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Abstract	This document captures the decisions made by TG4 group by the end of session 12 held in Hilton Head. This document will lead to the text for the TG4 PHY standard applicable for the WirelessHUMAN systems based on the consensus reached the session 12 held in Hilton Head.
Purpose	To Create Strawman Text for the TG4 PHY Standard
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Strawman Text for the TG4 PHY Standard

TG4 PHY group is trying to create the text for the TG4 PHY standard. The group made a lot of progress in that regard in last few sessions including the last session (session 12) head in Hilton Head. This document captures the decisions made by TG4 group by the end of session 12 held in Hilton Head. The outline of various sections and the language used in this text was agreed to by the TG4 PHY group. The group assigned 12 teams with a team leader to complete each of the 12 sections based on the decisions we made at the March meeting. Over next few weeks TG4 PHY chair will coordinate with each of the teams to refine the strawman text further for each of the sections listed here. The group will have periodic conference calls and discussions using the email reflector. There are additional decisions that will probably have to be made at the May meeting to further refine and narrow the strawman text. This document will lead to the text for the TG4 PHY standard applicable for the WirelessHUMAN systems based on the consensus reached.

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1. Notations

Comments and TBD issues are marked using italics.

2. Introduction (Octavian)

The 64 and 256 FFT modes are mandatory and the 1024 FFT mode is optional.

The 64 and 256 modes use OFDM / TDMA and the optional 1024 FFT mode is OFDMA

10 MHz or 20 MHz channel bandwidths are mandatory and 5 MHz is optional

3. Time and frequency description (Nico –Bob Editing Team)

An OFDM symbol is made up from carriers, the amount of carriers determines the FFT size used. There are several carrier types:

- Data carriers – for data transmission
- Pilot carriers – for different estimation purposes
- Null carriers – no transmission at all, for guard bands and DC carrier.

The purpose of the guard bands is to enable the signal to naturally decay and create the FFT “brick Wall” shaping.
Fclock = clock frequency at output of IFFT
BW = channel bandwidth (20, 10, 5MHZ), 5 MHz is optional only
The number and position of pilots and Fclock/BW can be modified with 50% simple majority.

OFDM 64 mode: 48 data carriers, 4 pilots, 1 null in center (Yossi to do the picture), Fclock/BW= 1 Same frequency structure as 802.11a.
The carrier allocation for 64-FFT mode is shown in Figure ??. Carrier 0 is the DC carrier and it is not used. There are 4 pilot carriers at positions –21, -7, 7 and 21. On both positive and negative side of the spectrum, there are 6, 13 and 5 data carries allocated between DC and first pilot, between pilots and at the band edge, respectively.

OFDM 256 mode: 192 data carriers, 12 pilots, 1 null in center (Yossi to do the picture) Fclock/BW=16/15
The carrier allocation for 256-FFT is shown in Figure ??. Carrier 0 is the DC carrier and it is not used. There are 12 pilot carriers at positions: -94, -77, -60, -43, -26, -9, 9, 26, 43, 60, 77 and 94. Between pilots, there are blocks of 16 data carriers. Blocks of 8 data carriers are allocated at both DC sides and both band edges. This allows for a total of 196 data sub-carriers, 12 pilot carriers and 1 DC carrier, for a total of 205 carriers. The other 51 carriers (-103 and below, as well as 104 and above) serve as guard-band.

OFDMA 1024 mode downlink: 81 pilots, 1 null in the center, 16 subchannels where each subchannel has: 48 data carriers (Yossi to do the picture) Fclock/BW=8/7
OFDMA 1024 mode uplink: 1 null in the middle 16 subchannels where each subchannel has: 48 data carriers, 5 pilots (Yossi to do the picture) Fclock/BW=8/7

3.1. Frame and burst structure

3.1.1. Downlink and uplink bursts
3.1.2. FFT size and frequency structure
3.1.3. 256 FFT mode with TDMA
3.1.4. 64 FFT mode with TDMA
3.1.5. 1024 FFT mode with OFDMA
3.1.6. OFDM Preambles – ranging, AGC, synchronization and equalization
3.1.7. Time and Power Ranging of the users
3.1.8. Up-Stream

4. Data encoding (Octavian- Brian, Editing Team)

4.1. Dynamic adaptive modulation and coding combined with ARQ

Inputs required on alternative FEC schemes from the following coding schemes: convolutional, block turbo codes convolutional turbo codes and concatenated Reed Solomon / convolutional codes. FEC will be discussed with interleaving.

4.2. Data scrambler

Use data scrambler from 802.11a

The data scrambler can be modified with 50% simple majority.

4.3. Convolutional encoder and puncturing

One proposed convolutional encoder :

The serial data (to add later where it comes from: randomizer/scrambler or outer interleaving, to specify the padding) shall be coded with a convolutional encoder of coding rate R=1/2, 2/3 or 3/4 corresponding to the desired data rate (to decide later the data rates i.e. valid combinations of modulation and coding rates). The convolutional encoder shall use the industry standard generator polynomials g0=1338 and g1=1718 of rate R=1/2 as shown in Figure 1. Bit denoted as “A” shall output from the encoder before the bit denoted as “B”. Rates of 2/3 and 3/4 shall be derived by employing “puncturing”, i.e. by omitting some of the encoded bits in the transmitter based on known patterns. The puncturing patterns are illustrated in Figure 2 for R=3/4 and Figure 3 for R=2/3. The rate R=1/2 is illustrated in Figure 4. Decoding by the Viterbi algorithm is recommended.

Figure 1: Convolutional encoder

Figure 2: Puncturing for R=3/4, transmission and reception

Figure 3: Puncturing for R=2/3, transmission and reception

Figure 4: Bit ordering for R=1/2, transmission and reception

4.4. Bit interleaving for the convolutional encoder proposed in the previsou section (derivate from 802.11a)

4.4.1. 64-FFT mode

All encoded data bits shall be interleaved by block interleaver with a block size corresponding to the number of coded bits per OFDM symbol, NCBPS. The interleaver is defined by a two step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent subcarriers. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits (LSB).

Let NBPSC be the number of bits per subcarrier, i.e. 1, 2, 4 or 6 for BPSK, QPSK, 16QAM ro 64QAM, respectively. Let s = max(NBPSC/2,1). Let k be the index of the coded bit before the first permutation at transmission, m be the index after the first and before the second permutation and j be the index after the second permutation, just prior to modulation mapping.

The first permutation is defined by the rule:

$$m = (NCBPS/16)\,(k \bmod 16) + \mathrm{floor}(k/16) \qquad k = 0, 1, \ldots, NCBPS-1$$

The second permutation is defined by the rule:

$$j = s * \mathrm{floor}(m/s) + (m + NCBPS - \mathrm{floor}(16 * m/NCBPS)) \bmod s \qquad m = 0, 1, \ldots, NCBPS-1$$

The deinterleaver, which performs the inverse operation, is also defined by two permutations. Let j be the index of the received bit before the first permutation, m be the index after the first and before the second permutation and k be the index after the second permutation, just prior to delivering the coded bits to the convolutional decoder.

The first permutation is defined by the rule:

$$m = s * \mathrm{floor}(j/s) + (j + \mathrm{floor}(16 * j/NCBPS)) \bmod s \qquad j = 0, 1, \ldots, NCBPS-1$$

The second permutation is defined by the rule:

$$k = 16 * m - (NCBPS-1) * \mathrm{floor}(16 * m/NCBPS) \qquad m = 0, 1, \ldots, NCBPS-1$$

The first permutation in the deinterleaver is the inverse of the second permutation in the interleaver, and conversely. Both permutations can be applied as they are for any number of subcarriers provided that NCBPS is a multiple of 16. They can be easily changed so that this requirement is changed to NCBPS be a multiple of 8 or 4.

4.4.2. 256-FFT mode

Will use the same algorithm. NCBPS to be decided – to choose from 4 blocks of 48 carriers or 1 block of 196 carriers (Nico).

4.4.3. 1024-FFT mode

(Zion)

4.5.

5. Constellation Mapping (Yossi – Editing Team)

5.1. Data Modulation

Data modulation one proposed scheme to be discussed along with others

The data bits after bit interleaving enter serially to the mapper. The mapping constellations are presented in Tables (Octavian) and Figure ?? (Yossi to change QPSK to PSK in first figure).

Figure 5: BPSK, QPSK, 16QAM and 64 QAM constellations

The complex number z shall be normalized by the value c, before mapping onto the carriers, by using the factor defined in the next table:

Modulation scheme	Normalization FactorReference 0dB
BPSK	
QPSK	
16QAM	
64QAM	

The complex number c, resulting from the normalization process, shall be modulated onto the allocated data carriers. The data mapping shall be done by sequentially modulating these complex values onto the relevant carriers.

5.2. Pilot Modulation

6. RF characteristics (Drayt, – Nico Editing Team)

6.1. Regulatory issues

6.1.1. Introduction

The 802.16.4 PHY shall operate in the 5 GHz band as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic specific regulatory domains e.g. global, regional, and national. The particular channelization to be used for this standard is dependent on such allocation as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In the USA, the FCC is the agency responsible for the allocation of the 5 GHz U-NII bands.

In some regulatory domains several frequency bands may be available for 802.16.4 PHY based FWA devices. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains and of bands within the domains shall be indicated by PLME attributes RegDomainsSupported and FrequencyBandsSupported.

6.1.2. FCC Regulatory issues

The interpretation of Title 47, $15.407 below is provided for convenience. No rights may be derived from this text, and accuracy is not guaranteed.

The lower U-NII band is restricted to indoor use only. As at least one device on an FWA link needs to be outdoors (typically the base station), this band is not available for FWA. As a result of this, the rule that the device must meet the maximum -27 dBm/MHz limit below 5250 MHz and above 5350 MHz applies. For the upper U-NII, the limits are maximum -27 dBm/MHz below 5715 MHz and above 5835 MHz, and maximum -17 dBm/MHz in the band 5715 - 5725 MHz and 5825 - 5835 MHz.

In the middle U-NII band, the transmit power is limited to the lesser of 24 dBm (250 mW) and 11+10log(B26dB) dBm, with the peak power density (n.b. this is not the peak power) not exceeding 11 dBm/MHz. In the upper U-NII band, the transmit power is limited to the lesser of 30 dBm (1W) and 17+10log(B26dB) dBm, with the peak power density not exceeding 17 dBm/MHz. For any system using directional antenna with gain over 6 dBi, limits for both bands are reduced by the antenna gain in excess of 6dBi.

6.2. Channelization

6.2.1. Channel Numbering

Channel center frequencies are defined at every integral multiple of 5 MHz above 5 GHz. The relationship between center frequency and channel number is given by the following equation:

Channel center frequency = 5000 + 5 * nch (MHz)

where nch = 0,1,…200. This definition provides a unique numbering system of all channels with 5 MHz spacing from 5 GHz to 6 GHz to provide flexibility to define channelization sets for all current and future regulatory domains.

6.2.2. Valid operating channels

The set of valid operating channel numbers by regulatory domain is defined in Table 1. The numbers in paranthesis are optional channels, the others are mandatory.

Table 1: Valid operating channels

Regulatory domain	Band	20 MHz channelization	10 MHz channelization
USA	U-NII-middle 5.25-5.35GHz	(52), 56, 60, 64, (68)	(51), 53, 55, 57, 59, 61, 63, 65, 67
USA	U-NII-upper 5.725-5.825GHz	149, 153, 157, 161	(146), 148, 150, 152, 154, 156, 158, 160, 162

Figure 6 shows the channelization scheme for this standard which shall be used with the FCC U-NII frequency allocation. The middle U-NII subband accommodates 3 channels of 20MHz, while the upper U-NII band supports 4 channels. Both U-NII bands accommodate 8 channels of 10 MHz. Additionally, two optional 20 MHz channels are defined in the middle U-NII band and one 10 MHz channel in each of the bands.

Figure 6: USA frequency plan

6.3. Transmit Power Levels

The maximum allowable output power according to FCC regulation is shown in Table 2.

Table 2: Maximum output power

Regulatory Domain	Band	Maximum Output Power	Comments

		20 MHz	10 MHz	
USA	U-NII middle	23 dBm	20 dBm	Up to 6 dBi antenna gain
USA	U-NII upper	29 dBm	26 dBm	Up to 6 dBi antenna gain

6.4. Transmit spectrum mask

The transmitted spectral density of the transmitted signal shall fall within the spectral mask as shown (in dBr vs MHz) in Figure 7, for both the 10MHz and 20MHz channelization. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

The actual mask has to be discussed for all FFT sizes.

Figure 7: Transmit spectrum mask

6.5. Transmit center frequency and symbol clock frequency tolerance

The transmitted center frequency and the symbol clock frequency shall be derived from the same reference oscillator. At the BS the reference frequency tolerance shall be +/- 20ppm (TBD) maximum for 64-FFT and 256-FFT modes and +/- 2ppm (TBD) maximum for 1024-FFT mode. At the SS, both the transmitted center frequency and the symbol clock frequency shall be synchronized to the BS with a tolerance of maximum 1% of the inter-carrier spacing (TBD). During the synchronization period as described in the 802.16 MAC, the SS shall acquire frequency synchronization with the specified tolerance before attempting any uplink transmission. During normal operation, the SS shall track the frequency changes and shall defer any transmission if synchronization is lost.

7. Coexsitence in the middle UNII band (Demosthenes Kostas – Editing Team)

8. Recommended practice (optional) for base station frame synchronization or coordination mechanism in sectorized environments (call for comments) (Octavian - Editing Team)

In sectorized environments, where several BS's are collocated in the same hub, the co-channel and adjacent channel interference can be significantly reduced if BS's are frame synchronized, i.e. they switch between transmit and receive and reverse at the same time.

For synchronization, the BS's need a common time reference. Therefore, the BS should be able to synchronize the start of the MAC frame with 1Hz pulses received on an external input. The same pulses triggers the changes in the frame size and uplink/downlink partition in all BS's at the same time. To preserve synchronization over a long period of time, the BS's need also a common reference frequency. Consequently, the BS should be able synchronize (lock) its reference oscillator to an external 10MHz reference. Both the 10MHz and 1Hz external inputs should use GPS like interface and levels. However, these signals must not necessarily be provided from a GPS source.

To implemes1nt this, the hub controller (or network controller) has (must have) access to the statistics of the uplink and downlink requests in all BS's, from which it can decide on an optimum u plink/downlink partition for the entire hub. The hub controller is (must be) also allowed to set the frame size and the uplink/downlink partition for the BS's. Therefore, the MAC provides (must provide) a standardized interface (TBD) to the hub controller. The MAC is (should be) capable to:

- report upon request, the sizes (e.g. Kbytes) of total downlink and total uplink pending requests
- set its frame size upon request
- set its uplink/downlink partition upon request

9. Ranging and Access schemes (call for comments) (Tal - Group X)

The 802.16 MAC provides several mechanisms that can be used by an SS to request from BS additional bandwidth: piggyback, unicast polling and multicast polling. In the later case, all SS's matching the group address can place their bandwidth request in the BW Request Contention part of the uplink. The (proposed) subcarrier based polling is an alternate way to answer the multicast polling without contention.

With subcarrier based polling each SS sends just one bit as opposed to sending a complete BW request packet (in contention window). If this bit is "1" then the SS needs additional BW and the BS must send a unicast polling addressed to the corresponding SS, at the earliest opportunity. If the bit is "0", the BS knows it does not need to inquire further the SS. The subcarrier based polling response is transmitted using OFDMA with DBPSK modulation. Each SS needs one slot, where a slot occupies one carrier during two OFDMA symbols. The first OFDMA symbol is used as reference and can be the corresponding subcarrier of the long preamble. The second OFDMA symbol encodes differentially the BW request bit. The second OFDMA symbol preserves the phase from the first OFDMA symbol when the BW request bit is "0" and shifts the phase with 180 degrees when BW request bit is "0".

To avoid channel fades, the slot positions are randomly permutated from polling to polling. Let the maximum number of SS's allowed in a system be NmaxSS (it could be useful to make NmaxSS a multiple of the number of data subcarriers NSC). The subcarrier based polling requires NmaxSS OFDMA slots occupying 2*ceil(NmaxSS / NSC) OFDMA symbols. Assume the slots indexed in the range 0…NSC*ceil(NmaxSS / NSC)-1, first by the carrier and then by the OFDMA symbol. At registration, the BS assigns to each SS a number SSID in the range 0… NmaxSS-1. Then, with each multicast polling, the BS broadcasts a random number R in the range 0…NSC*ceil(NmaxSS / NSC)-1. Each SS calculates the position of its BW request slot from its SSID and the random number R received from BS, by formula (SSID+R)mod(NSC*ceil(NmaxSS / NSC)).

10. Additional Possible Features (T.J. – Editing Team)

10.1. Adaptive Arrays
10.2. Transmit diversity Alamouti's Space-Time Coding
10.3. STC for FFT sizes 64 and 256
10.4. STC for FFT size 1k
10.5. Alamouti STC Encoding

11. Annex A - Channel and Traffic Model (Tal - Editing Team)

12. Annex B – MAC - PHY interface (Radu – Itzik, Jori, + Editing Team)