FullMAX vs Standard IEEE 802.16 Air Interface Protocol Overhead

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## General

1. The FullMAX air interface protocol overhead consists of the following overhead components:
	1. PHY layer overhead
	2. Per-frame overhead
	3. MAC layer overhead

These overhead components are discussed in details in this document.

1. Overhead reduction and high frequency utilization is essential to maintain broadband experience in the relatively narrow channels for which the ieee802.16s standard is designed.

## PHY Layer Overhead

1. Guard band:
	1. As an unused portion of the available band, the guard bands can be viewed a PHY overhead component. Minimization of this overhead is done by maximizing the sampling clock to fit the active subcarriers within the available band subject to the applicable FCC spectrum mask (e.g., FCC Part 27 for the Upper 700 MHz A Block). Full Spectrum proposal with sampling clock = 1.12 MHz and band AMC, results in all 108 active subcarriers occupying 945 KHz in both downlink (including preamble) and uplink direction.

* 1. As an example with PUSC, a different number of active subcarriers is used for the preamble, for the data portion of the DLSF and for the ULSF. The sampling clock has to be adjusted based on the preamble (which employs the highest number of active subcarriers) but the rest of the symbols in both DLSF and ULSF employ a much smaller number of active subcarriers. Bandwidth is effectively “left on the table”.

1. Subcarrier overhead:

This is due to the pilots and the DC subcarriers. The guard subcarriers are not considered overhead because the sampling clock can be adjusted such that the active subcarriers fall within the available band subject. Minimization of subcarrier overhead is therefore accomplished by minimizing the number of pilots subject to the coherent bandwidth. Assuming a maximum delay spread of 10 µs, coherent bandwidth = 100 KHz. Full Spectrum AMC 3X2 and AMC 6X1 proposal has 12 pilots across the 1 MHz channel, i.e., the pilot spacing @ 1 MHz channel is 83 KHz.

1. CP overhead:

FullMAX currently employ CP = 1/8, i.e., 16 samples for 128 FFT. For a sampling clock of 1.12 MHz, CP = 14.28 µs relative to the standard WiMAX CP = 11.4µs. Except for very extreme cases, the delay spread is significantly lower than 7 µs so we could go with CP = 1/16 which will reduce PHY layer overhead relative to CP = 1/8, by 6.25%.

1. Modulation and coding:

The CINR needed for 64QAM5/6 (the highest utilization scheme) is 24 dB. We could add a higher utilization scheme which may be applicable to certain (non-common) deployments.

## Per-Frame Overhead

1. General:

The per-frame overhead includes the preamble, FCH, the DL-MAP and the UL-MAP all of which are carried in every DLSF. As such, the per-frame percentage overhead increases as the frame capacity is reduced, i.e., as the frame duration is smaller and as the number of sub-channels is lower. The per-frame overhead components are broadcast messages which need to be received by all remotes in the sector. As such, a robust modulation and coding schemes (typically QPSK ½) is used.

1. Preamble:

The preamble is one symbol long. It is used by the remote to derive RF frequency, sampling clock and TDD frame synchronization. FullMAX supports a local GPS based synchronization mode which enables preamble removal.

1. DL and UL MAP:
	1. The standard DL and UL MAPs have an ieee802.16 MAC PDU structure. As such, they have a 10 bytes PDU overhead which consists of GMAC header and CRC.
	2. DL and UL MAP size reduction is done based on the following principles:
		1. Well known information should not be transmitted.
		2. Remove unwanted bits from IEs.
		3. Information which may change from frame to frame, should be encoded in IEs using minimum number of bits.
		4. Change the allocation definition in DL MAP as in UL MAP where only numbers of slots are conveyed in IEs. BS and RS should identify allocation geometry (time and frequency) by traversing first in frequency and then time for a given frame configuration. This also has an extra benefit of saving the rectangular fitting algorithm overhead.
		5. Reduce GMAC header to minimum size for MAP messages
		6. Reduce CRC size as these messages are less than 64 bytes long.
	3. The FullMAX DL MAP structure is shown in table 2 below. The compressed DL MAP size (relative to the standard length in parenthesis) is computed as follows:
		1. Reduced  DL MAP Length   =  2 bytes  ( Common DL MAP parameters ) from 14.5 bytes so reduction by 12.5 bytes
		2. Reduced DL-MAP\_IE Length  =  1.5 bytes from 7.5 bytes so reduction by 6 bytes
		3. Reduced PDU overhead = 3 bytes from 10 bytes so reduction by 7 bytes
		4. Reduced Minimum  DLMAP Length =  DL MAP Length + Length of DL-MAP\_IE  (carrying ULMAP message) + PDU Overhead (CRC+GMH)
		                 = 2 (14.5) bytes +1.5 (7.5) bytes + 3 bytes (10 bytes)
		                = 6.5 (32) bytes
		5. Example 1: (For one type of FEC burst information is carried in DL-MAP):

 1 Burst = Minimum  DLMAP Length + 1 DL-MAP\_IE
                   = 6.5 (32) + 1 \*1.5 (1\*7.5) bytes

                   = 8 (39.5 ) bytes so savings of 31.5 bytes

 = 2 slots @ QPSK1/2 so saving of 6 slots

* + 1. Example 2: (For worst case where 7 different types of FEC burst information is carried in DL-MAP):

 7 Burst =  Minimum  DLMAP Length + 7 DL-MAP\_IE
                   = 6.5 (32) + 7 \*1.5 (7\*7.5) bytes

                   = 17 (84.5 ) bytes so savings of 67.5 bytes

 = 3 slots @ QPSK1/2 so saving of 12 slots

* + 1. Table 1 below computes DL MAP size and overhead for standard MAC and for FullMAX MAC under the same configuration alternatives used in table 1 in your document. Lines #35 to #41 computes the slot overhead in a standard system and lines #42 to #48 computes the slot overhead for FullMAX. Couple of comments:
			- The computation is done for frequency re-use (1,3,3) with two AMC 3X2 sub-channels up and down.
			- The computation for the standard ieee802.16 case still assumes AMC permutations. I did not do the calculation for 512 FFT but I believe the DL MAP overhead will be the same if AMC is used. The percentage overhead will be even worse if PUSC is used. In addition, 512 FFT has 3 additional overhead slots because 512 FFT FCH employs 4 slots relative to a single slot in the case of 128 FFT.
			- The computation is done for AMC 3X2 and not for AMC 6 X 1. I expect however the overhead to be the same if the number of AMC6X1 sub-channels is twice the number of AMC 3X2 sub-channels.

**Table 1: DL MAP Overhead for Standard ieee802.16 vs FullMAX**



Table 2: DL MAP in FullMAX vs the ieee802.16 standard

|  |  |  |  |
| --- | --- | --- | --- |
| **S.NO** | **Features** | **As per Standard** **in bits** | **FullMAX Implementation in bits** |
| DL-MAP |
| 1 | DL-MAP MMM | 8  | **0** |
| 2 | Frame Duration Code  | 8  | **0** |
| 3 | Frame Number | 24  | **16** |
| 4 | DCD Count | 8  | **0** |
| 5 | BSID  | 48  | **0** |
| 6 | Number Of OFDMA symbols  | 8  | **0** |
| DL-MAP IE- If DIUC = 15 CID Switch IE |
| 1 | DIUC | 4  | **0** |
| 2 | Extended DIUC | 4  | **0** |
| 3 | Length | 4  | **0** |
| DL-MAP IE - If DIUC between 0 to 12 |
| 1 | DIUC | 4  | 4 |
| 2 | N\_CID (Number of CIDs) | 8  | **0** |
| 3 | CIDs (array of CIDs)  | 16  | **0** |
| 4 | Symbol Offset (Number of slots) | 8  | 8 |
| 5 | Subchannel Offset | 6  | **0** |
| 6 | No of Symbols | 7  | **0** |
| 7 | No of Sub-channels | 6  | **0** |
| 8 | Boosting | 3  | **0** |
| 9 | Repetition | 2  | **0** |
|  |  |  |  |
| GMAC header and CRC |
| 1 | HT | 1 | **0** |
| 2 | EC | 1 | **0** |
| 3 | Type | 6 | **0** |
| 4 | ESF | 1 | **0** |
| 5 | CI | 1 | **0** |
| 6 | EKS | 2 | **0** |
| 7 | Rsv | 1 | **0** |
| 8 | LEN | 11 | **8** |
| 9 | CID | 16 | **0** |
| 10 | HCS | 8 | 8 |
| 11 | CRC | 32 | **8** |

* 1. The FullMAX UL MAP structure is shown in table 3 below. The compressed UL MAP size (relative to the standard length in parenthesis) is computed as follows:
* For common part 8 bytes saved compared to standard
* For data 1.5 bytes saved compared to standard
* For CDMA-Alloc IE 4 bytes saved compared to standard
* For IR/PR 5 bytes saved compared to standard
* For Power Control 3 bytes saved compared to standard
* For PAPR 4.5 bytes saved compared to standard

**Example 1**: ULMAP size with 4 remotes transmitting within 1 ULSF + ranging allocation + CDMA alloc IE

1 IR/PR UL-MAP\_IE + 4 data UL-MAP\_IE + 1 CDMA-Alloc-IE =

Minimum  ULMAP Length + 1 IR/PR UL-MAP\_IE  + 4 data UL-MAP\_IE + 1 CDMA-Alloc-IE + PDU Overhead

 = 0 byte (32 bytes) + 1.5 bytes (6.5 bytes) + 4\* 2.5 bytes (4\*4 bytes) + 3.5 bytes (7.5 bytes) + 3 bytes (10 bytes)

 = 18 bytes (72 bytes) so 54 bytes saving i.e. @ QPSK ½ 9 slots savings

**Example 2:** ULMAP size with 1 remote transmitting per 1 ULSF and ignoring any periodic allocation

**1 data UL-MAP\_IE** =

 Minimum  ULMAP Length + 1 data UL-MAP\_IE + PDU Overhead

 = 0 byte (32 bytes) + 1\* 2.5 bytes (1\*4 bytes) + 3 bytes (10 bytes)

 = 5.5 bytes (46 bytes) so 40.5 bytes saving i.e. @ QPSK ½ 7 slots savings

**2 data UL-MAP\_IE** =

 Minimum  ULMAP Length + 1 data UL-MAP\_IE + PDU Overhead

 = 0 byte (32 bytes) + 2\* 2.5 bytes (2\*4 bytes) + 3 bytes (10 bytes)

 = 8 bytes (50 bytes) so 42 bytes saving i.e. @ QPSK ½ 7 slots savings

Table 3: UL MAP in FullMAX vs the ieee802.16 standard

|  |  |  |  |
| --- | --- | --- | --- |
| **S.NO** | **Features** | **As per Standard** **in bits** | **FullMAX Implementation** |
| 1 | ULMAP MMM | 8 | **0** |
| 2 | FDD Partition flag | 1 | **0**  |
| 3 | Reserved | 7 | **0** |
| 4 | UCD Count | 8  | **0** |
| 5 | Allocation Start Time | 32  | **0**  |
| 6 | Number Of OFDMA symbols | 8  | **0**  |
| ULMAP IE (common to all burst type)  |
| 1 | CID | 16  | **8** |
| 2 | UIUC | 4  | 4 |
| If UIUC = 12 IR IE / UIUC = 10 PR IE |
| 1 | OFDMA Symbol Offset | 8  | **0** |
| 2 | Sub-channel Offset | 7  | **0** |
| 3 | No of Symbols | 7  | **0** |
| 4 | No of Sub-channels | 7  | **0** |
| 5 | Ranging Method | 2  | **0** |
| 6 | Ranging Indicator | 1  | **0**  |
| If UIUC = 13 PAPR IE |
| 1 | OFDMA symbol offset | 8 | **4** |
| 2 | Sub-channel offset | 7 | **0** |
| 3 | No. OFDMA symbols | 7 | **0** |
| 4 | No. sub-channels/SZ Shift Value | 7 | **0** |
| 5 | PAPR Reduction/Safety Zone | 1 | **0** |
| 6 | Sounding Zone | 1 | **0** |
| 7 | *Reserved* | 1 | **0** |
| If UIUC = 1 to 8 DATA BURST IE |
| 1 | Duration | 10 | **8** |
| 2 | Repetition coding indication | 2 | **0** |
| If UIUC = 14 CDMA-ALLOC-IE |
| 1 | Duration  | 6 | **4** |
| 2 | UIUC  | 4 | 4 |
| 3 | Repetition Coding Indication  | 2 | **0** |
| 4 | Frame Number Index  | 4 | 4 |
| 5 | Ranging Code  | 8 | **4** |
| 6 | Ranging Symbol  | 8 | **0** |
| 7 | Ranging sub channel  | 7 | **0** |
| 8 | BW request mandatory  | 1 | **0** |
| If UIUC = 15 Extended UIUC for power control (We have changed UIUC =9) |
| 1 | Extended UIUC | 4 | **0** |
| 2 | Length | 4 | **0** |
| 3 | Power Control  | 8 | 8 |
| 4 | Power Measurement Frame | 8 | **0** |
| **GMAC header and CRC** |
| 1 | HT | 1 | 1 |
| 2 | EC | 1 | **0** |
| 3 | Type | 6 | **0** |
| 4 | ESF | 1 | **0** |
| 5 | CI | 1 | **0** |
| 6 | EKS | 2 | **0** |
| 7 | Rsv | 1 | **0** |
| 8 | LEN | 11 | **7** |
| 9 | CID | 16 | **0** |
| 10 | HCS | 8 | 8 |
| 11 | CRC | 32 | **8** |

## MAC PDU Overhead

##

1. General

The MAC PDU overhead is due to the IEEEE 802.16 GMAC header and CRC which is added in the process of encapsulating the SDU into an IEEE 802.16 PDU. The basic standard GMAC header is 10 bytes long. It becomes a significant overhead component in the following scenarios:

* 1. When the traffic has significant percentage of small SDUs
	2. When the capacity of the DLSF/ULSF is small resulting in fragmentation of long SDUs into small fragments
1. PDU overhead for small SDUs:
	1. In addition to the GMAC header overhead, IP SDUs have substantial additional percentage overhead including 14 bytes Ethernet header + 20 bytes IP header + UDP/TCP header + possible higher layer headers. A large portion of these headers can be compressed using Packet Header Suppression (PHS) which leads to even shorter compressed SDUs. Example:
		1. SDU size = 64 byte
		2. Compressed SDU size = 36 bytes (In the general case, at least 28 bytes can be suppressed).
		3. Standard MAC PDU size: 10 bytes
		4. MAC PDU overhead = 10/46 = 22%

The GMAC header size can be slightly reduced but this does not offer a substantial improvement. The best way to reduce PDU overhead is to pack multiple short SDUs in one long PDU.

* 1. MAC PDU Reduction by packing short SDUs:
		1. The standard IEEE 802.16 MAC layer supports packing of multiple SDUs of the same service flow into one long PDU. One 10 byte common GMAC header is used for the entire PDU plus a 4 byte sub-header is added to each SDU. Packing works well in the uplink direction because typically, the remote stations have only few service flows and a typical data session will be mostly related to a single service flow at any point of time. In the downlink however, given the base station serves a large number of remotes, the traffic typically consists of packets belonging to multiple service flows and as such, they cannot be packed in a single PDU.
		2. The solution to the above limitation is to enable in the downlink, packing of packets of different service flows as long as the downlink FEC code of the respective remotes is the same.
1. Fragmentation due to limited capacity of the DLSF/ULSF:

Fragmentation should be minimized by configuring the frame duration, the number of sub-channels in the downlink and in the uplink direction (while considering the downlink and uplink FEC codes), for sufficient DLSF and ULSF capacity to carry the bulk of the traffic un-fragmented. As in the case of per-frame overhead, this emphasizes the need to support extended frame sizes as the channel bandwidth/# of sub-channels is reduced.