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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <**<http://ieee802.org/16>**>** | |
| Title | **Representative Channel Performance for 802.16s** | |
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| Re: | IEEE 802.16s GRIDMAN Task Group | |
| Abstract | Performance for selected channel bandwidths from 0.100 MHz to 1.000 MHz with parameters based on draft 802.16s amendment to IEEE Std 802.16-20xx. | |
| Purpose | This is intended to provide further channel performance details for inclusion in SDD GRIDMAN Document | |
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The following table corrects an error in row 33, ‘TR-Gap Symbols for 40 mi Range’, from version in 16-17-0017-01-000s

**Table 1: OFDMA parameters and channel performance estimates for selected channel bandwidths**

| **1** | **Parameter** | **Channel Bandwidth** | |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **2** | **Nominal Channel BW** | **1.00 MHz** | **0.75 MHz** | **0.50 MHz** | **0.25 MHz** | **0.10 MHz** |
| 3 | FFT | 128 | 128 | 128 | 128 | 128 |
| 4 | Permutation | AMC 2x3 | AMC 2x3 | AMC 1x3 | AMC 1x3 | AMC 1x3 |
| 5 | DC Subcarriers | 1 | 1 | 1 | 1 | 1 |
| 6 | Guard Subcarriers - Left | 10 | 10 | 10 | 10 | 10 |
| 7 | Guard Subcarriers - Right | 9 | 9 | 9 | 9 | 9 |
| 8 | % Subchannels Used | 100% | 100% | 50% | 33% | 25% |
| 9 | Used Subcarriers (Pilots+Data) | 108 | 108 | 54 | 36 | 27 |
| 10 | Pilot Subcarriers | 12 | 12 | 6 | 4 | 3 |
| 11 | Data Subcarriers | 96 | 96 | 48 | 32 | 24 |
| 12 | Number of Inband Subchannels | 6 | 6 | 6 | 4 | 3 |
| 13 | Data Subcarriers per Subchannel | 16 | 16 | 8 | 8 | 8 |
| 14 | Pilot Subcarriers per Subchannel | 2 | 2 | 1 | 1 | 1 |
| 15 | Sampling Factor | 28/25 | 28/25 | 11/5 | 82/25 | 109/25 |
| 16 | Sampling Frequency (Clock) | 1.120 MHz | 0.840 MHz | 1.100 MHz | 0.820 MHz | 0.436 MHz |
| 17 | Subcarrier Spacing | 8.750 kHz | 6.563 kHz | 8.594 kHz | 6.406 kHz | 3.406 kHz |
| 18 | Occupied BW (incl DC Subcarrier) | 0.954 MHz | 0.715 MHz | 0.473 MHz | 0.237 MHz | 0.095 MHz |
| 19 | Occupied BW % of Nominal BW | 95.38% | 95.38% | 94.53% | 94.81% | 95.38% |
| 20 | Subchannel BW (excludes DC SC) | 0.158 MHz | 0.118 MHz | 0.077 MHz | 0.058 MHz | 0.031 MHz |
| 21 | Symbol Time-microsec | 114.29 us | 152.38 us | 116.36 us | 156.10 us | 293.58 us |
| 22 | Cyclic Prefix | 1/16 | 1/16 | 1/16 | 1/16 | 1/16 |
| 23 | Guard Time-microsec | 7.14 us | 9.52 us | 5.95 us | 7.52 us | 8.93 us |
| 24 | Symbol Duration-microsec | 121.43 us | 161.90 us | 122.32 us | 163.62 us | 302.51 us |
| 25 | Frame Duration-millisec | 5.0 ms | 5.0 ms | 5.0 ms | 10.0 ms | 20.0 ms |
| 26 | Frames per Second | 200 | 200 | 200 | 100 | 50 |
| 27 | Samples per Frame | 5600 | 4200 | 5500 | 8200 | 8720 |
| 28 | Total OFDMA Symbols per Frame | 41 Symbols | 30 Symbols | 40 Symbols | 61 Symbols | 66 Symbols |
| 29 | Symbols for TR Gap | 1 Symbol | 1 Symbol | 1 Symbol | 1 Symbol | 1 Symbol |
| 30 | OFDMA Symbols per Frame (after TR Gap) | 40 Symbols | 29 Symbols | 39 Symbols | 60 Symbols | 65 Symbols |
| 31 | TTG+RTG Gap in microsec | 142.86 us | 304.76 us | 229.68 us | 183.02 us | 337.07 us |
| 32 | Range Limit for selected TR-Gap | 13.31 mi | 28.39 mi | 21.39 mi | 17.05 mi | 31.40 mi |
| 33 | TR-Gap Symbols for 40 mi range | 3 Symbols | 3 Symbols | 3 Symbols | 3 Symbols | 2 Symbols |
| 34 | N = # Bins | 2 Bins | 2 Bins | 1 Bins | 1 Bins | 1 Bins |
| 35 | M = # Symbols | 3 Symbols | 3 Symbols | 3 Symbols | 3 Symbols | 3 Symbols |
| 36 | Preamble Overhead | 1 Symbol | 1 Symbol | 1 Symbol | 1 Symbol | 1 Symbol |
| 37 | UL OH Symbols (CQICH\*, ACK\*,Ranging) | 1 Symbol | 1 Symbol | 1 Symbol | 1 Symbol | 1 Symbol |
| 38 | Net OFDMA Symbols per Frame | 38 Symbols | 27 Symbols | 37 Symbols | 58 Symbols | 63 Symbols |
| 39 | Slots per Sector/Frame for Reuse 1,3,3 | 24 Slots | 18 Slots | 24 Slots | 19 Slots | 21 Slots |
| 40 | DL-MAP (bits) | 60 Bits | 60 Bits | 60 Bits | 60 Bits | 60 Bits |
| 41 | DL-MAP (Bytes) | 8 Bytes | 8 Bytes | 8 Bytes | 8 Bytes | 8 Bytes |
| 42 | UL-MAP (bits | 139 bytes | 139 bytes | 139 Bits | 139 Bits | 139 Bits |
| 43 | UL-MAP (Bytes) | 18 bytes | 18 bytes | 18 Bytes | 18 Bytes | 18 Bytes |
| 44 | Frame Control Header (FCH) | 1 Slot | 1 Slot | 2 Slot | 2 Slot | 2 Slot |
| 45 | Bytes per Slot at QPSK-1/2 (1 rep) | 6 Bytes | 6 Bytes | 3 Bytes | 3 Bytes | 3 Bytes |
| 46 | Total # OH Slots for DL-MAP+UL-MAP+FCH | 6 Slots | 6 Slots | 11 Slots | 11 Slots | 11 Slots |
| 47 | UL+DL Data Slots/Sector for scheduling | 18 Slots | 12 Slots | 13 Slots | 8 Slots | 10 Slots |
| 48 | Desired UL/DL Data Ratio | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| 49 | UL Data Slots/Sector for scheduling | 12 Slots | 8 Slots | 9 Slots | 6 Slots | 7 Slots |
| 50 | DL Data Slots/Sector for scheduling | 6 Slots | 4 Slots | 4 Slots | 2 Slots | 3 Slots |
| 51 | Unused Symbols | 2 Symbols | 0 Symbols | 1 Symbols | 1 Symbols | 0 Symbols |
| 52 | Actual UL/DL Data Slot Ratio | 2.00 | 2.00 | 2.25 | 3.00 | 2.33 |
| 53 | Avg SE over Coverage Area | 2.0 bps/Hz | 2.0 bps/Hz | 2.0 bps/Hz | 2.0 bps/Hz | 2.0 bps/Hz |
| 54 | Peak Bytes/Slot (64QAM-5/6) | 30 Bytes | 30 Bytes | 15 Bytes | 15 Bytes | 15 Bytes |
| 55 | Cell Edge Bytes/Slot (QPSK-1/2) | 6 Bytes | 6 Bytes | 3 Bytes | 3 Bytes | 3 Bytes |
| 56 | Avg Bytes/Slot | 12.0 Bytes | 12.0 Bytes | 6.0 Bytes | 6.0 Bytes | 6.0 Bytes |
| 57 | OTA Sector Rate for Reuse (1,3,3) & (SISO) |  |  |  |  |  |
| 58 | Peak UL PHY Rate per Sector | 576.0 kbps | 384.0 kbps | 216.0 kbps | 72.0 kbps | 42.0 kbps |
| 59 | Avg UL PHY Rate per Sector | 230.4 kbps | 153.6 kbps | 86.4 kbps | 28.8 kbps | 16.8 kbps |
| 60 | Peak DL PHY Rate per Sector | 288.0 kbps | 192.0 kbps | 96.0 kbps | 24.0 kbps | 18.0 kbps |
| 61 | Avg DL PHY Rate per Sector | 115.2 kbps | 76.8 kbps | 38.4 kbps | 9.6 kbps | 7.2 kbps |
| 62 | OTA Cell Rate for Reuse (1,3,3) & (SISO) |  |  |  |  |  |
| 63 | Avg UL PHY Rate per Cell | 691.2 kbps | 460.8 kbps | 259.2 kbps | 115.2 kbps | 50.4 kbps |
| 64 | Avg DL PHY Rate per Cell | 345.6 kbps | 230.4 kbps | 115.2 kbps | 38.4 kbps | 21.6 kbps |
| 65 | Avg Cell Spectral Efficiency | 1.04 bps/Hz | 0.92 bps/Hz | 0.75 bps/Hz | 0.61 bps/Hz | 0.72 bps/Hz |
| 66 |  |  |  |  |  |  |
| 67 | Subchannels included in per-cell OTA rate but not in per-sector rate | 0 | 0 | 0 | 1 | 0 |
| 68 |  |  |  |  |  |  |
| 69 | Maximum UL:DL or DL:UL Data Slot Ratio | > 10:1 | > 10:1 | > 10:1 | 7 | 9 |
| 70 | Increased Latency Relative to 5 ms Frame | 0 ms | 0 ms | 0 ms | 10 ms | 30 ms |

The following tables and graphs provide further details and design trade-offs for the channel performance based on proposed IEEE 802.16s amendment.

**FRAME DURATION OPTIONS:**

**Table 2: Frame durations for channel sub-group 4 per P80216s, Clause 12.9**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Subgroup 4 (1.20 to 0.55 MHz in 50 kHz increments)** | | | |
| **Nominal Channel BW** | **1.20 MHz** | **1.00 MHz** | **0.75 MHz** | **0.55 MHz** |
| **Permutation** | **AMC 2x3 or AMC 1x6** | **AMC 2x3 or AMC 1x6** | **AMC 2x3 or AMC 1x6** | **AMC 2x3 or AMC 1x6** |
| **Minimum Frame Duration** | 5.0 ms | 5.0 ms | 5.0 ms | 5.0 ms |
| **Alternative Frame Durations** | 10.0 ms | 10.0 ms | 10.0 ms | 10.0 ms |
|  | 12.5 ms | 12.5 ms | 12.5 ms | 12.5 ms |
|  | 20.0 ms | 20.0 ms | 20.0 ms | 20.0 ms |
|  | 25.0 ms | 25.0 ms | 25.0 ms | 25.0 ms |

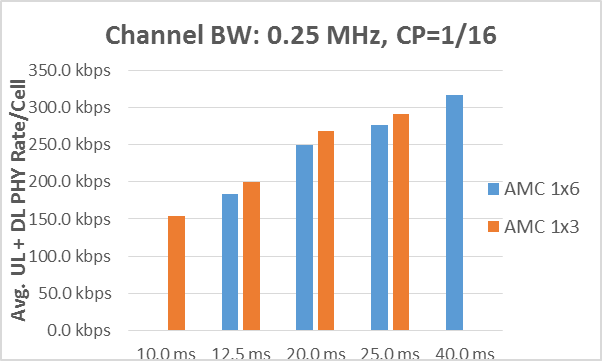
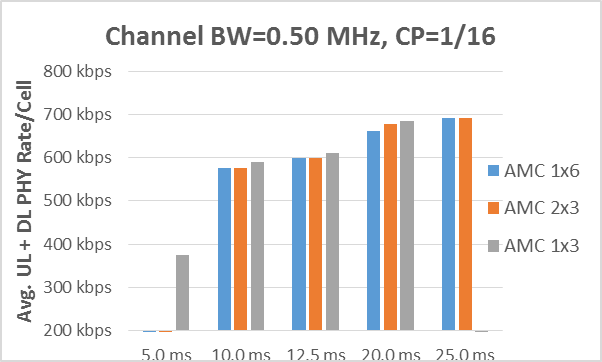
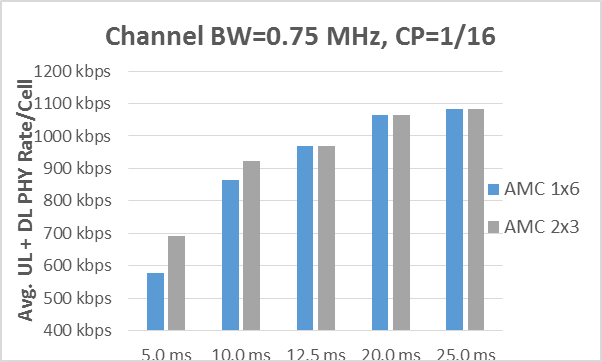
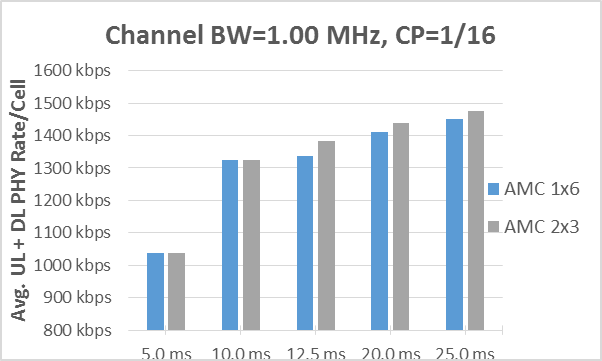
**Table 3: Frame durations for channel sub-groups 3, 2, and 1 per P80216s, Clause 12.9**

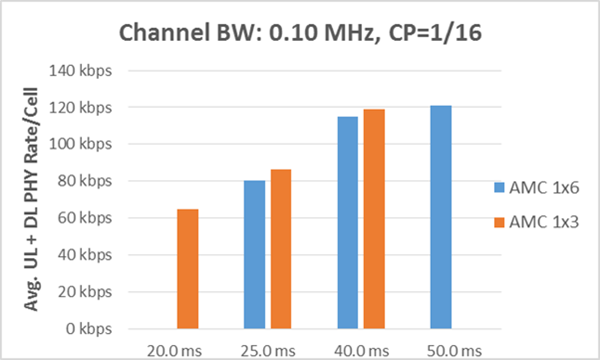
|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Subgroup 3** | | | | **Subgroup 2** | | | **Subgroup 1** | |
| **Nominal Channel BW** | **0.50 MHz** | **0.45 MHz** | **0.40 MHz** | **0.35 MHz** | **0.30 MHz** | **0.25 MHz** | **0.20 MHz** | **0.15 MHz** | **0.10 MHz** |
| **Permutation** | **AMC 1x3** | **AMC 1x3** | **AMC 1x3** | **AMC 1x3** | **AMC 1x3** | **AMC 1x3** | **AMC 1x3** | **AMC 1x3** | **AMC 1x3** |
| **Minimum Frame Duration** | 5.0 ms | 5.0 ms | 5.0 ms | 5.0 ms | 10.0 ms | 10.0 ms | 12.5 ms | 12.5 ms | 20.0 ms |
| **Alternative Frame Durations** | 10.0 ms | 10.0 ms | 10.0 ms | 10.0 ms | 12.5 ms | 12.5 ms | 20.0 ms | 20.0 ms | 25.0 ms |
| 12.5 ms | 12.5 ms | 12.5 ms | 12.5 ms | 20.0 ms | 20.0 ms | 25.0 ms | 25.0 ms | 40.0 ms |
| 20.0 ms | 20.0 ms | 20.0 ms | 20.0 ms | 25.0 ms | 25.0 ms | 40.0 ms | 40.0 ms |  |
| **Permutation** | **AMC 2x3 or AMC 1x6** | **AMC 2x3 or AMC 1x6** | **AMC 2x3 or AMC 1x6** | **AMC 2x3 or AMC 1x6** | **AMC 1x6** | **AMC 1x6** | **AMC 1x6** | **AMC 1x6** | **AMC 1x6** |
| **Minimum Frame Duration** | 10.0 ms | 10.0 ms | 10.0 ms | 10.0 ms | 12.5 ms | 12.5 ms | 20.0 ms | 20.0 ms | 25.0 ms |
| **Alternative Frame Durations** | 12.5 ms | 12.5 ms | 12.5 ms | 12.5 ms | 20.0 ms | 20.0 ms | 25.0 ms | 25.0 ms | 40.0 ms |
| 20.0 ms | 20.0 ms | 20.0 ms | 20.0 ms | 25.0 ms | 25.0 ms | 40.0 ms | 40.0 ms | 50.0 ms |
| 25.0 ms | 25.0 ms | 25.0 ms | 25.0 ms | 40.0 ms | 40.0 ms | 50.0 ms | 50.0 ms |  |

**CHANNEL THROUGHPUT VS. FRAME DURATION AND PERMUTATION CHOICE**

Assumptions for the following graphs are as follows:

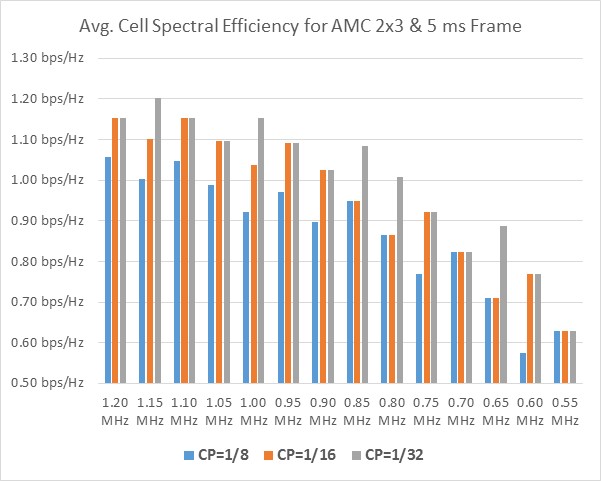
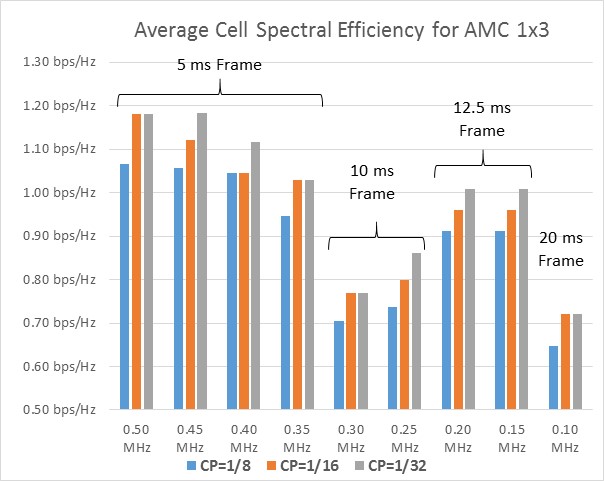
* Antenna: Single Input Single Output (SISO)
* Frequency reuse: Reuse 3, (1,3,3)
* Deployment: Uniform end-point distribution with uniform propagation characteristics over cell coverage area, average spectral efficiency over coverage area of 2 bps/Hz
* TR Gap: 1 Symbol
* Cyclic prefix: 1/16
* Frame duration: Per Table 2 and Table 3



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**IMPACT OF CYCLIC PREFIX** (at minimum recommended frame duration)

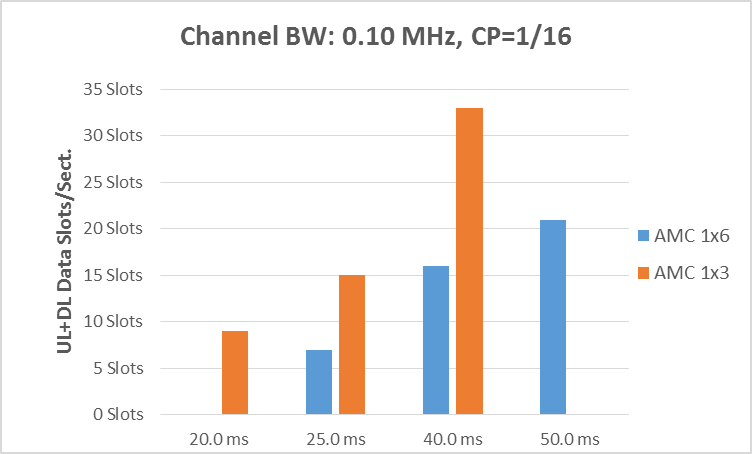
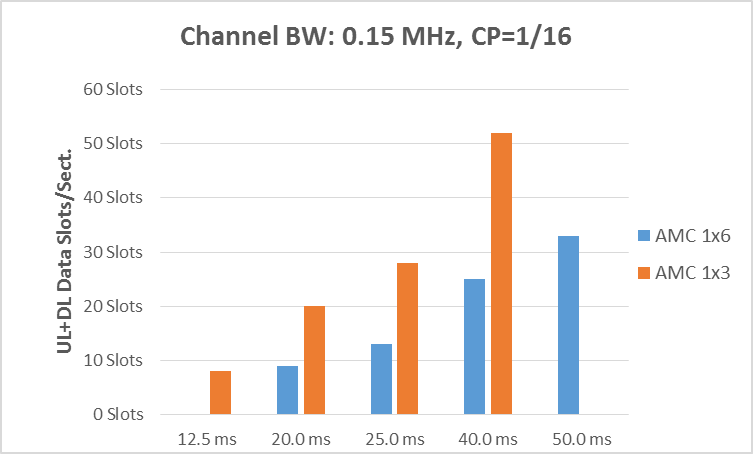
A reduced cyclic prefix will generally add throughput at the cost of increased potential for inter-symbol- interference (ISI). In many cases however, the number of added symbols due to a reduced cyclic prefix will not be sufficient to add an additional data slot, which for AMC 1x3 or AMC 2x3 requires a minimum of 3 additional symbols. In these cases a larger cyclic prefix is recommended unless additional symbols are required for a larger TR gap to support an increased propagation range.



**ADAPTIVE TDD SPLIT (10:1 TARGET)**

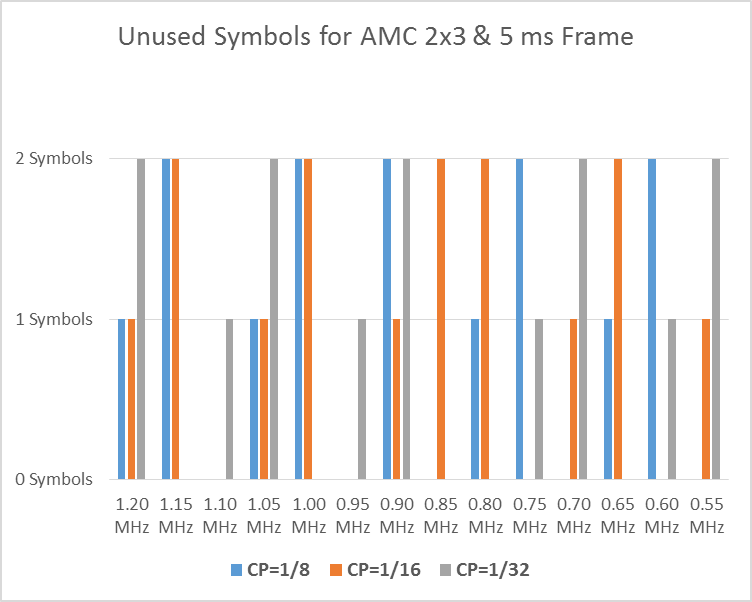
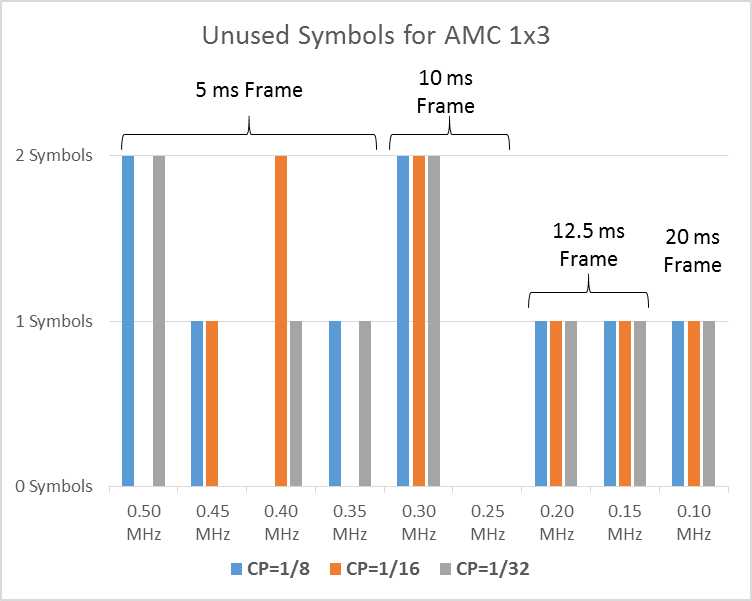
To support UL/DL or DL/UL ratios greater than or equal to 10, it is necessary to have 11 or more DATA SLOTS for scheduling. All channel bandwidths in subgroup 4 (1.2 MHz to 0.55 MHz) will support ATDD splits > 10:1 with either AMC 2x3 or AMC 1x6 and a frame duration ≥5 ms.

With smaller channel bandwidths it will be necessary to trade off LATENCY with the desired ATDD SPLIT. This is clearly illustrated in the following bar charts for channel bandwidths of 0.15 MHz and 0.10 MHz. Whereas, a 12.5 ms and 20 ms frame duration respectively, will provide a reasonable net throughput, the UL/DL or DL/UL ratio is limited to 7:1 and 8:1 respectively. A 20 ms and 25 ms frame duration with band AMC 1x3 is required for an ATDD split ≥ 10:1 for 0.15 MHz and 0.10 MHz BW respectively.



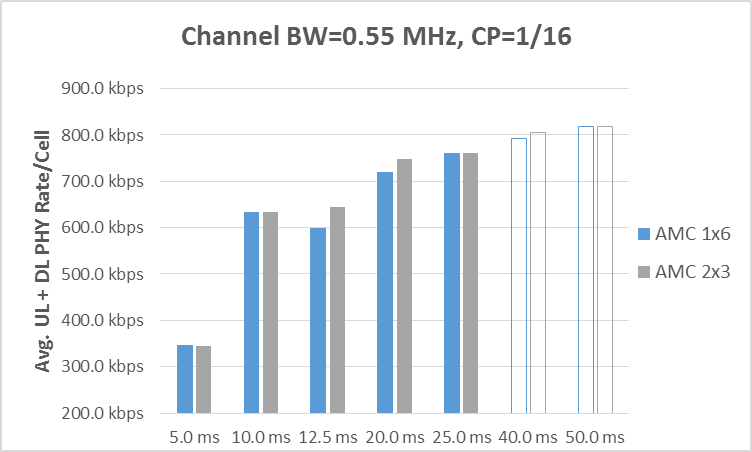
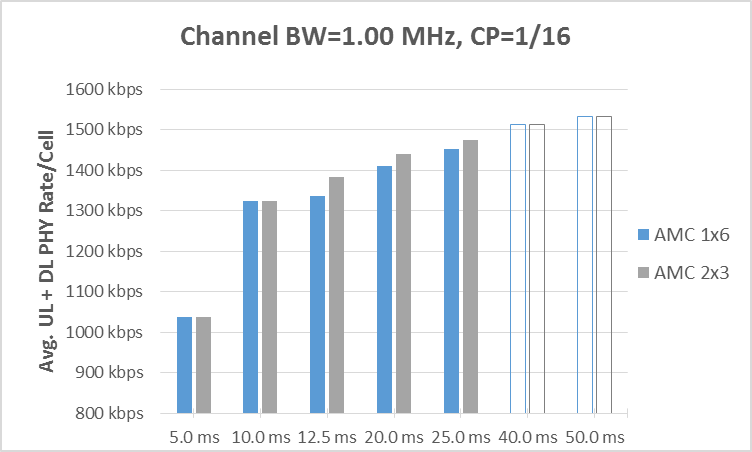
**40 MILE RANGE REQUIREMENT AND UNUSED SYMBOLS**

All of the above examples assume a TR Gap of 1 symbol and, as shown on row 32 in Table 1, supports a range of 13 to 31 miles for the channel BWs shown in the table. To achieve a 40 mile range as many as 3 additional symbols (Table 1, row 33) will be required for the TR-Gap. Since the available number of symbols must be a multiple of 3 for AMC 2x3 or AMC 1x3 and a multiple of 6 for AMC 1x6, there will, in many cases, be some unused symbols. These unused symbols can be allocated to the TR-Gap for increased range without impacting the throughput. The following shows the unused symbols with AMC 2x3 for channel bandwidths ≥ 0.55 MHz and with AMC 1x3 permutation for channel bandwidths between 0.50 MHz and 0.10 MHz.



**FRAME DURATION UP TO 50 MS FOR CHANNEL SUBGROUP 4**

As summarized in Tables 2 and 3, frame durations of 40 and 50 ms were not recommended profiles for channel bandwidths in subgroups 3 and 4. These large frame durations are not recommended due to the tradeoff between significantly increased latency for only a marginal improvement in throughput. The following graphs illustrate this for a 1.0 MHz and 0.55 MHz channel BW where frame durations of 40 ms and 50 ms are shown.



The throughput gain for increasing the frame duration from 25 ms to 40 ms and, subsequently to 50 ms is under 5% and under 2% respectively for a 1.0 MHz channel BW and about 6 % and 1.4 % for a 0.55 MHz channel BW. The latency, on the other hand will increase 60% for a frame duration of 40 ms and an additional 25% for a 50 ms frame duration.

The graph for 0.55 MHz channel BW also illustrates another issue that may arise with different parameter choices. Note that while increasing the frame duration from 10 ms to 12.5 ms provides a small (~1 %) increase in throughput for AMC 2x3, it results in a throughput decrease of almost 6 % for AMC 1x6. This is due to the larger number of unused symbols, 5 vs. 0, with the increased frame size. AMC 1x6 requires 6 symbols to support a data slot, in this particular case 11 symbols are added supporting only 1 additional data slot, a 14 % increase in data slots compared to a 25 % increase in the time duration. While the increased frame duration does result in more data slots with AMC 1x6 the slot increase as a percent is less than the frame duration increase, thus a reduction in the data rate. The following table provides further details.

**Table 4: 12.5 ms vs. 10 ms frame duration for 0.55 MHz channel BW with band AMC 1x6 permutation**

|  |  |  |
| --- | --- | --- |
| **Scenario 1** | **Scenario 2** | **Impact** |
| 10 ms Frame with AMC 1x6 & CP=1/16 | 12.5 ms Frame with AMC 1x6 & CP=1/16 | Frame duration increase = 25 % |
| 42 ‘Net’ Symbols per Frame,  Unused symbols = 0 | 53 ‘Net’ Symbols per Frame,  Unused symbols = 5 |  |
| Data slots per sector = 7 | Data slots per sector = 8 | Per sector data slot increase = 14 % for a  25 % time increase, thus a lower throughput. |
| In addition to increasing the frame duration the cyclic prefix can also be decreased from 1/16 to 1/32 | | |
|  | 12.5 ms Frame with AMC 1x6 & CP=1/32 | Frame duration increase = 25 %  CP reduced by 50 % |
|  | 55 ‘Net’ Symbols per Frame will support 9 data slots per sector  Unused symbols = 1 | Provides a sector data slot increase of 29 % compared to 10 ms frame duration with CP=1/16 |

It should be noted that, if the Cyclic Prefix (CP) were changed from 1/16 to 1/32 with the 12.5 ms frame size 2 additional symbols would be added and the number of data slots would increase by almost 30 % relative to a 10 ms frame and 1/16 CP. In this case there would only be 1 unused symbol.

**SUMMARY**

**Table 5: Some Pros and Cons of various parameter choices**

| **Parameter** | **PROs** | **CONs** |
| --- | --- | --- |
| Frame durations >20 ms | * Channel BWs ≤0.50 MHz: Essential for sufficient throughput * Channel BWs >0.50 MHz: Marginal throughput increase, may be OK for latency-tolerant applications | * Increased latency (linear relationship to frame duration) * Channel BWs >0.50 MHz: Generally insufficient throughput benefit to offset latency increase |
| Cyclic prefix decrease (1/32 vs. 1/8 or 1/16) | * Reduced OH * Will increase throughput in many (but not all) cases | * Increased inter-symbol-interference (ISI) * Must add sufficient number of symbols to gain at least 1 data slot |
| Band AMC 1x6 vs. Band AMC 2x3 | * 2x more sub-channels for increased flexibility with frequency reuse | * Potential for higher number of unused symbols (up to 5 for 1x6 vs. up to 2 for 2x3) |
| Band AMC 1x3 vs. Band AMC 1x6 (applicable for channel subgroups 1, 2, and 3) | * Potential for fewer unused symbols with Band AMC 1x3 (higher efficiency) * Channel BWs ≤0.50MHz: AMC 1x3 is essential for viable throughput at minimum frame duration (lower latency) | * Potential for higher number of unused symbols (up to 5 for 1x6 vs. up to 2 for 1x3) |