**IEEE P802.15**

**Wireless Personal Area Networks**

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| Re: | Contribution to IEEE 802.15.4ab  |
| Abstract |  |
| Purpose | This submission proposes text to for the IEEE Std 802.15.4ab specification framework document. |
| Notice | This document does not represent the agreed views of the IEEE 802.15 Working Group or IEEE 802.15.4ab Task Group. It represents only the views of the participants listed in the “Source(s)” field above. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein. |

***This document aims to further clarify the sensing consensus text proposal DCN 23-0538r7 and the sensing consensus slides DCN 23-0248r1***

## Sensing

### 10.36.4.5 Window-based CIR measurement report

*Change the sentence in Line 2-17 on page 75 as follows:*

Support for a variable bitmap mode in which the bitmap varies from packet to packet is optional.

### 10.36.7 Nested IEs for sensing

### 10.36.7.1 Application Control IE (AC IE)

*Change Figure 74 as follows.*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Octets: 2** | **0/4** | **0/1** | **0/1** | **0/2** | **0/1** | **0/Variable** | **0/Variable** |  |
| Content Control | Session ID | Block Duration | Round Duration | Slot Duration | Contention Slots Info | Ranging Control | Sensing Control |  |

*Change Line 5-6 on Page 81 as follows.*

|  |
| --- |
|  |
|  |

***Update the description of Figure 82 on page 81 as follows.***

The Sensing Control field is formatted as per Figure 82

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Bits: 0** | **1** | **2** | **3** | **4-7** | **Octets: 0/1** | **0 / variable** | **0 / variable** | **0 / variable** |
| Common Sensing Control Present | CIR Report Parameters Present | Frequency Stitching Parameters Present | Non-sensing TX CIR Report Parameters Present | Reserved | Common Sensing Control | CIR Report Parameters | Frequency Stitching Parameters | Non-Sensing TX CIR Report Parameters |

The Common Sensing Control Present field when one indicates that the Common Sensing Control field is present, or when zero that it is not present.

The CIR Report Parameters Present field when one indicates that the CIR Report Parameters field is present, or when zero that it is not present.

The Frequency Stitching Parameters Present field when one indicates that the Frequency Stitching Parameters field is present, or when zero that it is not present.

The Non-sensing TX CIR Report Parameters Present field when one indicates that the Non-sensing TX CIR Report Parameters field is present, or when zero that it is not present.

The Common Sensing Control field is formatted as per Figure 83.

|  |  |  |  |
| --- | --- | --- | --- |
| **Bits: 0-1** | **2** | **3-4** | **5-7** |
| Sensing Mode | Responder Role | Sensing Packet Format | Reserved |

Figure 83 – Common Sensing Control subfield of the Sensing Control field of the AC IE

The Sensing Mode field specifies the sensing mode to be used in the sensing round(s) that follow the AC IE. The Sensing Mode field shall have one of the values defined in Table x.1.

Table x.1 – Values of Sensing Mode subfield of the Common Sensing Control

|  |  |
| --- | --- |
| **Sensing Mode field value** | **Meaning** |
| 0 | Mono-static. |
| 1 | Bi-static. |
| 2 | Multi-static. |
| 3 | Sensing by proxy |

The Responder Role field specifies the role of the responder to be played in the sensing round(s) that follow the AC IE. The Responder Role field shall have one of the values defined in Table x.2.

Table x.2 – Values of Responder Role subfield of the Common Sensing Control

|  |  |
| --- | --- |
| **Responder Role field value** | **Meaning** |
| 0 | Responder is the transmitter of the sensing packet. |
| 1 | Responder is the receiver of the sensing packet. |

The Sensing Packet Format field specifies the packet format to be used in the sensing round(s) that follow the AC IE. The Sensing Packet Format field shall have one of the values defined in Table x.3.

Table x.3 - Values of Sensing Packet Format subfield of the Common Sensing Control

|  |  |
| --- | --- |
| **Sensing Packet Format field value** | **Meaning** |
| 0 | SENS packet configuration one. |
| 1 | SENS packet configuration two. |
| 2 | SENS packet configuration three. |
| 3 | Reserved. |

The CIR Report Parameters field is formatted as per Figure 84.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Bits:** **0-1** | **2-3** | **4-5** | **6** | **7** | **8** | **9-18** | **19-23** | **24** | **25-31** | **Octets:0/ 4/8/16/64**  |
| CIR I/Q number of bits | Bitmap mode | Length  | Process CIR report for Range | Process CIR report for Velocity | Process CIR report for AOA measurement | Bitmap offset | Bitmap Gap | Compression | Reserved | Bitmap |

The CIR IQ number of bits field is defined as the number of bits for encoding signed I/Q values each, normalized per Rx chain and per segment. The options of CIR IQ number of bits are 10 12 14 and 16, of which 16 is the mandatory option and others are optional.

The Bitmap Mode field defines the way to set the bitmap and shall have one of the values specified in Table 11.

**Table 11—Values of Bitmap Mode subfield of the CIR Report Parameters subfield**

|  |  |
| --- | --- |
| **Bitmap Mode subfield value** | **Meaning** |
| 0 | Initiator sets bitmap from predefined subset of bitmaps in 10.36.4.5. |
| 1 | Initiator sets bitmap from configs not specified in the defined subset |
| 2 | Responder sets bitmap and reports it |
| 3 | Reserved |

The Length field has two uses.

⎯ When the Bitmap Mode field is zero, the Length field specifies the sub-window length, as defined in Table 12. In this case, the bitmap is chosen from one of the predefined bitmap options. These options consist of two sub-window of equal length, both filled with all ones. The gap between these two sub-windows are determined by the Bitmap Gap field.

⎯ When the Bitmap Mode field is value is one or two, the Length field specifies the length of the Bitmap field, as defined in Table 12.

**Table 12—Values of Length subfield of the CIR Report Parameters subfield**

|  |  |  |
| --- | --- | --- |
| **Length field value** | **Meaning when Bitmap Mode field value is zero** | **Meaning when Bitmap Mode field value is one or two** |
| 0 | sub-window length is 16 | Bitmap Field length is 4 octets |
| 1 | sub-window length is 32 | Bitmap Field length is 8 octets |
| 2 | sub-window length is 64 | Bitmap Field length is 16 octets |
| 3 | sub-window length is 128 | Bitmap Field length is 32 octets |

The Process CIR report for Range field when one indicates the CIR is further processed to generated the range result of the sensing target, or when zero the range result is not generated.

The Process CIR report for Velocity field when one indicates the CIR is further processed to generated the velocity result of the sensing target, or when zero the velocity result is not generated.

The Process CIR report for AoA field when one indicates the CIR is further processed to generated the AoA result of the sensing target, or when zero the AoA result is not generated.

The Bitmap Offset field specifies the gap between of the first CIR tap within the window and the reference tap.

The Bitmap Gap (present if bitmap mode=0) field specifies the gap between the two sub-windows of the predefined bitmap.

The Compression field when set to one indicates that the CIR report is compressed based on DEFLATE method, and when zero that the CIR report is not compressed.

The Bitmap field (present if bitmap mode=1) indicates the CIR taps within the window will be reported or not by setting the corresponding bit in the Bitmap field to be one or zero.

The Frequency stitching Parameters field is formatted as per Figure 85.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Bits: 0** | **1-4** | **5-6** | **7** | **8-11** | **12-13** | **14-15** |
| Frequency Stitching Direction | Base Channel | Carrier Frequency Grid | Channel Sequence Order | Number of Transmissions | Frequency Stitching Type  | Feedback Control  |

**Figure 85-Frequency Stitching Parameters subfield of the Sensing Control field of the AC IE**

The Frequency Stitching Direction field indicates the center frequency change direction of the subsequent channels based on the base channel. When one, the base channel has the lowest center frequency, when zero, the base channel has the highest center frequency.

The Base Channel field indicates the starting channel for performing UWB sensing when frequency stitching is enabled.

The Carrier Frequency Grid field selects the carrier frequency grid for frequency stitching, as defined in Table 13.

**Table 13 – Values of Carrier Frequency Grid field**

|  |  |
| --- | --- |
| **Carrier Frequency Grid field value** | **Meaning** |
| 0 | 499.2 MHz carrier frequency grid,No overlap of consecutive frequency stitching channels.  |
| 1 | 374.4 MHz carrier frequency grid, 25% overlap of consecutive frequency stitching channels.  |
| 2 | 249.6 MHz carrier frequency grid, 50% overlap of consecutive frequency stitching channels.  |
| 3 | 124.8 MHz carrier frequency grid, 75% overlap of consecutive frequency stitching channels. |

The Channel Sequence Order field specifies the sequence of channel use in frequency stitching mode.

When the Channel Sequence Order field value is zero, if the Frequency Stitching Direction field is one, the channels used are selected in sequence starting at the channel defined by the Base Channel field value and increasing in frequency using the step size defined by the Carrier Frequency Grid field value. On the other hand, if the Frequency Stitching Direction field is one, the channels used are selected in sequence starting at the channel defined by the Base Channel field value and decreasing in frequency using the step size defined by the Carrier Frequency Grid field value. When the Carrier Frequency Grid field is 0 or 1, the Channel Sequence Order field value shall be 0.

When the Channel Sequence Order field value is one the channels used are selected according to the formula:

CH((p\*(OF+1) MOD (N)) + (p\*(OF +1) DIV (N)))

where p starts iterates sequentially from zero through to N-1,

OF is the overlap factor, which is equal to Carrier Frequency Grid field value,

MOD is the modulo operator, and DIV denotes integer division.

If the total number of transmissions is divisible by (OF+1), N is equal to the total number of transmissions. Otherwise, N is the smallest integer greater than the total number of transmissions and divisible by (OF+1). In this case, CH(0), CH(1), …, CH(N-1) is padded with unused channels, which corresponds to the idle transmitter.

The Number of Transmissions field value plus one, is the total number of transmissions to be done at the different channel center frequencies, i.e., the number of steps selecting different frequencies as dictated by the Channel Sequence Order field value.

The Frequency Stitching Type field specifies the type of frequency stitching, as defined in Table 14.

**Table 14 – Values of Frequency Stitching Type field**

|  |  |
| --- | --- |
| **Frequency Stitching Type field value** | **Meaning** |
| 0 | Intra-packet frequency stitching. |
| 1 | Inter-packet frequency stitching. |
| 2 | Combination of intra-packet frequency stitching and inter-packet frequency stitching. |
| 3 | Reserved. |

The Feedback Control field selects when the CIR report is generated, as defined in Table 15.

**Table 15 – Values of Feedback Control field**

|  |  |
| --- | --- |
| **Feedback Control field value** | **Meaning** |
| 0 | Report after each transmission. |
| 1 | Report for all transmission after the last transmission. |
| 2 | Report for the aggregated channel after the last transmission. |
| 3 | Reserved. |

### 10.36.7.2 CIR Report IE

The CIR report IE is used to send information on the CIR. This may be used by an SDEV to send a sensing report to a companion device participating in a sensing network. The Content field of the CIR report IE shall be formatted as shown in Figure 88.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bits: 0-1 | 2-3 | 4-13 | 14-15 | Octets: 4/8/16/32 | Variable$$ |
|  Number of Rx Antennas | Bitmap Length | Bitmap Offset |  Number of Segments | CIR Bitmap | Receive Report(s) |

**Figure 88—CIR report IE Content field format**

The Number of Rx Antennas field value plus one shall indicate the number of antennas being reported on. For each Rx antenna there shall be a separate Receive Report field included in the CIR report IE.

The Bitmap Length field indicates the length of the CIR Bitmap field. The values and meaning of the Bitmap Length field are given by Table 16.

**Table 16 –Bitmap Length field values**

|  |  |
| --- | --- |
| **Bitmap Length field value** | **Meaning** |
| 0 | The CIR Bitmap field is 32 bits (4 octets) long. |
| 1 | The CIR Bitmap field is 64 bits (8 octets) long. |
| 2 | The CIR Bitmap field is 128 bits (16 octets) long. |
| 3 | The CIR Bitmap field is 256 bits (32 octets) long. |

The Bitmap Offset field is an unsigned integer specifying the number of taps from the reference tap (defined in 10.36.4.5) to the tap position represented by bit-0 of the CIR Bitmap field.

The Number of Segments field value plus one shall indicate the number of sensing segments being reported on. For each sensing segment there shall be a separate Receive Report field included in the CIR report IE.

The CIR Bitmap field indicates which CIR taps are present in the Receive Report(s) field. A binary one indicates that the tap value is present in the Receive Report(s) field, while binary zero indicates the tap value is not present.

The Receive Report(s) field shall have a Receive Report field for each pair of the receiver chain and segment. The number of the receive reports (*N*) included in the Receive Report(s) field is equal to the number of receiver chain times the number of segments. Multiple receive reports included in the Receive Report(s) field shall be arranged in the sequence of antenna ID first and the segment index second. For example, there are two Rx antennas and two segments, the Receive Report(s) field is formatted as shown in Figure xx.

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: Variable | Variable | Variable | Variable |
| Receive Report for Antenna 1 and Segment 1 | Receive Report for Antenna 1 and Segment 2 | Receive Report for Antenna 2 and Segment 1 | Receive Report for Antenna 2 and Segment 2 |

Figure xx – Example of the Receive Report(s) field

Each Receive Report field shall be formatted as shown in Figure 89.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bits: 0-5 | 6-9 | 10-15 | Octets: 1 | Variable |
| Timing Offset | Normalization Factor | Reserved | RSSI | CIR Taps |

**Figure 89 - Format of the Receive Report field(s) of the CIR report IE**

The Timing Offset field reports the timing offset between the reference tap and the CIR report timing grid in the time units specified in 10.26.1.4 (Ranging counter time unit).

The Normalization Factor field specifies 4-bit power-of-two normalization factor applied to the CIR Taps being reported in the CIR Taps field, i.e., the I and Q (in-phase and quadrature) tap values in the CIR Taps field have each been shifted left by this amount.

The RSSI field is a measure of the received signal strength at the antenna for the received sequence used to generate this Receive Report field, e.g., for a SENS segment being received via a particular antenna.

The CIR Taps field, contains the CIR tap values, there is one CIR tap value for each bit in the CIR Bitmap that is set to a binary-one, each CIR tap consists of a signed 16-bit in-phase value and a signed 16-bit quadrature value.