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IEEE 802.16s

System Description Document

January 19, 2016

# Introduction

This document describes the technical approach for IEEE 802.16 operation in channels less than 1.25 MHz bandwidth.

PAR Scope (From 802.16-16-0038-00-000s):

This project specifies WirelessMAN-OFDMA TDD operation in exclusively-licensed spectrum with channel bandwidth from 100 kHz up to 1.25 MHz, including 1 MHz explicitly. The amendment will target operation in the 700 MHz band but will also support operation in other VHF/UHF bands. The project amends Clause 12 of IEEE Std 802.16, adding a new system profile and *amending other clauses as required to support the narrower channel widths*. The range and data rate supported by the added profile are commensurate with those of the base standard, as scaled by the reduced channel bandwidth.

The italicized phrase is the reasoning behind the section for MAC changes related to improving efficiency, which is necessary to meet SRD requirements in narrower channel bandwidths.

# Informative Section – rationale for changes:

## System-level PHY Design Aspects

* The amendment will support exclusive operation using Band AMC operation. The amendment must remove mandatory requirement for PUSC in Zone 1.
* Adjustment of sampling clock is used as a mechanism to adjust channel occupancy to better meet regulatory requirements in various regions.
* Disassociate preamble ID from sector ID (TBC)
* Provide information for auto-configuration of remotes, through a combination of periodic system information as well as scanning by the remotes.

### Definition of Band AMC

IEEE 802.16-2012 does not explicitly define the term “Band AMC”. The meaning is “a subcarrier allocation scheme in which all subcarriers in one sub-channel are adjacent to each other. “There are three Band AMC schemes used in this amendment.

Band AMC 2x3: Each sub-channel employs two bins, and each slot is defined as two bins by 3 OFDMA symbols.

Band AMC 1x6: Each sub-channel employs one bin, and each slot is defined as one bin by 6 OFDMA symbols.

Band AMC 1x3: Each sub-channel employs one bin, and each slot is defined as one bin by 3 OFDMA symbols.

A bin is 9 subcarriers, including 8 data subcarriers and 1 pilot.

### Performance Analysis (derived from SRD: 802.16-16-0044)

Quantifying the PHY Layer Throughput Benefits[[1]](#footnote-1)

**Summary of throughput enhancements for specific feature modifications, compared to 802.16-2012**

| **Baseline: 1 MHz channel BW, 128 FFT with PUSC in DL and optional UL PUSC, with 28/25 sampling factor, and 5 ms frame size** |
| --- |
| **Feature or Attribute** | **Change or Modification** | **Notes** | **Throughput Impact****Relative to baseline** |
| Permutation | PUSC to Band AMC | Mobility is a low priority & other PUSC ‘benefits’ less significant with smaller channel BWs | +33.3% |
| Frame Size | 2x Increase from 5 ms to 10 ms | Tradeoff with 2x increased latency | +24.1% |
| Further increases to 15 ms, 20 ms, & 25 ms | Subsequent increases will incur considerable additional latency | An additional gain of; +5.5%, +3.3%, +1.4% respectively |
| Cyclic Prefix | Reduce from 1/8 to 1/16 | Symbol OH is reduced from >11% to <6% | +11.5% |
| Sampling Factor | 28/25 to 57/50 to 144/125 | Adds 1 data symbol for each step increase from 28/25 | +3.85% and +3.70% respectively |

## The MAC overhead problem

The following table shows MAC overhead for the channel sizes and frame sizes shown above. This is without any MAC overhead reduction – the messages are per IEEE 802.16-2012.

This table illustrates the problem with MAC overhead in the IEEE 802.16-2012 standard. The section below on MAC modifications will present options for reducing overhead.

Table - Overhead for channels BW and frame duration (without MAC changes)

|  |  |
| --- | --- |
| Channel Size (KHz), % BW | Percentage overhead per Frame Duration (mS) |
|  | 5 | 10 | 12.5 | 20 | 25 | 50 |
|  |  |  |  |  |  |  |
| 1000, 100% | 26.24% | 12.23% | 9.39% | 6.94% | 5.15% | 2.30% |
| 1000, 33% | 62.89% | 30.45% | 23.96% | 16.04% | 12.44% | 5.95% |
| 500, 100% | 44.68% | 21.34% | 16.67% | 11.49% | 8.79% | 4.13% |
| 500, 33% | 117.54% | 57.77% | 45.81% | 29.71% | 23.36% | 11.41% |
| 250, 100% | 81.11% | 39.55% | 34.16% | 22.42% | 17.54% | 7.70% |
| 250, 33% | 226.82% | 112.41% | 92.44% | 58.85% | 46.68% | 22.34% |
| 125, 100% | 153,93% | 83.25% | 63.29% | 40.63% | 35.00% | 17.96% |
| 125, 33% | 445.36% | 228.96% | 179.86% | 113.48% | 93.30% | 47.11% |
| 100, 100% | 204.91% | 97.81% | 83.68% | 53.37% | 40.84% | 19.42% |
| 100, 33% | 569.20% | 279.66% | 229.39% | 144.44% | 113.70% | 55.85% |

The channel size column includes options for full channel use, and sub channel use (33%) for each channel BW.

The color highlighting identifies the values that are below 15% (Green) and above 15% (Orange)

This table assumes 2 concurrent DL FEC codes present in a single DL Subframe, and assumes 2 bursts maximum in an UL subframe. It does take into account the overhead of the DL MAP, UL MAP, preamble and gaps. This does not include the MAC frame header overhead. This table assumes a Cyclic Prefix of 1/16.

The following figures illustrate the relationship between throughput, latency, and frame size

**Figure 2 Left:** *Shows UL + DL PHY throughput for example 5, 10, 15, 20, and 25 mS frame sizes,* **Right:** *Shows minimal frame dependent UL latency for unsolicited grant service for same 5 frame sizes[[2]](#footnote-2)*

# PHY Description

The following table defines the key parameters defining the PHY operation affecting channel bandwidth.

Based on the SRD, Band AMC is assumed, and TDD is assumed.

# Parameter Ranges

|  |  |  |
| --- | --- | --- |
| **Primary** | **Description** | **Description** |
| X | Nominal Channel Bandwidth | 100 KHz to 1.25 MHz in steps of 50 KHz.  |
|  | Sampling frequency (MHz) | Nominal Channel BW \* (128 / 109) \* (Number of subchannels in permutation / number of subchannels used) \* Alpha  |
| X | FFT size | 128 |
|  | Subcarrier spacing (kHz) | Sampling Frequency / FFT Size |
| X | Subcarrier Allocation Scheme in downlink and in uplink (permutation) | Band AMC 2x3, 1x3, and 1x6 (Note: 802.16s operation is not defined for PUSC) |
| X | Number of Subchannels used (#Subchannels) | 3, 6, or 12 (based on channel width, in full channel) |
| X | Alpha | Percentage of nominal channel bandwidth used |
|  | Preamble Scheme  | Standard 128 FFT, or modified to fit into effective BW |
| X | Cyclic Prefix | 1/8, 1/16, and 1/32 |
|  | CDMA Codes | Standard 128 FFT, or modified to fit into effective BW |
| X | Frame Size (ms) | Frame Size (ms) 5, 10, 12.5, 20, 25, 40, 50mS |
|  | Duplexing Mode (assumed TDD) | TDD |
|  | Forward Error Correction | CTC mandatory for 802.16s |
| X | UL / DL Ratio Range | Defined in symbols, but supporting a range 10:1 to 1:10. To be defined per frame duration and per channel size |

\* Notes: Sampling frequency has to be selected to address out of band emission regulations.

From 802.16-17-0001r3:

| **Channel Plan for sub 1.25 MHz Channels** |
| --- |
| **Nominal Channel BW** | **Sampling Factor** | **Sampling Clock Frequency** | **Subcarrier Spacing** | **Permutation (AMC2X3 - 3, AMC1X6 - 6)** | **Total # of****Sub channels** | **% of sub channels used in Network** | **Occupied BW1 (includes DC subcarrier)** | **% Nominal Channel BW1** | **# Data+Pilot Sub carriers** | **Samples per 5 ms Frame** | **Rss2 (QPSK-1/2)** |
| **Group 1** | **Slot definition in DL and UL: AMC 1x6, 1 SC in 6 symbols** |
| 0.100 MHz | 109/25  | 0.436 MHz | 3.406 kHz | 6 | 12 | 25.0% | 0.095 MHz | 95.38% | 27 | 2180 | -106.3 dBm |
| 0.150 MHz | 109/25  | 0.654 MHz | 5.109 kHz | 6 | 12 | 25.0% | 0.143 MHz | 95.38% | 27 | 3270 | -104.6 dBm |
| **Group 2** | **Slot definition in DL and UL: AMC 1x6, 1 SC in 6 symbols** |
| 0.200 MHz | 82/25  | 0.656 MHz | 5.125 kHz | 6 | 12 | 33.3% | 0.190 MHz | 94.81% | 36 | 3280 | -103.3 dBm |
| 0.250 MHz | 3 7/25  | 0.820 MHz | 6.406 kHz | 6 | 12 | 33.3% | 0.237 MHz | 94.81% | 36 | 4100 | -102.3 dBm |
| 0.300 MHz | 3 7/25  | 0.984 MHz | 7.688 kHz | 6 | 12 | 33.3% | 0.284 MHz | 94.81% | 36 | 4920 | -101.5 dBm |
| **Group 3** | **Slot definition in DL and UL: AMC 1x6, 1 SC in 6 symbols, or AMC 2x3, 1 SC in 3 symbols** |
| 0.350 MHz | 11/5  | 0.770 MHz | 6.016 kHz | 6 | 12 | 50.0% | 0.331 MHz | 94.53% | 54 | 3850 | -100.8 dBm |
| 0.400 MHz | 2 1/5  | 0.880 MHz | 6.875 kHz | 6 | 12 | 50.0% | 0.378 MHz | 94.53% | 54 | 4400 | -100.3 dBm |
| 0.450 MHz | 2 1/5  | 0.990 MHz | 7.734 kHz | 6 | 12 | 50.0% | 0.425 MHz | 94.53% | 54 | 4950 | -99.8 dBm |
| 0.500 MHz | 2 1/5  | 1.100 MHz | 8.594 kHz | 6 | 12 | 50.0% | 0.473 MHz | 94.53% | 54 | 5500 | -99.3 dBm |
| **Group 4** | **Slot definition in DL and UL: AMC 1x6, 1 SC in 6 symbols, or AMC 2x3, 1 SC in 3 symbols** |
| 0.550 MHz | 28/25 | 0.616 MHz | 4.813 kHz | 3 | 6 | 100% | 0.525 MHz | 95.38% | 108 | 3080 | -98.8 dBm |
| 0.600 MHz | 1 3/25 | 0.672 MHz | 5.250 kHz | 3 | 6 | 100% | 0.572 MHz | 95.38% | 108 | 3360 | -98.4 dBm |
| 0.650 MHz | 1 3/25 | 0.728 MHz | 5.688 kHz | 3 | 6 | 100% | 0.620 MHz | 95.38% | 108 | 3640 | -98.1 dBm |
| 0.700 MHz | 1 3/25 | 0.784 MHz | 6.125 kHz | 3 | 6 | 100% | 0.668 MHz | 95.38% | 108 | 3920 | -97.8 dBm |
| 0.750 MHz | 1 3/25 | 0.840 MHz | 6.563 kHz | 3 | 6 | 100% | 0.715 MHz | 95.38% | 108 | 4200 | -97.5 dBm |
| 0.800 MHz | 1 3/25 | 0.896 MHz | 7.000 kHz | 3 | 6 | 100% | 0.763 MHz | 95.38% | 108 | 4480 | -97.2 dBm |
| 0.850 MHz | 1 3/25 | 0.952 MHz | 7.438 kHz | 3 | 6 | 100% | 0.811 MHz | 95.38% | 108 | 4760 | -96.9 dBm |
| 0.900 MHz | 1 3/25 | 1.008 MHz | 7.875 kHz | 3 | 6 | 100% | 0.858 MHz | 95.38% | 108 | 5040 | -96.7 dBm |
| 0.950 MHz | 1 3/25 | 1.064 MHz | 8.313 kHz | 3 | 6 | 100% | 0.906 MHz | 95.38% | 108 | 5320 | -96.4 dBm |
| 1.000 MHz | 1 3/25 | 1.120 MHz | 8.750 kHz | 3 | 6 | 100% | 0.954 MHz | 95.38% | 108 | 5600 | -96.2 dBm |
| 1.050 MHz | 1 3/25 | 1.176 MHz | 9.188 kHz | 3 | 6 | 100% | 1.001 MHz | 95.38% | 108 | 5880 | -96.0 dBm |
| 1.100 MHz | 1 3/25 | 1.232 MHz | 9.625 kHz | 3 | 6 | 100% | 1.049 MHz | 95.38% | 108 | 6160 | -95.8 dBm |
| 1.150 MHz | 1 3/25 | 1.288 MHz | 10.063 kHz | 3 | 6 | 100% | 1.097 MHz | 95.38% | 108 | 6440 | -95.6 dBm |
| 1.200 MHz | 1 3/25 | 1.344 MHz | 10.500 kHz | 3 | 6 | 100% | 1.145 MHz | 95.38% | 108 | 6720 | -95.4 dBm |

Note: The table includes a spectrum mask factor of 95% (this factor may be adjusted)

# MAC Changes related to overhead reduction

## MAC Layer Modifications for efficiency (From 16-16-0059r0)

1. The standard GMAC[[3]](#footnote-3) header is shown below. The number in bracket indicates the respective field size in bits. This structure is used ion the standard for both the DL and UL MAPs.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| HT (1) | EC(1) | Type (6) | ESF(1) | CI(1) | EKS(2) | Rsv(1) | LEN MSB(3) |
| LEN LSB (8)  | CID MSB (8) |
| CID LSB (8) | HCS (8) |

1. **Modified DLMAP GMAC header structure**: the DLMAP is always the first burst in the DLSF so it can be identified as DLMAP directly. CID indication is therefore not needed at the receiver side. The modified GMAC header consists of 1 byte length field and 1 byte for HCS field.

Modified DLMAP GMAC header:

|  |  |
| --- | --- |
| LEN (8) | HCS (8)  |

1. **Modified ULMAP GMAC header structure:**

* 1. The ULMAP, if present, is the first data burst in the DLSF after DL-MAP, but it may not always be present in a frame in which case, the first burst may carry data traffic. To avoid conflict, we propose to use the first bit HT = 1 as the key to identify the burst as ULMAP.
	2. The modified UL MAP has reserved 7 bits for ULMAP length indication as it cannot exceed 128 bytes.

Modified ULMAP GMAC header:

|  |  |  |
| --- | --- | --- |
| HT (1) | LEN (7) | HCS(8)  |

1. **CRC****:** The standard specifies 32 bit CRC for the PDU. The modified DL/UL MAP has 8 bit CRC. This is justified because the modified MAPs length is drastically reduced. Based on the length field the DLMAP does not exceed 256 bytes and the ULMAP field does not exceed 128 bytes. An 8 bit CRC is sufficient to protect such a short PDU size.

### CID switch IE

1. This IE Indicates whether DL-MAP includes CID information or not. We propose to drop this IE and to always drop the CID information in the modified MAP. This can be done since the CID is also included in the data PDU header. This contributes to 12 bits savings.

### Modified DL MAP IE structure

1. Rectangular burst geometry is replaced by slots allocation, similar to the ULMAP burst structure. Rectangular fitting of DL bursts is replaced with linear filling of DL bursts. The number of slots per downlink burst is transmitted in the DL MAP IE. Slots allocation per burst is continuous by traversing first in frequency and then in time for a given frame configuration. With linear DLMAP structure, the first slot of the next burst is identified by the last slot of the previous burst. The number of slots per burst is sufficient to define the architecture of the burst.
2. CID information is removed in the modified DLMAP. This implies the remote station PHY layer has to decode all downlink bursts. Filtering of the downlink PDUs of interest to a specific remote is done by the MAC layer based on the CID in the data PDU GMAC header.
3. The information per DL MAP IE includes:
	1. DIUC – 4 bits (this field is retained from the standard)
	2. Number of slots per burst – 8 bits (this filed is added).

1. The following fields in the standard DL MAP IE are dropped:
	* N\_CID - The number of CIDs in the burst. This is dropped because the CIDs are not transmitted in the DLMAP.
	* CIDs - This is dropped because the CIDs are not transmitted in the DLMAP.
	* Symbol Offset - This is dropped due to DL MAP IE geometry change
	* Sub-channel Offset - This is dropped due to DL MAP IE geometry change
	* No of Symbols - This is dropped due to DL MAP IE geometry change
	* No of Sub-channels - This is dropped due to DL MAP IE geometry change
	* Boosting – It is proposed to avoid per burst boosting.
	* Repetition - This is dropped because an unused DIUC value is employed to identify QPSK1/2 with repetition 2. Due to the high overhead, repetition 4 and 6 should not be used in narrow channels.

### Modified UL MAP IE structure

1. **IR/HR & PR/BR IEs**

Initial Ranging/Handover Ranging (IR/HR) and Periodic Ranging/Bandwidth Request (PR/BR**)** IEsare used to identify the regions in the ULSF allocated for IR/HR and PR/BR CDMA code transmission.

For 128 FFT, IR/HR and PR/BR extends over a full channel.

The following rules are proposed for the construction of IR and PR IEs:

* IR/HR and PR/BR allocations extend over a fixed number of OFDMA symbols (e.g., 3 symbols @ 1 MHz wide channel).
* IR/HR and PR/BR are not allocated at the same frame.
* IR/HR and PR/BR are always allocated as the first burst in the ULSF.
* IR/HR is identified by UIUC = 12. PR/BR is identified by UIUC = 10.

With the above rules, the need to identify the geometry of IR/HR and PR/BR bursts is avoided.

Fields retained in the IR/PR IE:

* UIUC - 4 bits

The following fields are dropped:

* OFDMA Symbol Offset - Transmission of geometry information not needed
* Sub-channel Offset - Transmission of geometry information not needed
* No of Symbols - Transmission of geometry information not needed
* No of Sub-channels - Transmission of geometry information not needed
* Ranging Method – 0b00 Indicates 2 symbol initial/handover ranging 0b10 Indicates 1 symbol periodic/BR ranging. This is indicated by separate UIUC so dropped
* Ranging Indicator - 0b0 Indicates normal ranging 0b1 Indicates dedicated ranging. This is dropped as we propose to always do normal ranging
* CID – IR and PR bursts are always transmitted using broadcast CID.
1. **DATA Burst IE (UIUC = 1 to 8)**

UL data burst geometry is defined by the “duration” field which contains the number of slots in the burst. Slots allocation per burst is continuous by traversing first in time and then in frequency for a given frame configuration. We propose to drop the repetition field and a new UIUC value for QPSK ½ with repetition 2.

The modified data burst IE includes:

* CID – 16 bits
* UIUC – 4 bits
* Duration – 10 bits
1. **CDMA-ALLOC IE (UIUC = 14)**

CDMA-ALLOC IE identifies the region in the ULSF in which a remote station should transmit a ranging message.

Modified CDMA- ALLOC IE fields:

* UIUC- 4 bits
* Duration – 4 bits (Usually 9 slots allocation so 4 bits are sufficient).
* Frame Number Index- 4 bits. Indicates the frame number in which the CDMA code to which this message responds was transmitted.
* Ranging Code – 8 bits. Indicates ranging code sent by the remote.
* BW request mandatory - Indicates whether the remote shall include a BR in the allocation.

Fields dropped:

* Ranging Symbol - Well known, can be dropped.
* Ranging sub channel - Well known, can be dropped.
1. **Power Control IE** (UIUC = 9)

The standard power control IE which is carried in extended UIUC is replaced with un-used UIUC value 9.

Fields used in the modified power control IE:

* CID – 8 bits
* UIUC – 4 bits
* Power control – 8 bits (change in power level).

Fields dropped:

* Extended UIUC
* Length
* Power Measurement Frame

### MAC Management Message (MMM) Structure

1. **DL MAP MMM Structure Modifications:**

Fields used:

* Frame number: this field is retained from the standard DL MAP MMM but its length is reduced from 24 bites to 16 bits.

Fields dropped:

* Management Message Type = 2

DLMAP is always the 2nd burst (after FCH) in the DLSF and it is carried in every frame. As such, it can be identified without the presence of the type field which therefore can be dropped.

* Frame Duration Code

This field conveys frame duration with which BS is transmitting. For the given deployment, this is well known information so need not be transmitted every frame and hence dropped

* DCD Count

We propose to maintain DIUC to burst profile/FEC code mapping static per deployment and as such, this parameter can be dropped.

* Base Station ID

This information does not need to be carried in DL-MAP every frame. Instead BS can send this information as an additional parameter in registration response. This way this information is exchanges only during network entry which should be sufficient.

* Number Of OFDMA symbols

This filed carrier information about total number of symbols in DL SF

This information changes based on deployment and it is fixed for a given deployment. So it can be statically configured at the remote

1. **UL MAP MMM Structure Modifications:**

Fields used: None

Fields dropped

* Management Message Type = 3

ULMAP is always the 3rd  burst (after FCH and DLMAP) in the DLSF and it is carried in every frame. As such, it can be identified without the presence of the type field which therefore can be dropped.

* FDD Partition flag

This is FDD specific flag hence dropped as system is TDD

* Reserved (7 bits) – not used
* UCD Count

We propose to maintain UIUC to burst profile/FEC code mapping static per deployment and as such, this parameter can be dropped.

* Allocation Start Time

UL allocation start time is relative to start of frame. This is well-known at the remote and can be dropped.

* Number Of OFDMA symbols

This field carries information about total number of symbols in ULSF. This information changes based on deployment and it is fixed for a given deployment. So it can be statically configured at the remote.

Further MAP related changes:

See potential changes to MAP in document [16-16-0051-00-000s-proposed-mac-changes](https://mentor.ieee.org/802.16/dcn/16/16-16-0051-00-000s-proposed-mac-changes.xlsx).

Notes for further discussion:

* Consider increasing periodicity of certain MAC messages. Certain messages could be sent every N frames, depending on their rate of change.
* Encryption Control DL-MAP always non encrypted hence dropped. (Note: need to add explanation of how dropping this does not impact link security, and the MAP encryption was never used)
1. 16-16-0047-01-000s-benefits-of-specific-phy-layer-parameters-to-support-1mhz-channels [↑](#footnote-ref-1)
2. From: 16-16-0047-01-000s-benefits-of-specific-phy-layer-parameters-to-support-1mhz-channels [↑](#footnote-ref-2)
3. In 802.16-2012, GMAC is not used, but spelled out as Generic MAC [↑](#footnote-ref-3)