IEEE P802.11
Wireless LANs

Specification Framework for TGah

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Abstract

This document provides the framework from which the draft TGah amendment will be developed. The document provides an outline of each the functional blocks that will be a part of the final amendment. The document is intended to reflect the working consensus of the group on the broad outline for the draft specification. As such it is expected to begin with minimal detail reflecting agreement on specific techniques and highlighting areas on which agreement is still required. It may also begin with an incomplete feature list with additional features added as they are justified. The document will evolve over time until it includes sufficient detail on all the functional blocks and their inter-dependencies so that work can begin on the draft amendment itself.

0 Revision Notes

R0	Initial draft document with a table of content
R1	Added supporting bandwidth modes [11/1294r0] Added the number of tones for 2MHz PHY transmission and the tone spacing for all other bandwidth modes [11/1311r0]
R2	Added max number of space-time streams [11/1275r1] Added channelization [11/1329r1]
R3	Modified South Korea channelization [11/1422r0] Added support for a new frame format for a short beacon [11/1503r1]
R4/5	Added the motions passed in January 2012
R6	Added the motions passed in March 2012
R7/8/9	Added the motions passed in May 2012
R10	Added the motions passed in July 2012
R11	Added the motions passed in September 2012
R12	Added the motions passed in November 2012
R13	Added the motions passed in January 2013
R14	Added the motions passed in March 2013
R15	Added the motions passed in May 2013

1 Definitions

2 Abbreviations and Acronyms

S1G	sub 1 GHz
PLCP	physical layer convergence procedure
STA	station
MAC	medium access control
MCS0	BPSK, ½ code rate
SUBF	single user beamforming
MU-MIMO	multi-user, multiple input, multiple output
Non-TIM STA	a STA that does not include its paged status in TIM
TIM STA	a STA that includes its paged status in TIM

3 S1G Physical Layer

This section describes the functional blocks of the physical layer.

R.3.A: PHY mandatory features: [Nov 2012 meeting minutes, 11-12/1333r0]

1. An 11ah non-AP STA shall support:
    a. 1MHz and 2MHz channel width
    b. 1MHz PPDU, 2MHz PPDU with short preamble
    c. Single spatial stream MCS0 to 2, and MCS10 (for 1MHz PPDU only)
    d. Binary convolutional coding
    e. Normal Guard Interval
    f. Fixed Pilots

2. An 11ah AP STA shall support:
    a. 1MHz and 2MHz channel width
    b. 1MHz PPDU, 2MHz PPDU with short preamble
    c. Single spatial stream MCS0 to 7, and MCS10 (for 1MHz PPDU only)
    d. Binary convolutional coding
    e. Normal Guard Interval
    f. Fixed Pilots

3.1 Channelization

R.3.1.A: The draft specification shall include support for 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz PHY transmissions. [11/1294r0]

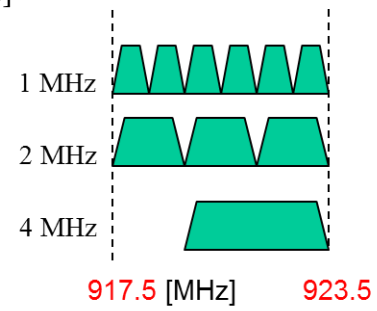
R.3.1.B: An 802.11ah STA shall support reception of 1 MHz and 2 MHz PHY transmissions. [11/1294r0]

R.3.1.C: The 2 MHz PHY transmission shall be an OFDM based waveform consisting of a total of 64 tones (including tones allocated as pilot, guard and DC). Note: This implies a tone spacing of 31.25 kHz. [11/1311r0]

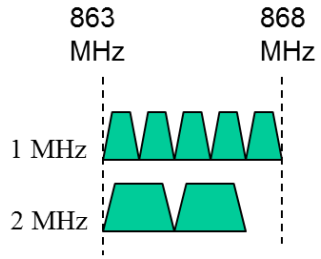
R.3.1.D: The tone spacing for all other bandwidths PHY transmissions shall be same as the tone spacing in the 2 MHz PHY transmission. [11/1311r0]

R.3.1.E: The draft specification shall include the following channelization [11/1329r1]

1. South Korea [11/1422r0]



2. Europe



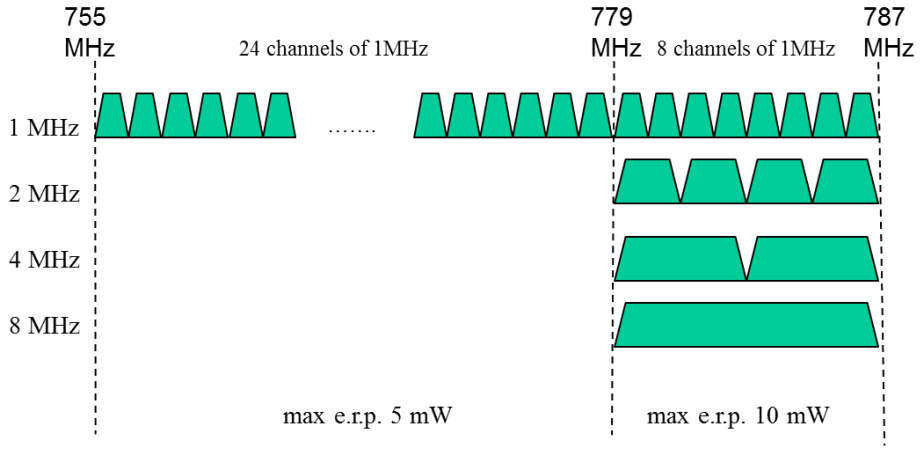
* Assumes 600 KHz , 868 - 868.6 as guard band

3. Japan

1MHz Channel (*):	1	2	3	4	5	6	7	8	9	10	11
f_c [MHz]	917.0	918.0	919.0	920.0	921.0	922.0	923.0	924.0	925.0	926.0	927.0
Tx low [mW]	1	1	1	1	1	1	1	1	1	1	1
Tx med [mW]					20	20	20	20	20	20	20
Tx high [mW]					250	250	250				

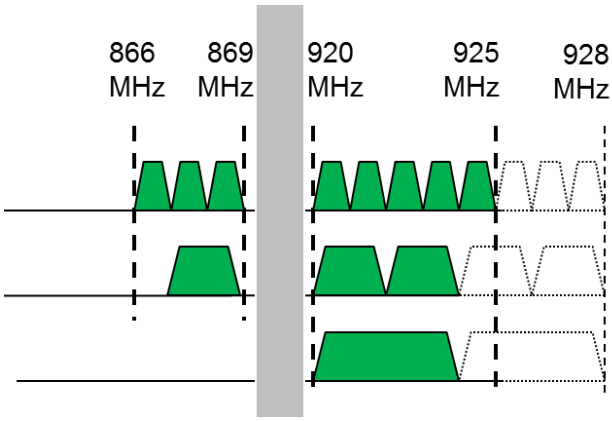
- **Proposed Japanese 1MHz Channelization for 802.11ah**
  Start: 916.5MHz, channel 1, f_c=917.0MHz
  End: 927.5 MHz, channel 11, f_c=927.0 MHz
  (*) ARIB may apply additional conditions and restrictions, e.g., traffic pattern, etc.

4. China

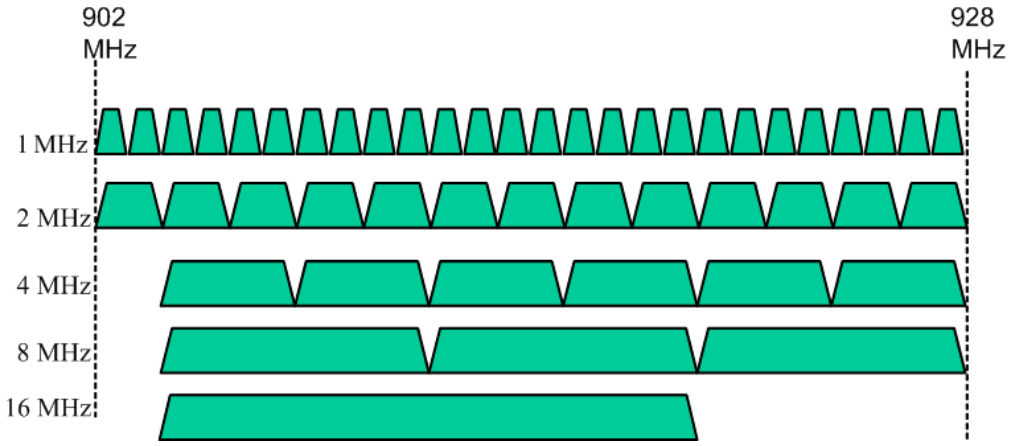


- 32 channels of 1MHz
- 4 channels of 2MHz
- 2 channels of 4MHz
- 1 channels of 8MHz

5. Singapore [12/111r1]:
   1. Supporting bands: 866-869 MHz, 920-925MHz



6. United States [May 2012 meeting minutes, 12/0613r0]
   2. 26 1MHz channels, 13 2MHz channels, 6 4MHz channels, 3 8MHz channels and one 16MHz channel



R.3.1.F: PHY and MAC management entity of 11ah shall provide appropriate parameters (TBD) of PLME and MLME service primitives to support Spectrum access and Tx Control functions in order to comply to each regulatory domain. [July 2012 meeting minutes, 1-12/871r1]

a. These appropriate parameters to be added are TBD so far, but are supposed to be a part of "behavior limit set" entry in the Annex Table which corresponds to new operating classes of 11ah.

3.1.1 Transmission rules

R.3.1.1.A: The draft specification shall support the following 1 MHz transmission rules. [12/309r1][Nov 2012 meeting minutes, 11-12/1313r0]

1. When establishing a 2/4/8/16MHz BSS, the AP determines and announces the location of 1MHz primary channel located at either upper or lower side of the 2MHz primary channel.
2. A 11ah STA that does not participate in the frequency selective transmission protocol shall neither transmit nor be transmitted to, a 1 MHz non-duplicated PPDU on 1MHz subchannels other than the primary 1Mhz channel of a 2/4/8/16 MHz BSSs.
3. A non-duplicated 1MHz transmission from a STA that participates in the frequency selective transmission protocol in a 4/8/16MHz BSS, shall use the same upper or lower 1MHz subchannel in any of the allowed 2MHz channel(s).

3.1.2 Channel selection rules

R.3.1.2.A: Among all available channels, the new BSS should select an idle channel which can help keep maximum number of idle (available) wider bandwidth channels after it is selected (Details TBD). [2012 July meeting minutes, 11-12/816r1]

3.2 S1G PLCP Sublayer

R.3.2.A: 11ah defines single stream pilots in the LTF, SIG and Data fields of short preamble packets, using the first column of P matrix for multi-stream mapping, as below:

1. For SIG field in Short Preamble Format, the transmitted pilot tone signals, in the k-th tone and n-th OFDM symbol in each 2MHz subband of the >=2MHz short preamble format SIG field is expressed as: [May 2012 meeting minutes, 12/363r2]

   $[\mathbf{X}_k(n)]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times N_{STS}} [\mathbf{D}_{CSD}^{(k)}]_{N_{STS}\times N_{STS}} [\mathbf{P}_{*1}]_{N_{STS}\times 1} . p_n P_k$

   k is the tone index that belongs to pilot tones

   $n = 0,1$ is the symbol index for the 2 SIG symbols

   $\mathbf{Q}_k$: spatial mapping matrix in tone k, of size $N_{TX} \times N_{STS}$

   $\mathbf{D}_{CSD}^{(k)}$: diagonal CSD phase shift matrix in tone k, of size $N_{STS} \times N_{STS}$

   $\mathbf{P}_{*1}$: the 1st column of P matrix, of size $N_{STS} \times 1$

   p_n is defined in 18.3.5.10 (OFDM modulation) of 11a spec

   P_k is defined in 18.3.5.10 (OFDM modulation) of 11a spec

2. For SIGA Field in >=2MHz Long Preamble Format, the transmitted pilot tone signals, in the k-th tone and n-th OFDM symbol in each 2MHz subband of the >=2MHz long preamble format SIGA field is expressed as:

   $[\mathbf{X}_k(n)]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times 1} . p_n P_k$

   $n = 0,1$ is the symbol index for the 2 SIGA symbols

3. For >=2MHz LTFs in Short Preamble format, and D-LTFs in the Long preamble format, the transmitted pilot tone signals, in the k-th tone of each LTF field in the >=2MHz short preamble format, and of each D-LTF field in the >=2MHz long preamble format is expressed as:

   $[\mathbf{X}_k(n)]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times N_{STS}} [\mathbf{D}_{CSD}^{(k)}]_{N_{STS}\times N_{STS}} [\mathbf{P}_{*1}]_{N_{STS}\times 1} . LTF_k$

   where LTF_k is LTF sequence in the kth subcarrier

   This equation is applicable for the pilot tones, which are the same as the corresponding 11ac pilot tone positions with the same FFT sizes.

4. For >=2MHz SIGB/Data, the transmitted pilot tone signals, in the k-th tone and n-th OFDM symbol in SIGB (when applicable) and Data fields in >=2MHz PPDUs is expressed as:

$$[\mathbf{X}_k(n)]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times N_{STS}} [\mathbf{D}_{CSD}^{(k)}]_{N_{STS}\times N_{STS}} [\mathbf{P}_{*1}]_{N_{STS}\times 1} . p_{n+2} P_n^{\mathrm{k}}$$

p_n is defined in 18.3.5.10 (OFDM modulation) of 11a spec

P_n^k is defined in 22.2.10.10 (Pilot Subcarriers) of 11ac D2.0

$n = 0,1,2,...$is the symbol index, continuously counted from the 1st Data symbol for short preamble format and long preamble in SU mode, and from SIGB for long preamble when in MU mode.

[July 2012 meeting minutes, 11-12/832r2]

The pilot mapping P_n^k and values for 2/4/8/16 MHz transmissions, respectively, refer those for 20/40/80/160 MHz transmissions in section 22.3.10.10 (Pilot subcarriers) of IEEE P802.11ac™/D2.0. [May 2012 meeting minutes, 12/363r2-motion2]

5. For 1MHz LTFs, the transmitted pilot tone signals, in the k-th tone and in each LTFs for 1MHz PPDU is expressed as:

$$[\mathbf{X}_k(n)]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times N_{STS}} [\mathbf{D}_{CSD}^{(k)}]_{N_{STS}\times N_{STS}} [\mathbf{P}_{*1}]_{N_{STS}\times 1} . LTF_k$$

where LTF_k is LTF sequence in the kth subcarrier

This equation is applicable for the pilot tones in -7 and +7

6. For 1MHz SIG field and Data Field, the transmitted pilot tone signals, in the k-th tone and n-th OFDM symbol of 1MHz SIG and Data fields is expressed as:

$$[\mathbf{X}_k(n)]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times N_{STS}} [\mathbf{D}_{CSD}^{(k)}]_{N_{STS}\times N_{STS}} [\mathbf{P}_{*1}]_{N_{STS}\times 1} . p_n P_n^{\mathrm{k}}$$

p_n is defined in 18.3.5.10 (OFDM modulation) of 11a spec

$n = 0,1,2,...$is the symbol index, continuously counted among SIG field and Data field symbols, starting from the 1st SIG field symbol as 0, and jump over the additional LTF symbols between SIG field and Data field (if any).

For a 1MHz transmission, two pilot tones shall be inserted in $k \in \{-7,7\}$. The pilot mapping P_n^k for subcarrier *k* for symbol *n* shall be as specified in the following equation. [May 2012 meeting minutes, 12/363r2-motion1]

$$P_n^{k\in\{-7,7\}} = \{\psi_{(n \bmod 2)+2}, \psi_{((n+1) \bmod 2)+2}\}$$

$$P_n^{k\notin\{-7,7\}} = 0$$

where, ψ_m is given in Table 22-20 of IEEE P802.11ac™/D2.0 and where *n* is the DATA symbol index.

3.2.1 Preamble

R.3.2.1.A: In any 11ah short GI packet, short GI starts from the 2nd Data symbol, and the 1st Data symbol is always long GI.

- Include Multi-stream or MU packets

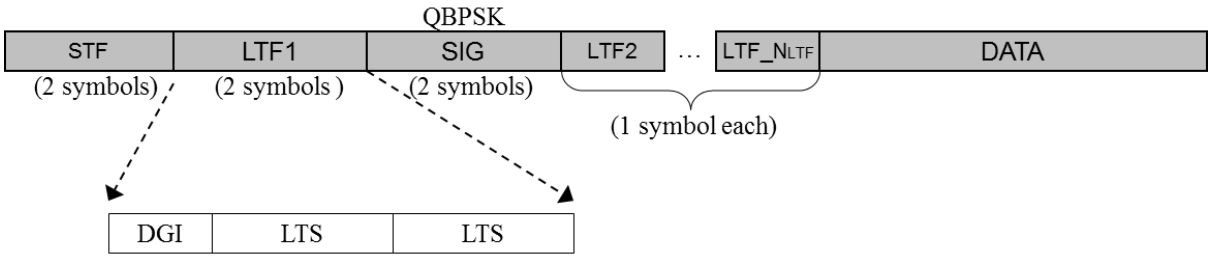
R.3.2.1.B: The draft specification shall include 2-bit Ack Indication (00: No Response; 01: NDP Response; 10: Normal Response; 11: Long Response) in SIG.

1. The definition of value (b11) response frame type to indicate the presence of a frame that is not ACK, CTS or BA following current transmission. [July 2012 meeting minutes, 11-12/834r0]

R.3.2.1.C: The 4-bit CRC in 11ah 2MHz and 1MHz SIG(A) fields shall be calculated using the same procedure as the 11n HTSIG field 8-bit CRC, except that the generator polynomial G(D) = $D^4 + D + 1$. The draft specification shall use the same 11n HTSIG field 8-bit CRC in SIGB field of the >=2MHz long preamble when in MU mode [May 2012 meeting minutes, 12/596r0; July 2012 meeting minutes, 12/832r2][12/1092r0, September 2012 meeting minutes].

3.2.1.1 PHY greater than or equal to 2 MHz

R.3.2.1.1.A: The general short preamble structure for greater than or equal to 2 MHz PHY packet is defined as in the figure below: [July 2012 meeting minutes, 11-12/819r1]



Each field is defined as follows:

1. STF Field
    a. Use the same tone design as in 11n, i.e. in each 2MHz, STF occupies 12 non-zero tones in {±4 ±8 ±12 ±16 ±20 ±24}.
    b. None-zero tones are mapped to space-time streams using the first column of P matrix, the same way as in 11n GF preamble.

$[STF_k]_{N_{TX}\times 1} = \mathbf{Q}_k \mathbf{D}_{CSD}^{(k)} \mathbf{P}_{*1} x_k$

$\mathbf{Q}_k$: spatial mapping matrix in tone k, of size $N_{TX} \times N_{STS}$

$\mathbf{D}_{CSD}^{(k)}$: diagonal CSD phase shift matrix in tone k, of size $N_{STS} \times N_{STS}$

x_k: non-zero STF value in tone k.

2. LTF Fields
    a. Define the 11ah LTF signs for >= 2MHz PPDUs the same as the VHTLTF signs in the corresponding 11ac packets with the same FFT sizes.
        i. This is also applicable to the LTF1 and D-LTFs fields in the long preamble format. [12/597r0 –motion1]
    b. In data tones of LTF, the mapping from N_{STS} space-time streams to N_{LTF} LTFs is the same as in 11n green field preamble, with the P matrix.

$$[LTF1_k, LTF2_k, ..., LTFN_{LTF\_k}]_{N_{TX}\times N_{LTF}} = \mathbf{Q}_k \mathbf{D}_{CSD}^{(k)} \mathbf{P}_{N_{STS}\times N_{LTF}} s_k$$

$$\mathbf{P}_{4\times 4} = \begin{bmatrix} 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 \end{bmatrix}$$

s_k: LTF pilot sign in tone k, being either +1 or -1

3. SIG Field
    a. 2 symbols, each modulated using Q-BPSK, same as in 11n green field preamble.
    b. 48 data tones occupying tones {-26:26} within each 2MHz subband, and modulated using 11n/11ac MCS0. [12/308r2, Motion1]
    c. Data tones are mapped to multiple space-time streams using the first column of P matrix—the same as in 11n GF preamble.

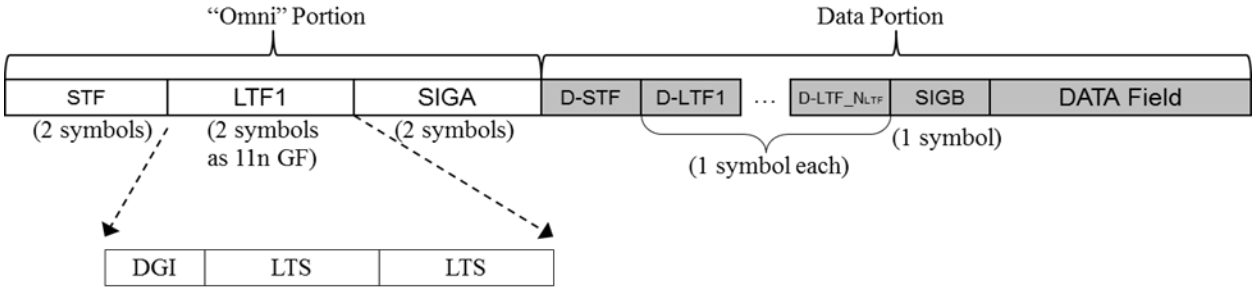
$$[SIG_k]_{N_{TX}\times 1} = \mathbf{Q}_k \mathbf{D}_{CSD}^{(k)} \mathbf{P}_{*1} d_k$$

4. The following CSD table (to be applied Per-Per-Space-Time-Stream) shall be used for the >=2MHz Short Frame format [2012 July meeting minutes, 11-12/833r1: motion1, 2]

T_cs(n) for >=2MHz, Short Frame Format and Data portion of Long Frame Format				
Total number of space-time streams	Cyclic shift (for Tx Stream n) (μs)			
	1	2	3	4
1	0	-	-	-
2	0	-4	-	-
3	0	-4	-2	-
4	0	-4	-2	-6

R.3.2.1.1.B: The long preamble structure uses a "mixed-mode" format shown below: (long preamble)

– This frame format can be used for MU and SUBF [12/373r0]



1. Omni Portion
    a. SIGA field has 48 data tones, occupying tones {-26:26} as in 11n/11ac SIG fields [12/597r0-motion1]
    b. STF/LTF1/SIG fields applies single stream in each subcarrier (without the 1st column P matrix mapping as seen in short preamble), similar to the legacy portion of 11n MM preamble and 11ac preamble.

$[\mathbf{x}_k]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times 1} d_k$, where $\mathbf{Q}_k$ may contain

the phase shifts in tone k caused by the time domain CSD

    c. SIG field subfield definition is different from short preamble, and the two symbols in SIG field are modulated using QBPSK and BPSK respectively
        i. Refer to R.3.2.1.1.C.
    d. The following CSD table (to be applied Per-Antenna) shall be used for the >=2MHz Omni portion of the Long Frame format [2012 July meeting minutes, 11-12/833r1:motion1,3]:

T_cs(n) for >=2MHz, Omni Portion of Long Frame Format				
Total number of Tx antennas	Cyclic shift (for Tx Antenna n) (μs)			
	1	2	3	4
1	0	-	-	-
2	0	-4	-	-
3	0	-4	-2	-
4	0	-4	-2	-6

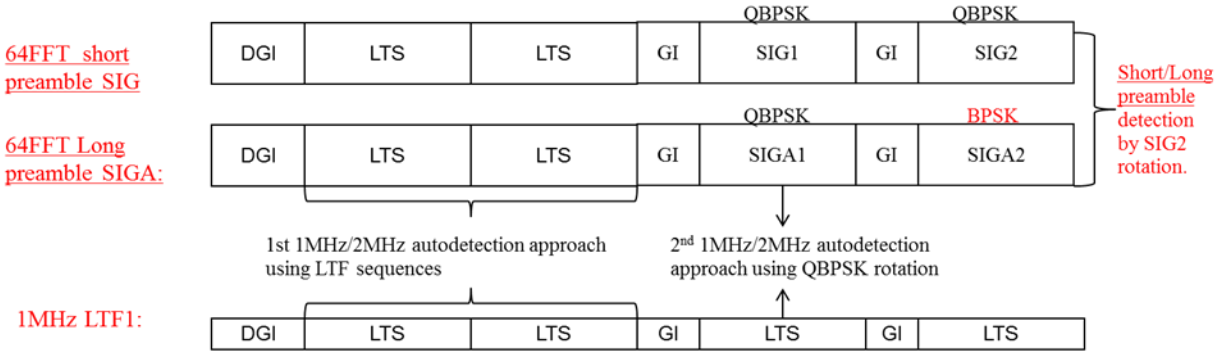
2. Data Portion
    a. D-STF is the same as (downclocked) 11ac VHT-STF.
    b. Modulation flows of D-STF, D-LTFs, and SIGB are the same as 11ac MU packets.
        i. i.e. all streams for all users are trained by D-LTFs.
        ii. Up to 4 space-time stream across all users (refer to [11/1275r1]).
    c. The following CSD table (to be applied Per-Per-Space-Time-Stream) shall be used for the >=2MHz Data portion of the Long Frame format [2012 July meeting minutes, 11-12/833r1: motion1, 2]:

T_cs(n) for >=2MHz, Short Frame Format and Data

portion of Long Frame Format				
Total number of space-time streams	Cyclic shift (for Tx Stream n) (μs)			
	1	2	3	4
1	0	-	-	-
2	0	-4	-	-
3	0	-4	-2	-
4	0	-4	-2	-6

R.3.2.1.1.C: Auto-detection between 1MHz and 2MHz and between >=2MHz short and long preambles [July 2012 meeting minutes, 11-12/815r0]

1. Auto-detection between short and long >=2MHz preambles is facilitated by having a 90 degrees phase rotation on the 2nd SIG symbol as shown in the figure below.
2. Auto-detection between 1MHz and 2MHz preambles is facilitated using two options as shown in the figure below
    a. The first auto-detection method uses the property of orthogonal LTF sequences as described in 11/1482r4 and 12/0115 and defined by the orthogonality metric in Appendix-A of 12/0115.
    b. The second auto-detection method is facilitated by noting that for >=2MHz short preamble and long preamble the 1st SIG symbol is always QBPSK whereas the corresponding time-wise symbol of the 1MHz preamble (in the figure below) is BPSK modulated - refer to 11/1482r3.



R.3.2.1.1.D: 4/8/16 MHz frame format

1. For 4MHz, 8MHz, and 16MHz packets, the STF/LTF/SIG field designs are similar to 11ac 40/80/160MHz.
    a. STF/SIG fields are repeated and phase rotated (same as in 11ac) over each 2MHz subband.

R.3.2.1.1.E: SIG field content for >=2MHz

1. 2MHz SIGA [July 2012 meeting minutes, 11-12/825r2]

–

	Short preamble	Long preamble	
	SU	**SU**	**MU**
SU/MU Indication	-	1	1
Length / Duration	9	9	9
MCS	4	4	-
BW	2	2	2

Aggregation	1	1	-
STBC	1	1	1
Coding	2	2	5
SGI	1	1	1
GID	-	-	6
Nsts	2	2	8
PAID	9	9	-
Ack Indication	2	2	2
Smoothing	1	-	-
Beam-change Indication/smoothing	-	1	-
NDP Indication	1	-	-
Doppler	1	1	1
Reserved	2	2	2
CRC	4	4	4
Tail	6	6	6
Total	**48**	**48**	**48**

a. LENGTH/DURATION: in number of symbols when aggregation is 1, is in number of bytes when aggregation is 0, Mandate AMPDU for packet sizes > 511 bytes and for MU.
b. STBC: Same as in 11ac (Alamouti code on all streams or none) and set to 0 for MU PPDU [13/0497r0, May 2013 meeting minutes].
c. Nsts: for SU (2 bits), represents 1~4 STS; for MU (8 bits), represents 0~3 STS per user for the 4 users.
d. Coding: for SU 1 bit indicates BCC/LDPC, the other bit indicates additional symbol during LDPC encoding process; for MU, 4 bits of Coding-I indicate BCC/LDPC of 4 clients, and 1 bit of Coding-II indicates whether additional symbols happens for any user when encoding LDPC (same as 11ac). [12/1102r1, September 2012 meeting minutes]
e. MCS: for SU, 4 bit MCS index; for MU, reuse 3 bits for BCC/LDPC indicator for users 2~4—similar as in 11ac VHTSIGA.
f. Aggregation: Mainly applicable for SU, reserved for MU.
g. CRC: 4 bits of CRC should be enough as shown in the Appendix
h. GID: 6-bit GID as in 11ac for MU, not needed for SU.
i. PAID: 9 bits PAID, not needed for MU.
    i. Patial AID rules [12/1079r0, September 2012 meeting minutes]:
        1. A STA that transmits a PPDU to an AP shall set the TXVECTOR parameter PARTIAL_AID to (dec(BSSID[39:47]) mod (2^9-1))+1
        2. AP should not assign an AID to a STA that results in the PARTIAL_AID value, as computed using Equation (9-8a) (defined in IEEE 802.11ac Draft 3.0), being equal to either (dec(BSSID[39:47]) mod (2^9-1))+1 or (dec(Overlapping BSSID[39:47]) mod (2^9-1))+1
j. Ack Indication: 2 bits [refer to R.3.2.1.B]
k. Beam-change/smoothing indication bit: a value of 1 indicates that Q matrix is changed; a value of 0 indicates that Q matrix is un-changed. [July 2012 meeting minutes, 11-12/825r2]. . If Nsts>1, a value of 1 indicates that channel smoothing

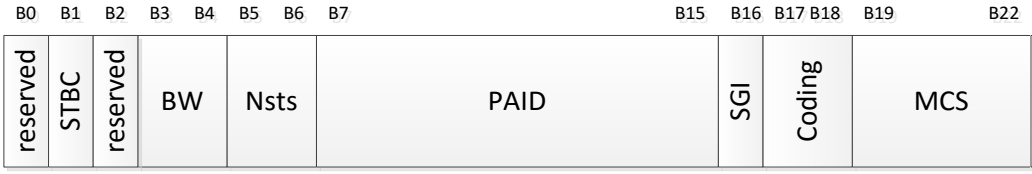
is recommended, otherwise channel smoothing is not recommended [13/0497r0, May 2013 meeting minutes].

l.
    i. Note: When Nsts=1, if the beam-change indication bit in long preamble is set to 0, the receiver may do channel smoothing. Otherwise, smoothing is not recommended.

m. NDP Indication: this bit is used to indicate this frame is a MAC NDP frame. [Nov 2012 meeting minutes, 11-12/]

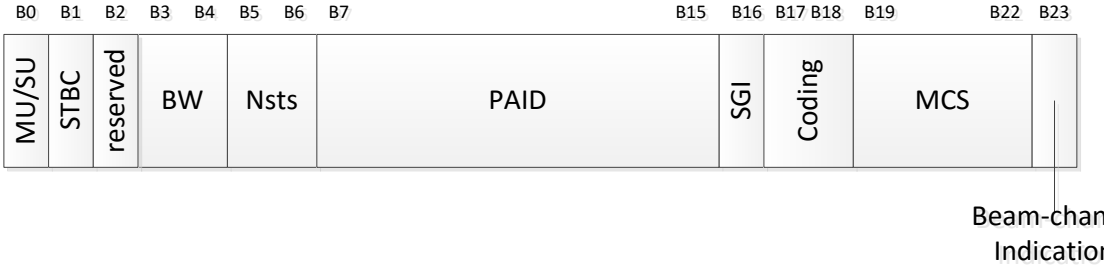
n. Doppler: This bit indicates the traveling pilots usage in the packet. [Nov 2012 meeting minutes, 11-12/1322r0]

o. Short preamble bit ordering [12/1102r1, September 2012 meeting minutes]
    i. 1st symbol of SIG



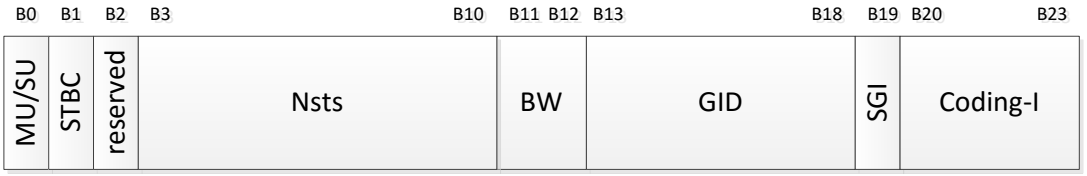
    ii. 2nd symbol of SIG

p. Long preamble, SU bit ordering [12/1102r1, September 2012 meeting minutes]
    i. 1st symbol of SIG-A



    ii. 2nd symbol of SIG-A

q. Long preamble, MU bit ordering [12/1102r1, September 2012 meeting minutes]
    i. 1st symbol of SIG-A

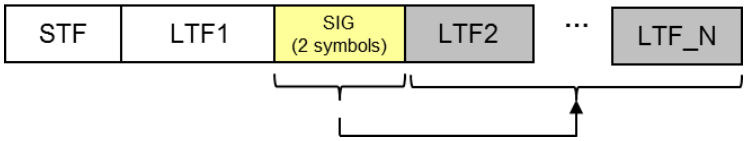


ii. 2nd symbol of SIG-A

2. For MU-MIMO transmission the 2MHz SIGB content is as shown in the following table. For SU-MIMO transmission the SIGB symbol is identical to D-LTF1. [July 2012 meeting minutes, 11-12/832r2]

	BW (MHz)			
	2	**4**	**8**	**16**
MCS	4	4	4	4
Tail	6	6	6	6
CRC	8	8	8	8
Reserved	8	9	11	11
Total	26	27	29	29

R.3.2.1.1.F: The draft specification shall include the following 11ah NDP format [May 2012 meeting minutes, 617r0-motion1]



The 11ah NDP format is same with 2MHz PHY short frame format defined in R.3.2.1.1.A.

1. The SIG field of 11ah NDP shall include following fields [May 2012 meeting minutes, 617r0-motion2]:
   a. MCS : set to 0
   b. Length/Duration: set to 0

c. BW : set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding VHT NDP Announcement frame
d. Nsts : indicates two or more space-time streams

R.3.2.1.1.G: The draft specification shall support that all NDP frames sent in >=2MHz use the short preamble format, including Short-ACK, and all future NDP short MAC frames [May 2012 meeting minutes, 617r0-motion3].

R.3.2.1.1.H: The draft specification shall support the following rules regarding >= 2MHz preambles [July 2012 meeting minutes, 1-12/819r1][Nov 2012 meeting minutes, 11-12/1333r0].

1. For a any device,
    a. If it supports only 1MHz/2MHz, short preamble is mandatory, and long preamble is optional (exchanged by capability fields).
    b. Otherwise, both short and long preambles are mandatory.
2. Any device shall be able to detect and decode SIGA field in the long preamble for CCA.

3.2.1.2 1 MHz mode PHY

R.3.2.1.2.A: The 802.11ah specification shall use the following STF and LTF sequences for 32 FFT:
- STF and LTF sequences for higher FFT sizes are based on 11ac [12/186r0,26.2.9]

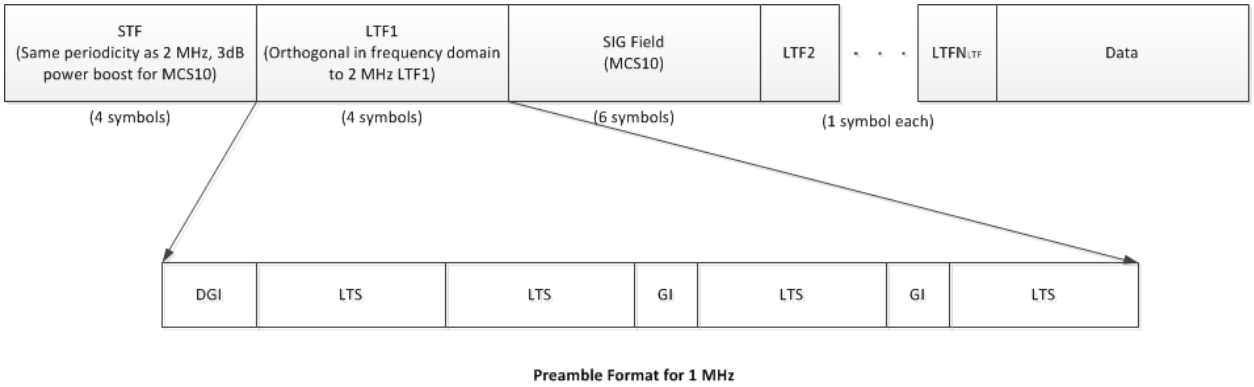
1. STF sequence [12/115r0,slide4]
    – Tone index=[-12 -8 -4 4 8 12]
    – Values: [0.5, -1, 1, -1, -1, -0.5]x(1+j)x γ where γ is a normalization factor
    – γ = 2.4 for MCS0 rep2, 1.7 otherwise
2. LTF sequence [12/115r0, slide7]
    – Tone index is [-16 -15 -14 …. -1 0 1 ….. 14 15]
    =[0 0 0 1 -1 1 -1 -1 1 -1 1 1 -1 1 1 1 0 -1 -1 -1 1 -1 -1 -1 1 -1 1 1 1 -1 0 0]

R.3.2.1.2.B: The 802.11ah draft specification shall have a 4 symbol packet detection section for the 1 MHz mode [11/1482r4, motion2].

1. A 3 dB power boost is only applied for 2x repetition MCS
2. Have same periodicity as 2 MHz STF with following tone allocations:
    a. For 2MHz {±4 ±8 ±12 ±16 ±20 ±24}
    b. For 1MHz {±4 ±8 ±12}.

R.3.2.1.2.C: The 802.11ah draft specification shall have the general preamble structure for 1MHz SU open loop packet as in the figure below [11/1482r4, motion3][Nov 2012 meeting minutes, 11-12/1363r1].

1. The relationship between N_{STS} and N_{LTF} is the same as 11n/11ac (for 2 through 4 streams), using the same P matrix (for 1 through 4 streams)



Preamble Format for 1 MHz

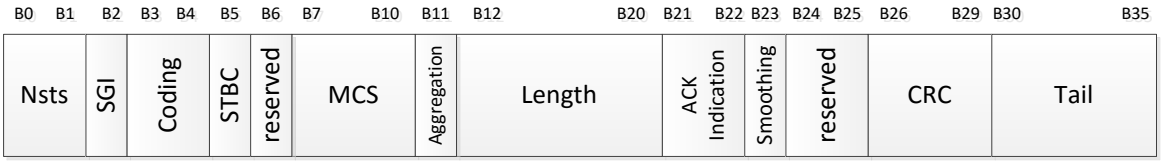
R.3.2.1.2.D: The 802.11ah draft specification shall have 1MHz SIG field contents as follows.

SIG Field	Bits	Comments
STBC	1	Same as in 11ac
Num STS	2	Number of space time streams for SU [12/1085r0, September 2012 meeting minutes]
SGI	1	Short Guard Interval
Coding	2	1st bit is coding type (LDPC/BCC), 2nd bit is for LDPC N_{sym} ambiguity
MCS	4	MCS
Aggregation bit	1	Signals use of AMPDU
Length	9	Length field (in symbols when aggregation is ON, is in bytes when aggregation is OFF, Mandate AMPDU for packet sizes > 511 bytes
Ack Indication	2	00: No Response; 01: NDP Response; 10: Normal Response; 11: Long Response [refer to R.3.2.1.B]
Smoothing	1	[12/1085r0, September 2012 meeting minutes]
NDP Indication	1	This bit is used to indicate this frame is a MAC NDP frame. [Nov 2012 meeting g minutes, 11-12/]
Doppler	1	This bit is used to indicate the traveling pilots usage in the packet. [Nov 2012 meeting minutes, 11-12/1322r0]
Reserved	1	Some possible uses are MAC bits or any other new features etc. Details TBD
CRC	4	4 bits of CRC should be enough
Tail	6	
Total	**36**	

- **SIG goes at BPSK-rate ½ -rep 2**

- **No MU transmissions for the 1MHz mode**
- **No AID supported**

1. Bit ordering of 1 MHz SIG field [12/1102r1, September 2012 meeting minutes]



R.3.2.1.2.E: The following CSD table (to be applied Per-Space-Time-Stream) shall be used for the 1 MHz frame format [2012 July meeting minutes, 11-12/83r1:motion1, 4]:

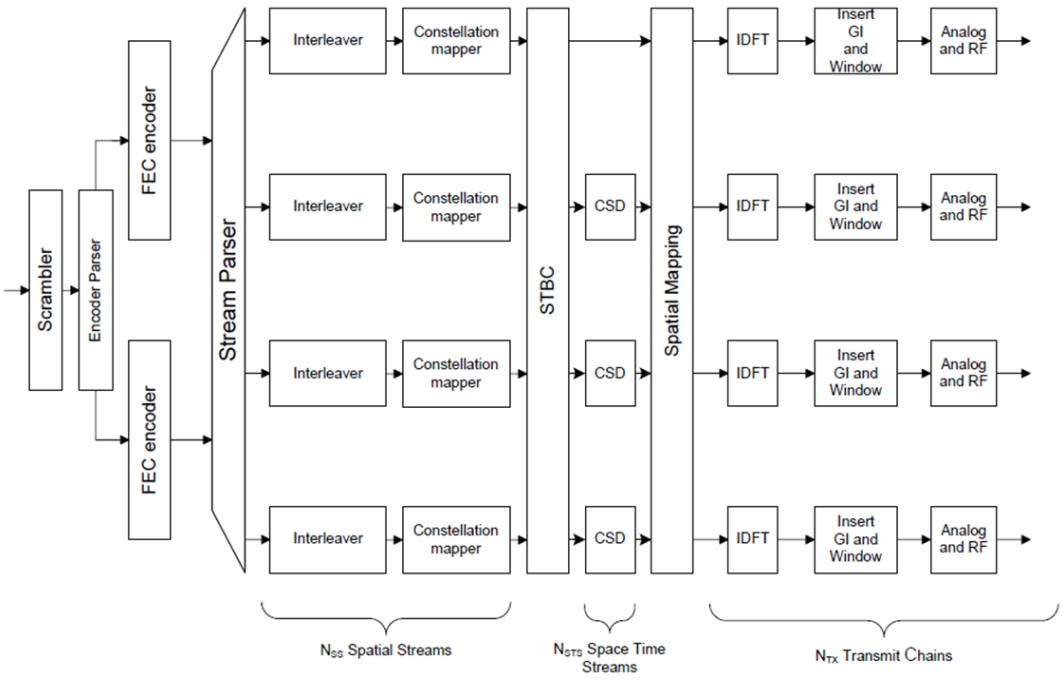
T_cs(n) for 1MHz Frame Format				
Total number of space-time streams	Cyclic shift (for Tx Stream n) (μs)			
	1	2	3	4
1	0	-	-	-
2	0	-4	-	-
3	0	-4	-1	-
4	0	-4	-1	-5

3.2.2 Transmission flow

3.2.2.1 Transmission flow for 11ah regular non-repetition MCSs

R.3.2.2.1.A: The general transmission flow for 11ah regular non-repetition MCSs is shown below.

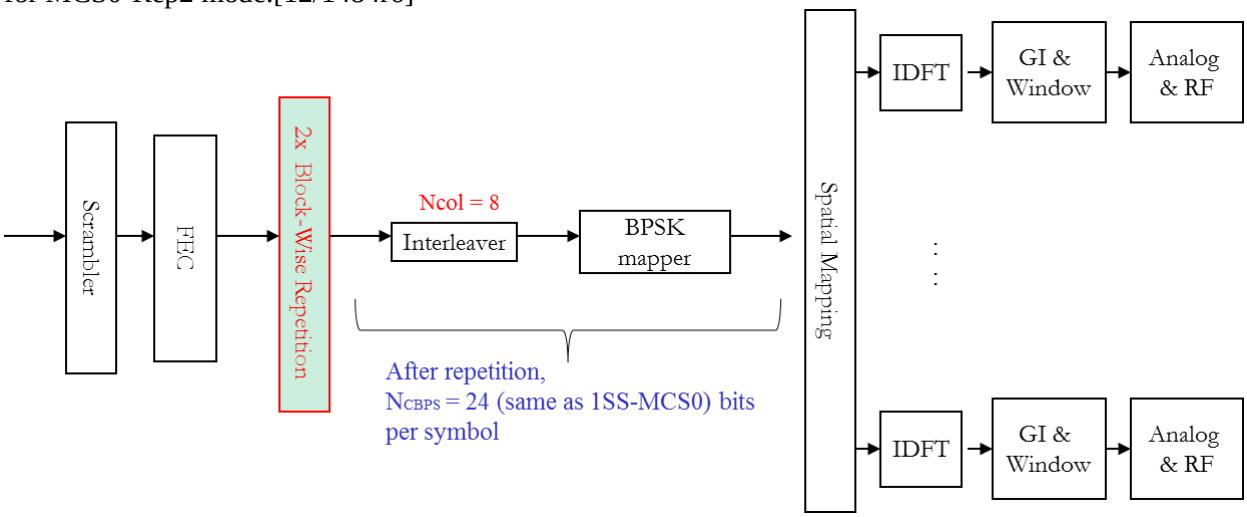
- Apply the same Tx flow in 11ac in the data tones for the data field.



- The 11ah stream parser is the same as 11ac.
- The 11ah encoder parser and segment parser (16MHz only) are the same as 11ac; NES in the MCSs of 2/4/8/16MHz is the same as the corresponding values in 11ac; and $N_{ES} = 1$ in all the MCSs of 1MHz.

3.2.2.2 Transmission flow for MCS0-Rep2 mode

R.3.2.2.2.A: The 802.11ah specification framework shall have the following transmission flow for MCS0-Rep2 mode.[12/1484r6]



- MCS0 Rep2 is applied only for single space-time stream.
  - N_{SS}=1, no STBC
- The "2x block-wise repetition" performed on a per-OFDM symbol basis:
  - C_{out}=[[C_1….C_{2NDBPS}], [C_1….C_{2NDBPS}] XOR s], where [C_1….C_{2NDBPS}] are the FEC output bits per symbol and s=[1 0 0 0 0 1 0 1 0 1 1 1]. [Nov 2012 meeting minutes, 11-12/1315r0]
  - Interleaver parameters are the same as regular MCS0.

- Receiver may conduct MRC combining to improve SNR.

3.2.2.3 Padding

R.3.2.2.3A: 11ah BCC encoded single user PPDU shall use the following padding flow [July 2012 meeting minutes, 11-12/818r0]:

Step1: Compute NSYM: $N_{SYM} = m_{STBC} \left\lceil \frac{8.PSDU\_LENGTH + N_{service} + 6.N_{ES}}{m_{STBC}.N_{DBPS}} \right\rceil$

If DURATION is indicated in SIG field: directly send NSYM in LENGTH/DURATION subfield of SIG field.

If LENGTH is indicated in SIG field: directly send PSDU_LENGTH in number of bytes in LENGTH/DURATION subfield of SIG field.

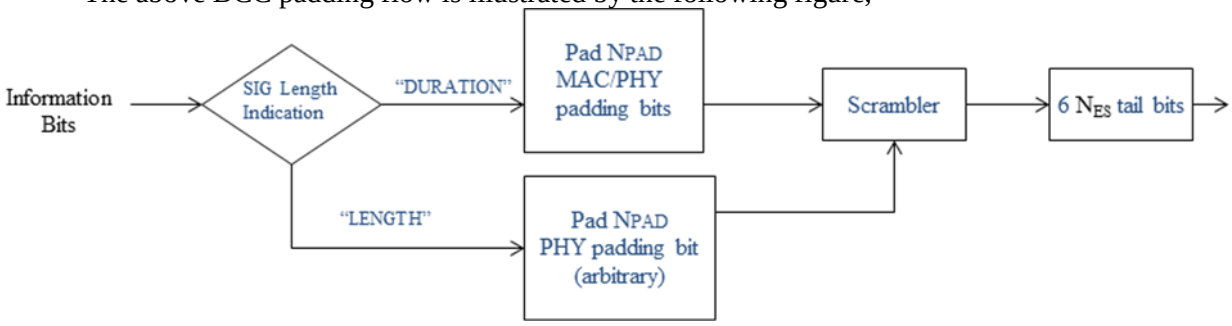
Step 2: Compute NPAD: $N_{PAD} = N_{SYM}.N_{DBPS} - 8.PSDU\_LENGTH - N_{service} - 6.N_{ES}$

Step 3: Padding:

If DURATION is indicated in SIG field: Right after the PSDU data Pad the MAC AMPDU delimiters till the last integer byte of the NPAD padding bits, then pad the remaining 0~7 PHY padding bits (arbitrary1 or 0 bits)—i.e. same as 11ac padding. Scramble the PSDU and padding bits. The 6.NES BCC tails bits are added at the end of the PPDU.

If LENGTH is indicated in SIG field: Right after the PSDU data, pad the NPAD padding bits (arbitrary 1 or 0 bits). Scramble the PSDU and padding bits. The 6.NES BCC tails bits are added at the end of the PPDU.

The above BCC padding flow is illustrated by the following figure;



R.3.2.2.3.B: 11ah LDPC encoded single user PPDU shall use the following encoding flow [July 2012 meeting minutes, 11-12/818r0]:

Step 1: Compute Npld and Navbits as in 11ac:

$$N_{SYM,init} = m_{STBC} \left\lceil \frac{8.PSDU\_LENGTH + N_{service}}{m_{STBC}.N_{DBPS}} \right\rceil$$

$$N_{pld} = N_{SYM,init}.N_{DBPS}$$

$$N_{avbits} = N_{SYM,init}.N_{CBPS}$$

Step 2: Padding: compute NPAD:

$$N_{PAD} = N_{SYM\ init} N_{DBPS} - 8.PSDU\_LENGTH - N_{service}$$

If DURATION is indicated in SIG field: Right after the PSDU data, pad the MAC AMPDU delimiters till the last integer byte of the NPAD padding bits, then pad the remaining 0~7 PHY padding bits (regardless of 1 or 0 bits)—i.e. same as 11ac padding. Scramble the PSDU and Padding bits.

If LENGTH is indicated in SIG field: Right after the PSDU data, pad the NPAD padding bits (regardless of 1 or 0 bits). Scramble the PSDU and Padding bits.

Step 3: After Scrambling, conducts the regular LDPC encoding flow as in 11n spec: shortening, puncturing, repetition, and derive updated N'_{avbits}, hence the updated NSYM,

$N_{SYM} = N'_{avbits} / N_{CBPS}$.

Step 4: Setting the SIG Field:

If DURATION is indicated in SIG field: send NSYM in LENGTH/DURATION subfield of SIG field.
If LENGTH is indicated in SIG field: send PSDU_LENGTH in LENGTH/DURATION subfield of SIG field.

In both cases, if NSYM > NSYM, init, the "additional symbol in LDPC" bit in SIG is set to 1.

For 2/4/8/16MHz LDPC encoded PPDUs, after constellation mapping, apply the 11ac LDPC tone mapper w.r.t. the same FFT sizes. For 1MHz LDPC encoded PPDUs, no LDPC tone mapper is applied.

R.3.2.2.3.C: For 11ah Multiuser PPDUs, the BCC padding and LDPC encoding flows are the same as 11ac. [July 2012 meeting minutes, 11-12/818r0]

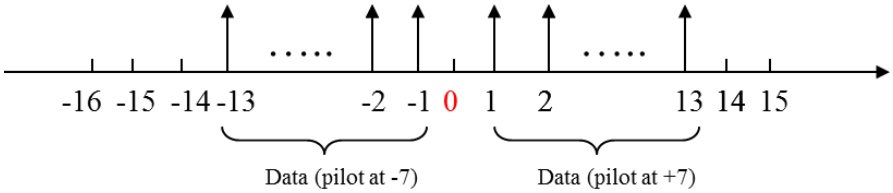
3.2.3 Tone plans

3.2.3.1 >= 2MHz PHY

R.3.2.3.1.A: >=2MHz follows the same tone plans as the corresponding FFT sizes in 11ac [11/1484r6].

3.2.3.2 1 MHz PHY

R.3.2.3.2.A: Define the 1MHz tone allocation as: 24 Data tones, 2 Pilot tones at tone indices +/-7, 3 Guard tones on left and 2 guard tones on right, and 1 DC tone [11/1484r6].



R.3.2.3.2.B: The 802.11ah specification shall use N_{col}=8, N_{rot}=2 as the 32 FFT interleaver choice. [12/369r0, 12/113r0]

3.2.4 Duplicate mode

R.3.2.4.A: The draft specification shall define the bandwidth and dynamic bandwidth indication in the Frame Control fields of Control frames with details TBD, whether this is to be applied to non-duplicate control frames except 1 or 2 MHz is TBD. [13/0294r0]

3.2.4.1 1 MHz duplicate mode in wider bandwidth

R.3.2.4.1.A The draft specification shall define 1 MHz duplicate mode in wider bandwidth: [Nov 2012 meeting minutes, 11-12/1313r0]

1. Preamble and Data portions of 1MHz signal is duplicated in each 1MHz sub-channel of 2MHz/4MHz/8MHz/16MHz.
2. Either 1MHz data PPDU or 1MHz NDP may be duplicated.
3. Phase shift value in each 1MHz sub-channel for PAPR reduction is as follows [13/521r0, May 2013 meeting minutes].

Bandwidth in MHz of the 1MHz DUP Frame	Phase shift values
2	[1 -1]
4	[1 j -j -1]
8	[1 -1 1 1 1 1 -1 -1]
16	[1 1 1 -1 1 1 1 -1 -1 -1 1 -1 1 1 -1 1]

3.2.4.2 2 MHz duplicate mode in wider bandwidth

R.3.2.4.2.A The draft specification shall define 2 MHz duplication mode as follows: [13/0060r0]

1. Preamble and Data portions of 2MHz signal is duplicated in each 2MHz sub-channel of 4MHz/8MHz/16MHz.
2. Phase shift is applied in each 2MHz sub-channel of the duplicate signal.
   a. 4MHz: [1, j]
   b. 8MHz: [1 -1 -1 -1]
   c. 16MHz: each 8MHz half is identical to a stand-along 8MHz signal.

3.2.5 S1G PMD receiver specification

3.2.5.1 Receiver minimum input sensitivity

R.3.2.5.1.A: The packet error rate (PER) shall be less than 10% for a PSDU length of 256 octets with rate-dependent input levels TBD. [Nov 2012 meeting minutes, 11-12/1326r0]

R.3.2.5.1.B: The draft specification shall define the receiver minimum input level sensitivity as below: [13/0061r0]

Modulation	Rate (R)	Minimum Sensitivity (1MHz PPDU) (dBm)	Minimum Sensitivity (2MHz PPDU) (dBm)	Minimum Sensitivity (4MHz PPDU) (dBm)	Minimum Sensitivity (8MHz PPDU) (dBm)	Minimum Sensitivity (16MHz PPDU) (dBm)
BPSK	1/2 & 2x repetition	-98	n.a.	n.a.	n.a.	n.a.
BPSK	1/2	-95	-92	-89	-86	-83
QPSK	1/2	-92	-89	-86	-83	-80
QPSK	3/4	-90	-87	-84	-81	-78
16-QAM	1/2	-87	-84	-81	-78	-75
16-QAM	3/4	-83	-80	-77	-74	-71
64-QAM	2/3	-79	-76	-73	-70	-67
64-QAM	3/4	-78	-75	-72	-69	-66
64-QAM	5/6	-77	-74	-71	-68	-65
256-QAM	3/4	-72	-69	-66	-63	-60
256-QAM	5/6	-70	-67	-64	-61	-58

3.2.6 Data field

3.2.6.1 SERVICE field

R.3.2.6.1.A: The draft specification shall define the11ah SERVICE field as follows: [13/0062r0]

1. The SERVICE field has 8 bits, in which first 7 bits are used for the scrambler seed, and the remaining 1 bit reserved.

3.3 Modulation and Coding Scheme (MCS)

R.3.3.A: The 802.11ah specification shall allow following 11ah MCSs [11/1484r6]:

1. For 1MHz, 11ac MCS0~9, as well as MCS10 and more modes TBD.
2. For >=2MHz, the MCS tables for BCC and LDPC are the same as the corresponding tables in 11ac before downclocking, i.e. same MCS exclusions as in 11ac. [13/0297r0]

R.3.3.B: The 802.11ah specification shall adopt MCS0 rep 2 as the lowest rate for 1 MHz [11/1484r4, motion1].

1. MCS0~9, same constellation sizes and coding rates as defined in 802.11ac [12/1085r0, September 2012 meeting minutes]
2. MCS10, BPSK, rate ½, and 2x repetition [12/1085r0, September 2012 meeting minutes]

3.4 Spatial Multiplexing

R.3.4.1.A: The maximum number of space-time streams (N_{STS}) in a data PPDU transmission shall be less than or equal to 4. [11/1275r1]

3.5 Transmit Beamforming

R.3.5.A: The 802.11ah specification shall support, for all applicable BW, the SUBF and MU-MIMO feedback structure and protocol as specified in the following sections of IEEE P802.11ac™/D2.0, as an optional feature [12/371r0] [Nov 2012 meeting minutes, 11-12/1312r0]:

- 8.4.1.46 VHT MIMO Control field
- 8.4.1.47 VHT Compressed Beamforming Report field - contents of feedback frame
- 8.4.1.48 MU Exclusive Beamforming Report field - contents of MU frame
- 9.31.5 VHT sounding protocol
- 22.3.11 and its subsections: SU-MIMO and MU-MIMO Beamforming

- Tone grouping values (Ng) and the corresponding tone map for each Ng when bandwidth >=2MHz are the same as in 11ac with the same FFT sizes.
- For MU feedback, and SU feedback with Nc>1, angle alignment, angle quantization bitwidth and the definition of the codebook info subfield of VHT MIMO Control field are the same as in 11ac.
- For SU feedback with Nc=1, modify the codebook info subfield of VHT MIMO control field as below:
  - Set to 0 for 2 bits for ϕ, and ψ is not fed back.
  - Set to 1 for 2 bits for ψ, and 4 bits for ϕ.
- The angle alignment table is as below.
- Beamformer shall be capable of receiving and processing a beamforming feedback frame with any tone grouping and angle quantization bitwidth.
- When the ψ angle is not included in the feedback frame, in the case of SU feedback Nc=1, ψ angle values are assumed as given below, which correspond to the first column of the V matrix having elements with equal magnitude:

$$4\times 1: \psi_{21} = 0.25\pi, \psi_{31} = 0.196\pi, \psi_{41} = 0.167\pi$$
$$3\times 1: \psi_{21} = 0.25\pi, \psi_{31} = 0.196\pi$$
$$2\times 1: \psi_{21} = 0.25\pi$$

Order of angles in the Compressed Beamforming Feedback Matrix subfield **if the Feedback Type is SU**

Size of *V* (*Nr* × *Nc*)	**Codebook Information Field**	**Number of angles (*Na*)**	**The order of angles in the Compressed Beamforming Feedback Matrix subfield**
2×1	0	1	ϕ11
2×1	1	2	ϕ11, ψ21
2×2	0 or 1	2	ϕ11, ψ21

3×1	0	2	$\phi 11, \phi 21$
3×1	1	4	$\phi 11, \phi 21, \psi 21, \psi 31$
3×2	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
3×3	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
4×1	0	3	$\phi 11, \phi 21, \phi 31$
4×1	1	6	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41$
4×2	0 or 1	10	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42$
4×3	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$
4×4	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$

Order of angles in the Compressed Beamforming Feedback Matrix subfield **if the Feedback Type is MU**

Size of *V* (*Nr* × *Nc*)	**Codebook Information Field**	**Number of angles (*Na*)**	**The order of angles in the Compressed Beamforming Feedback Matrix subfield**
2×1	0 or 1	2	$\phi 11, \psi 21$
2×2	0 or 1	2	$\phi 11, \psi 21$
3×1	0 or 1	4	$\phi 11, \phi 21, \psi 21, \psi 31$
3×2	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
3×3	0 or 1	6	$\phi 11, \phi 21, \psi 21, \psi 31, \phi 22, \psi 32$
4×1	0 or 1	6	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41$
4×2	0 or 1	10	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42$
4×3	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$
4×4	0 or 1	12	$\phi 11, \phi 21, \phi 31, \psi 21, \psi 31, \psi 41, \phi 22, \phi 32, \psi 32, \psi 42, \phi 33, \psi 43$

3.6 Spatial Mapping Matrix

The auto-detection between 1MHz and 2MHz preambles as described in sub-section 2a of section R.3.2.1.1.C assumes channel smoothness. It is recommended that the spatial mapping matrix Q applied to LTF1 is chosen such that it preserves the smoothness of the physical channel. This can, for example, be achieved by minimizing the amplitude and phase variation of each element of Q in successive tones. [July 2012 meeting minutes, 11-12/815r0]

Examples:

- The following Q may be used: Q as defined for cyclic shift diversity using the values specified in the corresponding tables.
- The following Q should not be used – antenna hopping as described in 802.11REVmb section 20.3.11.11.2 (C)-(2) - the values of Q on successive tones flip between 1 and 0.

3.7 Traveling Pilots

R.3.7.A: Traveling pilots are an optional feature used to improve channel estimation under high Doppler scenarios. [Nov 2012 meeting minutes, 11-12/1322r0]

R.3.7.B: Support for traveling pilots receive capability shall be indicated by two bits – the first indicating one space time stream and the second two space time stream. [Nov 2012 meeting minutes, 11-12/1322r0]

R.3.7.C: Traveling pilots design [Nov 2012 meeting minutes, 11-12/1322r0]

1. 32FFT
   a. N_{sts}=1

Pilot Index \ Pattern Index	0	1	2	3	4	5	6	7	8	9	10	11	12
0	-2	-10	-5	-13	-8	-3	-11	-6	-1	-9	-4	-12	-7
1	12	4	9	1	6	11	3	8	13	5	10	2	7

   b. STBC for N_{sts}=2 (cover odd tones)

Pilot Index \ Pattern Index	0	1	2	3	4	5	6
0	-3	-13	-9	-5	-1	-11	-7
1	11	1	5	9	13	3	7

2. 64FFT
   a. N_{sts}=1

Pilot Index \Pattern Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	-28	-24	-20	-16	-26	-22	-18	-27	-23	-19	-15	-25	-21	-17
1	-12	-8	-4	-2	-14	-10	-6	-11	-7	-3	1	-13	-9	-5
2	4	8	12	16	2	6	10	5	9	13	17	-1	3	7
3	20	24	28	26	14	18	22	21	25	23	27	11	15	19

   b. STBC for N_{sts}=2 (cover even tones)

Pilot Index \Pattern Index	0	1	2	3	4	5	6
0	-28	-24	-20	-16	-26	-22	-18
1	-12	-8	-4	-2	-14	-10	-6
2	4	8	12	16	2	6	10
3	20	24	28	26	14	18	22

3. 128FFT
   a. N_{sts}=1

Pilot Index \Pattern Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	-49	-41	-33	-25	-17	-9	-58	-50	-42	-34	-26	-18	-10	-2	-51	-43	-35	-27	-19
1	-30	-22	-14	-6	-55	-47	-39	-31	-23	-15	-7	-56	-48	-40	-32	-24	-16	-8	-57
2	-11	-3	-52	-44	-36	-28	-20	-12	-4	-53	-45	-37	-29	-21	-13	-5	-54	-46	-38
3	11	19	27	35	43	51	2	10	18	26	34	42	50	58	9	17	25	33	41
4	30	38	46	54	5	13	21	29	37	45	53	4	12	20	28	36	44	52	3
5	49	57	8	16	24	32	40	48	56	7	15	23	31	39	47	55	6	14	22

b. STBC for N_{sts}=2 (cover even tones)

Pilot Index \Pattern Index	0	1	2	3	4	5	6	7	8	9
0	-50	-44	-38	-32	-26	-20	-14	-8	-2	-56
1	-30	-24	-18	-12	-6	-58	-54	-48	-42	-36
2	-10	-4	-58	-52	-46	-40	-34	-28	-22	-16
3	10	16	22	28	34	40	46	52	58	4
4	30	36	42	48	54	58	6	12	18	24
5	50	56	2	8	14	20	26	32	38	44

4. 256FFT

a. N_{sts}=1

Pattern Index \ Pilot Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	-122	-118	-114	-110	-106	-102	-98	-94	-120	-116	-112	-108	-104	-100	-96	-92	-121	-117	-113	-109	-105	-101	-97	-93	-119	-115	-111	-107	-103	-99	-95	-91
1	-90	-86	-82	-78	-74	-70	-66	-62	-88	-84	-80	-76	-72	-68	-64	-60	-89	-85	-81	-77	-73	-69	-65	-61	-87	-83	-79	-75	-71	-67	-63	-59
2	-58	-54	-50	-46	-42	-38	-34	-30	-56	-52	-48	-44	-40	-36	-32	-28	-57	-53	-49	-45	-41	-37	-33	-29	-55	-51	-47	-43	-39	-35	-31	-27
3	-26	-22	-18	-14	-10	-6	-2	2	-24	-20	-16	-12	-8	-4	2	4	-25	-21	-17	-13	-9	-5	-2	3	-23	-19	-15	-11	-7	-3	2	5
4	6	10	14	18	22	26	30	34	8	12	16	20	24	28	32	36	7	11	15	19	23	27	31	35	9	13	17	21	25	29	33	37
5	38	42	46	50	54	58	62	66	40	44	48	52	56	60	64	68	39	43	47	51	55	59	63	67	41	45	49	53	57	61	65	69
6	70	74	78	82	86	90	94	98	72	76	80	84	88	92	96	100	71	75	79	83	87	91	95	99	73	77	81	85	89	93	97	101
7	102	106	110	114	118	122	120	-120	104	108	112	116	120	122	-2	-122	103	107	111	115	119	121	2	-121	105	109	113	117	121	121	-2	-121

b. STBC for N_{sts}=2 (cover even tones)

Pilot Index \ Pattern Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	-122	-118	-114	-110	-106	-102	-98	-94	-120	-116	-112	-108	-104	-100	-96	-92
1	-90	-86	-82	-78	-74	-70	-66	-62	-88	-84	-80	-76	-72	-68	-64	-60
2	-58	-54	-50	-46	-42	-38	-34	-30	-56	-52	-48	-44	-40	-36	-32	-28
3	-26	-22	-18	-14	-10	-6	-2	2	-24	-20	-16	-12	-8	-4	2	4
4	6	10	14	18	22	26	30	34	8	12	16	20	24	28	32	36
5	38	42	46	50	54	58	62	66	40	44	48	52	56	60	64	68
6	70	74	78	82	86	90	94	98	72	76	80	84	88	92	96	100
7	102	106	110	114	118	122	120	-120	104	108	112	116	120	122	-2	-122

R.3.7.D: Modulation of the traveling pilots [Nov 2012 meeting minutes, 11-12/1322r0]

1. For single space time stream, traveling pilots in data field are modulated the same way as fixed pilots in data field (with the exception of boosting by a factor of 1.5).

$$[\mathbf{X}_k(n)]_{N_{TX}\times 1} = [\mathbf{Q}_k]_{N_{TX}\times 1} \cdot p_n P_n^{\mathrm{k}} \cdot 1.5$$

2. For STBC, the traveling pilots tones across two consecutive data symbols are modulated the same way as the data tones in LTF.

$$[\mathbf{X}_k(n) \quad \mathbf{X}_k(n+1)]_{N_{TX}\times 2} = [\mathbf{Q}_k]_{N_{TX}\times 2} [\mathbf{D}_{CSD}^{(k)}]_{2\times 2} \mathbf{P}_{2\times 2} \cdot \begin{bmatrix} p_n P_n^{\mathrm{k}} \cdot 1.5 & 0 \\ 0 & p_{n+1} P_{n+1}^{\mathrm{k}} \cdot 1.5 \end{bmatrix}$$

3.8 Timing-Related Constants

R.3.8.A: The draft specification shall include the following timing-related constants: [Nov 2012 meeting minutes, 11-12/1363r1]

Parameter	CBW1	CBW2	CBW4	CBW8	CBW16	Description
N_{SD}	24	52	108	234	468	Number of data subcarriers per OFDM symbol
N_{SP}	2	4	6	8	16	Number of pilot subcarrier per OFDM symbol
N_{ST}	26	56	114	242	484	Total number of useful subcarriers per OFDM symbol
N_{SR}	13	28	58	122	250	Highest data subcarrier index per OFDM symbol
Δ_F	31.25 kHz					Subcarrier frequency spacing
T_{DFT}	32 μs = $1/\Delta_F$					IDFT/DFT period
T_{GI}	8 μs = $T_{DFT}/4$					Guard interval duration
T_{DGI}	16 μs					Double guard interval
T_{SGI}	4 μs = $T_{DFT}/8$					Short guard interval duration
T_{SYML}	40 μs = $T_{DFT} + T_{GI} = 1.25 \times T_{DFT}$					Duration of OFDM symbol with normal guard interval
T_{SYMS}	36 μs = $T_{DFT} + T_{GIS} = 1.125 \times T_{DFT}$					Duration of OFDM symbol with short guard interval
T_{SYM}	T_{SYML} or T_{SYMS} depending on the GI used					OFDM symbol duration
T_{STF}	160 μs = $4 \times T_{SYML}$	80 μs = $2 \times T_{SYML}$				STF field duration
T_{DSTF}	n.a.	40 μs = T_{SYML}				≥2 MHz long preamble D-STF field duration
T_{LTF1}	160 μs = $4 \times T_{DFT} + 2 \times T_{GI} + T_{GI2}$	80 μs = $2 \times T_{DFT} + T_{GI2}$				First LTF field duration
T_{LTFs}	40 μs = T_{SYML}					Second and subsequent LTF field duration
T_{DLTF}	n.a.	40 μs = T_{SYML}				≥2 MHz long preamble D-LTF field duration

T_{SIG}	240 μs = 6 × T_{SYML}	80 μs = 2 × T_{SYML}	SIG field duration
T_{SIGA}	n.a.	80 μs = 2 × T_{SYML}	≥2 MHz long preamble SIGA field duration
T_{SIGB}	n.a.	40 μs = T_{SYML}	≥2 MHz long preamble SIGB field duration

3.9 S1G PLME

3.9.1 PHY characteristics

[12/1104r2, September 2012 meeting minutes]

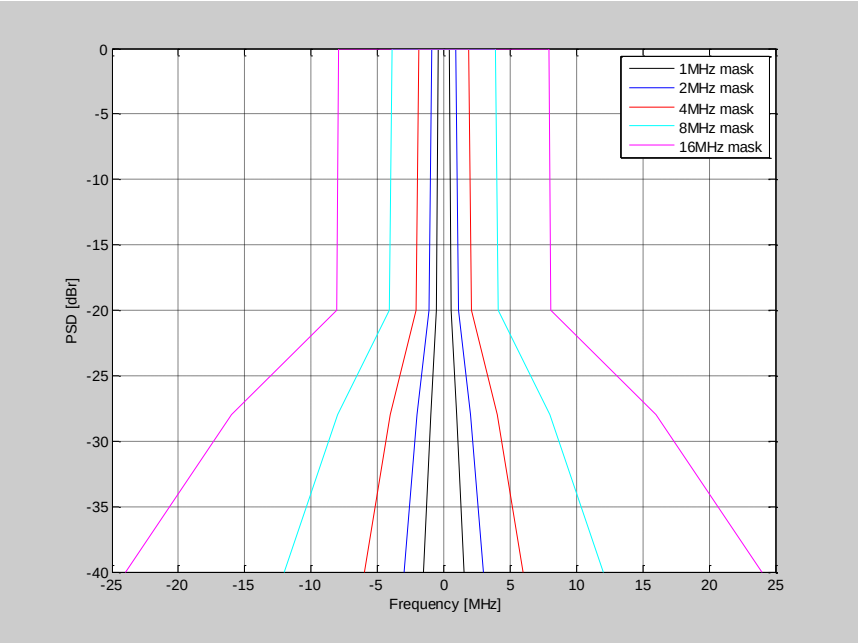
Characteristics	Value
aSlotTime	52 us
aCCATime	40 us
aAirPropagationTime	6 us
aSIFSTime	160 us
aPHY-RX-START-Delay	1MHz preamble: 600us 2MHz/4MHz/8MHz/16MHz: 280us [13/0496r0, May 2013 meeting minutes]

3.10 S1G transmit specification

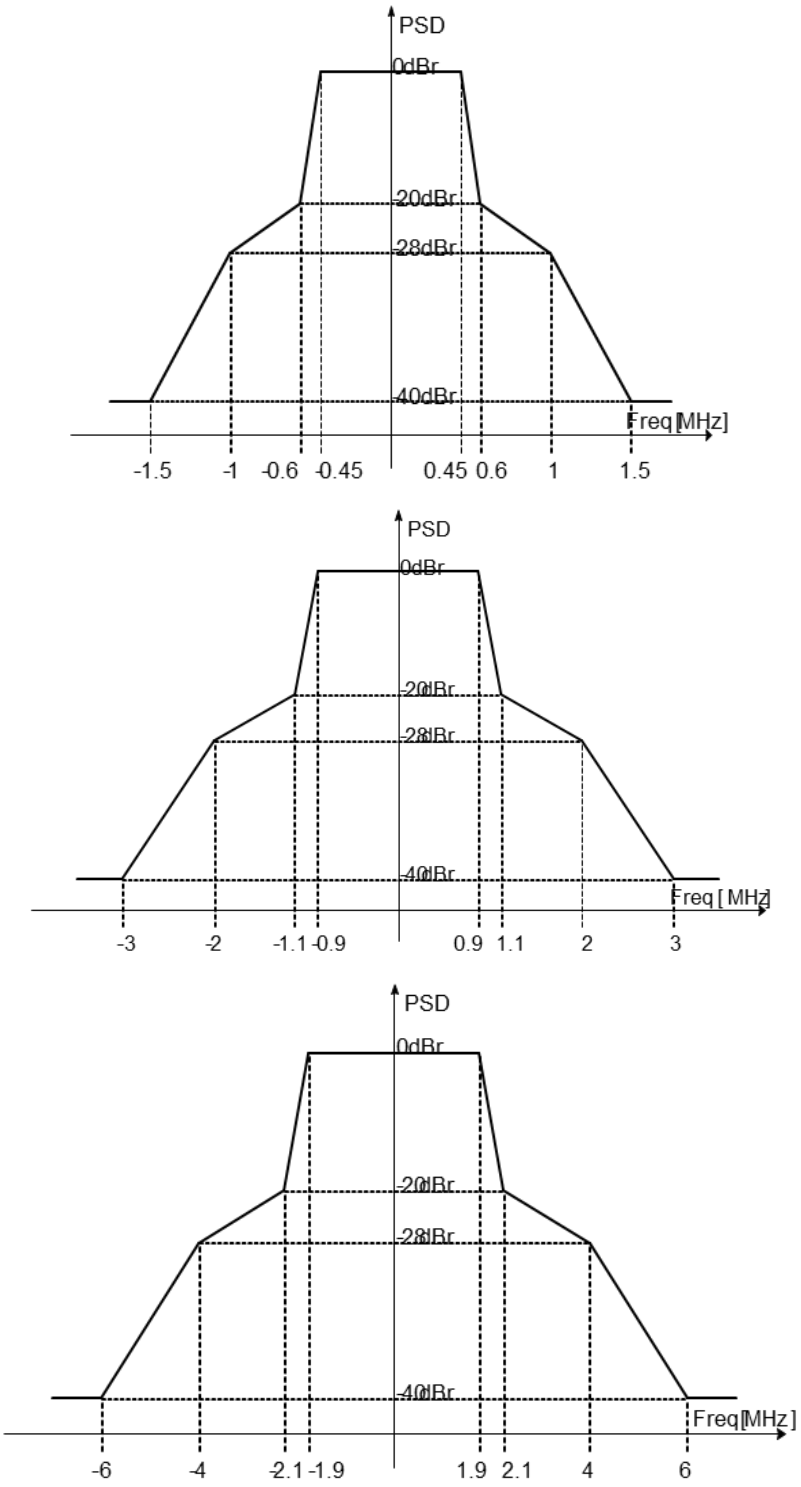
3.10.1 1/2/4/8/16 MHz Spectral Mask

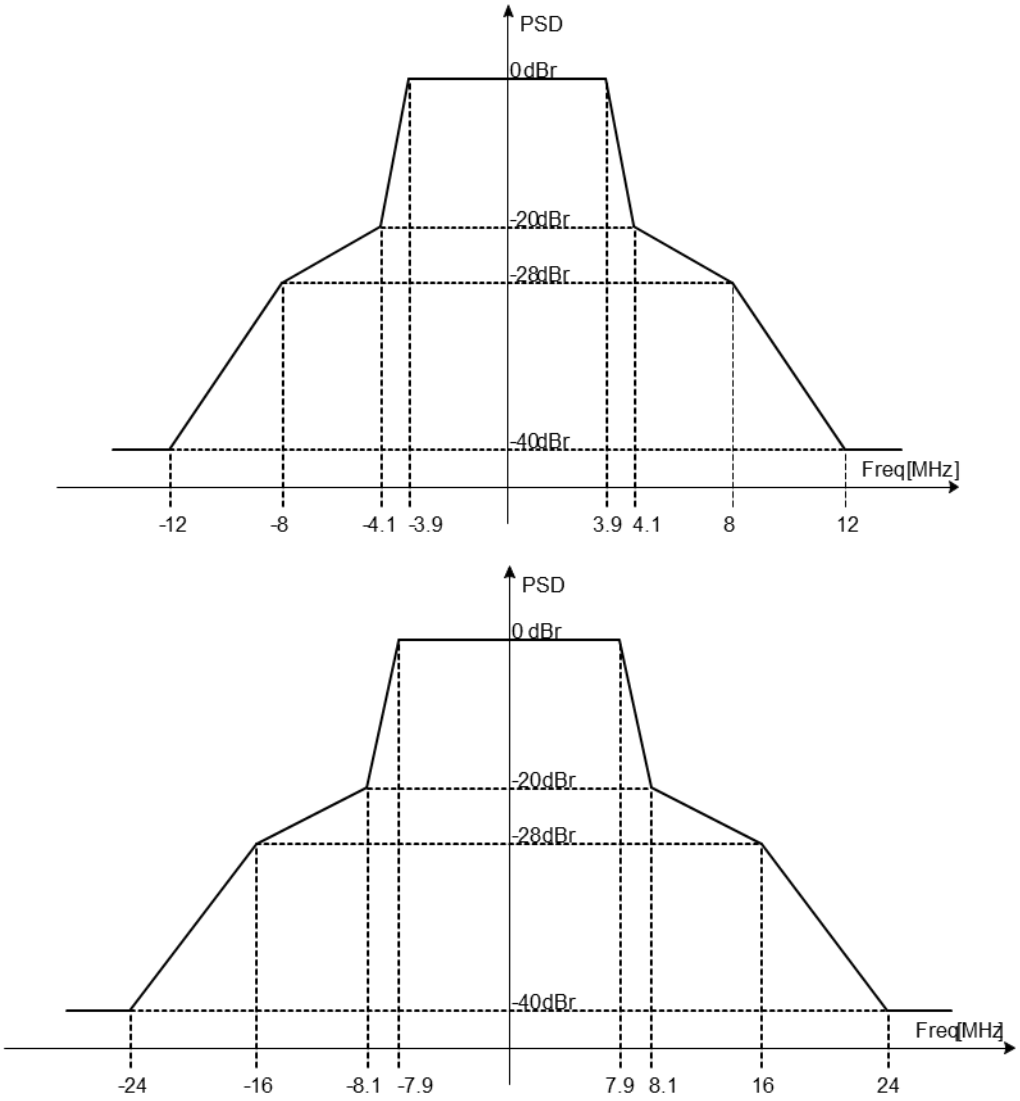
R.3.10.1.A: The draft specification shall support 1/2/4/8/16 MHz spectral masks shown below [13/0084r0]:

BW(MHz)	0dBr	-20dBr	-28dBr	-40dBr
1	±0.45	±0.6	±1	±1.5
2	±0.9	±1.1	±2	±3
4	±1.9	±2.1	±4	±6
8	±3.9	±4.1	±8	±12
16	±7.9	±8.1	±16	±24



1. The bottleneck of meeting a 1 MHz mask (scaled 11ac mask without relaxation) is at the band edge (See Appendix)
2. Move out 0.55MHz (scaled 11ac mask) to 0.6 MHz in the first slope to relax the 1 MHz mask's band edge requirement
3. As in 11ac, low TX power devices may not be required to meet -40 dBr, and generic values may be allowed. Assuming -40 dBr level for a 0 dBm transmission
    a. For 1 MHz channel, the transmit spectrum should have the maximum of -40 dBr and -40 dBm/MHz at 1.5 MHz frequency offset and above
    b. For 2 MHz channel, the transmit spectrum should have the maximum of -40 dBr and -43 dBm/MHz at 3 MHz frequency offset and above
    c. For 4 MHz channel, the transmit spectrum should have the maximum of -40 dBr and -46 dBm/MHz at 6 MHz frequency offset and above
    d. For 8 MHz channel, the transmit spectrum should have the maximum of -40 dBr and -49 dBm/MHz at 12 MHz frequency offset and above
    e. For 16 MHz channel, the transmit spectrum should have the maximum of -40 dBr and -49 dBm/MHz at 24 MHz frequency offset and above


PSD
0dBr
-20dBr
-28dBr
-40dBr
Freq [MHz]
-1.5
-1
-0.6
-0.45
0.45
0.6
1
1.5
PSD
0dBr
-20dBr
-28dBr
-40dBr
Freq [MHz]
-3
-2
-1.1
-0.9
0.9
1.1
2
3
PSD
0dBr
-20dBr
-28dBr
-40dBr
Freq [MHz]
-6
-4
-2.1
-1.9
1.9
2.1
4
6



R.3.10.1.B: The draft specification shall support a resolution BW of 10kHz.

3.10.2 Spectral flatness [13/307r0]

1. 802.11ah 1/2/4/8/16MHz Spectral Flatness

Transmission BW(MHz)	**Averaging subcarrier indices (inclusive)**	**Tested subcarrier indices (inclusive)**	**Maximum Deviation (dB)**
1	-8 to -1 and +1 to +8	-8 to -1 and +1 to +8	±4
		-13 to -9 and +9 to +13	+4/-6
2	-16 to -1 and +1 to +16	-16 to -1 and +1 to +16	±4

		-28 to -17 and +17 to +28	+4/-6
4	-42 to -2 and +2 to +42	-42 to -2 and +2 to +42	±4
		-58 to -43 and +43 to +58	+4/-6
8	-84 to -2 and +2 to +84	-84 to -2 and +2 to +84	±4
		-122 to -85 and +85 to +122	+4/-6
16	-172 to -130, -126 to -44, +44 to +126, and +130 to +172	-172 to -130, -126 to -44, +44 to +126, and +130 to +172	±4
		-250 to -173, -43 to -6, +6 to +43, and +173 to +250	+4/-6

2. 802.11ah Spectral Flatness for 2 MHz DUP Mode

Transmission BW(MHz)	**Averaging subcarrier indices (inclusive)**	**Tested subcarrier indices (inclusive)**	**Maximum Deviation (dB)**
4	-42 to -33, -31 to -6, +6 to +31, and +33 to +42	-42 to -33, -31 to -6, +6 to +31, and +33 to +42	±4
		-58 to -43 and +43 to +58	+4/-6
8	-84 to -70, -58 to -33, -31 to -6, +6 to +31, +33 to +58, +70 to +84	-84 to -70,-58 to -33, -31 to -6, +6 to +31, +33 to +58, +70 to +84	±4
		-122 to -97, -95 to -85 and +85 to +95, +97 to +122	+4/-6
16	-172 to -161, -159 to -134, -122 to -97, -95 to -70, -58 to -44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172	-172 to -161, -159 to -134, -122 to -97, -95 to -70, -58 to -44, +44 to +58, +70 to +95, +97 to +122, +134 to +159, +161 to +172	±4
		-250 to -225, -223 to -198, -186 to -173, -43 to -33, -31 to -6, +6 to +31, +33 to +43, +173 to +186, +198 to +223, +225 to +250	+4/-6

3. 802.11ah Spectral Flatness for 1 MHz DUP Mode

Transmission BW(MHz)	Averaging subcarrier indices (inclusive)	Tested subcarrier indices (inclusive)	Maximum Deviation (dB)
2	-15 to -3 and +3 to +15	-15 to -3 and +3 to +15	±4
		-29 to -17 and +17 to +29	+4/-6
4	-42 to -35, -29 to -17, -15 to -3, +3 to +15, +17 to +29, and +35 to +42	-42 to -35, -29 to -17, -15 to -3, +3 to +15, +17 to +29, and +35 to +42	±4
		-61 to -49, -47 to -43, +43 to +47, and +49 to +61	+4/-6
8	-84 to -81, -79 to -67, -61 to -49, -47 to -35, -29 to -17, -15 to -3, +3 to +15, +17 to +29, +35 to +47, +49 to +61, +67 to +79, and +81 to +84	-84 to -81, -79 to -67, -61 to -49, -47 to -35, -29 to -17, -15 to -3, +3 to +15, +17 to +29, +35 to +47, +49 to +61, +67 to +79, and +81 to +84	±4
		-125 to -113, -111 to -99, -93 to -85, +85 to +93, +99 to +111, and +113 to +125	+4/-6
16	-172 to -163, -157 to -145, -143 to -131, -125 to -113, -111 to -99, -93 to -81, -79 to -67, -61 to -49, -47 to -44, +44 to +47, +49 to +61, +67 to +79, +81 to +93, +99 to +111, +113 to +125, +131 to +143, +145 to +157, and +163 to +172	-172 to -163, -157 to -145, -143 to -131, -125 to -113, -111 to -99, -93 to -81, -79 to -67, -61 to -49, -47 to -44, +44 to +47, +49 to +61, +67 to +79, +81 to +93, +99 to +111, +113 to +125, +131 to +143, +145 to +157, and +163 to +172	±4
		-253 to -241, -239 to -227, -221 to -209, -207 to -195, -189 to -177, -175 to -173, -43 to -35, -29 to -17, -15 to -3, +3 to +15, +17 to +29, +35 to +43,+173 to +175, +177 to +189, +195 to +207, +209 to +221, +227 to +239, and +241 to +253	+4/-6

3.10.3 Transmit center frequency and symbol clock frequency tolerance

R.3.10.3.A: The draft specification shall support frequency inaccuracy maximum tolerance of ±20 ppm. [13/497r0, May 2013 meeting minutes]

3.10.4 Modulation accuracy [13/0508r0, May 2013 meeting minutes]

24.3.17.4.1 Introduction to modulation accuracy tests

- **Transmit modulation accuracy specifications are described in 24.3.17.4.2 (Transmit center frequency leakage) and 24.3.17.4.3 (Transmitter constellation error). The test method is described in 24.3.17.4.4 (Transmitter modulation accuracy (EVM) test).**

24.3.17.4.2 Transmit center frequency leakage

- **TX LO leakage shall meet the following requirements for all formats and bandwidths :**
  - When the RF LO is in the center of the transmitted PPDU BW, the power measured at the center of transmission BW using resolution BW 31.25 kHz shall not exceed the average power per-subcarrier of the transmitted PPDU, or equivalently, ( ), where P is the transmit power per antenna in dBm, and N_{ST} is defined in Table 24-4 (Timing-related constants).
  - When the RF LO is not at the center of the transmitted PPDU BW, the power measured at the location of the RF LO using resolution BW 31.25 kHz shall not exceed the maximum of -27dB relative to the total transmit power and -15dBm, or equivalently P-10log10(N_{ST}), where P is the transmit power per antenna in dBm.
- **The transmit center frequency leakage is specified per antenna.**

24.3.17.4.3 Transmitter constellation error

- The relative constellation RMS error, calculated by first averaging over subcarriers, OFDM PPDUs and spatial streams (see Equation (20-89)) shall not exceed a data-rate dependent value according to Table 24-32 (Allowed relative constellation error versus constellation size and coding rate). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS}=N_{STS}$ (no STBC) shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 1 MHz, 2 MHz, 4 MHz, 8 MHz and 16 MHz transmissions.
- Table 24-32

* Allowed relative constellation error versus constellation size and coding rate		
Modulation	Coding rate	Relative constellation error (dB)
BPSK	1/2 rep2	TBD
BPSK	1/2	-5
QPSK	1/2	-10
QPSK	3/4	-13
16-QAM	1/2	-16
16-QAM	3/4	-19
64-QAM	2/3	-22
64-QAM	3/4	-25
64-QAM	5/6	-27

256-QAM	3/4	-30
256-QAM	5/6	-32

24.3.17.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted; except that for duplicate transmissions, each 1 MHz or 2 MHz subchannel may be tested independently while all subchannels are being transmitted.
The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.
b) Transition from STF to LTF1 shall be detected and fine timing shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) Symbols in a PPDU shall be de-rotated according to estimated frequency offset.
e) For each LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and de-rotate the subcarrier values according to the estimated phase.
f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.
g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, de-rotate the subcarrier values according to the estimated phase, group the results from all the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.
h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.
i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (20-89).

The test shall be performed over at least 20 PPDUs (as defined in Equation (20-89)). The PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

4 MAC Layer

This section describes the functional blocks of the MAC layer.

4.1 Power Save

R.4.1.A: An AP may provide its TSF timer accuracy information to non-AP STAs [12/130r0].
R.4.1.B: The 802.11ah draft specification shall define the following operation mode. [12/127r1]

1. STA may send a PS-Poll at any time
2. AP shall respond immediately to a PS Poll with either
    a. Data for the requesting STA, or
    b. ACK frame with 1bit-field indicating

i. 1: traffic is buffered (as indicated in the TIM map), stay awake (i.e. a service period starts)
ii. 0: no traffic is buffered, go back to sleep
iii. The bit used in current ACK frame format is the More Data field

R.4.1.C: The draft specification shall support that BSS Max Idle Period shall be able to set to a longer value (~days) by changing the unit of Max Idle Period larger than 1000 TU (1s). [May 2012 meeting minutes].

1. An AP advertises its capability of supporting "very long Max Idle Period" in probe response frame and beacon frame as an IE [July 2012 meeting minutes, 11-12/845r0]
2. A STA includes its preferred Max Idle Period value in the (Re) Association Request frame, the AP select one of its supported Max Idle Period based on the STA's preferred Max Idle Period value, and indicates its accepted value to the STA in the (Re)Association Response frame [July 2012 meeting minutes, 11-12/845r0]

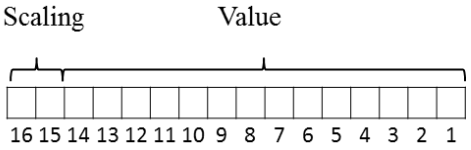
R.4.1.D: The draft specification shall support that the AP shall be able to support multiple Max Idle Periods. [May 2012 meeting minutes]

R.4.1.E: The draft specification shall support the concept that a non-TIM STA shall transmit at least one PS-Poll or trigger frame every Listen Interval and the non-TIM STA is not required to wake to receive a beacon each Listen Interval. [May 2012 meeting minutes, 12/618r0]

R.4.1.F: The draft specification shall support that an AP may reply to the PS-Poll with a timer indicating the re-scheduling of doze/awake time. [July 2012 meeting minutes, 11-12/409r6]

- Re-scheduling doze/awake time
  - PS-Poll not followed by DATA or immediate ACK, AP replies to STA with a timer indicating when it should wake up again
  - The timer is considered short enough without causing too much clock drift
  - The reply may contain traffic indication for STAs
    - If PS-Polling STA knows no buffered frame, it goes to sleep
    - If PS-Polling STA knows buffered frame for itself, it may go to sleep and wake up again after timer expires
    - Other STAs may make use of this timer
  - STA can re-sync to the beacon with the help of the timer
  - AP determines to use the protocol [11-12/127r1] or this proposed scheme

R.4.1.G: The draft specification shall define a mechanism to extend the BSS Max Idle Period, Listen Interval and WNM-Sleep Interval by introducing unified scaling factors i.e. using the first two MSBs to represent the Scaling Factor (SF) and the remaining 14 bits to indicate the actual value. [12/656r1, September 2012 meeting minutes]



1. The definition of the unified scaling factors are shown in the table below:

Two MSBs	Scaling Factor (SF)
00	1

01	10
10	1000
11	10000

R.4.1.H: The draft specification shall define a frame classification mechanism to enable classification and the subsequent processing (e.g., filtering) based on the MAC Header content. [12/1089r0, September 2012 meeting minutes]

R.4.1.I: The draft specification shall support the following listen interval update: [13/0089r0]

1. A STA can update the listen interval when it changes its operation mode from TIM to Non-TIM mode.
2. A STA may inform to an AP its updated listen interval and the AP may response to the STA.
3. The updated listen interval is optionally included in an existing frame (e.g. conditional update at TIM to Non-TIM mode change in the AID switch request frame)

4.2 Channel Access

R4.2.A: The draft specification shall support the highest channel access priority to the sensor type of STAs [May 2012 meeting minutes, 1230r1].

1. The draft specification shall support the concept of defining multiple EDCA parameters sets (signaling TBD; per STA/Type/group TBD). [July 2012 meeting minutes, 11-12/861r0]

R.4.2.B: The draft specification shall support the concept of utilizing information from an AP to spread out uplink transmissions over a period of time to mitigate the hidden node problem [May 2012 meeting minutes, 12/606r1]

R.4.2.C: Grouping of STAs shall be introduced to the draft specification for controlling the number of STAs performing channel access and to save energy. [May 2012 meeting minutes, 12/650r0]

R.4.2.D: The draft specification shall include a mechanism to set wake times and intervals for clients [July 2012 meeting minutes, 12/823r0]

1. An AP can assign a TWT group ID to the STA and provide zero phase offset TWT value to each group [13/0079r0]
2. The draft specification shall include a channel indication in TWT setup [13/0071r0]

R.4.2.E: The draft specification shall define synch frame procedures as follows:

1. When requested by a STA, the AP sends a synch frame at the slot boundary or the target wake time of the STA, if the channel is idle, to help the STA quickly synch to the medium. (optional to AP and STA) [July 2012 meeting minutes, 11-12/840r0]
   a. It is recommended that the AP sends a NDP CTS frame defined in 4.4.2.3 as a synch frame. [12/840r1, September 2012 meeting minutes]
   b. An AP should not send a synch frame at each slot boundary within a RAW period if Cross-Slot Boundary transmission is not allowed within the RAW period unless NAV protection is requested by the STA [13/0507r0, May 2013 meeting minutes]

2. When requested by a STA, the AP schedules a DL (downlink) NDP Paging frame at the slot boundary or the target wake time of the STA as the next frame for transmission [Nov 2012 meeting minutes, 11-12/1324r0]

a. When setting up a TWT, a STA may request the following protocol to be used [13/0319r0]

- Request though additional field in the TWT Information Element

b. AP shall send the NDP Paging frame as the first frame to the STA during the agreed NDP TWT period if:
   - There are buffer units for the STA
   - There are critical change to the beacon
   - A max time until the previous NDP Paging frame has expired
     - For time synch purpose and also latency requirement guarantee
     - Open on this part; Initial text required this interval to be equal to the TWT period

   Otherwise AP shall not send any frame to the STA during the NDP TWT duration

c. At TWT, STA will listen to medium for an NDP Paging frame from AP

d. After Receiving the NDP Paging frame, STA may go to sleep and wakeup later to perform an action

i. Actions include:

1. Sending PS-Poll/ trigger frame
2. Wakeup after T (time unit)
3. Receiving the Beacon

R.4.2.F: The draft specification shall include the concept of speed frame exchange and use of More Data field. [July 2012 meeting minutes, 11-12/834r0]

1. For speed frame exchange, when AP receives More Data set to 0 from a non-AP STA and AP has remaining BU for this STA, the AP may indicate [Nov 2012 meeting minutes, 11-12/1329r0]
   - More Data to 1, Ack Indication to 11 in ACK, and STA shall stay awake for downlink transmissions from AP after SIFS
   - More Data to 1, Ack Indication to 10 in ACK, and STA shall stay awake until AP sends downlink transmissions
   - More Data to 0, Ack Indication to 10 in ACK, and STA may go back to sleep
2. A PS-Poll frame is allowed as the first up link frame in speed frame exchange [Nov 2012 meeting minutes, 11-12/1325r1]
3. The draft specification shall support to include (equivalent) ACK Indication by using the following reserved values for Duration Indication and Duration fields of (Modified) NDP ACK [13/519r0, May 2013 meeting minutes]
   - Duration Indication = 0 & Duration = 0 indicates No response
   - Duration Indication = 1 & Duration = 0 indicates long response
4. The draft specification shall support to include Speed frame exchange based on NDP ACK/modified NDP ACK. [13/519r0, May 2013 meeting minutes]
   - NDP PS-Poll frame can be the first frame for speed frame exchange

R.4.2.G: AP may indicate to TIM STAs RAW information during which no TIM STA is allowed to contend. [July 2012 meeting minutes, 11-12/867r0]

1. Periodic Restricted Access Window (PRAW) [Nov 2012 meeting minutes, 11-12/1311r0]
   a. AP allocates resource for group of scheduled active polling STAs and indicates the resource allocation once in a long while.
      i. Not indicated in every short beacon frame (E.g., once in every long beacon frame)

b. Once PRAW is setup, AP allocates the resource periodically to a group of scheduled active polling STAs.
c. Allocated resource for PRAW will not be changed until updated PRAW information is broadcasted.
d. Resource for scheduled active polling STAs can be allocated within the PRAW duration.
    i. Whenever scheduled active polling STA has data packet to send, it wakes up at its designated slot within the PRAW and send the packet after basic CCA.
e. TIM STAs are not allowed to access the channel during this window.
f. Within PRAW, each STA follows EDCA based channel access scheme.

R.4.2.H: AP may indicate a window in beacon, and during that window offloading STAs can not access medium to send uplink data. [July 2012 meeting minutes, 11-12/892r0]

R.4.2.I: The 11ah should support a mode of operation where only a selected group of stations is allowed to transmit during a specified time interval. When a STA finds that belongs to a transmission group it shall transmit only in the time interval reserved for that group and not transmit in the time interval allocated to another group. [July 2012 meeting minutes, 61]

1. The transmission group may be identified by a group ID and a group definition field that identifies a logical grouping (such as an AID range of addresses) or a physical grouping, for example using an antenna beam pattern. [July 2012 meeting minutes, 61]
2. The transmission group definition field, the time interval reserved for the group transmission and its repetition period or the time till the next transmission may be advertised via (short) beacons, probe response or another management frame TBD. [July 2012 meeting minutes, 61]
3. A STA may optionally feedback sector/group ID to AP and AP to associate the STA with a specific group based on STA's sector. [12/1103r0, September 2012 meeting minutes]

R.4.2.J: The draft specification shall support the separation between BSS Sensor Only, Offloading Only, and BSS Mixed mode. [12/1083r0, September 2012 meeting minutes]

1. Identification of STA device types: Sensor Only, Offloading Only, and Mixed Mode STAs
2. The Sensor/Offload/Mixed BSS type is provided in beacons/Probe Response frame

R.4.2.K: A STA may transmit an immediate Block ACK with lower (or more robust) modulation and coding rate than that of the eliciting AMPDU [12/662r3, September 2012 meeting minutes]

1. The STA informs the AP the preferred MCS for downlink (indication format TBD) in the ADDBA response and the AP notes uplink MCS used by the STA and records the MCS difference for computing the duration of an immediate BA. [Nov 2012 meeting minutes, 11-12/662r4]

R.4.2.L: AP should be able to limit the number of STA to be authenticated/associated at the same time. [12/112r4, September 2012 meeting minutes]

1. AP is allowed to broadcast a value in the beacon to control the authentication/association of STA.

R.4.2.M: An active polling STA can solicit the information listed below from an AP upon waking up. AP may provide the information immediately or suggest the STA to check beacons. [12/1101r1, September 2012 meeting minutes]

1. BSS change sequence (one byte)
2. Current timestamp

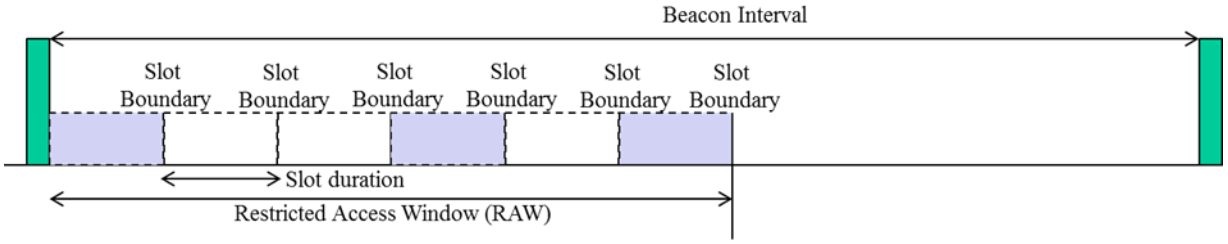
R.4.2.N: A low power mode QoS STA shall use AC_VO to send PS-Poll frame as the default setting. [Nov 2012 meeting minutes, 11-12/1310r1]

1. The AP may inform the low-power mode QoS STA of the access category for sending PS-Poll frames at Beacon and Probe Response frames, overwriting the default value.
2. The AP and a low power mode QoS STA may negotiate the access category of sending PS-Poll frame through association request/response frame or later through a management frame exchange.
3. Upon receiving a PS-Poll, AP may use RTS/CTS protection scheme to send buffered data until no more data or TXOP limit which comes first. The RTS shall be regarded as the immediate acknowledgement to PS-Poll.

4.2.1 Uplink Channel Access

R. 4.2.1.A: General procedure [2012 July meeting minutes, 11-12/831r0]

1. A Restricted Access Window (RAW) is divided in time slots.
2. STA wakes up at TBTT and it listens to a Beacon frame that indicates the slot duration for each Restricted Access Window (RAW).
    a. Slot duration for each RAW may be different
3. STA determines its channel access slot assigned by AP.
4. STA may sleep before its channel access slot.
5. STA shall start to access the channel at the slot boundary of its channel access slot based on EDCA.
6. AP indicates whether the following TXOP rule is applied in each RAW:
    a. A TXOP or transmission within a TXOP shall not extend across a slot boundary
    b. If the above TXOP rule is applied, the STA does not wait for ProbeDelay when waking up at the slot boundary.



4.2.2 Downlink Buffered BU Delivery Procedure

R.4.2.2.A: Procedure [2012 July meeting minutes, 11-12/831r0]

1. AP may indicate to a paged STA a channel access slot after which the STA is allowed to contend
    a. Preferred an implicit indication, based on TIM, so that the Beacon is not overloaded
        i. Paged STA starts the contention at slot boundary defined as a function of STA position in the TIM IE and additional info determined by Association or Beacon frame. [July 2012 meeting minutes, 11-12/860r0]
    b. Additional information [TBD] for determining a RAW duration may be needed in (short) Beacon
2. After receiving TIM, STA transmits the PS-Poll/Trigger frames to a AP not earlier than the slot boundary of its channel access slot based on EDCA
3. AP may indicate to a paged STA, that it will be sending traffic to a STA not earlier than a given downlink BU delivery slot.
    a. Indication of the downlink BU delivery slot should not overload the beacon
        i. New management frame indicates the downlink BU delivery slot per each STA after all PS-Poll/Trigger frame transmission completed.
4. AP may protect the PS-Poll/Trigger frames by setting the NAV

a. The paged STAs can ignore the NAV set by the AP. If NAV is set, then only paged STAs can send PS-Poll/Trigger frames during the RAW

4.2.3 Uplink Frame Delivery Procedure

R.4.2.3.A: Procedure [2012 July meeting minutes, 11-12/831r0]

1. AP may allow a STA/group-of-STA to transmit an uplink frame anytime.
2. AP may assign to each STA/group-of-STA a channel access slot at which the STA is allowed **to** contend through a Beacon frame
    a. STA wakes up at TBTT and it listens to a Beacon frame
    b. STA determines its channel access slot through the Beacon frame
    c. STA starts to access the channel not earlier than the slot boundary of its channel access slot; access is based on EDCA.
3. When requested by a STA, AP may assign to the STA a channel access slot at which the STA is allowed to contend, at association or later through a management frame exchange
    a. STA starts to access the channel not earlier than its slot boundary of its channel access slot; access is based on EDCA.

4.2.4 RAW slot assignment procedure

R.4.2.4.A: Procedure [2012 Nov meeting minutes, 11-12/1321r0]

1. Define a field in the slot definition field that indicates the slot duration (T_S)
2. Derive N_{RAW} by dividing the RAW duration (T_{RAW}) with the slot duration (T_S)
    a. i.e. $N_{RAW} = T_{RAW}/T_S$
3. Define a STA-Slot mapping function $f(x)$:
    a. $f(x) = (x + N_{offset})\ mod\ N_{RAW} = i$ (the slot index assigned to a STA)
    b. If the RAW is for both paged and unpaged STAs
        i. x is the AID of a STA
    c. If the RAW is restricted to paged STAs only
        i. x is the position index of a paged STA among all the paged STAs when sequentially arranged based on their AIDs
            1. For example, if there are n paged STAs in front of the paged STA, x=n (assuming that the first paged STA's bit position is defined to be x=0).
    d. N_{offset} is an offset value in the mapping function that is provided to address fairness among the STAs indicated in the TIM
        i. The 2 least significant bytes of the FCS field of the received Beacon frame shall be used for N_{offset}. [13/0286r0]
    e. $mod\ X$ indicates the modulo X operation

4.2.5 TXOP truncation

R.4.2.5.A: CF-END rule [Nov 2012 meeting minutes, 11-12/1302r0]

1. Duration field value of CF-END frame is set to either zero or a truncated time.
2. *If* the Duration field value of the received CF-END frame is set to zero, *then* all STAs reset its NAV.
3. *Else if* the Duration field of the received CF-END frame is matched with the local NAV of a STA, *then* the STA resets its NAV.
    a. The matching condition allows for a tolerance of +/-TBD microsecond.
4. *Else* the received CF-END frame is discarded.

4.2.6 Backoff Procedure in RAW

R.4.2.6.A: The draft specification shall support the following backoff procedure in RAW: [13/0080r0]

1. STA suspends backoff at the start of a RAW and stores the backoff function state
2. If STA is participating in the RAW, STA invokes a new backoff function using the RAW backoff parameters
3. STA may count down backoff only in its assigned slots within the RAW unless cross boundary is set to true, in which case the STA may continue to count down backoff after its slot
4. When the RAW ends, the previously stored backoff function state is restored and the backoff function resumes

4.3 Large Number of STAs Support

4.3.1 Traffic Indication Map (TIM) operation

R.4.3.1.A: The complete traffic indication bitmap shall be divided into one or more segments and transmitting in one or more TIM elements for a large network [12/117r0].

R.4.3.1.B: When the complete traffic indication bitmap is divided into multiple segments, the range of the AIDs (bitmap) each segment is covering shall be known to the STAs [12/117r0].

R.4.3.1.C: 11ah STAs can choose not to have a TIM entry for the DL traffic signalling. For these stations, the AP will store the DL data and deliver it when the STA request it. [May 2012 meeting minutes, 12/610r0-motion 1]

R.4.3.1.D: 11ah STAs shall inform AP if they do not need a TIM entry for the DL signalling during the association process. [May 2012 meeting minutes, 12/610r0-motion2]

R.4.3.1.E: A STA can switch between TIM mode (STAs have a TIM entry) and non-TIM mode (STAs do not have a TIM entry) during operation. [July 2012 meeting minutes, 11-12/891]

1. AP may reassign a new AID to STA when it switches between TIM mode and non-TIM mode
2. TIM mode switch notify procedure [Nov 2012 meeting minutes, 11-12/1304r0]
    a. A STA transmits an AID Switch Request frame to an AP to inform the switch between TIM mode and non-TIM mode
    b. After receiving the AID Switch Request frame, the AP shall transmits an AID Switch Response frame to the STA

R.4.3.1.F: AP and STA inform each other their capability of supporting Non-TIM mode in association procedure with a non-TIM support field in Extended Capabilities element. [Nov 2012 meeting minutes, 11-12/1309r1]

1. STA carries a “Non-TIM” indication in Association Request frame to inform AP whether it supports Non-TIM mode.
2. Upon receiving STA's Association Request frame with Non-TIM indication, AP confirms STA whether it allows the STA entering Non-TIM mode in Association Response frame.

Bit	Information	Note

	Non-TIM support	For non-AP STA: 0: STA does not support Non-TIM mode, it needs TIM entry as in legacy PS mode 1: STA request Non-TIM mode and it does not need TIM entry when in Non-TIM mode For AP: 0: AP does not support STA 's Non-TIM mode 1: AP can support STA 's Non-TIM mode

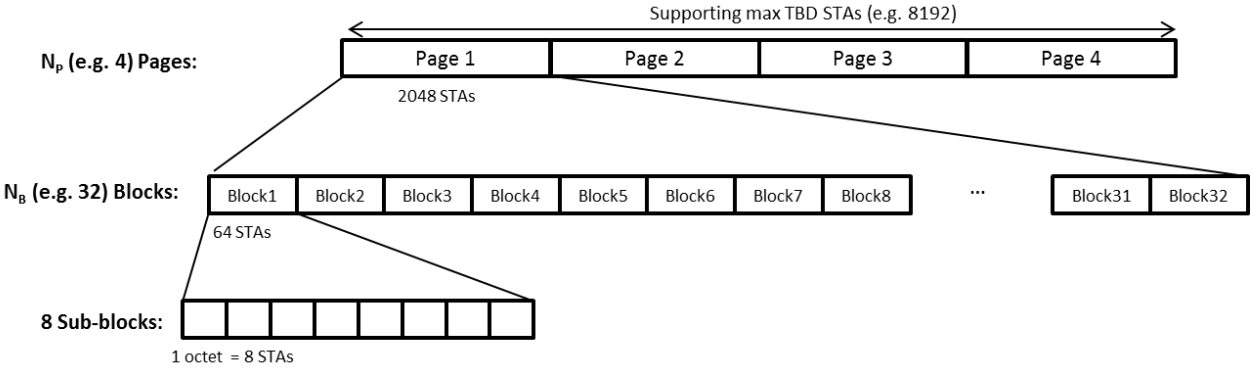
3. AP may recommend a value of listen interval different from that in Association Request frame based on its buffer management consideration in Association Response frame.
4. If a STA is NOT allowed to be in Non-TIM mode through negotiating by association procedure, the STA shall work in TIM mode.

R.4.3.1.G: The draft specification shall support that an AID can indicate a group of STAs. [13/0104r0]

4.3.2 TIM structure

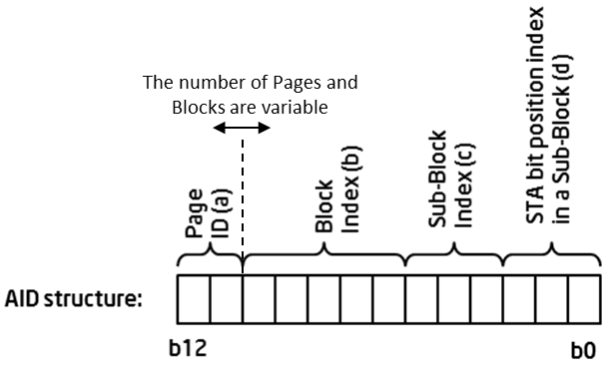
R.4.3.2.A: TIM shall have the three level hierarchical structure shown in the below figure [May 2012 meeting minutes, 12/388r2].

- Three level hierarchy: Page/Block/Sub-Block:



R.4.3.2.B: Based on the TIM structure shown in R.4.3.2.A, the association identifier (AID) structure shall be maintained as the below figure [May 2012 meeting minutes, 12/388r2].

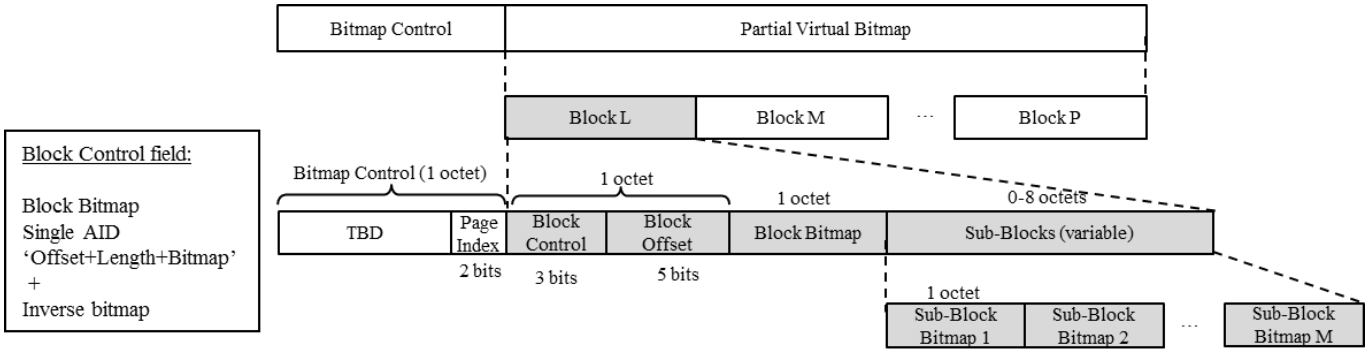
- STAs are grouped into Page, Blocks, Sub-Blocks:



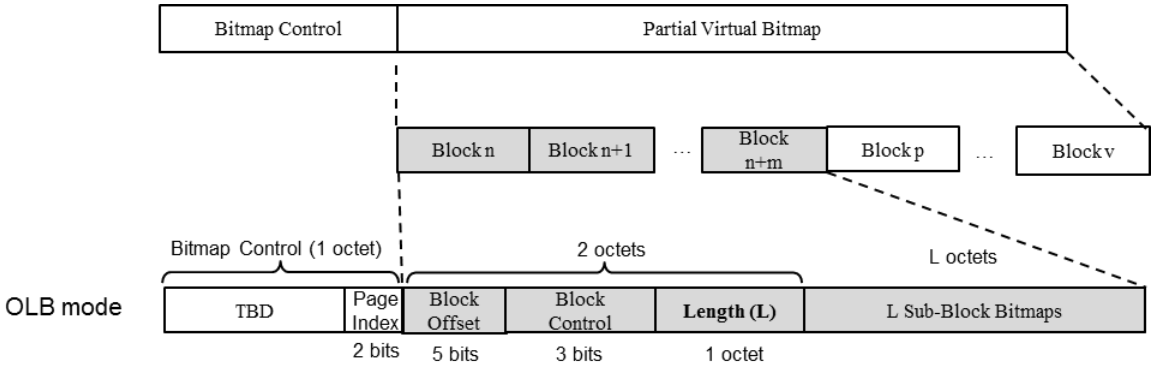
4.3.3 TIM encoding

R.4.3.3.A: The Partial Virtual Bitmap field shall be encoded in Block level as shown in the below figure [May 2012 meeting minutes, 12/388r2].

- Partial Virtual Bitmap consists of one or more encoded Blocks of a single Page.
- Basic Block encoding: Block Offset (5 bits) + Block Control(3 bits) + Block Bitmap (1 octet) + Sub-Block Bitmaps (variable)
- Block Control field: controls how the Block Bitmap and the Sub-Block Bitmap fields are used
    1. Block bitmap encoding: AID = [Page Index(2b), Block Offset(5b), n(3b), m(3b)]
        - The n-th bit position of the Block Bitmap indicates whether the n-th Sub-Block Bitmap is present in the Sub-Block field
        - The m-th bit position of the Sub-Block Bitmap indicates whether the m-th STA has data buffered at the AP
    2. Single AID: when there is a single AID in a Block, 6 bits of the Block Bitmap field is used to indicate the AID and the Sub-Block field is not present (total 2 octets): AID = [Page Index(2b), Block Offset(5b), Block Bitmap[5:0]]
    3. Inverse bitmap: if there are many 1s in the bitmap of the Block, inverse the bitmap and encode the inversed bitmap

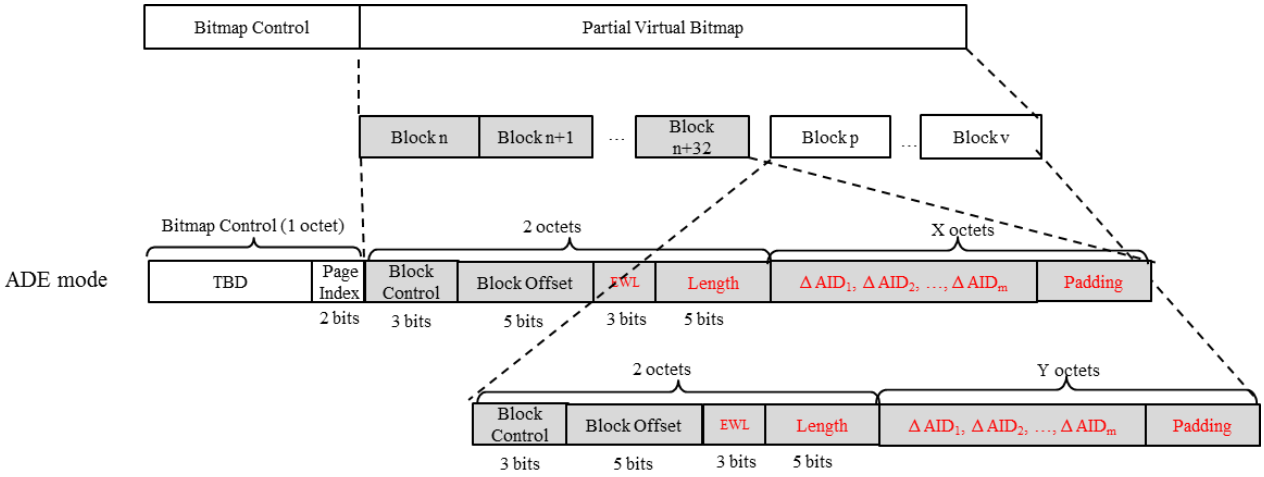


4. Offset+Length+Bitmap: encodes more than 8 Sub-Block Bitmaps [20, 21]
    - The Block Bitmap field is used to indicate the *length* of Sub-Block Bitmaps following the Block Bitmap field.
    - **AID = [Page Index (2b), Block Offset(5b),zeros(6b)]+ p,** the p-th bit position of the Sub-Block Bitmap field indicates whether the p-th STA has data buffered at the AP.
    - This mode is used when more than 8 contiguous Sub-Blocks are transmitted.



5. AID Differential Encode (ADE) mode (optional at both transmitter and receiver side) [Nov 2012 meeting minutes, 11-12/370r3]
    - Each block encodes up to 256 consecutive AIDs.
    - Last block can be shorter.
    - The Block Bitmap field consists of following fields:
        - **Encoded Word Length (EWL) (3 bits)**: number of bits required to encode differential AID value.

- **Length (5 bits):** the length of encoded block bitmap, in number of octets
- Concatenated bits of differential encoded AID values of paged STAs: ΔAID_1, ΔAID_2, …, ΔAID_m
  - $\Delta AID_1 = AID_1 - \text{Block Offset}*8$
  - $\Delta AID_i = AID_i - AID_{i-1}$, i = 2, …, m.
- **Padding(1-7 bits)**: padding the encoded block to the boundary of octets and indicating the termination state



4.3.4 TIM and Page Segmentation

4.3.4.1 Page Segmentation

[12/1084r4, September 2012 meeting minutes]

R.4.3.4.1.A: The draft specification shall use a fixed length page segment per TIM segment within one DTIM beacon interval as described below:

1. Length of page segment may vary over multiple DTIM beacon intervals
2. Length of page segment = (Number of blocks in one page / number of TIM segments in DTIM beacon interval)
3. Each ordered page segment is assigned sequentially to TIM segments, first page segment being assigned to DTIM segment
4. The draft specification include the "TIM offset" field in Segment Count IE to allow AP to indicate the TIM Beacon offset to the DTIM Beacon which carries the segment Count IEs of the pages. [13/0516r0, May 2013 meeting minutes]
   a. The TIM for the first page segment of a specific page can be allocated at the indicated TIM offset to the DTIM
   b. The TIM Segments can be flexibly scheduled for page segments of different pages over beacon intervals

R.4.3.4.1.B: The draft specification shall introduce a Page Bitmap field for early indication of Block-level buffered data.

R.4.3.4.1.C: The draft specification shall define a Segment Count IE for indication of assignment of STAs in TIM segments as described below:

1. Segment count IE is only transmitted in DTIM beacon frames and not in TIM segments
2. This element indicates assignment of STAs in TIM segments
   a. Indicates wake-up interval for STAs within page segments

3. STAs within the assigned page segment wake up at corresponding TIM segment sequentially based on the page segment count field in the IE
4. Length of page segment = (Number of blocks in Page Bitmap /page segment count)
5. Page offset and Page segment count fields in the segment count IE indicate initial block offset and range of TIM element in each TIM segment
    a. Block offset / start = page offset + ((length of page segment) * (TIM segment number - 1)) + 1
    b. Block Range = page offset + length of page segment * TIM segment number
6. STAs with their block bit set to 0 in the Page Bitmap field may not wake up at assigned TIM segment

4.3.5 AID assignment procedure

R.4.3.A: The draft specification shall support that a STA's AID can be reassigned for channel access management [May 2012 meeting minutes, 12/364r3]

R.4.3.5.B: The draft specification shall define the following AID switch procedure [Nov 2012 meeting minutes, 11-12/1304r0]

1. A STA transmits an AID Switch Request frame to an AP
2. After receiving AID Switch Request frame, the AP transmits an AID Switch Response frame to the STA or the AP transmits an unsolicited AID Switch Response frame to the STA

R.4.3.5.C: The draft specification shall support that a STA informs TDLS peer STAs of the updated AID information when its AID is switched. [13/0291r0]

1. A STA informs TDLS peer STAs of the updated AID information when its AID is switched.
2. To notify the updated AID to a TDLS peer STA, a STA sends the TBD frame (e.g., TDLS Update Announce frame) including updated AID information to the TDLS peer STA.
3. Upon receiving the TBD frame including the updated AID, the STA updates the AID information of the TDLS peer STA based on the received AID information and sends the ACK frame after SIFS.

4.4 Frame Formats

4.4.1 Management frames

4.4.1.1 Short Beacon frame format

R.4.4.1.1.A: The draft specification shall provide support for a new frame format for a short beacon (content is TBD). [11/1503r1]
R.4.4.1.1.B: The draft specification shall define a Short Beacon interval, in units of TUs, and to require that the Beacon Interval is an integer multiple of the Short Beacon Interval.
R.4.4.1.1.C: The Frame Control type/subtype indication for the Short Beacon.

- Frame Control
    - To indicate a Short Beacon we build on type/subtype field modifications proposed by 11ad
    - Propose: B3 B2 = 11
      B7 B6 B5 B4 = 0 0 0 1 (currently reserved)
      as indication of Short Beacon

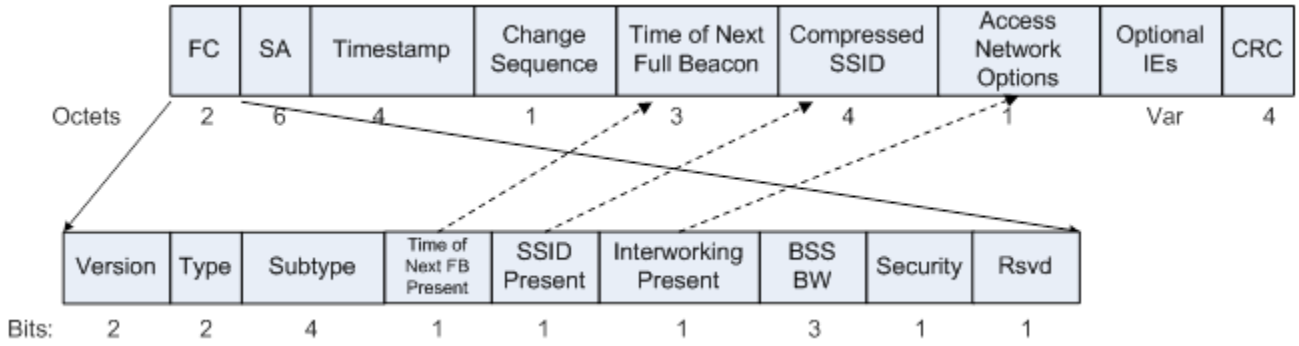
R.4.4.1.1.D: The Short Beacon should include a compressed SSID field.

a. Compressed SSID is computed as the CRC of SSID. CRC is computed using the same function as used to compute the FCS of MPDUs [May 2012 meeting minutes, 12/129r3]

R.4.4.1.1.E: The Short Beacon shall include a 4 byte Timestamp containing the 4 LSBs of the AP Timestamp.
R.4.4.1.1.F: The Short Beacon shall include a 1 byte Change Sequence Field that is incremented whenever critical network information changes.
R.4.4.1.1.G: The Short Beacon should optionally include a field indicating the time of next full beacon.

1. Time of next full beacon is indicated as the higher 3 bytes of the 4 LSBs of the AP time stamp at the next full beacon [May 2012 meeting minutes, 12/129r3]
2. The Time of Next Full Beacon field shall be always present in the short Beacon frame if an AP transmits full (long) Beacon frames periodically [May 2012 meeting minutes, 12/129r3]

R.4.4.1.1.H: The draft specification may include an optional Access Network Options field in the short beacon [May 2012 meeting minutes, 12/129r3]
R.4.4.1.1.I: The 3 bit BW field shall be included in the FC field as shown in the figure below: [May 2012 meeting minutes, 12/129r3]

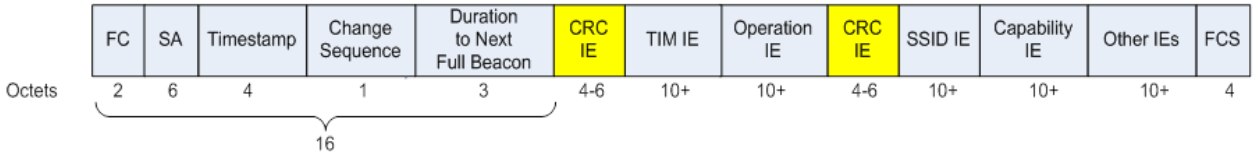


R.4.4.1.1.J: The following indications shall be in the short beacon: [May 2012 meeting minutes, 12/129r3]

- Presence of Time of Next Full Beacon field
- Presence of Compressed SSID field
- Presence of Access Network Options field

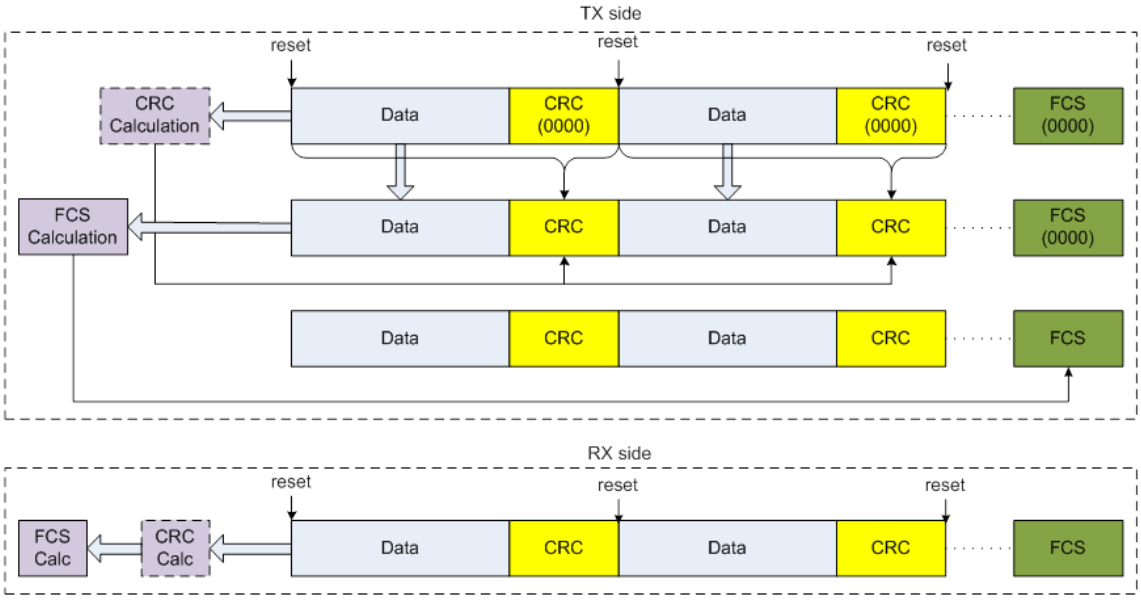
R.4.4.1.1.K: The draft specification shall support the concept of a unified beacon format for short beacon and full beacon based on the short beacon format already present in the TGah SFD. [July 2012 meeting minutes, 12/838r0]

R.4.4.1.1.L: The draft specification shall support the Mid-CRC concept [12/1100r1, September 2012 meeting minutes]:



- Beacons with some long IEs can be sent pretty frequently to attract new STAs, indicate buffered data, and control channel access, etc.
- An associated STA may not be interested in any IEs (esp. when change sequence is up-to-date), or may be interested in only a few IEs
- The Mid-CRC IE can help a STA stop processing a long beacon earlier and save power

1. Mid-CRC design



a. Mid-CRC calculation and End-FCS calculation are separated
    i. Note that Mid-CRC can be shorter than End-FCS
b. Mid-CRC coverage starts from the end of the last Mid-CRC; End-FCS covers the whole frame
c. Both Mid-CRC TX and RX are optional
    i. A STA not supporting Mid-CRC transmission need not insert any Mid-CRC IE
    ii. A STA not supporting Mid-CRC receiving can decode the whole frame, ignore all Mid-CRCs, and check End-FCS only

R.4.4.1.1.M: The draft specification shall support that a STA may send the Probe Request frame including the change sequence which the STA has to AP when the STA receives the short beacon including the change sequence which is different from the sequence which the station stores. [12/1093r0]

1. AP may send the optimized probe response frame which includes only system information elements which need to be updated by STA and the change sequence when the AP receives the probe request frame including the change sequence from the STA.

4.4.1.2 NDP Probe Request frame format

R.4.4.1.2.A: The draft specification shall define a NDP Probe Request frame format as follows: [July 2012 meeting minutes, 11-12/830r0]

STF	LTF1	SIG

1. SIG field format for 1 MHz mode PHY [11-12/1080r0, September 2012 meeting minutes]

B0 B3	B4	B5 B12	B13 B20	B21 B25	B26 B29	B30 B35
MCS	SSID/Interworking Present	Access Network Option	Reserved	Reserved	CRC	Tail
		Compressed SSID				

2. SIG field format for 2MHz mode PHY [11-12/1080r0, September 2012 meeting minutes]

B0 B3	B4	B5 B12	B13 B36	B37	B38 B41	B42 B47
MCS	SSID/Interworking Present	Access Network Option	Reserved	Reserved	CRC	Tail
		Compressed SSID				

Note – The position of the MCS field is TBD.

4.4.1.3 Short Beamforming Report Poll frame format

R.4.4.1.3.A: The draft specification shall define a short Beamforming Report Poll frame format as follows (SIG field content TBD): [July 2012 meeting minutes1, 11-12/842r2]

STF	LTF1	SIG

4.4.1.4 Short Probe Response frame format

R.4.4.1.4.A: 11ah STA may use short Probe Response frame for active scanning which is a shortened version of Probe Response frame [July 2012 meeting minutes, 11-12/869r0]

R.4.4.1.4.B: Short Probe Response frame contains Timestamp, Change Sequence, either Compressed SSID or full SSID, optional Next TBTT, optional Access Network Options, and optional IEs [13/0530r0, May 2013 meeting minutes]

- When a full SSID is requested, Full SSID IE is included in the Optional IE part in the short probe response frame
- Short Beacon Compatibility Element may be included in the optional IE part .

a. Frame control field of Short Probe Response frame contains Next TBTT present field, Full SSID Present field which indicates whether Full SSID or Compressed SSID is included, BSS Bandwidth field, Security field, and Interworking Present field

b. Short Probe Response frame format:

FC	DA	SA	Time stamp	Change Sequence	Next TBTT (option)	Compressed SSID	Access Network Options (option)	Optional IEs	FCS
2	6	6	4	1	3	4	1	Var	4

c. Frame Control field format:

Protocol Version	Type	Subtype	Next TBTT present	Full SSID Present (0: compressed SSID, 1: Full SSID)	Interworking Present	BSS BW	Security	Reserved
2	2	4	1	1	1	3	1	1

R.4.4.1.4.C: STA may indicate in the Probe Request which optional information to be included in the short Probe Response frame in optimized way

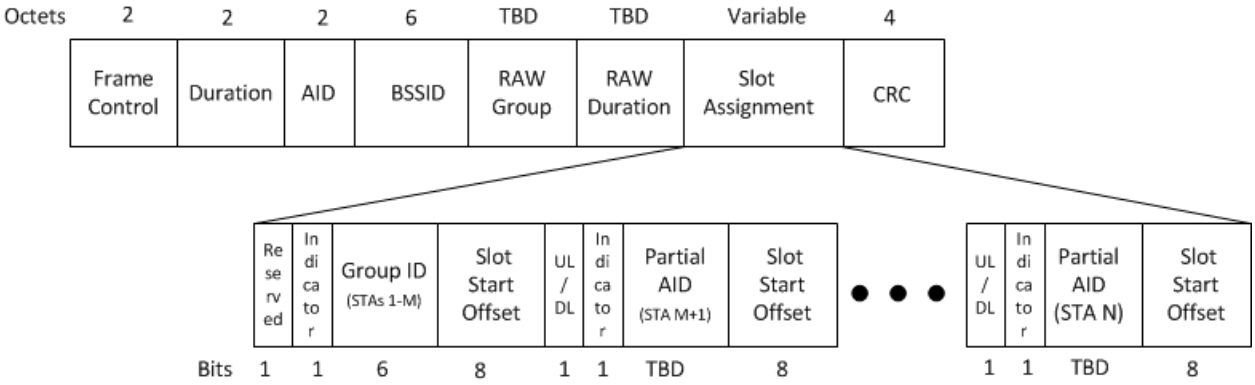
4.4.1.5 NDP Paging frame format

R.4.4.1.5.A: The draft specification shall define a short NDP frame for paging that includes (at least) the following fields. [Nov 2012 meeting minutes, 11-12/1324r0]

1. A (Partial) identifier of the target STA(s)/group of STAs(# bits TBD)
2. BU present (1 bit)
3. Partial TSF (# bits TBD)
4. Check beacon (# bits TBD)

4.4.1.6 Resource Allocation frame format

R.4.4.1.6.A: The draft specification shall define the Resource Allocation frame as follows: [13/0285r0]



1. RAW Group (TBD octets) is identical to the group in RPS IE
2. RAW Duration (TBD octets) is revised from RAW Duration in RPS IE based on PS-Polls and UDIs
3. Slot assignment (2 octets/MU Group and TBD octets/STA) defines access slot allocations for STAs
    a. Independent of TIM bitmap
    b. 1 bit indication for SU-STAs within RAW for UL (bit set to 0) or DL traffic, bit reserved for MU-MIMO group
    c. Multi-user MIMO supported when multiple STAs are assigned identical slot within RAW
4. STA Address may be either a partial AID (TBD bits) or a Group ID (6 bits) for a MU group
    a. 1 bit indicator prior to the address for indication of either partial AID (bit set to 0) or Group ID (bit set to 1)
5. Slot Start Offset (1 octet) is start time of STA's medium access, relative to the end of the RA frame, in TBD units
    a. Offset determined by AP based on buffered DL data for STAs from whom PS-Polls were received
    b. Offset from UDIs indicating amount of buffered traffic

4.4.2 Control frames

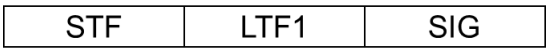
R.4.4.2.A: The following NDP MAC control frames are mandatory for non-AP STAs. [13/296r0]

– ACK, CTS, BA

R.4.4.2.B: An AP and associated STAs shall know preferred frame format for ACK, CTS, and BA (normal vs. NDP) of each other by defining a mandatory rule in the specification to use NDP unless other frame is needed. [13/296r0]

4.4.2.1 NDP ACK frame format

R.4.4.2.1.A: The draft specification shall support the following NDP ACK format [12/324r2, Motion1].



1. The following NDP ACK SIG fields are the same as those in normal SIG[12/324r2, Motion2].
    - CRC (4 bits)
    - Tail (6bits - TBD)
2. A reserved MCS value shall be used to indicate the NDP ACK frame [12/324r2, Motion3].
3. The NDP ACK SIG shall include an ACK ID field (bits TBD), and use [12/324r2, Motion4].
    - partial FCS and
    - the information from the scrambling seed in the SERVICE field of the frame being acknowledged for the computation of the ACK ID for NDP ACK frames.
4. The NDP ACK SIG shall include a Relayed Frame bit for TXOP operation defined in R.4.5.B-3.

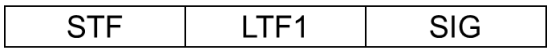
4.4.2.2 NDP Block Ack (BA) frame format

R.4.4.2.2.A: The draft specification shall define a NDP BA frame format as follows with: [July 2012 meeting minutes, 11-12/859r0]

1. Block ACK ID (length TBD)
2. Starting Sequence Control (12 bits)
3. Block Bitmap with length (TBD)
4. Other fields (TBD)

4.4.2.3 NDP CTS frame format

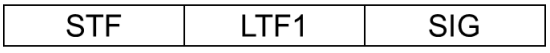
R.4.4.2.3.A: The draft specification shall define a NDP CTS format as follows with SIG field design TBD: [May 2012 meeting minutes, 12/643r0]



1. The NDP CTS frame shall include the following fields:
    a. A duration field [13/0078r0]
    b. 1 bit indicator to indicate whether the following bits are unicast address RA or partial BSSID [13/0078r0]
        i. Partial BSSID field implies a broadcast RA
    c. 1 bit early sector indicator from reserved bits for the sectorized transmission in NDP CTS-to-self (which precedes SO condition 1 or SO Condition 2) to facilitate the detection of SO conditions. [13/0081r1]

4.4.2.4 NDP PS-Poll frame format

R.4.4.2.4.A: The draft specification shall define a NDP type PS-Poll frame format as follows: [July 2012 meeting minutes, 11-12/848r0]



1. The NDP PS-Poll frame shall include the following fields:
    a. An uplink data indication (UDI) field [Nov 2012 meeting minutes, 11-12/1308r0]
2. 1 MHz mode NDP PS-Poll frame format [13/0074r0]
    a. Bitwidth for all subfields is TBD.
    b. Preferred MCS subfield for 1MHz is TBD

Field	Bit width	Comments
Message type indicator	TBD	1 bit: NDP indication 3bits: sub-type indication
RA	TBD	PBSSID
TA	TBD	PAID
Preferred MCS	TBD	TBD
UDI	TBD	0: no data, 1: data
Reserved bit	TBD	
Tail bits	6	
CRC	4	
TOTAL	**36**	

3. 2 MHz mode NDP PS-Poll frame format [13/0074r0]
   a. Bitwidth for all subfields is TBD.

Field	Bit width	Comments
Message type indicator	TBD	1 bit: NDP indication 3bits: sub-type indication
RA	TBD	PBSSID
TA	TBD	PAID
Preferred MCS	TBD	Explicit MCS indication
UDI	TBD	0: no data, Non-zero value indicates duration of uplink data in number of symbols
Reserved bit	TBD	
Tail bits	6	
CRC	4	
TOTAL	**48**	

4.4.2.5 PS-Poll frame format

R.4.4.2.5.A: The draft specification shall allow the AID field of the PS-Poll frame to be switched to Duration. [Nov 2012 meeting minutes, 11-12/1325r1]

2B	2B	6B	6B	4B
Frame Control	Duration/ ID	BSSID (RA)	TA	FCS

4.4.2.6 Modified NDP ACK frame for NDP PS-Poll frame

R.4.4.2.6.A: The draft specification shall define a modified NDP ACK to acknowledge NDP PS-Poll as follows: [13/0082r0]

Field	Bit width	Comments
Message type indicator	4	Indicate NDP ACK for NDP PS-Poll.
ACK ID	12-14	For non-NDP type: ACK ID and Duration fields are same as original NDP ACK [**12/324r2**] **For NDP-type PS-Poll:** -No Duration field -ACK ID + ACK ID Extension = 18-21 bits -ACK ID & ACK ID Extension computation based on **all or part of PBSSID(9)+PAID(9)+CRC(4)**
Duration/**ACK ID Extension**	6-8	
More Data	1	Same as original NDP ACK [**12/324r2**]
Tail bits	6	Same as original NDP ACK [**12/324r2**]
CRC	4	Same as original NDP ACK [**12/324r2**]
TOTAL	**36**	Same as original NDP ACK [**12/324r2**] with 12 reserved bits for 2MHz

4.4.3 Management frame body components

4.4.3.A: The specification shall support to indicate service type during association. [May 2012 meeting minutes, 12/612r0]

4.4.3.1 Information elements

4.4.3.1.1 Open-Loop Link Margin Index element

R.4.4.3.1.1.A: The draft specification shall include Open-Loop Link Margin Index element as defined below [May 2012 meeting minutes, 12/0645r1]:

where the Open-Loop Link Margin Index is computed according to the following equation.

$$LM_{index} \overset{\Delta}{=} P_{tx\_AP} + R_{sensitivity\_AP}$$

The detailed format and description are as follows:

– The format of open-loop link margin index field is (-128+D*0.5) dBm, where D is an integer number within [0, 255]. [13/0301r0]

4.4.3.1.2 RPS (RAW (Restricted Access Window) Parameter Set) element

R.4.4.3.1.2.A: The draft specification shall include the concept of an optionally present RAW Parameter Set element in the (short) beacon and the following sub fields in the RAW Parameter Set IE. [July 2012 meeting minutes, 11-12/843r0]

- RAW Group (Page ID, RAW Start AID, RAW End AID)
- RAW Start Time
- RAW Duration
- Options Fields
    a. Access restricted to paged STA only
    b. Group/Resource allocation frame indication
- Slot definition

Feature	**Value**	**Interpretation**
Short RAW Description indication [13/522r0]	1 bit	When the bit is set to 1, the access is restricted to previous identified STAs, e.g. TWT STAs or doze awake cycle rescheduled STAs. Only the RAW Start Time, RAW Duration, and Channel Indication fields are present. Otherwise, this bit is set to 0.
Same Group Indication [13/0290r0]	1 bit	1. Same group = 1: "RAW group" field is not present in the current RAW definition and the RAW group is the same as previous one 2. Same group = 0: "RAW group" field is present, indicating different RAW group from previous one 3. In RAW 1 Assignment, Same Group Indication (1) indicates that the RAW Group information of the RAW 1 Assignment is decided based on the information of STAs included in TIM Bitmaps [13/510r1, May 2013 meeting minutes]
RAW Start Time Present [13/510r1, May 2013 meeting minutes]	1 bit	1. This field indicates that the RAW starts immediately after the end of the previous RAW a. In case of the RAW 1 Assignment, RAW Start Time Present (0) indicates that the RAW starts immediately after the end of the beacon frame transmission b. If the RAW Start Time Present is set to 0 in a RAW N Assignment field, then RAW Start Time subfield is not present in the RAW Assignment field
PRAW Indication [13/0295r0]	1 bit	1. If PRAW indication = 0, it means this RAW indication is for a normal RAW definition. 2. If PRAW indication is set to 1, a. it includes PRAW specific information such as i. Periodicity (TBD bits): Period of PRAW occurrence in the unit of short beacon interval ii. Start Offset (TBD bits): Offset value to a short beacon frame that the first window of the PRAW appears from a reference point. (How to set a reference point and unit is TBD) b. Also, Option and Slot definition subfields can be removed if PRAW indication is set. i. As PRAW broadcasting is for TIM STAs who are not allowed to attend during PRAW duration, detailed slot definition within PRAW is not informative. c. RAW group, RAW start time, and RAW duration are included. i. RAW group: Indicates Non-TIM user group that may be scheduled in the PRAW.

		ii. RAW start time: Indicates start time of PRAW with respect to the end of beacon transmission. iii. RAW duration: Indicates duration of PRAW.
Page ID	TBD bits	Indicates the page index for hierarchical AID (based on hierarchical AID) of the allocated group
RAW Start AID	11 bits	RAW Start AID field is 11 bits in length and indicates the 11 LSBs of the AID of the STA with the lowest AID in the RAW. [13/0286r0]
RAW End AID	11 bits	RAW End AID field is 11 bits in length and indicates the 11 LSBs of the AID of the STA with the highest AID in the RAW. [13/0286r0]
RAW Start Time	8 bits	Duration in TU from end of beacon transmission to RAW Start time
RAW Duration	TBD bits	Duration of RAW in TU
Access restricted to paged STA only	2 bits	Bit 1: Set to 1 if only STA with their TIM bit set to 1 are allowed to perform UL transmissions Bit 2: Set to 1 if RAW is reserved for frames with duration smaller than slot duration, such as PS-Polls / trigger frames (ignored if Bit 1 is not set)
Group/Resource allocation frame indication	1 bit	Set to 1 to indicate if STAs need to wake up at the beginning of the RAW to receive group addressed frames such as resource allocation (format of the resource allocation frame TBD)
Sounding RAW	1 bit	Set to 1 to indicate if non-AP STAs are prohibited to transmit but are allowed to listen the entire RAW. Set to 0 otherwise.
Slot definition	TBD bits	Include • Slot duration signaling • Slot assignment to STA • Cross boundary transmissions allowed/not allowed Format is TBD

1. The draft specification shall define an indication from AP to signal that AP may be in doze state except for the times explicitly allocated by RAW/TWT. [13/0070r1]
   a. In this case, AP shall indicate a RAW for other types of traffic (ex. Association)
2. The draft specification shall define a signaling in RAW definition to indicate that AP is in Doze state for the RAW duration. [13/0070r1]
3. A channel indication field shall be defined in the RPS (RAW Parameter Set) IE [13/0071r0]
4. The indication of a 'omni group' shall be defined in the RPS IE [13/0071r0]
5. A STA is in the RAW group if the AID of the STA is within the range of [Page ID (2bits) +RAW Start AID (11 bits)] and [Page ID (2bits) +RAW End AID (11 bits)]. [13/0286r0]

4.4.3.1.3 Segment Count element

[12/1084r4, September 2012 meeting minutes]

R.4.4.3.1.3.A: The segment count IE (4-8 octets) shall consist of the following fields:

1. Element ID (1 octet): Identification of the segment count IE
2. Length (1 octet): Length of this IE

3. Page Index (2 bits): Indication of page currently assigned in beacon
4. Page Segment Count (5 bits) field indicating number of TIM segments; for instance,
   a. A value of 4 indicates 4 TIM segments in DTIM beacon interval
   b. A value of 8 indicates 8 TIM segments in DTIM beacon interval
5. Page Offset (5 bits) field indicating the first block in assigned page segments
6. TIM Offset (4 bits): Indicating the TIM Beacon offset [13/0516r0, May 2013 meeting minutes]
7. Page Period (8 bits): this field indicates the number of beacon intervals between successive beacons that carry the Segment Count IE for the associated page[13/0518r0, May 2013 meeting minutes]
8. Page Bitmap (0- 4 octets) field for blocks of all page segments in DTIM element

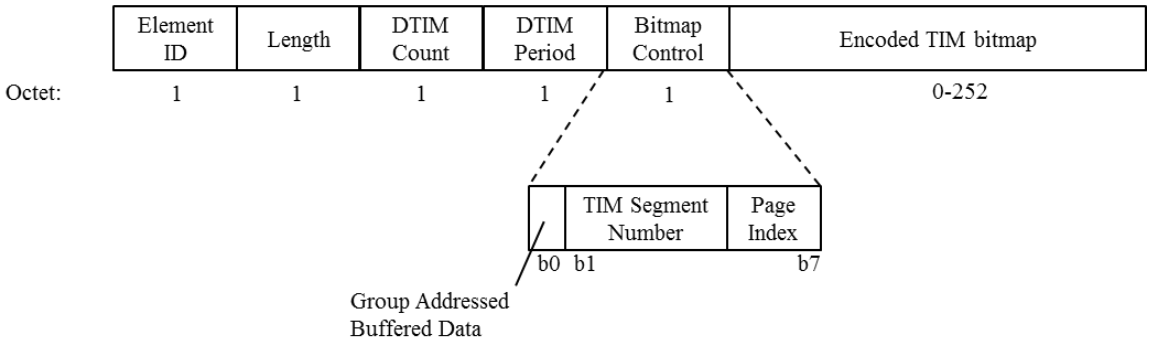
1 octet	1 octet	2 bits	5 bits	5 bits	4 bits	0-4 octets
Element ID	Length	Page Index	Page Segment Count	Page Offset	TIM offset	Page Bitmap

4.4.3.1.4 TIM element

R.4.4.3.1.4.A: The TIM element shall include the TIM Segment Number field in the Bitmap Control field as shown in in R.4.4.3.1.4.B [12/1084r4, September 2012 meeting minutes]:

1. TIM Segment Number field (5 bits): indicates the index of the TIM Segment
2. The TIM bitmap information covered in the TIM IE is calculated as follows:
   a. TIM segment start = page offset + ((length of page segment) * (TIM segment number - 1)) + 1
   b. TIM segment end = page offset + length of page segment * TIM segment number

R.4.4.3.1.4.B: The Group Addressed Buffered Data field (Bit 0 of the Bitmap Control field) is set to 1 when one or more group addressed MSDUs/MMPDUs are buffered at the AP. [12/1086r1, September 2012 meeting minutes]



R.4.4.3.1.4.C: If there is no bit in the traffic indication bitmap set to 1 in the TIM IE, the Encoded TIM Bitmap field is not present and the Length field is set to 3. [12/1086r1, September 2012 meeting minutes]

4.4.3.1.5 AID Request element

R.4.4.3.1.5.A: The draft specification shall define the AID Request element as follows: [Nov 2012 meeting minutes, 11-12/1304r0] [13/328r0]

Element ID	Length	AID Request Mode	Wakeup Interval/Multicast Listen Interval (optional)	Peer STA Address (optional)	Service Type (optional)	Group Address (optional)

octet	1	1	1	0 or 2	0 or 6	0 or 1	0 or 6

1. AID Request Mode: Indicate the option field of AID Request IE
    a. B0 is set to 1 when Wakeup Interval field is included
    b. B1 is set to 1 when Peer STA Address field is included
    c. B2 is set to 1 when Service Type field is included
    d. B3 is set to 1 when STA switches from TIM mode to non-TIM mode
    e. B4 is set to 1 when STA switches from non-TIM mode to TIM mode
    f. B5 is set to 1 when the Group Address field is present. [13/328r0]
    g. B6 – B7 are reserved.
2. Wakeup Interval: New wakeup interval (in the unit of BI) of STA
3. Multicast Listen Interval: This field indicates how often the STA listens to the DTIM Beacon for group addressed BUs. The value is the units of DTIM interval. If Group Address Present bit is set to 1, "Wakeup Interval/Multicast Listen Interval" field is filled with the value of Multicast Listen Interval. [13/328r0]
4. Peer STA Address: MAC Address of peer STA for STA-to-STA communication
5. Service Type: New Service Type of STA
6. Group Address: The group MAC address of the STA. [13/328r0]

4.4.3.1.6 AID Response element

R.4.4.3.1.6.A: The draft specification shall define the AID Response element as follows: [Nov 2012 meeting minutes, 11-12/1304r0] [13/328r0]

	Element ID	Length	AID/MID	AID Switch Count	Wakeup Interval
octet	1	1	2	1	2

1. AID/MID: the AID / MID field contains AID or MID that is assigned to the requesting STA [13/328r0]
    a. New AID assigned from AP
        i. If AP doesn't want to change AID of STA, AID field is set to the same AID.
    b. If it's MID, the STA should link the MID to its corresponding Group Address and Multicast Listen Interval. [13/328r0]
        i. 13bits MID can be used in short MAC header and as Partial MID (the computing rule is same as AID) [13/328r0]
2. AID Switch Count: the number of Beacon Intervals until the STA switches to the new AID
3. Wakeup Interval: the wakeup interval (in the unit of BI) for listening to Beacon frame having TIM segment of new AID

4.4.3.1.7 Sectorization Type 0 element

R.4.4.3.1.7.A: The draft specification shall define the Sectorization Type 0 element as follows: [13/0081r1]

Element ID	Length	S. Scheme	C.R. Period	O. Ind	Sector ID	Group ID1	…	Group ID k	Sub-period	reserved
1 octet	1 octet	1 bit	6 bits	1 bit	3 bits	TBD		TBD	5 bits	7 bits

1. S Scheme (Sectorization Scheme): 0 - Type 0 sectorization scheme
2. C.R.Period (Complete Rotation Period) : the complete rotation period (# of beacon intervals) for all sectors
3. O. Indicator (omni-directional sector indicator): 1 = omni, 0 = non-omni (In omni, all STAs can access the medium)
4. Sector ID: the current sector ID

5. Group ID 1, …, Group ID k corresponding to the current sector ID
6. Sub-period: the sub-period for current sector ID (sub-period* integer = complete period)

4.4.3.1.8 Sectorization Type 1 element

R.4.4.3.1.8.A: The draft specification shall define the Sectorization Type 1 element as follows: [13/0081r1]

Element ID	Length	S. Scheme	P.Training Ind.	Training Period	Remaining BI	reserved
1 octet	1 octet	1 bit	1 bits	6 bit	6 bits	TBD bits

1. S. Scheme (Sectorization Scheme): 1 (Type 1 Sectorization scheme)
2. P. Training Ind.: P. Training ON/OFF Indicator: 0 - Periodic Training not Present, 1 – Present
3. Training Period (# of Beacon Intervals for the periodic training)
4. Remaining BI: remaining beacon intervals to the periodic training (including the current beacon interval)

4.4.3.1.9 Probe Response Option element

R.4.4.3.1.9.A: The draft specification shall define the Probe Response Option element as follows: [13/308r0]

Element ID	Length	Probe Response Group Bitmap	Probe Response Option Bitmap 0	…	Probe Response Option Bitmap n
1 octet	1 octet	1 octet	1 octet		1 octet

- Included in the Probe Request
- Information to be included in the short Probe Response is categorized into 8 bitmaps (Detailed information included in the bitmap is TBD)
    a. Request full SSID: If it is set to 1, Full SSID is included in the Short Probe Response frame. Otherwise, compressed SSID is included
    b. If each bit in the bitmap is set to 1, the corresponding information should be included in the Probe Response frame
    c. Only bitmaps with at least one 1 are included in the Probe Response Option IE.
    d. Probe Response Group bitmap indicates which Probe Response Option bitmap is included in the Probe Response Option IE
- Define bitmap 0 as a default bitmap that contains frequently used options
    a. If only bitmap 0 is chosen to be included in the Probe Response Option IE, Probe Response Group bitmap may be omitted.
- Probe Response Option Bitmap 0: contains frequently used options

Request Full SSID	Request Next TBTT	Request Access Network Options	Request Short Beacon Compatibility IE	Request Supported Rates	Request S1G Capability	Request Extended Capabilities	Reserved
Bits: 1	1	1	1	1	1	1	1

    - Request Short Beacon Compatibility IE: request Short Beacon Compatibility IE (Capability, Beacon, Timestamp Completion)
    - Request S1G Capability: request S1G Capabilities element

- Probe Response Option Bitmap 1: contains options for additional 11ah related features

Request RPS	Request Segment Count	Request TSF Timer Accuracy	Request Relay Discovery	Request RootAP BSSID	Reserved	Reserved	Reserved
Bits: 1	1	1	1	1	1	1	1

- Probe Response Option Bitmap 2: contains options frequently used in the baseline spec

Request Country	Request Power Constraint	Request TPC Report	Request Extended Supported Rates	Request RSN	Request BSS Load	Request EDCA Parameter Set	Request Supported Operating Classes
Bits: 1	1	1	1	1	1	1	1

- Probe Response Option Bitmap 3: contains 11k related options

Request Measurement Pilot Transmission	Request Multiple BSSID	Request RM Enabled Capabilities	Request AP Channel Report	Request BSS Average Access Delay	Request Antenna	Request BSS Available Admission Capacity	Request BSS AC Access Delay
Bits: 1	1	1	1	1	1	1	1

- Probe Response Option Bitmap 4: contains options related to 11v and other misc options (Mobility domain, CF Parameter Set, DSE registered location)

Request Mobility Domaind	Request DSE registered location	Request CF Parameter Set	Request QoS Traffic Capability	Request Channel Usage	Request Time Advertisement	Request Time Zone	Reserved
Bits: 1	1	1	1	1	1	1	1

- Probe Response Option Bitmap 5: contains 11u related options

Request Interworking	Request Advertisement Protocol	Request Roaming Consortium	Request Emergency Alert Identifier	Reserved	Reserved	Reserved	Reserved
Bits: 1	1	1	1	1	1	1	1

4.4.3.1.10 Relay Discovery element [13/0511r1, May 2013 meeting minutes]

A Relay Discovery IE can be optionally included in Probe Request, Probe Response or Beacon frame.

1. **Common fields for Probe Request, Response and Beacon**

	Element	Length	Relay Discovery Info	UL Min Data Rate	UL Mean Data rate	UL Max Data Rate	DL Min Data Rate	DL Mean Data Rate	DL Max Data Rate
Octets	1	1	1	1	1	1	1	1	1

2. **Optional fields for Probe Request**

	Delay Bound Requirement	Min PHY Rate Requirement
Octets	1	1

3. **Optional fields for Probe Request**

	Channel Utilization	Relay Station Count
Octets	1	1

4. **Relay Discovery Information Field**

	Relay Station Indication	Min Data Rate Included	Mean Data Rate Included	Max Data Rate Included	Delay and Rate Requirement Included/ Utilization and Count Included	Information Not Available	Optional Information Not Available	Reserved
Bits	B0	B1	B2	B3	B4	B5	B6	B7

- Relay Station Indication bit: the relay station shall set this field to "1". Otherwise, this bit shall be set to "0".
- Min Data Rate Included bit: if the UL and DL min data rate are included in the Relay Discovery IE, this bit shall be set to "1". Otherwise, it shall be set to "0".
- Mean Data Rate Included bit: if the UL and DL mean data rate are included in the Relay Discovery IE, this bit shall be set to "1". Otherwise, it shall be set to "0".
- Max Data Rate Included bit: if the UL and DL max data rate are included in the Relay Discovery IE, this bit shall be set to "1". Otherwise, it shall be set to "0".
- Delay and Rate Requirement Included / Utilization and Count Included bit :
- In Probe Request, this bit means "Delay and Rate Requirement Included". If the "Delay Bound Requirement" and "Min PHY Rate Requirement" fields are included in Relay Discovery IE, this bit shall be set to "1". Otherwise, it shall be set to "0".
- In the Probe Response or Beacon, this bit means "Utilization and Count Included" . if the "Channel Utilization" and "Relay Station Count" fields are included in the Relay Discovery IE, this field shall be set to "1". Otherwise, it shall be set to "0".

- Information Not Available bit: this bit shall be set to "1" if the relay station cannot provide requested information in the fixed fields of Relay Discovery IE. Otherwise, it shall be set to "0".
- Optional Info Not Available bit: this bit shall be set to "1" if the relay station cannot provide the requested information of the optional fields. Otherwise, it shall be set to "0".

5. UL and DL Min/Mean/Max Data Rates

- These fields shall be included if the bit of "Min Data Rate Included", "Mean Data Rate Included", and "Max Data Rate Included" is set to "1".
- In the Probe Request frame, those fields denote the UL and DL minimum data rates, UL and DL mean data rates, or UL and DL maximum data rates of the direct path between the station and AP in the step of 100 kbps if they are included.
- In the Probe Response frame or beacon frame, those fields denote the UL and DL minimum data rates, UL and DL mean data rates, or UL and DL maximum data rates of relay link between the relay node and AP in the step of 100 kbps if they are included.

6. Delay Bound Requirement

- This field is included only in Probe Request if the "Delay and Rate Requirement Included" is set to "1".
- This field indicates the delay bound requirement of the channel access through the relay node.

7. Min PHY Rate Requirement

- This field is included only in Probe Request if the "Delay and Rate Requirement Included" is set to "1".
- This field indicates the minimum PHY data rate requirement set by the requesting station.
- The responding station determines whether or not to respond the Probe Request according to received information such as UL and DL Min/Mean/Max Data Rates, Delay Bound Requirement and/or Min PHY Rate Requirement, which depends on the implantation.

8. Channel Utilization

- This field is included only in the Probe Response if the "Utilization and Count Included" is set to "1".
- This field denotes the ratio of time that relay observes the busy level on the relay link between the relay and AP. "255" means 100% busy and "0" means idle.

9. Relay Station Count

- This field is included only in the Probe Response if the "Utilization and Count Included" is set to "1".
- This field denotes the number of stations currently associated with the relay node.

4.4.4 MAC header compression

R.4.4.4.A: The draft specification shall support the concept of storing constant MAC header information (e.g. A3/A4) at the transmitter/receiver through a management exchange as an optional feature [May 2012 meeting minutes, 12/646r0]

4.4.4.1 Short MAC Header

R.4.4.4.1.A: The draft specification shall include the short MAC Header Format as shown below [May 2012 meeting minutes, 12/646r0]:

	2B	2B	6B	2B	6B
From-DS = 1	FC	A1 (AID)	A2 (BSSID)	Sequence Ctrl.	A3 (Optionally present)

	2B	6B	2B	2B	6B
From-DS = 0	FC	A1 (BSSID/RA)	A2 (AID)	Sequence Ctrl.	A3 (Optionally present)

1. A3 is optionally present with an A3 present indication
2. Sequence Control field format [July 2012 meeting minutes, 11-12/857r0]

b0 – b3	b4 – b15
Fragmentation Number	Sequence Number

3. A TID field shall be included in the short MAC header [13/0027r0]
4. The 2 Byte address field is called Short ID (SID) field and it includes the following subfields:

- Association ID (AID), A3 Present, A4 Present, A-MSDU

Bits: 13	1	1	1
Association ID (AID)	A3 Present	A4 Present	A-MSDU

R.4.4.4.1.B: The draft specification shall support the addressing method in the following table (addressing interpretation indication for DL/UL/Direct is TBD; A3 is optionally present based on an indication TBD). [May 2012 meeting minutes, 12/646r0]

Data				
Direction	**Address Interpretation (From-AP)**	**A1**	**A2**	**A3 (SA/DA)**
DL	1	Rx-AID	BSSID	(SA)
UL	0	BSSID	Tx-AID	(DA)
Direct	0	RA	Tx-AID	

R.4.4.4.1.C: The draft specification shall define the following fields in the Frame Control field of the short MAC Header for data frames: [July 2012 meeting minutes, 11-12/857r0]

1. Protocol version (2b), Type field (4b), From DS (1b), More Fragments (1b), Power Management (1b), More Data(1b), Protected Frame (1b), EOSP (1b), TID (3b), Relayed Frame (1b)

- Move the A3 Present subfield to the SID field
- Include the 3 LSB bits of the TID
- Relayed Frame field: 1-bit to indicate if a frame is relayed within a TXOP [13/0288r0]

a. The short MAC header is indicated by a new value of the Protocol Version field [12/1122r0, September 2012 meeting minutes]

bits 2	4	1	1	1	1	1	1	1	3
Protocol Version	Type	From DS	More Fragments	Power Management	More Data	Protected Frame	EOSP	Relayed Frame	TID

R.4.4.4.1.D: The draft specification shall define a frame format for the Short MAC Header as shown below. The indication of the format is TBD. [12/1106r0, September 2012 meeting minutes]

Octets:	2	6	6	2	variable	4
	FC	Dest MAC Address	Src MAC Address	Sequence Control	Body	FCS

4.4.4.2 Duplicate detection for Short MAC frame

R.4.4.4.2.A: The draft specification shall make following changes for the duplication detection: [13/0027r0]

1. Transmitter Side:
    a. A STA operating as a QoS STA shall maintain one modulo-4096 counter, per <STA MAC Address identified by Address 1, TID>, for individually addressed QoS Data frames.
    b. Sequence numbers for these frames are assigned using the counter identified by the Address 1 field and the TID subfield of the QoS Control field of the frame, and that counter is incremented by 1 for each MSDU or A-MSDU corresponding to that < STA MAC Address identified by Address 1, TID> tuple.
2. Receiver Side:
    a. The receiving QoS STA shall keep a cache of recently received < STA MAC Address identified by Address 2, TID, sequence-number, fragment-number> tuples from QoS Data frames from all STAs from which it has received QoS data frames.
    b. A receiving QoS STA shall reject as a duplicate frame any QoS Data frame ~~in which the Retry bit in the Frame Control field is 1 and~~ that matches an < STA MAC Address identified by Address 2, TID, sequence-number, fragment number> tuple of an entry in the cache that contains tuples of that format.

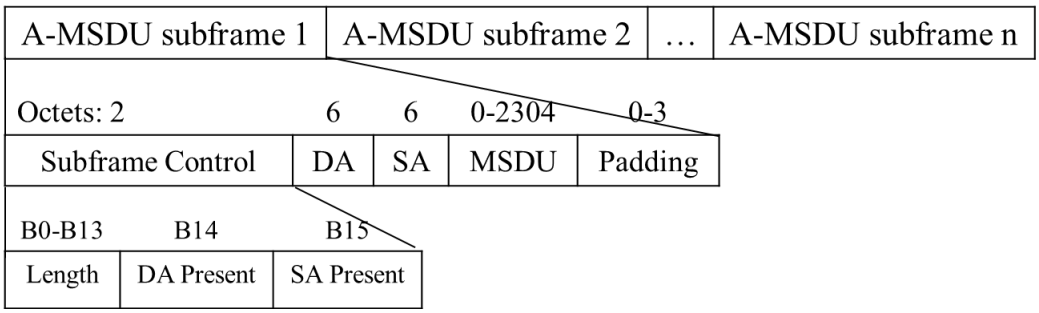
4.4.4.3 Dynamic A-MSDU format

R.4.4.4.3.A: The draft specification shall include the AID and MAC address based short management frame with the management indication in FC TBD [13/0509r0, May 2013 meeting minutes]

R.4.4.4.3.B: In an A-MSDU the transmitter may remove one or both of the SA, DA from an A-MSDU subframe which are same as the addresses in frame header or are negotiated between the transmitter and the receiver with A-MSDU format. [13/0509r0, May 2013 meeting minutes]

- One or both of the SA, DA from an A-MSDU subframe which are same as the addresses in frame header or are negotiated between the transmitter and the receiver
- Presence of DA/SA is indicated with DA/SA Present bits in Subframe Control field
    - Enables dynamic indication of different DA(SA) for each A-MSDU subframe
        - Relays can aggregate multiple MSDUs from/to different SA/DA and indicate it for each MSDU if DA(SA) is different from A3/A4 of MAC Header

- Short A-MSDU format is used in short frame
- 14 bits for Length field are sufficient for current Max MSDU length (2304 octets)
  - Can indicate up to 16384 octets of maximum MSDU length



4.4.5 Action frame format details

4.4.5.1 AID Switch Request frame

[Nov 2012 meeting minutes, 11-12/1304r0]

	Category	Action	Dialog Token	AID Request IE
octets:	1	1	1	variable

4.4.5.2 AID Switch Response frame

[Nov 2012 meeting minutes, 11-12/1304r0]

	Category	Action	Dialog Token	AID Response IE
octets:	1	1	1	variable

4.4.5.3 TBD (e.g. TDLS Update Announce) frame [13/0291r0]

	Category	Action	Dialog Token	Type	Updated AID IE (optional)	PAID IE for relay (optional)
octets:	1	1	1	TBD	TBD	TBD

- If the Type = 0, the updated AID information is included and the detailed IE format is TBD
- If the Type = 1, the associated STA's PAID is included for relay operation and the detailed IE format is TBD (Refer to 13/0075r0, Implicit ACK for Relay)

4.4.5.4 Relay Flow Suspend frame [13/506r0, May 2013 meeting minutes]

1. Relay Action field value

Field Value	Meaning
1	Relay Flow Suspend

2. Relay flow Suspend frame format

Order	Information
1	Category
2	Relay Action
3	Suspend Duration (usec)

4.4.5.5 Relay Flow Resume frame [13/506r0, May 2013 meeting minutes]

a. Relay Action field value

Field Value	Meaning
2	Relay Flow Resume

2. Relay Flow Resume frame format

Order	Information
1	Category
2	Relay Action

4.5 Relay

R.4.5.A: The draft specification shall define a simple bi-directional relay that is limited to two hops only. [Nov 2012 meeting minutes, 11-12/1330r0]

R.4.5.B: The draft specification shall support the concept of sharing one TXOP for relay (for explicit ACK exchange) to reduce the number of channel contentions. [Nov 2012 meeting minutes, 11-12/1330r0]

1. The draft specification shall define a Relayed Frame bit in the Frame Control field for TXOP operation. [13/0288r0]
2. The draft specification shall define a Relayed Frame bit in the NDP ACK SIG for TXOP operation. [13/0288r0]
3. TXOP sharing operation: [13/0288r0]
    a. When a Relay receives a valid frame, the Relay may response with
        i. An Implicit ACK in next-hop transmission after SIFS, if Relay has received Relayed Frame bit set to 1
        ii. An ACK after SIFS with Relayed Frame bit set to 1, and continue with next-hop DATA transmission after SIFS
        iii. An ACK after SIFS with Relayed Frame bit set to 0, and does not continue to use the remaining TXOP
    b. A relay may set Relayed Frame bit to 1 only if it has received a More Data bit set to 0.

R.4.5.C: The draft specification shall define a flow control mechanism at the relay. [Nov 2012 meeting minutes, 11-12/1330r0]

1. To suspend frame transmissions to Relay, a Relay may send a unicast or broadcast Relay Flow Suspend action frame, and Suspend Duration > 0 [13/506r0, May 2013 meeting minutes]
    a. STAs shall not transmit data frames to the STA addressed in the TA for the amount of time indicated in Suspend Duration field
    b. STAs may resume normal procedure for data frame transmission when the Suspend Duration time has expired
2. To restart frame transmissions to Relay, a Relay may send a unicast or broadcast Relay Flow Resume action frame [13/506r0, May 2013 meeting minutes]
    a. STAs shall cancel the flow suspend time, and resume normal procedure for data frame transmissions to the STA addressed in the TA
    b. The sending of Relay Flow Resume action frame by the Relay is optional, and may be used by the Relay to cancel an existing Suspend Duration
3. The draft specification shall define a 1-bit field in FC in one of the S1G control response frame which includes a time field for Relay flow control signalling.

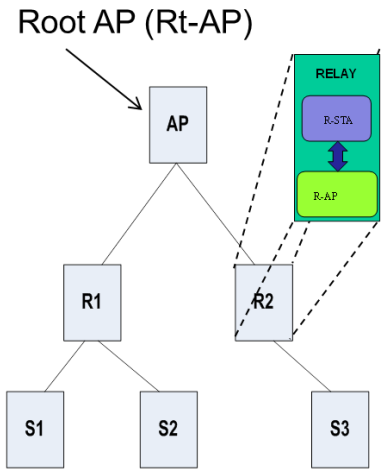
R.4.5.D: The draft specification shall support to use Probe Request for Relay discovery, and optionally, include information on AP-STA link budget. [Nov 2012 meeting minutes, 11-12/1330r0]

1. The STA initiates the discovery process.
2. The STA selects a relay based on the probe responses received.

4.5.1 Relay entity

R.4.5.1.A: The draft specification shall define a relay entity which constitutes of R-STA and R-AP as described below. [Nov 2012 meeting minutes, 11-12/1323r0]

1. R-STA is a non-AP STA with the following capabilities
    a. 4 address support
        i. Capable of transmitting/receiving a {ToDS=1,From DS=1} frame to /from the root AP it is associated with
    b. Supports forwarding and receiving frames from the R-AP
2. R-AP is an AP with the following additional capabilities
    a. 4 address support mandatory, i.e.
        i. R-AP is allowed to send/receive {To DS = 1, From DS = 1} frames to an associated STA based on STA capability
        ii. R-AP capable receiving a 4 address frame and forwarding the frame with 3 addresses to an associated STA
    b. Supports forwarding and receiving frames to/from the R-STA
    c. Able to indicate it is a R-AP (1 bit or indicate root-AP address/SSID in beacon, TBD)



R.4.5.1.B: A relay should include the root AP's SSID in Beacon/Probe Response frames. [Nov 2012 meeting minutes, 11-12/1323r0]

R.4.5.1.C: The draft specification shall support the frame delivery mechanism using A-MSDU format between the root AP and a relay. [Nov 2012 meeting minutes, 11-12/1323r0]

R.4.5.1.D: The draft specification shall support the ReachableAddress message that is used to update the forwarding tables. [13/0076r0]

1. Content and format TBD

4.5.2 Group addressed MPDU transfer procedure for relay

R.4.5.2.A: The draft specification shall support the following group addressed MPDU transfer procedure: [13/0068r0]

Step 1) A group addressed MPDU is transferred from STA to R-AP in a unicast manner.
R-AP does not broadcast the group addressed MPDU transferred from STA

Step 2) A group addressed MPDU is transferred from R-STA to Root AP in a unicast manner.
Either 4 Address format or A-MSDU format is used

Step 3) Root AP broadcasts the group addressed MPDU transferred from R-STA.

Step 4) R-AP broadcasts the group addressed MPDU transferred from Root AP.

4.5.3 Implicit ACK for Relay

R.4.5.3.A: The draft specification shall support the concept of sharing one TXOP for relay with implicit ACK, where PAID in SIG field is used for ACK purpose as described below: [13/0075r0]The source station identifies if following packet is relay station's forwarding packet by checking the SIG field of the following packet.

a. 9bit PAID subfield is defined for 2MHz SIG field.
b. When a relay station forwards a received packet to a destination station, the destination station's PAID shall be included in the PAID subfield.
c. If the source station knows the destination station's PAID, the source station can identify that following packet is relay station's forwarding packet, by checking the PAID subfield of the following packet's SIG field.
d. Therefore, the source station can check its transmission success or not by checking SIG field of following packet only without decoding data payload part.

R.4.5.3.B: The draft specification shall support that a relay station indicates an associated STA's PAID to root AP when the STA becomes associated or the STA's AID is changed, and indicates the BSSID of the root AP to newly associated STAs: [13/0075r0]

- And the BSSID of the root AP can be indicated in beacon frame.

4.6 Sectorized beam operation

R.4.6.A: Sectorized beam operation [Nov 2012 meeting minutes, 11-12/1355r1]

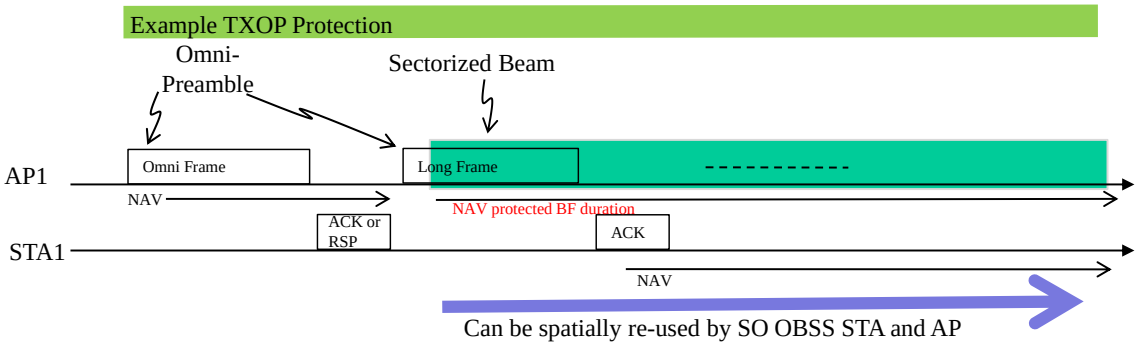
1. AP can switch back and forth between sectorized beam(s) and omni beam.
2. Sectorized beam is used only when AP is aware of the STA's sector either in scheduled transmission such as RAW or during a TXOP of a STA. AP switches back to omni otherwise.
3. The sectorized receive beam is used in conjunction with the sectorized transmit beam within a TXOP.
4. AP indicates the sectorized beam operation in Beacons, Probe Response, or Association Response.
5. This proposal requires an AP to be able to transmit/receive both omni and sectorized beam. (Only AP (not STA) uses sectorized beam).
6. The forming of the sector beam is implementation specific.

R.4.6.B: Spatial Re-use Channel Access Rules [Nov 2012 meeting minutes, 11-12/1355r1]

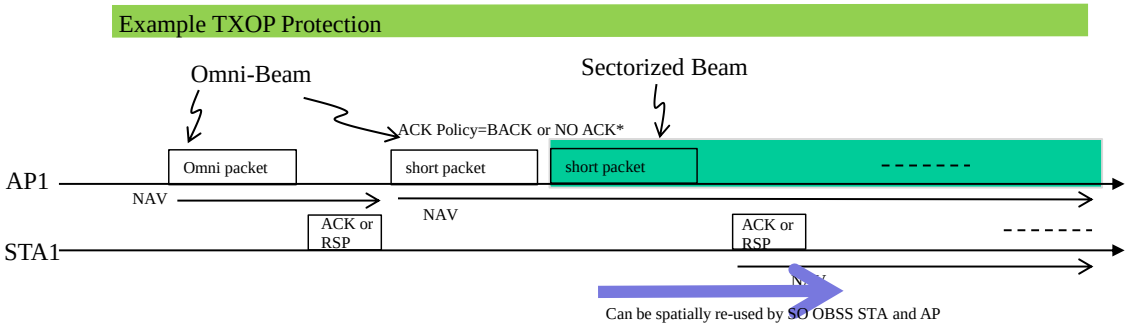
1. When the protection is set up by omni transmission for a duration within a TXOP and if the SO condition is confirmed by an OBSS STA/AP, the OBSS STA/AP can cancel its NAV to initiate a new SO exchange starting with a non-BF RTS/CTS.
2. Once an AP switches to the sectorized beam transmission during an exchange, it shall continue with greenfield sectorized beam transmission for the remainder of the protected duration.
3. Note: SO (Spatially Orthogonal) condition is defined as an OBSS STA/AP which receives the omni transmission but not the sectorized transmission from the AP (which is either the TXOP holder or responder) and not the transmission from the STA (which is either the TXOP responder or holder).

R.4.6.C: SO (Spatially Orthogonal) conditions [Nov 2012 meeting minutes, 11-12/1355r1]

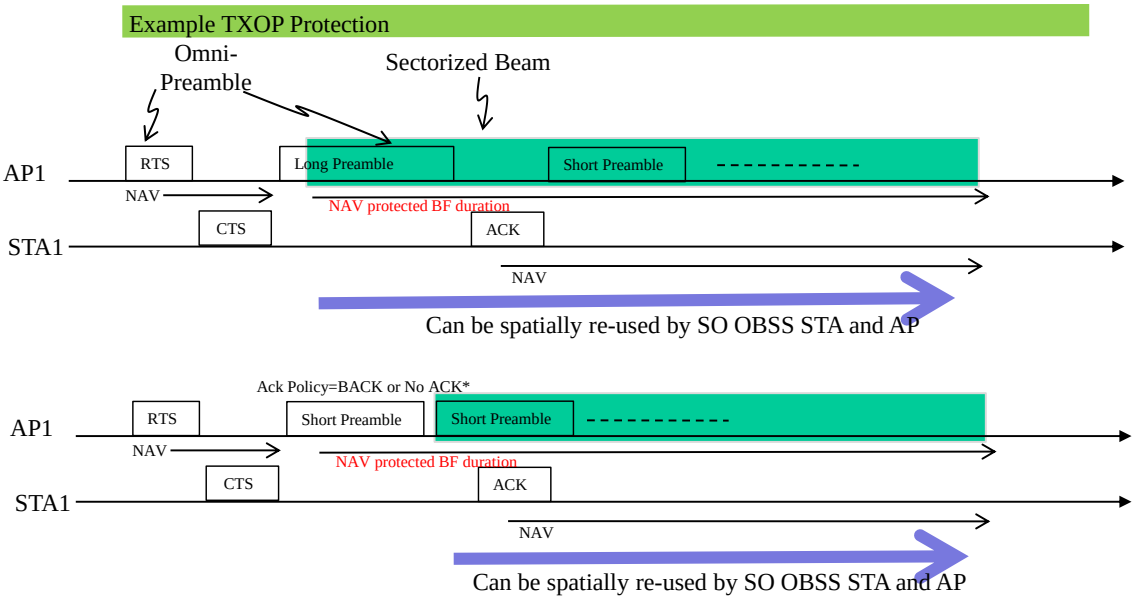
1. SO condition 1
    a. AP can use omni-preamble to set up TXOP protection for the sectorized beam transmission.
    b. Once the proper TXOP protection is set up with a long preamble, the sectorized transmission (with greenfield BF) shall be used for the remainder of the TXOP.
    c. SO condition is confirmed by an OBSS STA/AP not receiving
        i. STA1's transmission (OBSS STA expects a following STA1 transmission when it sees Ack Indication= 00, Ack Indication=10, Ack Indication=11/Ack Policy=00 in the AP1 Omni packet packet), and the AP1's sectorized transmission portion within the long preamble.



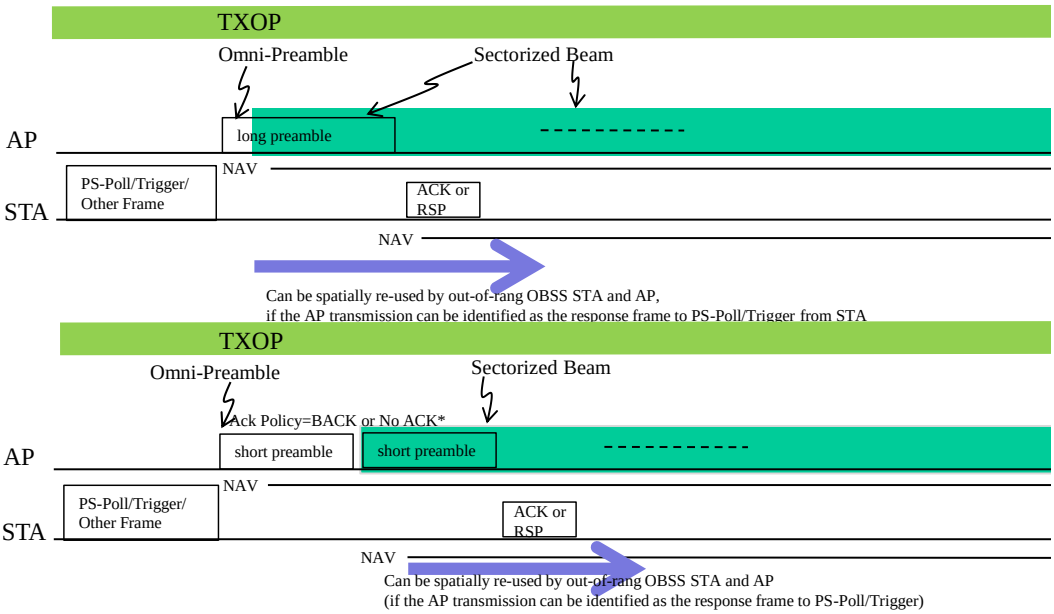
2. SO condition 2
    a. AP can also use the short-preamble with omni-transmission to set up TXOP protection for the sectorized beam transmission.
    b. As shown in the examples, the TXOP protection is set up at the second transmission by AP.
    c. Once the proper TXOP protection is set up, the sectorized transmission (with greenfield BF) shall be used for the remainder of the TXOP.
    d. SO condition is confirmed by an OBSS STA/AP not receiving
        i. STA1's transmission (OBSS STA expects a following STA1 transmission when it sees Ack Indication= 00, Ack Indication=10, or Ack Indication=11/Ack Policy=00 in the AP1 Omni packet packet)), and the AP1's sectorized transmission (following the omni packet with ACK Policy=Block Ack*).



3. SO condition 3: RTS/CTS



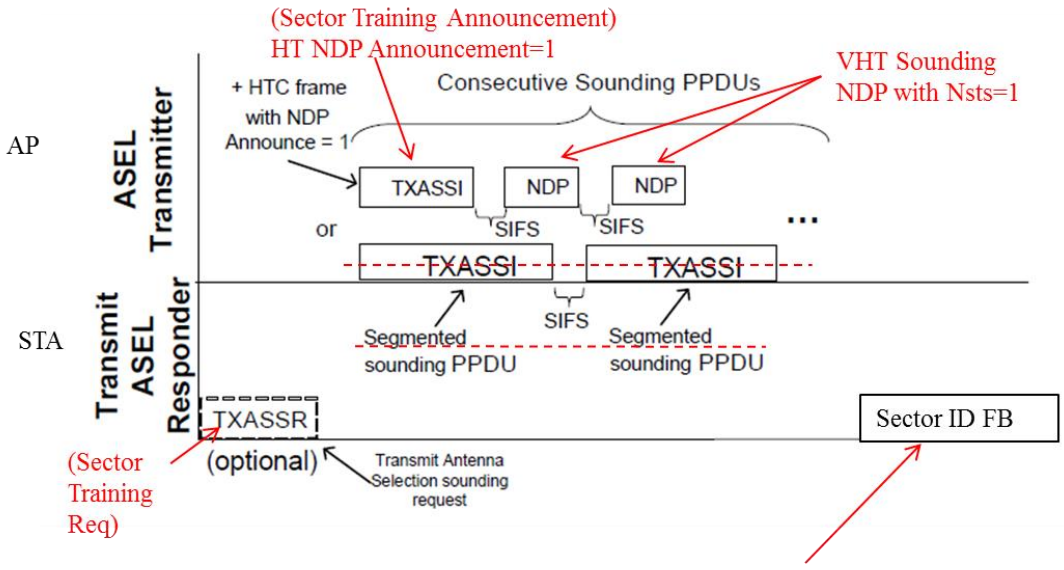
4. SO condition 4
    a. The followings illustrate an exchange initiated by STA.



R.4.6.C: The draft specification shall support the following sectorized beam training: [13/0081r1]

1. SDF R.4.2.I 3: STA can optionally feedback sector/group ID
2. AP indicates the sectorized beam operation
3. STA joining a sectorized beam operation BSS shall indicate whether it supports sectorized beam feedback in the sectorized beam feedback capability field (1=support)
4. STA indicates through capability exchange that it support request/feedback

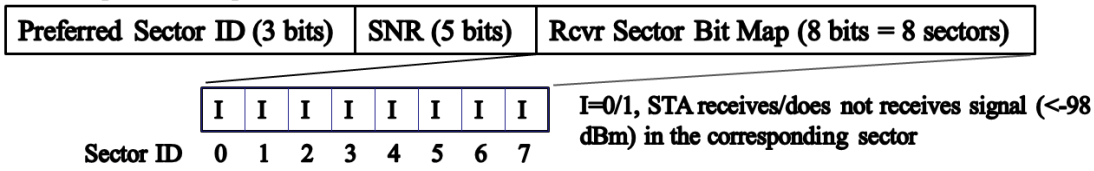
5. Propose to re-use the HT Variant Control Link Adaptation Field (setting MAI=14, or MRQ=0, MSI=7) for requesting or indicating "Sector Training"
6. TXASSR (transmit antenna selection request) → Sector training request
7. HT NDP Announcement field =1 → Indicate NDP sounding (preceding training packets)
8. Use VHT Sounding NDP with Nsts=1 for sector beam training



9. Use a VHT Action frame (8.5.23.1 in 11ac) for (solicited and unsolicited) Sector ID feedback.

Order	Information
1	Category
2	VHT Action
3	Sector ID Index

   a. VHT action = 3 (or higher)
   b. Sector ID index
      i. Format: [13/0302r1]



1. Preferred Sector ID: the sector that the STA receives highest quality AP signal
2. SNR: received SNR at the preferred Sector, 0 to 31 represents SNR values -3 to 27 dB respectively. When the SNR value is greater than 27db, set to 30. If the SNR value is less than -3dB, set to 0. 31 indicates no feedback.
3. Receive Sector Bit Map: 0 indicates that the station does not receive the AP signal in a specific Sector. The position of the bit map (0 to 7) corresponding to the sector ID. This allows the AP to know which sectors the STA are in.

10. Use the NDP CTS frame with the Address Indicator field set to 0 and the RA field set to Partial BSSID for sector training. [13/0302r1]
    a. The NDP CTSs with the Address Indicator set to 0 and RA set to Partial BSSID will be transmitted through the Sectorized Beams (with assending Sector ID starting with Sector ID=0) during the sector training.

R.4.6.D: Sector Report RAW may be assigned after Sounding RAW (sector training) for fast sector discovery (signaling TBD) [13/306r0]

4.7 Frequency selective transmission

R.4.7.A: General procedure [Nov 2012 meeting minutes, 11-12/1338r0]

1. A STA is allowed to choose one 2 MHz subchannel of a wideband BSS on which to transmit and receive when permitted by the AP.
2. The draft specification shall include the option for the beacon to include information about subsequently transmitted frames that allow for sounding measurements to be made at recipient STAs, e.g. number of signals, type of signals, frequency location and timing.
3. An AP may send more than one Beacon per TBTT on more than one subchannel of the BSS.
4. The draft specification shall include the concept of a subchannel permission bitmap in the Beacon to identify on which subchannels associated STA may transmit.

4.8 OBSS mitigation procedures

- [Nov 2012 meeting minutes, 11-12/1336r0]

R.4.8.A: The draft specification shall support the usable secondary channel indication mechanism as follows and includes transmitter and receiver capability information [13/0525r1, May 2013 meeting minutes]:

1. When the data is received correctly by a receiver:
   – The receiver returns full bandwidth >= 2MHz short ACK on the primary and usable secondary channels.
   – Only return full bandwidth >= 2MHz short ACKs on contiguous channels
2. The number of secondary channels can be reduced
   – The transmitter can avoid the secondary channels with the high level of interference

4.9 Small battery operated STA support

R.4.9.A: Maximum awake duration indication [13/0304r1]

1. A receiver STA indicates to a transmitter STAs the maximum continuous duration of time it can be in awake state
   - Let's call this time the MAX_awake_duration
   - STA communicates the limitation to the AP or to the peer TDLS STA in e.g. the Capabilities element that is included in Probe request, (Re) Association request, TBD.
     - A fixed value; not many reasons to have this dynamically changed during operation
2. A transmitter STA receiving this indication shall plan for frames exchanges compatible with the receiver STA's limitation
   - U-APSD: similar to existing U-APSD coexistence
   - TWT: indicate a max awake time
   - RAW: indicate a max awake time from star of the slot, or max slot size
   - When the transmitter cannot complete a frames exchanges within MAX Awake duration, a new back-off procedure is invoked after stopping the current transmission.

R.4.9.B: Recovery time indication [13/0304r1]

1. STA indicates a Recovery time that a transmitter should wait after the end of a previous awake period of the STA, before sending a new PPDU addressed to the STA
   a. STA communicates the limitation to the AP or to the peer TDLS STA by including it in e.g. the Capabilities element that is included in Probe request, (Re) Association request, TBD
      i. A fixed value; not many reasons to have this dynamically changed during operation
2. A transmitter STA receiving this indication shall plan for frames exchanges compatible with the receiver STA's limitation

4.10 DCF

4.10.1 PPDU Recovery Procedure

R.4.10.1.A: The draft specification shall define the following PPDU recovery procedure [140]:

1. After transmitting an MPDU that requires an immediate frame as a response, the STA shall wait for a timeout interval of duration of aSIFSTime + aSlotTime + aPHY-RX-START-Delay, starting at the PHY-TXEND.confirm primitive
   a. The value for aPHY-RX-START-Delay is dependent on the PHY type, and each such value can be found within the PHY-Characteristics table for each individual PHY within its own clause.

b. In S1G PHY, the aPHY-RX-START-Delay is determined by the preamble _type parameter of TXVECTOR.
c. When the TXVECTOR FORMAT is equal to 1MHz preamble, aPHY-RX-START-Delay is set to 600us.
d. When the TXVECTOR FORMAT is equal to >= 2MHz short/long preamble, aPHY-RX-START-Delay is set to 280us.

2. When a capability element of STA indicates that 1MHz control response will be used, a 1MHz preamble transmission as the response of >= 2MHz short/long preamble is allowed.
    a. A S1G STA that sends a control frame in response to a frame carried in an S1G PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same or lower as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.
    b. Channel Bandwidth of PPDU during the multiple frame exchange sequences in a TXOP shall be the same or narrower than the Channel Bandwidth of the preceding PPDU.

Otherwise, a 1MHz preamble transmission as the response of >= 2MHz short/long preamble is not allowed. AP chooses the ACK timeout depending on the preamble type of the frame eliciting the control response.

c. A S1G STA that sends a control frame in response to a frame carried in an S1G PPDU shall set the TXVECTOR parameter CH_BANDWIDTH to indicate a channel width that is the same as the channel width indicated by the RXVECTOR parameter CH_BANDWIDTH of the frame eliciting the response.

4.10.2 Virtual Carrier Sensing

R.4.10.2.A: The draft specification shall support the following [13/0517r1, May 2013 meeting minutes]:

1. The Virtual CS mechanism should be based on both NAV and RID, and
2. If the STA obtains both ACK Indication and Duration from the single reception, the STA shall reset RID to zero.
3. The medium condition at the MAC is BUSY if PHY_CS indicates BUSY or the NAV counter has a non-zero value or the RID counter has a non-zero value or STA transmitter status is equal to "transmitting".
    a. MediumBUSY = (PHY_CS == BUSY) OR (NAV != 0) OR (RID != 0) OR (STA transmitter status == transmitting)

4.10.3 EIFS rules [13/0152r0, May 2013 meeting minutes]

R.4.10.3.A: The draft specification shall support the EIFS calculation based on the following rules:

ACK Indication	Response	Aggregation	Response Length	EIFS Calculation*
0	No Response	Any	0	DIFS
1	NDP	Any	NDP	SIFS + DIFS + NDPTxTime
2	Normal	0	NDP + 14 Bytes	SIFS + DIFS + ACKTxTime
		1	NDP + 32 Bytes	SIFS + DIFS + BATxTime
3	Long	Any	Max PPDU	SIFS + DIFS + MaxPPDUTxTime

1. ACK Indication = 1: NDP Response
    a. EIFS = aSIFSTime + DIFS + NDPTxTime
    b. Calculation is based in the value of ACK indication
        i. NDPTxTime depends on BW of NDP response frame
        ii. 560us for 1MHz and 240us for >=2MHz NDP frames
2. ACK Indication = 2: Normal Response
    a. Aggregation = 0: EIFS = aSIFSTime + DIFS + ACKTxTime
    b. Aggregation = 1: EIFS = aSIFSTime + DIFS + BATxTime
        i. The response MCS is determined based on the PHY mandatory MCS set
    c. TxTime depends on response frame's BW and MCS
3. ACK Indication=3: Long Response
    a. EIFS = aSIFSTime + DIFS + Max PPDUTxTime
    b. Calculation is based only in the value of ACK indication

4.11 MLME

R.4.11.A: The draft specification shall support that an AP includes dot11AssociationSAQueryMaximumTimeout in Association Response frame or Re-association Response frame with status code set to success. [13/0026r0]

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11/1294r0 Spec Framework Text for 11ah Bandwidth Modes
11/1311r0 Spec Framework Text for PHY Numerology
11/1275r1 Spatial stream support in TGah specification
11/1329r0 Motions and Strawpoll on Channelization for 11ah
11/1318r0 Japanese Channelization for 802.11ah
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12/838r0 full beacon
12/816r1 Channel selection for 802.11ah
12/831r0 Uplink channel access general procedure
12/830r0 NDP probing
12/851r1 Tail bits in 1 MHz SIG field
12/843r0 Restricted Access Window Signaling for Uplink Channel Access
12/823r0 Target WakeTime
12/840r0 AP assisted medium synchronization
12/834r0 Speed frame exchange
12/867r0 non-TIM allocation
12/860r0 Collision reduction
12/892r0 Uplink data delivery
12/853r0 sectorization for hidden node mitigation
12/842r2 Short beamforming report poll frame
12/845r0 Max Idle Period extension
12/859r0 Short BA
12/857r0 Short MAC header design
12/848r0 NDP Type PS-Poll frame
12/832r2 SIG fields design of long preamble
12/825r2 Smoothing bit and beam_change indication bit

12/818r0 11ah padding
12/819r1 preamble discussion
12/815r0 Q matrix requirements for 1MHz 2MHz detection
12/891r0 AID reassignment for TIM and non TIM modes switching
12/409r6 Channel access supporting low power operation
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12/1080r0 SIG Field of NDP Probe Request
12/1085r0 1MHz SIG Field Discussions
12/1102r1 SIG field ordering
12/1079r0 Partial AID
12/1093r0 System information update procedure for 11 ah
12/656r1 Extended Sleep mode for battery powered STAs
12/1106r0 A Short-Header Frame Format
12/1122r0 Short MAC Header Signaling
12/112r4 Supporting Authentication/Association for Large Number of Stations
12/662r3 Block ACK Transmission
12/1100r1 Mid-CRC in Long Beacon
12/1101r1 Active Polling
12/1083r0 Sensor Only BSS
12/1084r4 TIM and Page Segmentation
12/1086r1 TIM Compression for No Buffered Unicast Traffic
12/1104r2 11ah Interframe Spacing Values
12/1092r0 4-bit CRC Revisited
12/1089r0 Frame Classification Based on MAC Header Content
12/1103r0 Sectorized beam operation
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12/1321r0 RAW slot assignment
12/370r3 TIM compression
12/662r4 Block Ack transmission
12/1326r0 PSDU Size for Receiver Sensitivity Power Level
12/1308r0 Uplink Data Indication in NDP PS-Poll
12/1333r0 Mandatory Optional PHY Features for 11ah
12/1302r0 TXOP truncation
12/1304r0 AID assignment protocol
12/1309r1 Non-TIM mode negotiation
12/1310r1 PS-POLL TXOP Using RTS/CTS Protection
12/1311r0 Periodic channel access
12/1315r0 PAPR reduction
12/1322r0 Traveling pilots
12/1338r0 Frequency selective transmission
12/1313r0 1 MHz dup mode
12/1330r0 Two-hop relaying
12/1329r0 PS-Poll for Downlink Bufferable Units
12/1312r0 Beamforming Feedback for Single Stream
12/1355r1 Sectorized beam operation follow up
12/1335r1 SIG field Overload indication to support NDP Frames
12/1324r0 Very Low Energy Paging
12/1323r0 Relay
12/1363r1 Clarifications on 1 MHz Preamble and Timing-Related Constants
12/1325r1 PS-Poll TXOP
12/1336r0 Overlapping OBSS of different sizes
13/0084r0 Spectral Masks for 11ah
13/0076r0 Reachable Address Message
13/0070r1 Enabling AP Sleep

13/0071r0 Channel indication in RAW/TWT
13/0082r0 Short Response Frame for NDP PS-Poll
13/0060r0 2 MHz duplicate mode
13/0061r0 Receiver Sensitivity Levels
13/0062r0 SERVICE Field
13/0079r0 TWT Grouping and Assignment for Z-Class STAs
13/0078r0 NDP-CTS Frame in Broadcast mode as Synch Frame for Uplink Channel Access
13/0026r0 Security Association Procedure for Long Sleeper
13/0027r0 Duplicate Detection of Short MAC Frame
13/0068r0 Group Addressed MPDU Transfer in Relay
13/0080r0 Backoff Procedure in RAW
13/0074r0 NDP Type PS-Poll Frame Follow-Up
13/0075r0 Implicit ACK for Relay
13/0104r0 Flexible Multicast
13/0089r0 Listen Interval Update
13/0081r1 Sectorization Follow Up 2
13/0286r0 Restricted Access Window - Slot Assignment Follow Up
13/0297r0 TGah MCS Table
13/301r0 Format of Open-Loop Link Margin Index Field
13/295r0 PRAW Follow Up
13/0296r0 Response Frame Indication
13/0307r0 Spectral Flatness for 11ah
13/0288r0 TXOP Sharing Operation for Relay
13/0290r0 RAW Operation Improvement
13/0294r0 Duplicate Bandwidth and Operation
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13/0302r1Sectorized Beam Operation Follow-up 3
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13/0517r1 Combining Process in Virtual CS for 11ah
13/0510r1RAW Assignment follow up
13/0522r0 Non-TIM Allocation Followup
13/0508r0 modulation accuracy
13/0518r0 Page scheduling
13/0519r0 Speed frame exchange using short frames
13/0512r0 ACK Indication and EIFS
13/0509r0 Short management and A-MSDU frame
13/0525r1 OBSS mitigation
13/0511r1 Relay comments