OFDMA PHY proposal for the 802.16.3 PHY layer

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This proposal should be used as the baseline for the PHY specification of the TG3.

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OFDMA PHY proposal for TG3

PHY Planning Issues

Guidelines for PHY Planning

Larger FFT's gives better multipath handling due to their longer GI

- Larger FFT's gives better spectral masks
- Less throughput overhead (GI) for larger FFT's
- OFDMA concept has many advantages

OFDM FFT Sizes Supported

The next table shows the GI length for different FFT sizes (mandatory modes only)

FFT size	64	4 (64 mod	e)	25	6 (256 mod	de)	10	024 (1k moo	le)	204	48 (2k mod	e)
GI	3 MHz	6 MHz	12 MHz	3 MHz	6 MHz	12 MHz	3 MHz	6 MHz	12 MHz	3 MHz	6 MHz	12 MHz
1/32	N.A.	N.A.	N.A.	*2.6u s	*1.3us	*0.6u s	10.6u s	*5.3us	*2.6u s	21.3us	*10.6u s	*5.3u s
1/16	N.A.	N.A.	N.A.	*5.3u s	*2.6us	*1.3u s	21.3u s	*10.6u s	*5.3u s	42.6us	21.3us	10.6u s
1/8	*2.6u s	*1.3u s	*0.би s	*10.6 us	*5.3us	*2.6u s	42.6u s	21.3us	*10.6 us	85.3us	42.6us	21.3u s
1/4	*5.3u s	*2.6u s	*1.3u s	21.3u s	*10.6u s	*5.3u s	85.3u s	42.6us	21.3u s	170.6u s	85.3us	42.6u s

OFDM FFT Size Planning

- Remember, Larger FFT size give longer GI and better multipath handling !!!!
- Smaller granularity for each user, gives better throughput.
- Allocation of high data rates have better multiplexing gain

OFDMA Symbol Structure

OFDMA symbol structure

The usable carriers are divided into groups called Sub-Channels.



Dividing into Sub-Channels

when using DS each Sub-Channel contains 48 data carriers, for the US a Sub-Channel contains 53 overall carriers (Data and Pilots).

- 64 Sub-Channels for the 4k mode
- 32 Sub-Channels for the 2k mode
- 16 Sub-Channels for the 1k mode
- 8 Sub-Channels for the 512 mode
- 4 Sub-Channels for the 256 mode
- 2 Sub-Channels for the 128 mode
- 1 Sub-Channel for the 64 mode

<u>Using Special Permutations for</u> <u>Carrier Allocation</u>

Carriers are allocated by concatenating a basic series, and cyclic permutations of it, for example (1k mode):

• Basic Concatenated Series:

0, 4, 5, 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 6, 2, 8, 2, 6, 7, 14, 12, 15, 3, 13, 5, 1, 0, 9, 11, 8, 4, 10, 4, 8, 9, 0, 14, 1, 5, 15, 7, 3, 2, 11, 13, 10, 6, 12, 6, 10, 11, 2, 0, 3

- After One cyclic permutation we get:
 - 4, 5, 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 6, 2, 8, 2, 6, 7, 14, 12, 15, 3, 13, 5, 1, 0, 9, 11, 8, 4, 10, 4, 8, 9, 0, 14, 1, 5, 15, 7, 3, 2, 11, 13, 10, 6, 12, 6, 10, 11, 2, 0, 3, 0



User 1 = 0 ,4 ,5 , 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 60, 3 User 2 = 4 ,5 , 12, 10, 13, 1, 11, 3, 15, 14, 7, 9, 6, 2....3, 0

System Properties and Access Methods

Access method for the 512 and above modes

DS symbols are allocated for data only, US Sub-Channels within a symbol are allocated for data and Ranging



Adaptive features

- FFT size setting
- Adaptive FEC
- Adaptive Modulation
- Adaptive Bandwidth per Allocation (by using adaptive Sub-Channel Allocation)
- Power administration (FAPC)

Coding schemes

- Concatenated RS(255,239,8) and tail biting convolutional coding (k=7, G1=171, G2=133)
- Block Turbo Codes (the same BTC as for TG1)

Coding Schemes are treated the same way by the MAC, both are block oriented, with the same block sizes

System Characteristics

- FFT size : 4096, 2048, 1024, 512
- Guard Intervals : ¹/₄, 1/8, 1/16, 1/32
- Coding :
 - Concatenated RS(255,239,8) and tail biting convolutional coding (k=7, G1=171, G2=133)
 - Block Turbo Codes
- QPSK, 16QAM and 64QAM
- Down Stream Mapping sets the Sub-Channel allocation and parameters (modulation, coding and power)
- throughput administration based upon Sub-Channel allocation
- Sub-Channels Power Manipulation (Forward Automatic Power Control – FAPC and Backward Automatic Power Control -BAPC)

Down Stream Properties

Framing Structure

Framing structure build upon TG1 principles, downstream can be divided into different modulation and coding regions.



512 and above modes – framing structure

Allocation on the DS enables the use of Forward Automatic Power Control (for better power usage, and cell covering)



<u>512 and above modes – DS Data</u> <u>Symbol Structure</u>

Based on variable and continues pilots.



Up Stream Properties

Sub-Channel structure

Every Sub-Channel contains 53 carriers (5 pilot carriers and 48 data carriers). Variable pilots are used for CSI update as well as for tracking.



US allocation

Basic allocation of 4 Sub-Channels, the first used as a preamble the rest as data. Allocation can be increased by allocating Sub-Channels or more time symbols.



<u>Using CDMA like</u> <u>Synchronization</u> (Preamble based only)

<u>Using CDMA like</u> <u>Synchronization</u>

- The CDMA like synchronization is achieved by allocating one or several Sub-Channels for Ranging or fast bandwidth request purposes.
- Onto the Ranging Sub-Channels users modulate a Pseudo Noise (PN) sequence using BPSK modulation
- The Base Station detects the different sequences and uses the CIR that he derives from the sequences for:
 - Time and power synchronization
 - Decide on the user modulation and coding
 - Bandwidth allocation

Ranging Interval

- Long Ranging for initial synchronization, taking care of possible ambiguity in the time of arrival
- Short Ranging for maintenance ranging and fast bandwidth request
- Several Ranging interval could be allocated.



Ranging Results

- Colliding codes can be separated
- No Slotted-Aloha inefficient based mechanism
- Small Ranging Intervals, and faster response time



Supporting Space Time Coding

Alamouti Transmission Scheme

OFDM/OFDMA Alamouti's scheme adaptation



Alamouti Block Diagram



Remote

Supporting Broad-Band Adaptive Antenna

Adaptive Antenna Array

- Broad-Band Antenna Arrays are a well known technology for many years.
- OFDMA capabilities could be enhanced by using Adaptive Antenna Arrays
- Current system design and framing structure gives full support for Broad-Band Adaptive Antenna Array Technology

OFDMA System -Throughput

System Throughput

The table was calculated for 3MHz channel, using the 2k mode.

Modulation	ation Bits per	code rate	Net bit rate (Mbps) for different Guard intervals				
	Sub-camer		1/4	1/8	1/16	1/32	
QPSK	2	1/2	2.06	2.29	2.4	2.49	
	2	2/3	2.74	3.05	3.21	3.33	
	2	3/4	3.09	3.43	3.61	3.74	
16-QAM	4	1/2	4.11	4.57	4.8	4.98	
	4	2/3	5.49	6.1	6.42	6.65	
	4	3/4	6.17	6.86	7.83	7.47	
64-QAM	6	1/2	6.17	6.86	7.2	7.47	
	6	2/3	8.23	9.15	9.63	9.98	
	6	3/4	9.26	10.29	10.83	11.2	

Power Concentration

Power Concentration

- In the Up Stream due to Sub-Channel allocation (53 carriers per Sub-Channel) a **15dB** gain for the 2k mode is achieved for one Sub-Channel allocation.
- In the Down Stream due to Sub-Channel allocation (53 carriers per Sub-Channel) a **10dB** gain can be achieved for one Sub-Channel busted (FAPC).
- This additional power gain enables better communication range, penetration into buildings, and a better coverage.
- This additional gain could be used for:
 - Bigger cell radius
 - Better coverage and availability
 - Better capacity
 - Chipper and smaller power amplifiers
 - Simpler antennas

Power Concentration - Example

- Estimating the cell radius for the system with the following parameters:
- 3MHZ channel Bandwidth
- 64QAM modulation
- One Sub-Channel transmission
- Receiver NF=4dB
- Assuming power emission of 30dBm
- using a 30° antenna at the SS and 60° at the BS
- Simple propagation model for LOS and NLOS We get the following results:

64 mode: 4.8Km for LOS, 690m for NLOS

2k mode: 26.9Km for LOS, 1.64km for NLOS

Cellular Deployment and Sectorization

Cell dimensions of OFDM and SC



RSS Le	gen	d (base)	
Default	Mo	del : G2-M	MDS A
Connec	tior	1: Previous	(R\$\$)
<u>Rang</u>	e	Colo	r <u>Distribution</u>
Min	to	- 103dB 📕	11.172 %
-103dB	to	-99dB 📒	17.717 %
-99dB	to	-95dB 📒	12.341 %
-95dB	to	-91dB 📃	8.573 %
-91dB	to	-88dB 📘	4.701 %
-88dB	to	-83dB 📃	5.428 %
-83dB	to	-79dB 📘	2.886 %
-79dB	to	-75dB	1.998 %
-75dB	to	-72dB	1.107 %
-72dB	to	Max	3.518 %

Using a Reuse Factor of 1

By allocating different Sub-Channels to different sectors we can reach reuse factor of 1 with up to 12 sectors (changing the polarity enhances the performance)



Throughput Enhancement

For a Full capacity cell deployment and no interferers we gain up to 25% in the throughput.

For Multi-Cell environment with a dynamic allocation the improved are expected to sharply increase.

PAPR Reduction

PAPR Reduction

- Using shaping on the signal peaks
- Limiting the PAPR to a constant value by vector reduction
- Possibility to use some pilot carrier for PARP reduction

Crest Factor (Down Stream)



BER/SNR for different Crest Factor achieved by clipping for a 2k FFT 16QAM OFDM Symbol (Uncoded)

OFDMA System Summary

Advantages - Summary (1)

- Averaging interference's from neighboring cells, by using different basic carrier permutations between users in different cells.
- Interference's within the cell are averaged by using allocation with cyclic permutations.
- Enables orthogonality in the uplink by synchronizing users in time and frequency.
- Enables Multipath mitigation without using Equalizers and training sequences.
- Enables Single Frequency Network (SFN) coverage, where coverage problem exists and gives excellent coverage.

Advantages - Summary (2)

- Enables spatial diversity by using antenna diversity at the Base Station and possible at the Subscriber Unit.
- Enables adaptive modulation for every user QPSK, 16QAM and 64QAM
- Enables adaptive carrier allocation in multiplication of 53 carriers (one Sub-Channel) up to full Symbol capacity
- Gives Frequency diversity by spreading the Sub-Channel carriers all over the used spectrum.
- Gives Time diversity by optional interleaving of Sub-Channels in time.
- Time Space Coding for better performance and channel handling

Advantages - Summary (3)

- Using the cell capacity to the outmost by adaptively using the highest modulation a user can use for the uplink, this is allowed by the gain added when less carriers are allocated (15dB gain for the 2k mode), therefore gaining in overall cell capacity.
- Reaching users with higher modulation and capacity in the down Stream by power concentration on specific Sub-Channels at the down Stream (up to **10dB** more gain on a Sub-Channel) using FAPC.
- The power gain can be translated to distance 2.5 times the distance for R^4 (NLOS) and 5.5 time for R^2 (LOS).
- Enabling the usage of Indoor Omni Directional antennas for the users.
- MAC complexity is the same as for TDMA systems.

Advantages - Summary (4)

- Allocating carrier by OFDMA/TDMA strategy.
- Using Small burst per user with granularity of 48 symbols for better statistical multiplexing and smaller jitter.
- User OFDM symbol with large FFT size gives better immunity to channel multipath.
- Using sophisticated ECC schemes to the outmost by error detection of disturbed frequencies.
- Gives a reuse factor of 1

Advantages - Summary (5)

- Efficient Methods for PARP reduction
- DFS used by the Base Station
- Antenna diversity
- Antenna array could be supported