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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <**<http://ieee802.org/16>**>** | |
| Title | **Proposed PHY Layer Parameters for IEEE 802.16s** | |
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| Re: | Call for Contributions: IEEE 802.16 Working Group on Broadband Wireless Access GRIDMAN Task Group: Project 802.16s  IEEE 802.16-16-0035-01-000s | |
| Abstract | Describes Full Spectrum’s proposed PHY layer parameters for IEEE802.16s. This is an extension of the original proposal “FullMAX Air Interface Parameters for Upper 700 MHz A Block v1.0” from March 23 2015. This extension is required to support operation within a narrower channels down to a bandwidth of 100 KHz. | |
| Purpose | For consideration during Working Group Session #104 | |
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# General

* 1. This document describes the proposed PHY layer parameters for IEEE802.16s. It is an extension of the original proposal “FullMAX Air Interface Parameters for Upper 700 MHz A Block v1.0” from March 23 2015. This extension is needed to support operation within a narrower channels down to a channel bandwidth of 100 KHz.
  2. Paragraph 2 describes some of the consideration which led to the proposed PHY layer paramaters. Paragraph 3 includes the proposed parameters for 1 MHz, 500 KHz, 250 KHz, 125 KHz and 100 KHz wide channels.
  3. Some of the configurations require a modification of the standard 802.16 preamble and CDMA codes. These modifications are not described in this document.

# Considerations

* 1. It is assumed the delay spread of 802.16s deployments does not exceed 10 µs, and therefore the minimum Cyclic Prefix (CP) should be 10 µs. In order to avoid excessive CP overhead, we will maintain CP = 1/8 of useful symbol time, i.e., minimum useful symbol time = 80 µs and minimum total symbol duration = 90 µs. For a 1 MHz wide channel, a 1.12 MHz sampling clock is proposed which leads to a subcarrier spacing of 8.75 KHz. The total symbol duration is 128.57 µs which meets the 90 µs. Moreover, the pilot spacing in the 1 MHz proposal is 78.75 KHz. This is less than the 100 KHz coherent bandwidth for a 10 µs delay spread. This proposal therefore also satisfies the pilot based channel estimation requirement.
  2. Further reduction of the subcarrier spacing relative to 8.75 KHz does not provide any advantage. On the other hand this degrades performance due to:
  + Peak to Average Power ratio (PAPR) increases as the number of subcarriers increase
  + Inter Carrier Interference (ICI) increases as the number of subcarriers increase
  + For a given oscillator, the frequency error (due to the limited accuracy) as a percentage of the subcarrier spacing, increases as the subcarrier spacing is reduced.[[1]](#footnote-1)

It is therefore preferable to fit the signal into the available channel bandwidth by reducing the number of subcarriers first and reduce the sampling clock only as the last resort.

* 1. Support of channel bandwidth below 1 MHz and down to 100 KHz is done using a combination of the following schemes:
  + Use the band AMC subcarrier allocations scheme which employs adjacent subcarriers per sub-channel.
  + Reduce the number of sub-channels down to a minimum of 3 as needed to enable a frequency re-use of (1,3,3) in addition to the more aggressive frequency re-use (1,3,1). As an example, the proposal for 1 MHz wide channel has 6 AMC 2X3 sub-channels. The proposal for 500 KHz maintains only 3 of them so no need to change the sampling clock and the subcarrier spacing.
  + Reduce the sampling clock. For example, it is proposed to reduce the sampling clock to 560 KHz and the subcarrier spacing to 4.4375 KHz for a channel bandwidth of 125 KHz and to further reduce the sampling clock to 448 KHz and the subcarrier spacing to 3.5 KHz for a channel bandwidth of 100 KHz.
  1. Support reverse asymmetrical TDD frame configuration ratio of up to DL:UL = 1:10. This will effectively double the throughput for SCADA applications relative to FDD.
  2. Support of 40 miles radius is required. This translates into a round trip delay of 430 µs. In order not to exceed the minimum necessary gaps overhead, the gaps duration in samples, should be configurable according to the longest distance in the system and the sampling clock.
  3. The relatively narrow channel does not offer much benefit in frequency diversity. Continuous subcarriers per sub-channel offers greater flexibility to reduce interference in both transmit and receive directions.
  4. Frame Duration: Some applications require very low latency and therefore a frame duration of 5 ms needs to be supported. On the other hand, delay tolerant applications may require high throughput which increases with the increase in frame duration due to the reduction in the per frame overhead and reduced fragmentation.
  5. The use of multiple zones in downlink and uplink sub-frames offers the opportunity to create groups of Remote Stations in the sector and optimize certain parameters for each of the groups. The downside however is the related inefficiency. It is recommended to maintain a single AMC zone in the downlink and in uplink directions.
  6. Maximization of throughput within 1 MHz wide channel is accomplished by:
  + Minimize the PHY layer overhead
  + Minimize the per-frame overhead
  + Minimize the MAC PDU overhead
  + Maximize FEC code in both the downlink and uplink.
  + Automatic PHS

An analysis of the standard IEEE802.16 overhead when operating in narrower channels and the proposed modifications to the standard to reduce the overhead, are described in the document “FullMAX vs Standard IEEE802.16 Air Interface Protocol Overhead – v1”. These modifications are not described in this document.

# Proposed Air Interface Parameters

* 1. Proposed Air Interface Parameters for s 1 MHz wide channel

| **Nominal Channel Bandwidth** | **1 MHz** |
| --- | --- |
| Sampling frequency (MHz) | 1.12 MHz |
| FFT size | 128 |
| Subcarrier spacing (kHz) | 8.75 KHz |
| Subcarrier Allocation Scheme in downlink and in uplink | AMC 2 x 3 and AMC 1 x 6 |
| Subchannels in downlink and in uplink | 6 and 12 |
| Actual Bandwidth (centered on nominal channel) for full channel | 945 KHz |
| Actual Bandwidth (centered on nominal channel) for single subchannel with AMC 2 x 3 | 157.5 KHz |
| Actual Bandwidth (centered on nominal channel) for single subchannel with AMC 1 x 6 | 78.75 KHz |
| Preamble | Preamble Off or standard ieee802.16, 128 fft preamble (transmitted over 33 subcarriers). |
| CDMA Codes | Standard ieee802.16, 128 fft CDMA codes (transmitted over 96 subcarriers) |
| Frame Size (ms) | 5, 10, 12.5, 20, 25 |
| Number of samples per frame | 5600 @ 5 ms, 11,200 @ 10 ms, 14,000 @ 12.5 ms, 22,400 @ 20 ms, 28,000 @ 25 ms |
| Number of symbols per frame | Up to 38 for 5 ms frame,  Up to 77 for 10 ms frame,  Up to 97 for 12.5 ms frame,  Up to 155 for 20 ms frame,  Up to 194 for 25 ms frame |
| Number of samples per symbol | 144 |
| Symbol duration (µs) | 128.57 |
| Useful symbol duration (µs) | 114.26 |
| Slot definition in downlink and in uplink | AMC 2 x 3: 1 SC x 3 symbols  AMC 1 x 6: 1 SC x 6 symbols |
| Duplexing Mode | TDD |

Notes:

* The bandwidth for N consecutive subchannel is N \* 157.5 KHz, N = 1…,6 for AMC 2x3 and N \* 78.5 KHz for AMC 1X6.
* Preamble Off requires GPS synchronization at both Base Station and Remote Station.
* (Total # of symbols per frame) X 144 + TTG + RTG = # of samples per frame.
  1. Proposed Air Interface Parameters for 500 KHz wide channel

| **Nominal Channel Bandwidth** | **500 KHz** |
| --- | --- |
| Sampling frequency (MHz) | 1.12 MHz |
| FFT size | 128 |
| Subcarrier spacing (kHz) | 8.75 KHz |
| Subcarrier Allocation Scheme in downlink and in uplink | AMC 2 x 3 and AMC 1 x 6 |
| Sub-channels in downlink and in uplink | 3 for AMC 2 x 3 and 6 for AMC 1 x 6 |
| Actual Bandwidth (centered on nominal channel) for full channel | 472.5 KHz |
| Actual Bandwidth (centered on nominal channel) for single subchannel with AMC 2 x 3 | 157.5 KHz |
| Actual Bandwidth (centered on nominal channel) for single subchannel with AMC 1 x 6 | 78.75 KHz |
| Preamble | Preamble Off or modified preamble (e.g., transmitted over 33 consecutive instead of interleaved subcarriers). |
| CDMA Codes | Should be modified to be transmitted over 54 subcarriers only. |
| Frame Size (ms) | 5, 10, 12.5, 20, 25 |
| Number of samples per frame | 5600 @ 5 ms, 11,200 @ 10 ms, 14,000 @ 12.5 ms, 22,400 @ 20 ms, 28,000 @ 25 ms |
| Number of symbols per frame | Up to 38 for 5 ms frame  Up to 77 for 10 ms frame  Up to 97 for 12.5 ms frame  Up to 155 for 20 ms frame  Up to 194 for 25 ms frame |
| Number of samples per symbol | 144 |
| Symbol duration (µs) | 128.57 |
| Useful symbol duration (µs) | 114.26 |
| Slot definition in downlink and in uplink | AMC 2 x 3: 1 SC x 3 symbols  AMC 1 x 6: 1 SC x 6 symbols |
| Duplexing Mode | TDD |

Notes:

* The bandwidth for N consecutive subchannel is N \* 157.5 KHz, N = 1…,6 for AMC 2x3 and N \* 78.5 KHz for AMC 1X6.
* Preamble Off requires GPS synchronization at both Base Station and Remote Station.
* (Total # of symbols per frame) X 144 + TTG + RTG = # of samples per frame
  1. Proposed Air Interface Parameters for 250 KHz wide channel

| **Nominal Channel Bandwidth** | **250 KHz** |
| --- | --- |
| Sampling frequency (MHz) | 1.12 MHz |
| FFT size | 128 |
| Subcarrier spacing (kHz) | 8.75 KHz |
| Subcarrier Allocation Scheme in downlink and in uplink | AMC 1 x 6 |
| Sub-channels in downlink and in uplink | 3 |
| Actual Bandwidth (centered on nominal channel) for full channel | 236.25 KHz |
| Actual Bandwidth (centered on nominal channel) for single subchannel with AMC 1 x 6 | 78.75 KHz |
| Preamble | Preamble Off or modified preamble transmitted over 27 subcarriers |
| CDMA Codes | Should be modified to be transmitted over 27 subcarriers only. |
| Frame Size (ms) | 5, 10, 12.5, 20, 25 (\*) |
| Number of samples per frame | 5600 @ 5 ms, 11,200 @ 10 ms, 14,000 @ 12.5 ms, 22,400 @ 20 ms, 28,000 @ 25 ms |
| Number of symbols per frame | Up to 38 for 5 ms frame  Up to 77 for 10 ms frame  Up to 97 for 12.5 ms frame  Up to 155 for 20 ms frame  Up to 194 for 25 ms frame |
| Number of samples per symbol | 144 |
| Symbol duration (µs) | 128.57 |
| Useful symbol duration (µs) | 114.26 |
| Slot definition in downlink and in uplink | AMC 1 x 6: 1 SC x 6 symbols |
| Duplexing Mode | TDD |

Notes:

* The capacity of 5 and 10 ms frames may be too small and the per frame overehad too high if ferquency re-use (1,3,3) scehme is used.
* Preamble Off requires GPS synchronization at both Base Station and Remote Station.
* (Total # of symbols per frame) X 144 + TTG + RTG = # of samples per frame
  1. Proposed Air Interface Parameters for 125 KHz wide channel

| **Nominal Channel Bandwidth** | **125 KHz** |
| --- | --- |
| Sampling frequency (MHz) | 560 KHz |
| FFT size | 128 |
| Subcarrier spacing (kHz) | 4.375 KHz |
| Subcarrier Allocation Scheme in downlink and in uplink | AMC 1 x 6 |
| Sub-channels in downlink and in uplink | 3 |
| Actual Bandwidth (centered on nominal channel) for full channel | 118.125 KHz |
| Actual Bandwidth (centered on nominal channel) for single subchannel with AMC 1 x 6 | 39.375 KHz |
| Preamble | Preamble Off or modified preamble transmitted over 27 subcarriers |
| CDMA Codes | Modified CDMA codes transmitted over 27 subcarriers |
| Frame Size (ms) | 10, 12.5, 20, 25, 50 (\*) |
| Number of samples per frame | 5,600 @ 10 ms, 7,000 @ 12.5 ms, 11,200 @ 20 ms, 14,000 @ 25 ms, 28,000 @ 50 ms |
| Number of symbols per frame | Up to 38 for 10 ms frame  Up to 77 for 20 ms frame  Up to 97 for 25 ms frame  Up to 194 for 50 ms frame |
| Number of samples per symbol | 144 |
| Symbol duration (µs) | 257.14 µs |
| Useful symbol duration (µs) | 228.57 µs |
| Slot definition in downlink and in uplink | AMC 1 x 6: 1 SC x 6 symbols |
| Duplexing Mode | TDD |

Notes:

* The capacity of 5 and 10 ms frames may be too small and the per frame overehad too high if ferquency re-use (1,3,3) scehme is used.
* Preamble Off requires GPS synchronization at both Base Station and Remote Station.
* (Total # of symbols per frame) X 144 + TTG + RTG = # of samples per frame
  1. Proposed Air Interface Parameters for 100 KHz wide channel

| **Nominal Channel Bandwidth** | **100 KHz** |
| --- | --- |
| Sampling frequency (MHz) | 448 KHz |
| FFT size | 128 |
| Subcarrier spacing (kHz) | 3.5 KHz |
| Subcarrier Allocation Scheme in downlink and in uplink | AMC 1 x 6 |
| Sub-channels in downlink and in uplink | 3 |
| Actual Bandwidth (centered on nominal channel) for full channel | 94.5 KHz |
| Actual Bandwidth (centered on nominal channel) for single subchannel with AMC 1 x 6 | 31.5 KHz |
| Preamble | Preamble Off or modified preamble transmitted over 27 subcarriers |
| CDMA Codes | Modified CDMA codes transmitted over 27 subcarriers |
| Frame Size (ms) | 12.5, 20, 25, 50 (\*) |
| Number of samples per frame | 5,600 @ 12.5 ms, 8,960 @ 20 ms , 11,200 @ 25 ms, 24,400 @ 50 ms |
| Number of symbols per frame | Up to 38 for 12.5 ms frame  Up to 62 for 20 ms frame  Up to 77 for 25 ms frame  Up to 169 for 50 ms frame |
| Number of samples per symbol | 144 |
| Symbol duration (µs) | 321.43 µs |
| Useful symbol duration (µs) | 285.71 µs |
| Slot definition in downlink and in uplink | AMC 1 x 6: 1 SC x 6 symbols |
| Duplexing Mode | TDD |

Notes:

* The capacity of 5 and 10 ms frames may be too small and the per frame overehad too high if ferquency re-use (1,3,3) scehme is used.
* Preamble Off requires GPS synchronization at both Base Station and Remote Station.
* (Total # of symbols per frame) X 144 + TTG + RTG = # of samples per frame

1. The degradation due to higher number of subcarriers and reduced subcarrier spacing within a given channel bandwidth is quantified in a separate document. [↑](#footnote-ref-1)