**IEEE P802.15**

**Wireless Personal Area Networks**

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| Title | Proposal for IEEE802.15.3e - MIMO PHY | |
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| Re: |  | |
| Abstract | Draft proposal MIMO section in SC PHY section (12a.2.SC and MIMO) | |
| Purpose | Final proposal | |
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1. HRCP PHY specification for millimeter wave

**12a.2.SC and MIMO**

**12a.2.8.MIMO PHY**

**12a.2.8.1.Introduction to MIMO in SC-PHY**

This section describes the MIMO transmission PHY specification for high transmission rates, above 100 Gbit/s. For such high rate, spatial division multiplexing is required besides higher order constellation and frequency channel aggregation. MIMO modes are 5 types. the number of branches (=the number of spatial streams) are, 4, 8, and 16.

x2 mode: SISO + 2 channels aggregation

x4 mode: [4x4 MIMO in 1 channel]

x8 mode: [4x4 MIMO in 2 channels] or [8x8 MIMO in 1 channel]

x16 mode: [8x8 MIMO in 2 channels] or [16x16 MIMO in 1 channel]

Channel aggregation should be three types:

(1) 1 and 3

(2) 2 and 4

(3) 1 and 4

Channel bonding is [TBD].

**Table 12a.2.8-1. MCS using MIMO**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | \* Pilot word length/sub-block length = 8/64 | | | | | | | | | |
| **Modulation** | **Code Rate** | **PHY transmission rate, Gbit/s** | | | | | | | | | |
| **x1 mode**  **(Not MIMO)** | | **x2 mode** | | **x4 mode** | | **x8 mode** | | **x16 mode** | |
| **without pilot word** | **with pilot word\*** | **without pilot word** | **with pilot word\*** | **without pilot word** | **with pilot word\*** | **without pilot word** | **with pilot word\*** | **without pilot word** | **with pilot word\*** |
| QPSK | 14/15 | 3.3 | 2.9 | 6.6 | 5.7 | 13.1 | 11.5 | 26.3 | 23.0 | 52.6 | 46.0 |
| 16QAM | 11/15 | 5.2 | 4.5 | 10.3 | 9.0 | 20.7 | 18.1 | 41.3 | 36.1 | 82.6 | 72.3 |
| 16QAM | 14/15 | 6.6 | 5.7 | 13.1 | 11.5 | 26.3 | 23.0 | 52.6 | 46.0 | 105.1 | 92.0 |
| 64QAM | 11/15 | 7.7 | 6.8 | 15.5 | 13.6 | 31.0 | 27.1 | 62.0 | 54.2 | 124.0 | 108.4 |
| 64QAM | 7/8 | 9.3 | 8.1 | 18.6 | 16.2 | 37.0 | 32.4 | 74.0 | 64.8 | 148.0 | 129.6 |
| 64QAM | 14/15 | 9.9 | 8.6 | 19.7 | 17.2 | 39.4 | 34.5 | 78.8 | 69.0 | 157.7 | 138.0 |

**12a.2.8.2. Link setup procedure for MIMO mode**

In this subsection link setup procedure for MIMO transmission mode is described. Figure12a.5-1 shows the procedure．DEV1, which intends to use *M*1 spatial streams (= the number of MIMO branches), is assumed to be a PPC (P2P coordinator). DEV1 has *Marray* antenna elements in its antenna array. DEV1 selects and switches on well-placed *M* antenna elements before starting MIMO mode. At first Beacon is sent in SISO mode from DEV1 to DEV2 which intends to use *M*2 spatial streams. This SISO transmission is done using antenna element #1 (TBD) at DEV1 and antenna element #1 (TBD) at DEV2.

DEV1 sends a beacon which comprises followings:

(1) The number of MIMO branches which DEV1 intends to handle, *M*1

(2) The number of Association Request commands which DEV1 request to the DEV2, *Nar*

When DEV2 comes into close proximity region with DEV1, the beacon is received by DEV2. DEV2 decides the number of branches, *M*, which is used in the MIMO mode that follows current SISO mode. The number of branches, *M* is decided min(*M*1, *M*2).

After *M* is decided, DEV2 starts to send Association Request frame to DEV1 using its antenna element which was used in the beacon reception.

The Association Request commands contain value of *M* and the remaining number of that commands as well. The number of Association Request commands sent from DEV2 is *Nar* which is notified by the Beacon. Change the time interval of sending Association Request commands into a fixed value. (e.g. 6 us.)

The multiple of Association Request frame transmission is necessary for the antenna selecting procedure, which is described in the following subsection.

When the first Association Request frame is received by DEV1, DEV1 knows the number of MIMO branches *M* which will be used in the MIMO mode, stops sending Beacons, and sends an Association Response command.

When transmission of Association Request commands is completed, DEV1 selects, if necessary, *M* antenna elements, from *Marray*, elements that are going to be used in following MIMO mode. When DEV1 is ready to switch into MIMO mode, DEV1 sends an Association Response to DEV2.

After that both devices switch into MIMO mode and start MIMO frame exchange.

The MIMO mode cannot be turned into SISO mode until the communication session ends.



**Figure:12a.2.8-1. Setup sequence for MIMO transmission**

**12a.2.8.3 Selecting antenna element**

When MIMO transmission is used in the close proximity wireless communication, the use of line-of-sight (LOS) MIMO that requires no multipath propagation effect will be assumed. In LOS-MIMO transmission, the displacement of antenna arrays between transmitter and receiver will cause significant degradation in the channel capacity. Hence the use of large-scale (e.g. up to 256 elements) array in one of DEV (for example the kiosk which is allowed to put antenna array with large footprint) and selecting well-placed elements which is faced well to the array of the portable terminal will overcome such issues.

The concept is shown in Figure 12a.2.8-2. The procedure of selecting antenna elements is done in the link setup procedure shown above (Figure 12a.2.8-2). Though how to select antenna is the implementation matter, an example is shown here. The kiosk has the large array whose number of elements is *Marray* = 256 and the kiosk selects *M* element for MIMO transmission. While the portable terminal sends *Nar* Association Request frames from its antenna element #1, the kiosk measures reception level of these frames. After the measurements, kiosk selects *M* elements with largest reception level. They will be used for following PHY frame transmission in MIMO mode.



**Figure 12a.2.8-2．Concept of antenna element selection**

**12a.2.8.4. MIMO PHY Preamble**

Preamble comprises Frame synchronization (SYNC), Start frame delimiter (SFD) and Channel estimation sequence (CES) as shown in Figure 12a.2.8-3. The figure shows an example of the number of elements *M* is 4. Each antenna element transmits the same STF signal.

After SFD transmission each antenna sends CES by turns. In other words, when one antenna transmits the CES, other antennas transmits unmodulated RF signals. As the figure shows, total time for CES transmission is in proportion to *M*.

MIMO PHY assumed the implementation using frequency domain equalization (FDE). At the transmitter, Golay code generated in the frequency domain is converted into time domain signal using IDFT. In each LTF block the same signal is repeated by 4 (TBD) times.



**Figure12a.2.8-3．PHY frame structure in MIMO mode**

**12a.2.8.4.1. SYNC and SFD**

SYNC and SFD is the same as SISO mode.

**12a.2.8.5. Data processing for multi-stream transmission**

At Tx side, a bitstream received from MAC is divided into *M* streams for MIMO transmission. At Rx side, divided *M* bitstreams has to be correctly combined into single stream. Each substream should have number tag for combination at the Rx. PHY header for the combination is needed.

**12a.2.8.6. PHY Header**

Information for MIMO bitstream processing (12a.2.8.5) shall be included in header.

The same as SISO as described in 12a.2.3.2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **bits:2** | **[TBD]** | **…** | **[TBD]** | **4** | **[TBD]** |
| Reserved | [TBD] | … | [TBD] | Stream No.  (0~15) | [TBD] |

**Figure12a.2.8-4 PHY header format for MIMO PHY**

**12a.2.8.7. Payload**

The same as SISO as described in 12a.2.3.3.

**12a.2.8.8. Scrambler**

The MIMO PHY payload shall use the scrambling process described in 12.2.2.10.