**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title | **Draft D1-PHY Layer Operating Modes and Specifications of** **MIMO-OOK scheme** | |
| Date Submitted | November, 2021 | |
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| Re: | Draft D1 Comment Resolution for MIMO-OOK scheme | |
| Abstract | Details of Resolutions regarding to the submitted Comments on D1 are suggested MIMO-OOK PHY Layer Operating Modes and PHY Specifications. | |
| Purpose | D1 Comments Resolutions | |
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# **PHY Layer Operating Modes**

The Multiple Input Multiple Output On-Off Keying (MIMO-OOK) Modulation based on RoI signaling for Optical IoT system uses the PHY VII – Multiple Point Source.

The PHY VII Operating Modes system specifications are given in Table 153. The additional PHY Operating Modes by MIMO-OOK for Smart Device is presented the Table 155– PHY VII Operating Modes.

**Table 155 – PHY VII Operating Modes**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **PHY Operating Modes** | | | | |
| **Modulation** | **RLL Code** | **Optical Clock Rate** | **FEC**  **(Reed Solomon)** | **Data Rate**  **(two LEDs)** |
| MIMO-OOK | Manchester | 20 Hz | RS (15,11) | 40 bps |
| 4B6B | 20 Hz | RS (15,11) | 40 bps |
| Manchester | 30 Hz | RS (15,11) | 60 bps |
| 4B6B | 30 Hz | RS (15,11) | 60 bps |

# **MIMO-OOK**

The PHY VII with supported data rates and operating conditions is shown in Table 153 – PHY VII Operating Modes for MIMO-OOK scheme with long-range OCC system uses the PHY VII

* 1. Reference architecture

A reference architecture to implement MIMO-OOK is shown in Figure 217



Figure 217. MIMO-OOK block diagram

* 1. MIMO-OOK encoder

2.1.1. Encoder configuration

A packet of data is modulated using OOK modulation. The optical clock rate is at 20 Hz or 30 Hz. The optical clock rate at which MIMO-OOK symbols are clocked out is configurable over PHY PIB attribute *phyMimoOokOpticalClockRate.*



Figure xx. MIMO-OOK data packet structure

The data packet structure is as shown in Figure xx. The clock rate of the MIMO-OOK scheme was set up lower than (at least two times) the camera frame rate to eliminate the variation effect of frame rate.

To access multiple light sources, we have added the node ID part to each frame. Each user will be defined by a unique ID, so that the receiver can categorize the signal from different users. Defining users by ID nodes helps the system accept dozens of users, up to hundreds of users.

Table 152—Data sub-packet format

|  |  |  |
| --- | --- | --- |
| **Preamble** | **Data sub-packet payload** | |
| **LED-ID** | **Payload** |
| 011100 | Manchester coding | |
| 0011111000 | 4B6B coding | |
| 00011111110000 | 8B10B coding | |

2.2.2. RLL coding

RLL coding shall be applied in the payload subfield to maintain an average brightness at 50%. Manchester code and 4B6B code are suggested for OOK mode. The configuration of RLL code shall be implemented over the PHY PIB attribute *phyMimoOokRLLCode*. Manchester code and 4B6B code are suggested for MIMO-OOK mode.

2.2.3. Forward error correction (FEC)

The data sub-packet payload may be coded by the inner FEC to protect the payload from error. Hamming (8,4) or (15,11) code may be used as an inner FEC.

Additionally, outer FEC may also be used to protect the PHR and PSDU. When outer FEC is enabled, RS(15,11) shall be implemented.

FEC shall be configured via the PHY PIB attribute *phyMimoOokFEC*

Both inner FEC and outer FEC shall be configured via the PHY PIB attribute *phyMimoOokFEC*.

Table xx shows PHY PIB attributes

|  |  |  |  |
| --- | --- | --- | --- |
| **Attribute** | **Type** | **Range** | **Description** |
| *phyMimoOokOpticalClockRate* | Integer | 0-7 | The optical clock rate (or symbol rate) applied for MIMO-OOK. 0: 20 Hz 1: 30 Hz Others: Reserved |
| *phyMimoOokRLLCode* | Integer | 0-7 | This specifies the RLL coding for MIMO C-OOK modulation. 0: Manchester 1: 4B6B coding  2: 8B10B coding Other values: Reserved |
| *phyMimoOokFec* | Integer | 0-7 | This attribute specifies FEC for MIMO-OOK modulation. 0: None 1: Hamming (8/4) 2: Hamming (15/11) 3: Hamming (8/4), 4: Hamming (15/11) Other values: Reserved |
| *phyMimoOokPreambleSymbol* | Integer | 0-7 | This attribute specifies the preamble symbol of PSDU of MIMO-OOK. 0: 6B symbol (preamble = 011100) 1: 10B symbol (preamble = 0011111000) 2**: 14B symbol (preamble=****00011111110000)**  Other values: Reserved |
| *phyMimoOokLedId* | Integer | 0-3 | This attribute specifies the length of LED-ID data for MIMO-OOK  0: 2 bits  1: 3 bits  Other values: Reserved |

* 1. MIMO-OOK decoder (annex)



MIMO-OOK Decoder architecture



Intensity of expected signal via RoI signaling



Intensity of noise signal via RoI signaling

As previously discussed, we added a preamble into each packet to detect the start frame. This is a special bit sequence, whose definition is based on the RLL code that has been used, and which both the transmitter and receiver know in advance. A preamble has two tasks. Firstly, the receiver can classify the signal light source and unexpected light sources (such as background light and noise light). By using the expected signal, payload data is inputted between two preambles. However, there is no significant change in the intensity of unexpected signals or noise signals.