IEEE 802.15  
Wireless Specialty Networks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| IEEE P802.15.13  Text changes for September | | | | |
| Date: 2019-09-19 | | | | |
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Abstract

# This document contains proposed text changes collected in the September 2019 meeting.

TG13 Editor: replace the text in P6 L29-33 with the following text:

All IEEE 802.15.13 OWPANs have a logical star topology. Hence, the protocol does not include fields to signal the type of topology explicitly. A single coordinator is involved in all data transmission between two devices or between external peers and the devices associated with the OWPAN as illustrated in Figure 1. The coordinator offers the MAC service at its MCPS-SAP. Data transmissions between two devices of the same OWPAN are forwarded by the coordinator.

TG13 Editor: replace the text in P9 L9-11 with the following text:

The hybrid topology involves an optional RF-based connection at each device. The realization of the hybrid topology is out of scope of the standard. It is expected that the coordination of the alternate OWC- and RF-based connections be performed above the 802.15.13 MAC, for example according to IEEE Std 802.1AX.

TG13 Editor: delete the text in P9 L22-26

TG13 Editor: add the following text after P11 L14:

The PHY layer receives PSDUs from the MAC layer and converts them to corresponding PPDU frames. It subsequently passes the PPDU, consisting of signal samples, to the OFE(s).

TG13 Editor: change the text in P12L35-P13L11 to:

The PM-PHY is intended for moderate data rates between 1 Mbit/s and several hundred Mbit/s, low power and low latency. It allows fast adaptation to the time-varying channel in mobile scenarios. The unique approach of the PM-PHY is to use a high optical clock rate (OCR) while keeping spectral efficiency low. Binary (two-level) pulse-amplitude modulation (2-PAM) with 8B10B line coding and variable optical clock rate are used or multi-level M-ary PAM with Hadamard-Coded Modulation (HCM), both combined with Reed-Solomon (RS) forward error correction (FEC). Moreover, the PM-PHY provides means to estimate the channel impulse response (CIR) of multiple LEDs simultaneously and thereby supports the use of advanced multiple-input multiple output (MIMO) schemes. The PM-PHY enables multiple LEDs transmitting the same data to a device (spatial diversity) as well as spatially multiplexed transmissions. In addition, PM-PHY supports relaying functionality.

TG13 Editor: change the text in P12 L13-24 to:

The HB-PHY is intended for very high data rates between 10 Mbit/s and 10 Gbit/s and low latency. It allows fast adaptation to the time-varying channel in mobile scenarios. The unique approach of the HB-PHY is to combine a high optical clock rate with a high spectral efficiency. For modulation of the LED, multiple optical clock rates (OCR) are used. Direct-current (DC) biased orthogonal frequency multiplexing (OFDM) is used in combination with adaptive bitloading, applying quadrature amplitude modulation (QAM) with variable constellation orders on each subcarrier /subcarrier group. Low-density parity-check codes (LDPC) with variable code rates and different block sizes assist as a powerful forward error correction scheme. Moreover, the HB-PHY provides means for the device to estimate the channel impulse response (CIR) of multiple LEDs simultaneously and thereby supports the use of advanced multiple-input multiple output (MIMO) schemes. The HB-PHY enables multiple LEDs transmitting the same data to a device (spatial diversity) as well as spatially multiplexed transmissions. In addition, HB-PHY supports relaying functionality.

TG13 Editor: change the text in P13L18-19 to:

The features of the MAC sublayer are association and disassociation, channel access, frame validation, and acknowledged frame delivery. Moreover, the 802.15.13 MAC supports the use of advanced MIMO schemes with distributed, networked optical wireless frontends and for multiple mobile devices.

TG13 Editor: delete clause 4.6.2

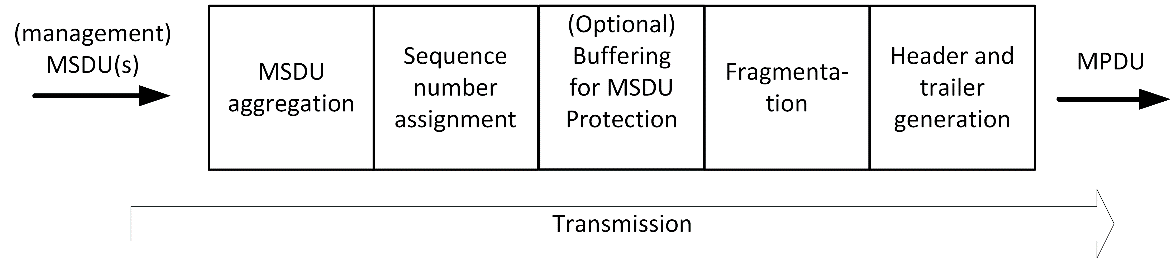
TG13 Editor: change the text in P20L11-12 to:

The MAC frame formats supporting the function of the MAC are specified in clause 6.Capabilities are specified in subclause 7.4.

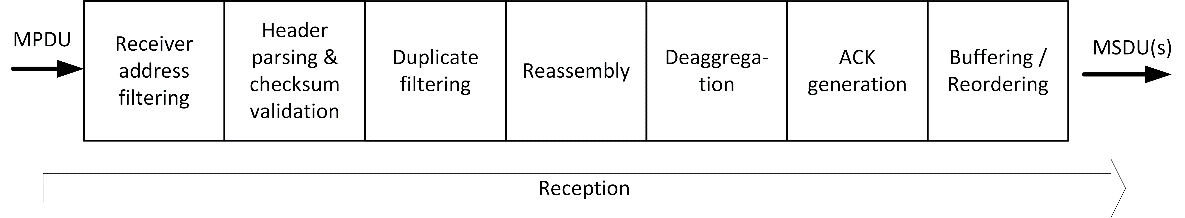
TG13 Editor: change the text in P20L24-28 to:

In addition, a 16-bit short address is issued to each device as part of the association process. The allocation of short addresses is at the discretion of the coordinator implementation. The short address 0x0000 shall always belong to the coordinator. Furthermore, the address 0xFFFF shall be regarded as the short broadcast address and hence received by all devices. It shall not be allocated to an associating device.

TG13 Editor: change figure 9 to:



TG13 Editor: change figure 10 to:



TG13 Editor: delete P21L28-P22L2

TG13 Editor: change the text in P22L8-9 to:

Finally, the MAC shall generate an acknowledgment for each successfully received protected MPDU according to clause 5.7.

TG13 Editor: change the text in P27L24-26 to:

Devices aid the coordinator in the GTS allocation process through providing information about their queue states. For that purpose, devices may transmit *GTS Request* elements to the coordinator.

TG13 Editor: change the text in P34L32-P35L2 to:

Devices shall support passive scanning for OWPANs. During a passive scan, the device listens for incoming frames and non-decodable signals whose received power exceeds an implementation-specific threshold. If a device makes use of multiple optical frontends, it shall listen on all frontends and try to decode receptions for each frontend individually.

TG13 Editor: change the text in P35L6-L8 to:

For every successfully decoded beacon or RA frame in the scan period, the device shall add the corresponding OWPAN ID to the scan result list. It shall furthermore add the received electrical SNR to the result list. The returned list shall not contain duplicate entries.

TG13 Editor: change the text in P35L24-L27 to:

The DME of the prospective coordinator shall select an OWPAN ID. The OWPAN ID shall also serve as the 48-bit MAC address of the coordinator. The DME shall provide the selected OWPAN ID and its short address as a parameter of the MLME-START.request.

TG13 Editor: change the text in P36L10-L12 to:

The association procedure describes how a device shall request association with an operating OWPAN. The association procedure is triggered by an MLME-ASSOCIATE.request by the DME either after a scan for OWPANs or based on

TG13 Editor: change the text in P36L21-L23 to:

The management frame shall make use of full 48-bit MAC address format. The *Receiver Address* of the management frame shall be set to the coordinator’s address. The *Transmitter Address* of the frame shall be set to the 48-bit MAC address of the device seeking association.

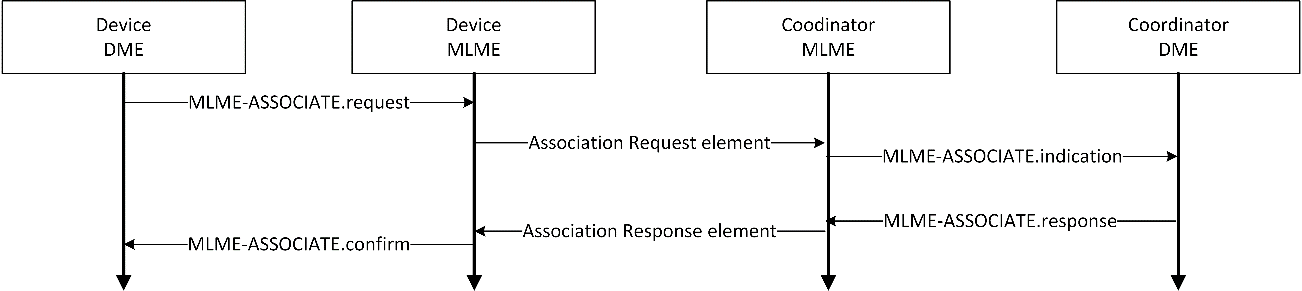
TG13 Editor: change the text in P36L21-L23 to:

After receiving the *Association* Request, the coordinator shall invoke the MLME-ASSOCIATE.indication primitive to the coordinator DME. The DME then decides whether to permit association of the device or not. If the coordinator DME decides to pursue association, it shall prepare a management frame containing the *Association Response* element based on the MLME-ASSOCIATE.response received from the DME.

The *Association Response* element shall include a set of negotiated capabilities to be used for the time of the starting association. The set of negotiated capabilities shall include no capabilities that were not indicated by the device in the *Association Request* element. The precise set of capabilities may be selected by the coordinator based on its supported capabilities. The coordinator shall transmit the *Association Response* to the requesting device.

If the DME decides not to pursue association, the MLME shall return an *Association Response* element with the appropriate *Status Code* set, as received from the DME.

A sequence chart of a successful association procedure is depicted in Figure 23.



1. Association procedure message exchange

Upon reception of a positive *Association Response*, the device shall update its PIB attributes accordingly.

* + - 1. Capability Negotiation

The *Association Request* includes a set of capabilities supported by the device seeking association. The coordinator, receiving the *Association Request*, on the other hand has an own set of supported capabilities. The capabilities negotiated and hence used throughout the following association shall be the intersection of both capability sets.

The coordinator shall include the negotiated capability set in the *Association Response* sent to the device if association was successful.

* + 1. Disassociating from an OWPAN

The disassociation of a single device from an OWPAN may be initiated by the DME of either the OWPAN coordinator or the affected device itself through the MLME-DISASSOCIATE.request primitive.

Upon reception of a *Disassociation Notification* element, the MLME of a device shall only acknowledge the reception of the corresponding frame. A response is not necessary, as the disassociation is non-negotiable.

* + 1. Deaggregation procedure

… Otherwise, it shall not transmit an acknowledgment.

The MAC shall buffer the MSDUs from each received MPDU before handing them to the higher layer if any of the MSDUs from an MPDU with a lower sequence number are missing. The MAC shall pass MSDUs to higher layer in order of their corresponding MPDU as indicated through the sequence number.

* + 1. Single acknowledgement

The receiver of a protected MPDU (acknowledging device) may acknowledge the successful reception of the protected MPDU by means of a single acknowledgement.

* + 1. Block acknowledgement

The source address field of the frame containing the *Block Acknowledgment* element identifies the acknowledging device.

The transmitter of a block acknowledgement shall ensure that the block acknowledgment arrives at the transmitter at most *macRetransmitTimeout* after the time of transmission of the first transmitted acknowledged MPDU.

* + 1. Retransmission

unacknowledged MPDUs, as acknowledged after receiving an *ACK* element or *Block ACK* element indicating the sequence numbers of these outstanding MPDUs.

A device shall not attempt more than *macMaxFrameRetries* retransmissionsof the same MPDU. After the last retransmission attempt failed, the device shall consider the transmission of all MSDUs in the MPDU as failed.

A device shall consider all MSDUs of a previously transmitted MSDU or A-MSDU as successfully received if it receives an acknowledgment for the sequence number of the corresponding MPDU or all MPDUs containing fragments of the MSDU.

* + 1. Multi-OFE channel feedback

Coordinators supporting the *capMultiOfeEstimation* capability shall be able to transmit multi-OFE pilots. All devices supporting the *capMultiOfeEstimation* capability shall be able to receive multi-OFE pilots and subsequently estimate the channels between each transmitter of multi-OFE pilots via the PHY as detailed in 9.1.2.

If a coordinator makes use of multiple OFEs, it may embed different divisions of the multi-OFE pilot symbol in the PPDU for every OFE. Division numbering is defined in the respective PHY clauses per PHY. The transmission of multi-OFE pilots of a single PPDU transmitted over multiple OFEs shall happen simultaneously at each OFE.

A device receiving a PPDU containing multi-OFE pilots shall be able to estimate the individual CSI between the transmitting OFE of each pilot division and its receiver. The gathered CSI comprises time domain taps, which are described by the respective signal power and delays relative to the very first received tap.

Upon reception of a PPDU containing multi-OFE pilot symbols, a device shall estimate the individual channels. The device shall then transmit a *Multi-OFE Feedback* element, containing the measured CSI for each identified transmitting OFE of orthogonal pilots, to the coordinator of the OWPAN. The *Multi-OFE Feedback* element shall be transmitted at the next opportunity. A device shall discard old multi-OFE channel feedback after newer multi-OFE pilots were received from the coordinator.

For each pilot division, the device shall embed an *OFE Feedback Descriptor* element into the *Multi-OFE Feedback* element. Each *OFE Feedback Descriptor* shall in turn contain one or more *Tap Descriptor* elements. Each *Tap Descriptor* element shall correspond to a single identified receive tap in the time domain. For each tap, the signal strength and delay shall be calculated and quantized as described in 6.6.8.

* 1. General MAC frame format

The general MAC frame structure is depicted in Figure 30.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 0/2 | 2/6 | 2/6 | 0/2/6 | 0/2 | | variable |  | 4 |
| Frame Control | Poll  ACK | Receiver Address | Transmitter Address | Auxiliary Address | Sequence Control |  | Payload | | FCS |
| MAC frame header (MHR) | | | | | | |

1. General MAC frame (MPDU) format
   * 1. Frame Control Field

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bits: 0-1 | 2-3 | 4-7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Frame Version | Type | Subtype | To Backhaul | From Backhaul | ***Reserved*** | ACK Request | Non-beacon-enabled | Short Addressing | Last Fragment | ***Reserved*** |

1. Frame Control element
   1. Data frames

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 0/2 | 2/6 | 2/6 | 0/6 | 2 | | variable |  | 4 |
| Frame Control | Poll  ACK | Receiver Address | Transmitter Address | Auxiliary Address | Sequence Control |  | MSDU /  A-MSDU | | FCS |
| MAC frame header (MHR) | | | | | | | Payload | |

1. Data frame structure
   1. Management frames

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 0/2 | 2/6 | 2/6 | 6 | 2 | | variable |  | 4 |
| Frame Control | Poll  ACK | Receiver Address | Transmitter Address | Auxiliary Address | Sequence Control |  | Management Information | | FCS |
| MAC frame header (MHR) | | | | | | | Payload | |

1. Management frame structure
   * 1. Poll Frame

All coordinators, operating in non-beacon enable mode, shall be capable of transmitting this command, although a coordinator is not required to be capable of receiving it. All devices shall be capable of receiving this command.

* + 1. Poll Request Frame

All devices, operating in non-beacon enable mode, shall be capable of transmitting this command, although a device is not required to be capable of receiving it. All coordinators shall be capable of receiving this command.

* + 1. Poll Response Frame

All devices, operating in non-beacon enable mode, shall be capable of transmitting this command, although a device is not required to be capable of receiving it. All coordinators shall be capable of receiving this command.

* 1. Control frames

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 0/2 | 2/6 | 2/6 | 6 | variable | 4 |
| Frame Control | ACK  Information | Receiver Address | Transmitter Address | Auxiliary  Address | Control  Information | FCS |
| MAC frame header (MHR) | | | | | Payload |

1. Control frame structure
   * 1. Capability List Element

**Capability Bitmap:** A bitmap indicating a set of capabilities as given in Table 40. In the bitmap, each bit represents the capability corresponding to the capability ID given by the bit’s offset from the leftmost bit. Hence, the leftmost bit, i.e. the bit to be processed first, corresponds to the ID 0. The rightmost bit, i.e. the bit to be processed last by the definition given in 6.1.1, corresponds to the ID Bitmap Width \* 8 – 1. If a capability is included in the set, the bit corresponding to the ID of the capability shall be set to 1. Otherwise, the bit shall be set to 0.

* + 1. Multi-OFE Feedback Element

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Bits: 0-2 | 4-7 | 8-13 | 14-15 | variable | | |
| Pilot  Symbol  Number | Division  Id | Number  of  Taps (M) | *Reserved* | Tap  Descriptor  1 | … | Tap  Descriptor  M |

1. OFE Feedback Descriptor element
   * 1. HCM Allocation Element

|  |
| --- |
| 1 octet |
| HCM Mask |

1. HCM Allocation element

**HCM Mask:** The HCM rows assigned to the device. Each bit corresponds to an HCM row. The MSBit, i.e. the leftmost bit, corresponds to row 0, while the rightmost bit corresponds to row 7.

* + 1. Supported MCS Element

|  |  |  |
| --- | --- | --- |
| Value | PHY | MCS Element |
| 0 | PM-PHY (clause 10) | PM-PHY Rates Element (6.6.19) |
| 1 | LB-PHY (clause 0) | LB-PHY Rates Element (6.6.20) |
| 2 | HB-PHY (clause 12) |  |
| 3-255 | ***reserved*** |  |

1. PHY IDs

**MCS 1…N:** A PHY-specific element indicating supported optical clock rates and MCS. The format depends on the value of the PHY ID field. The contained element for each PHY ID is given in **[missing ref]**.

* + 1. Probe Request Element

All devices operating in non-beacon-enabled channel access mode shall be capable of transmitting this command, although a device is not required to be capable of receiving it.

* + 1. Variable Element Container Element

Table 14 lists the IDs allocated to the various supported elements.

|  |  |  |
| --- | --- | --- |
| ID | Element | Clause |
| 1 | Association Request | 6.6.1 |
| 2 | Association Response | 6.6.2 |
| 3 | Disassociation Notification | 6.6.3 |
| 4 | GTS Descriptor List | 6.6.6 |
| 5 | GTS Descriptor | 6.6.7 |
| 6 | Multi-OFE Feedback | 6.6.8 |
| 7 | ACK | 6.6.10 |
| 8 | Block ACK Request | 6.6.11 |
| 9 | Block ACK | 6.6.12 |
| 10 | MCS Request | 6.6.13 |
| 11 | BAT Request | 6.6.14 |
| 12 | GTS Request | 6.6.15 |
| 13 | HCM Allocation | 6.6.16 |
| 14 | Alien Signal | 6.6.17 |
| 15 | Attribute Change Request | 6.6.24 |
| 16 | Attribute Change Response | 6.6.25 |
| 17-65535 | *Reserved* |  |

1. Element IDs

**0x0000**: Termination type (has id 0).

* + 1. MCPS-DATA.request

|  |  |  |
| --- | --- | --- |
| Parameter name | Range | Parameter description |
| DestinationAddress | 48-bit MAC addresses | The destination address of the MSDU. |
| SourceAddress | 48-bit MAC addresses | The source address of the MSDU. |
| Msdu | Octet Sequence | The actual MSDU. |
| Priority | [0, 7] | The priority of the MSDU, as detailed in IEEE Std 802.1AC. |
| Protected | TRUE, FALSE | Whether the associated MSDU shall be transmitted protected. |

1. Parameters of the MCPS-DATA.request primitive
   * 1. MCPS-DATA.indication

|  |  |  |
| --- | --- | --- |
| Parameter name | Range | Parameter description |
| DestinationAddress | 48-bit MAC addresses | The destination address of the MSDU. |
| SourceAddress | 48-bit MAC addresses | The source address of the MSDU. |
| Msdu | Octet Sequence | The actual MSDU data. |
| Priority | [0, 7] | The priority of the MSDU, as detailed in IEEE Std 802.1AC. |

1. Parameters of the MCPS-DATA.indication primitive
   * 1. MLME-ASSOCIATE

All devices shall provide an interface for the request and confirm association primitives. The indication and response association primitives are optional for devices that are no coordinator.

* + - 1. Request

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter name | Type | Value range | Parameter description |
| OwpanId | 48-bit MAC address | OWPAN IDs observed in a preceding scan or known otherwise | The OWPAN ID as indicated in the beacon or RA frames of the target OWPAN. |

1. Parameters of the MLME-ASSOCIATE.request primitive
   * + 1. Response
     1. MLME-DISASSOCIATE

The MLME-DISASSOCIATE primitive is invoked in order to disassociate a device from an OWPAN. The primitive may be invoked by a device or the OWPAN coordinator DME, as described in 5.4.5.2.

* + - 1. Request

The MLME-DISASSOCIATE.request indicates to the MLME to begin with the disassociation procedure as described in 5.4.5.2.

* + - 1. Confirm

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter name | Type | Value range | Parameter description |
| OwpanId | 48-bit MAC address | OWPAN ID which the device is associated with | The ID of the OWPAN to request disassociation from. |
| DeviceAddress | 48-bit MAC address | Device addresses | The 48-bit MAC address of the device requesting to be disassociated. |
| Reason | integer | Reason codes from Table 6 | The reason for disassociation |

1. Parameters of the MLME-DISASSOCIATE.confirm primitive
   * + 1. Indication

The MLME-DISASSOCIATE.indication is invoked by the MLME to indicate the disassociation of a device from an OWPAN. It may be used by the MLME of a coordinator or participant device of an OWPAN.

* 1. MAC PIB Attributes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable attributes | | | | | |
| Name | ID | Description | get  /  set | Bits | Unit / Range |
| Association and OWPAN membership | | | | | |
| *macOwpanId* | 1 | The ID of the OWPAN with which the device is associated. | get | 48 | Valid 48-bit  MAC addresses |
| *macAssociationTimeout* | 2 | The time after transmitting an association request to the coordinator after which an association response is expected | get  set | 16 | integer  milliseconds |
| *macDevShortAddress* | 4 | The short address assigned to the dev during association. | get | 16 | integer  [1, 65534] |
| *macDeviceTimeout* | 5 | The duration after which a coordinator assumes a device to be disassociated if it does not receive frames from that device. | get  set | 16 | [1, 65545]  milliseconds |
| ***Beacon-enabled channel access*** | | | | | |
| *macBeaconNumber* | 6 | The number of the current superframe, embedded by the coordinator in the beacon frame. | get | 16 | integer  [0, 65535] |
| *macNumSuperframeSlots* | 7 | The total number of superframe slots in a superframe | get | 16 | integer  [1, 65535]  superframe slots |
| *macCapMaxRetries* | 8 | The maximum retransmission attempts for CAP transmissions. | get  set | 8 | integer  [1, 255] |
| *macCapSlotLength* | 9 | The number of superframe slots that form a single CAP slot for the slotted ALOHA access in the CAP. | get | 8 | integer  [1, 255] superframe slots |
| *macNumCapSlots* | 10 | The total number of CAP slots in the CAP. | get | 8 | integer  [1, 255]  cap slots |
| *macMaximumCapCw* | 11 | The maximum value for CW in the CAP. | get  set | 8 | integer  [1, 255]  cap slots |

1. Variable MAC PIB attributes

Default values are required for the following PIB attributes:

* *macAssociationTimeout*
* *macDeviceTimeout*
* *macCapMaxRetries*
* *macCapSlotLength*
* *macMaximumCapCw*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable attributes (continued) | | | | | |
| Name | ID | Description | get  /  set | Bits | Unit / Range |
| Protected Transmission | | | | | |
| *macRetransmitTimeout* | 12 | The duration after which an ACK is required for a transmitted frame. Upon expiration, a MPDU is typically retransmitted. | get | 16 | unsigned integer  [1, 65535] µs |
| *macMaxFrameRetries* | 13 | The maximum number of attempted retransmissions, before the transmission of an MPDU is ultimately considered failed. | get  set | 8 | TRUE,  FALSE |

Table 38 Variable MAC PIB attributes (continued)

|  |  |  |  |
| --- | --- | --- | --- |
| Constant attributes | | | |
| Name | Description | Value | Unit |
| *aSuperframeSlotDuration* | The duration of a single superframe slot. | 1 | µs |
| *aInitialCapCw* | The value to select as contention window for the first retransmission in the CAP. | 1 | CAP  slots |
| *aClockAccuracy* | The required accuracy of the device system-clock. | 20 | ppm |
| *aMinFragmentSize* | The minimum size of a MSDU fragment. | 64 | octets |
| *aProtectedWindow* | The maximum number of unacknowledged MPDUs to be in-flight. | 1024 | MPDUs |
| *aMac48Address* | The device’s 48-bit MAC address. | valid address | 48-bit MAC address |

1. Constant MAC PIB attributes
   1. Capabilities

Capabilities formally indicate functionality that is supported, i.e. implemented, by a device. Each capability has a name and a numeric ID with a width of 16 bits. Some capabilities may require other capabilities to be implemented through the device. Capabilities are listed in Table 40.

|  |  |  |  |
| --- | --- | --- | --- |
| Name | ID | Description | Required capabilities |
| *-* | 0 | ***reserved*** |  |
| *capHbPhy* | 1 | The device supports usage of the HB-PHY. | *capMultiOfeEstimation* |
| *capMultiOfeEstimation* | 2 | The device supports orthogonal pilot channel estimation and feedback. |  |
| *capFullDuplex* | 3 | The device supports simultaneous transmission and reception. |  |
| *capBlockAcknowledgment* | 4 | The device supports the block acknowledgment mechanism. |  |
| *capPmPhy* | 5 | The device supports usage of the PM-PHY. |  |
| *capHcm* | 6 | The device supports HCM-coded modulation for the payload. | *capPmPhy* |
| *capInterferenceDetection* | 7 | The device supports the interference detection procedure in clause 5.4.7. |  |
| ***reserved*** | 8-2040 |  |  |

1. MAC capabilities
2. Security suite specifications

Security is not included in this standard and assumed to be handled on the higher layers.

* 1. PD-SAP

The PD-SAP constitutes a logical interface for requesting PSDU transmissions from the PHY at the MAC layer and indicating PSDU receptions to the MAC layer from the PHY layer. The PD-SAP is not explicitly specified within this standard but assumed vendor-internal.

* + 1. PHY MCS
    3. Multi-OFE channel estimation

Multi-OFE pilots have, in contrast to conventional pilots, more than one division. Supporting PHYs in this standard support up to 32 orthogonal divisions. Furthermore, a single PPDU may include up to seven sequential multi-OFE pilot symbols.

* + 1. Multi-OFE transmission
  1. PLME-SAP

The PLME-SAP constitutes a logical interface to invoke management functions on the PHY from the MAC layer. The PLME-SAP is assumed vendor-internal and is hence not specified within this standard. The PLME-SAP primarily exposes PHY PIB attributes to the MAC, through whose MLME primitives values for the PIB attributes shall be read- and writable by the DME. These PHY PIB attributes are listed in 9.2.1.

* + 1. PHY PIB Attributes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Name | Description | get/set | Range | Unit |
| phyMultiOfeDivisions | The number of orthogonal pilot divisions (e.g. subcarrier spacings or Hadamard codes). This attribute shall be present if the device implements the capMultiOfeEstimation capability. | get | [1, 32] | distinct orthogonal pilots |
| phyMultiOfeSymbols | The number of consecutive additional channel estimation symbols supported by the PHY. This attribute shall be present if the device implements the capMultiOfeEstimation capability. | get | [0, 7] | symbols |

1. Variable PHY PIB attributes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Name | Description | get/set | Range | Unit |
| aPhyMaxPsduSize | The maximum supported PSDU size. This attribute is PHY-specific. | get | [1, 65535] | octets |
|  |  |  |  |  |
|  |  |  |  |  |

1. Constant PHY PIB attributes
   * 1. Receiver synchronization

TG13 Editor: change the text in to:

TG13 Editor: change the text Annex B to:

The CRC field is 2 octets in length. The CRC shall be calculated using the following standard generator polynomial of degree 16:

The CRC shall be calculated for transmission using the following algorithm:

* Let be the polynomial representing the sequence of bits for which the checksum is to be computed.
* Multiply *M*(*x*) by *x*16, giving the polynomial *.*
* Divide modulo 2 by the generator polynomial, *G*16(*x*)*,* to obtain the remainder polynomial, .
* The CRC field is given by the coefficients of the remainder polynomial, *R(x)*.

Here, binary polynomials are represented as bit strings, in highest polynomial degree first order.

A typical implementation is depicted in **[missing ref]**.

