

The gaps duration should support the maximum distance requirement defined in this document.

**Mobility Requirements**

The standard shall support a relative speed of remote to base station of up to 614 mph.

The standard shall support seamless handover between base stations.

**Data transport requirements:**

The standard will support concurrent operation of low, medium and high throughput endpoint devices with the following characteristics:

* Low- throughput end point requirements:
* End user throughput < 1 kb/s. Given the periodicity characteristics, this seems to be a peak throughput, not average.
* End to end latency: in most cases, not time sensitive. One use case requires end to end latency < 100 msec. Other use cases require end to end latency below 1 second or higher.
* # of endpoints per base station: up to 150[[1]](#endnote-2)
* Most use cases in this category are fixed but some are mobile.
* Most use cases in this category are reverse asymmetrical but some are symmetrical, and some are asymmetrical. UL:DL ratio is in the range 90:10 to 10:90.
* Medium- throughput end point requirements:
* 1 kb/s < end user throughput < 10 kb/s
* End to end latency < 60 ms
* End to end jitter < 20 ms
* # of end points per sector < 60
* Fixed and mobile use cases. Some of the use cases, require high speed support.
* UL:DL ratio in the range 90:10 to 30:70
* High- throughput use cases characteristics.
* The amendment will support endpoint applications requiring up to 100 kb/s.
* End to end latency for high throughput applications < 20 ms

Specific use cases are summarized in IEEE [802.15-20-0213r6](https://mentor.ieee.org/802.15/dcn/20/15-20-0213-05-016t-ieee-802-16t-use-cases.xlsx). Figure 1 presents the use cases where all data is available for user throughput vs. latency vs. number of end points per sector. The use case IDs in the scatter plot are the same as the ones used in the use cases document.

**Additional general data transport requirements for operation in narrow channel bandwidths:**

* Frequency utilization: Spectral efficiency [[2]](#footnote-2)of higher than 4 bits/sec/Hz is an objective, but some modes of operation may trade off spectral efficiency for range or lower complexity.
* Air interface protocol overhead goals:
  + PHY layer excluding FEC: < 10%
  + MAC overhead: < 10%



Figure - User Throughput vs Latency for use case groups



**Predictable Performance:**

* Licensed band (mandated by the PAR)
* Central scheduling
* QOS

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

A base station to remote range of up to 200 miles will be supported subject to link budget constraints.

**Advanced Antenna Systems:**

The standard will support beam steering with one or multiple beams per base station.

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

The amendment will support coexistence of analog voice and data in low utilization voice channels referred to as “grey channels”. Voice will have priority over data. The voice may be carried as analog, NXDN, P.25, etc. Here are “grey channel” requirements:

* Utilization of a grey channel by a base station/remote station for data transmission is only allowed when the channel is idle. This will be verified by the base station/remote station by detecting no voice activity prior to start of data transmission. The signals to be detected and their minimum RSSI is TBD.
* A base station or remote station utilizing a grey channel will monitor the grey channel and vacate the channel as soon as voice activity is detected.
* Data transmission will not cause audible noise in idle voice terminal and will not block the establishment of new voice calls in the respective grey channel.

RF Requirements

* Meet applicable FCC spectrum emission mask requirements, e.g., FCC Part 90 requirements.
* Meet receiver sensitivity requirements for most robust MCS as follows:

Receiver sensitivity < noise floor + 5 dB (minimum required CINR) + 6 dB (noise floor + implementation loss).

* Meet Adjacent Channel Rejection (ACR) requirement as per ETSI EN 300 113
* Meet Adjacent Channel Leakage Ratio (ACLR) as per ETSI EN 300 113
* When multiple non-adjacent channels are combined, the RF requirements for each individual channel will be maintained.

**Cyber Security**

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

The requirements listed below will conform to the air interface protocol requirements in mission critical security standards including IEC-62443, CIP 005-5, DO-377 SER-08 and FIPS 140-3

1. The air interface protocol shall support the following options for data encryption/decryption algorithms and key sizes (amendment to 802.16-2017, section 7.5.1):

|  |  |  |  |
| --- | --- | --- | --- |
| Algorithm | Mode | key length | Reference in 802.16-2017 |
| AES (NIST.FIPS.197) | CBC (NIST.SP.800-38A) | 128, 192, 256 | Add to 802.16 |
|  | CCM / CTR (NIST.SP.800-38C) | 128,  Add: 192, 256 | 7.5.1.2, 7. 5.1.3 |
|  | GCM (NIST.SP.800-38D) | 128, 192, 256 | Add to 802.16 |
|  | XTS-AES (NIST.SP.800-38E) | 128,  Add: 192, 256 | Add to 802.16 |
|  | CBC with key wrapping (NIST.SP.800-38F) | 128, 192, 256 | 7.5.1.4 |
| DES | Remove option |  | 7.5.1.1 |

1. The air interface protocol shall support the following algorithms options for TEK encryption (amendment to 802.16-2017, section 7.5.2)

|  |  |  |  |
| --- | --- | --- | --- |
| Algorithm | Mode | key length | Reference in 802.16-2017 |
| TDEA (3-DES)  NIST.SP.800-67r2 | CBC (NIST.SP.800-38A/F)  Disallowed after 2023 | 128 | 7.5.2.1 |
| RSA |  | 1024  Add: 2048, 4096 | 7.5.2.2 |
| AES (NIST.FIPS.197) | ECB (NIST.SP.800-38A) | 128,  Add: 192, 256 | 7.5.2.3 |
|  | CBC with key wrapping (NIST.SP.800-38F) | 128, 192, 256 | 7.5.2.4 |

1. The air interface protocol shall support HMAC authentication with 112 bits key length or higher. HMAC (amendment to 802.16-2017, section 7.5.3) shall be calculated using SHA-2 (NIST.FIPS.180-4) or SHA-3 (NIST.FIPS.202) with key length ≥224
2. The air interface protocol shall support CMAC-AES or GMAC-AES for message authentication.
3. The air protocol will support the following public key encryption/decryption algorithm options for AK encryption (amendment to 802.16-2017, section 7.5.8):

|  |  |  |
| --- | --- | --- |
| Algorithm | Key length | Reference in 802.16-2017 |
| RSA | Remove: 1024,  Add: 2048, 4096 | 7.5.8 |
| ECC | 224 or higher | Add to protocol |

1. Key management: the air interface protocol shall support PKMv2 (amendment to 802.16-2017, section 7.2.2). It will not support PKMv1 only (amendment to 802.16-2017, section 7.2.1)
2. Authentication mode (amendment to 802.16-2017, section 7.8.2): mutual authentication mode will be used. The base station will send its X.509 certificate in the Authorization Reply message.

1. The number of endpoints per base station depends on the base station coverage which may be increased to reduce infrastructure cost. [↑](#endnote-ref-2)
2. Frequency utilization is the user data throughput including Service Data Unit (SDU) protocol overhead divided by the occupied bandwidth. The occupied bandwidth is the maximum bandwidth allowed for use by the applicable regulatory body within the nominal channel bandwidth. [↑](#footnote-ref-2)