**IEEE P802.15**

**Wireless Personal Area Networks**

|  |  |
| --- | --- |
| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title |  |
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| Re: | Resolutions and responses to LLDN-related problems in IEEE 802.15.4 REVc (Sponsor Ballot SB01).  |
| Abstract | This document provides and intermediate version of the base text of Low Latency Deterministic Networks (LLDN) to be included in IEEE 802.15.4 REVc. It is the textual basis for resolutions to issues in IEEE 802.15.4 REVc related to the LLDN mode (comments in Sponsor Ballot SB01). The text is adapted to version DF5 of the IEEE 802.15.4 REVc document.This document is the first step to a thorough resolution of comments and issues in IEEE 802.15.4 REVc related to Low Latency Deterministic Networks (LLDN) and based on the results of the July 2015 Waikoloa meeting, so that the LLDN mode stays in REVc of the IEEE 802.15.4 standard. |
| Purpose | Specification of Low Latency Deterministic Networks of IEEE 802.15.4e to be kept in REVc of IEEE 802.15.4. |
| Notice | This document has been prepared to assist the IEEE P802.15. 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. |
| Release | The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15. |

 **(Waikoloa)**

**Note: This text of the submission is an intermediate version only! A future version of this document will contain the final submission. The text of this version has not been finished yet. It’s purpose is to inform the BRC about the state and progress of the LLDN text.**

Text with a blue background has not been adapted yet (still in 15.4e version).

This document provides an intermediate version of the text of Low Latency Deterministic Networks (LLDN) to be included in IEEE 802.15.4 REVc. It is the textual basis for resolutions to issues in IEEE 802.15.4 REVc related to the LLDN mode. It follows the structure agreed to at the Waikoloa Meeting (July 2015) of IEEE 802.15.4.

The text is adapted to version DF5 of the IEEE 802.15.4 REVc document.

The purpose of the intermediate document is to inform the BRC of the IEEE 802.15.4 REVc of the state and progess of the LLDN submission.

The purpose of the final document is to keep the specification of Low Latency Deterministic Networks of IEEE 802.15.4e in the REVc of IEEE 802.15.4. The final document will be the submission in response to the LLDN comments of SB01 on IEEE 802.15.4 REVc.

To Editor: Insert in alphabetical order the following definitions in “3.1 Definitions”:

**downlink:** Data communication from the personal area network (PAN) coordinator to the PAN device.

**low latency deterministic network (LLDN):** A personal area network (PAN) organized as a star network with a superframe structure and using LLDN frames.

**low latency deterministic network (LLDN) device:** A device in an LLDN that is associated to an LLDN coordinator.

**slot owner:** A low latency deterministic network (LLDN) device that is assigned exclusive access rights at the beginning of a timeslot in an LLDN.

**uplink:** data communication from the personal area network (PAN) device to the PAN coordinator.

***To Editor: Insert in “3.2 Acronyms and abbreviations” the following abbreviations and acronyms in alphabetical order:***

ACK positive acknowledgment

CTS clear to send

GACK group acknowledgment

LL low latency

LLDN low latency deterministic network

RTS request to send

To Editor: Insert in “5.2 Special Application Spaces” the following clause 5.2.5a before clause “5.2.6 Medical body area network (MBAN) services”

### 5.2.5a Low Latency Deterministic Networks (LLDN)

Low Latency Deterministic Networks (LLDN) are defined for industrial applications with low latency transmission. LLDNs operate in a star topology with an LLDN superframe. LLDNs use LLDN frames. They can be distinguished by a specific Frame Type, so that the operation of LLDNs is independent of any other MAC mode operation. The detailed specification of LLDN is provided in Annex G.

To Editor: Insert in “5.5.1 Star network formation” the following paragraph as new 2nd paragraph:

A low latency deterministic network (LLDN) operates in a star topology. More information on the star topology of LLDNs is given in ”Applications of IEEE Std 802.15.4” [B2].

To Editor: Insert the following paragraph as 3rd item in the 2nd paragraph of “5.7.1 Superframe structure”

* + - * + Superframe structure described in G.xxx based on LL-Beacons defined in G.xxx.

To Editor: Insert the following clause 5.7.1.1a before “5.7.1.2 Slotframes”

5.7.1.1a Superframe structure based on LL Beacons

LLDN PANs use the LLDN superframe structure as described in more detail in G.xxx. The superframe is divided into an LLDN beacon slot, 0 or 2 LLDN management timeslots, and a number of LLDN timeslots of equal length and arranged in LLDN uplink time slots and LLDN bidirectional timeslots as shown in Figure 4b.



Figure 4b—General LLDN Superframe

The LLDN timeslots are assigned to the LLDN devices in the network. Adjacent LLDN timeslots may be concatenated to a larger LLDN timeslot. If there is more than one LLDN device assigned to an LLDN timeslot, the LLDN timeslot is referred to as shared group LLDN timeslot, otherwise it is referred to as dedicated LLDN timeslot.

Insert in clause 5.7.4 “Access methods” the following text as 5th item in the list in the second paragraph

* simplified slotted CSMA-CA used in LLDNs, as described in G.xxx

To Editor: Insert in “6.2.1 Superframe structure” after the first paragraph the following text:

For LLDN applications, an LLDN superframe structure with LLDN beacons is required, as described in G.xxx.

7.2.1 Frame Control field

Change 7.2.1 as indicated:

The Frame Control field for frames other than the LLDN frame, Multipurpose frame, Fragment frame, and Extended frame shall be formatted as illustrated in Figure 87. The Frame Control fields for the Multipurpose frame, Extended frame, and LLDN frame are specified in 7.3.5, 7.3.6, and G.xxx respectively.

**7.2.1.1 Frame Type field**

***Change Table 5 as indicated:***

 **Table 5—Values of the Frame Type field**

|  |  |
| --- | --- |
| **Frame type value b2 b1 b0** | **Description** |
| 000 | Beacon |
| 001 | Data |
| 010 | Acknowledgment |
| 011 | MAC command |
| 100 | LLDN |
| 101 | Multipurpose |
| 110 | Fragment or Frak1 |
| 111 | Extended |

***Change the third paragraph of 7.2.1.8 and Table 7 as follows:***

**7.2.1.8 Destination Addressing Mode field**

If the Frame Type field does not specify an LLDN frame or Multipurpose frame, and the Source Addressing and Destination Addressing Mode fields are set to zero, and the PAN ID Compression field is set to one, the Frame Version field (described in 7.2.1.9) shall be set to 0b10.

Table 7—Valid values of the Destination Addressing Mode and Source Addressing Mode fields

|  |  |
| --- | --- |
| **Addressing mode value b1 b0** | **Description** |
| 00 | PAN Identifier and Address fields are not present. |
| 01 | Address field contains an 8-bit simple address. |
| 10 | Address field contains a short address (16 bit). |
| 11 | Address field contains an extended address (64 bit). |

**7.2.1.9 Frame Version field**

***Change in 7.2.1.9 the Table 8 as follows:***

**Table 8—Frame Version field values**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame type** | **Frame Version 0b00** | **Frame Version 0b01** | **Frame Version 0b10** | **Frame Version 0b11** |
| Beacon | IEEE Std 802.15.4-2003 | IEEE Std 802.15.4-2006 | IEEE Std 802.15.4 | Reserved |
| Data | IEEE Std 802.15.4-2003 | IEEE Std 802.15.4-2006 | IEEE Std 802.15.4 | Reserved |
| Acknowledgment | IEEE Std 802.15.4-2003 | IEEE Std 802.15.4-2006 | IEEE Std 802.15.4 | Reserved |
| MAC Command | IEEE Std 802.15.4-2003 | IEEE Std 802.15.4-2006 | IEEE Std 802.15.4 | Reserved |
|  |  |  |  |  |
| LLDN | Different format of Frame Control field |
| Multipurpose | IEEE Std 802.15.4 | Reserved | Reserved | Reserve |
| Fragment | Frame Version field not present in frame |
| Extended | Frame Version field not present in frame |

Insert before “7.3.5 Multipurpose frame format” the following subclause 7.3.4a:

***Note to Editor: The LowLatencyNetworkInformation IE (0x20) of “5.2.4.2 Header Information Elements” (15.4e) has been omitted.***

***Note to Editor: The Group ACK IE (0x1f) of “5.2.4.2 Header Information Elements” (15.4e) and described in 5.2.4.12 “Group ACK IE” has been omitted.***

**7.5 MAC commands**

***To Editor: Change in 7.5 the first paragraph and Table 50 as follows. Not all lines are given in Table 50:***

The MAC commands are listed in Table 50 along with their associated command identifier. All FFDs shall be capable of transmitting and receiving all MAC command with Comamnd Identifier field of values 0x01–0x08, with the exception of the GTS Request command, while the requirements for an RFD are indicated by an “X” in the table. An FFD supporting one of TRLE, LLDN, DSME, RIT or DBS options shall support the associated MAC commands in the range 0x0d−0x1e as identified by the associated functional group prefix, e.g., “DSME ” for the DSME option.

1 **Table** **50—MAC commands**

|  |  |  |  |
| --- | --- | --- | --- |
| **Command identifier** | **Command name** | **RFD** | **Subclause** |
| **TX** | **RX** |
| 0x0b | [TRLE Management Response command](file:///D%3A%5CDATA%5Cmchn1520%5CDesktopPC%5CCT-LT%5CIEEE-802.15.4-2015%5CP802.15.4-REVc-DF3.docx#_bookmark1671) | X | X | [F.5.2.2](file:///D%3A%5CDATA%5Cmchn1520%5CDesktopPC%5CCT-LT%5CIEEE-802.15.4-2015%5CP802.15.4-REVc-DF3.docx#_bookmark1671) |
| 0x0c | Reserved |  |  |  |
| 0x0d | LL-Discover response | X |  | G.3.1 |
| 0x0e | LL-Configuration status | X |  | G.3.2 |
| 0x0f | LL-Configuration request |  | X | G.3.3 |
| 0x10 | LL-CTS shared group |  | X | G.3.4 |
| 0x11 | LL-Request To Send (RTS) | X | X | G.3.5 |
| 0x12 | LL-Clear to send (CTS) |  | X | G.3.6 |
| 0x13 | [DSME Association Request command](file:///D%3A%5CDATA%5Cmchn1520%5CDesktopPC%5CCT-LT%5CIEEE-802.15.4-2015%5CP802.15.4-REVc-DF3.docx#_bookmark457) | X |  | [7.5.12](file:///D%3A%5CDATA%5Cmchn1520%5CDesktopPC%5CCT-LT%5CIEEE-802.15.4-2015%5CP802.15.4-REVc-DF3.docx#_bookmark457) |

***To Editor: Insert the following paragraph and Table 8b [15.4e] as 3rd paragraph of “8.2.1 Primitives supported by the MLME-SAP interface”***

***To Editor: Change “8.2.3.1 MLME-ASSOCIATE.request“ and Table 60 as indicated:***

*To Editor: Add at the end of the list of parameters of MLME-ASSOCIATE.request():*

, LowLatencyNetworkInfo

*To Editor: Add the following line to Table 60:*

|  |  |  |  |
| --- | --- | --- | --- |
| LowLatencyNetworkInfo | Set of octets of variable length | — | Information for association specific to LLDN networks from the next higher layer. Only available if *macLLenabled* is TRUE. |

*To Editor: Add at the end of “8.2.3.1 MLME-ASSOCIATE.request“ the following paragraph:*

If the LowLatencyNetworkInfo parameter has a nonzero length and *macLLenabled* is FALSE, the MLME will issue the MLME-ASSOCIATE.confirm primitive with a status of UNSUPPORTED\_FEATURE.

***To Editor: Change ”8.2.3.2 MLME-ASSOCIATE.indication“ the semantics of this primitive and Table 61 as indicated:***

*To Editor: Add at the end of the list of parameters of MLME-ASSOCIATE.indication():*

, LowLatencyNetworkInfo

*To Editor: Add the following line to Table 61:*

|  |  |  |  |
| --- | --- | --- | --- |
| LowLatencyNetwork- Info | Set of octets of variable length | — | Information for association specific to LLDN networks from the next higher layer.Only available if *macLLenabled* is TRUE. |

***To Editor: Change in „8.2.3.3 MLME-ASSOCIATE.response“ the semantics of this primitive and Table 62 as indicated:***

*To Editor: Add at the end of the list of parameters of MLME-ASSOCIATE.response():*

, LowLatencyNetworkInfo

*To Editor: Add the following line to Table 62:*

|  |  |  |  |
| --- | --- | --- | --- |
| LowLatencyNetworkInfo | Set of octets of variable length | — | Information for association specific to LLDNs to the next higher layer.Only available if *macLLenabled* is TRUE. |

***To Editor: Change in “8.2.3.4 MLME-ASSOCIATE.confirm“ the semantics of this primitive and Table 63 as indicated***

*To Editor: Add at the end of the list of parameters of MLME-ASSOCIATE.confirm():*

, LowLatencyNetworkInfo

*To Editor: Add the following line to Table 63:*

|  |  |  |  |
| --- | --- | --- | --- |
| LowLatencyNetworkInfo | Set of octets of variable length | — | Information for association specific to LLDNs to the next higher layer.Only available if *macLLenabled* is TRUE. |

***To Editor: Insert in “8.4.2.1 General MAC PIB attributes for functional organization“ in „Table 134—General MAC PIB attributes for functional organization“***

***between lines „macTSCHcapable“ and „macDSMEcapable“ the following line:***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *macLLcapable* | Boolean | TRUE or FALSE | If TRUE, the device is capable of functionality specific to LLDNs | ⎯ |

***between lines „macTSCHenabled“ and „macDSM******enabled“ the following line:***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *macLLenabled* | Boolean | TRUE or FALSE | If TRUE, the device is using functionality specific to LLDNs | ⎯ |

**D.7.3.1 MAC sublayer functions**

***To Editor: Insert the following rows in Table D.6as MLF 16a between ”MLF15 TSCH Capability“ and „MLF16 DSME capabilities“:***

**Table D.6—MAC sublayer functions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item number** | **Item description** | **Reference** | **Status** | **Support** |
| **N/A** | **Yes** | **No** |
| MLF16a | LL Capability | Table 8b | O |  |  |  |
| MLF16a.1 | LL-MAC Management Services | 8.2,8.2.20a | MLF16a:M |  |  |  |
| MLF16a.2 | LL commands | 7.5.11a-7.5.11f | MLF16a:M |  |  |  |
| MLF16a.2.1 | LL: LL-Discover Response command, | 7.5.11a, | FD1:M |  |  |  |
| LL-Configuration Status command, | 7.5.11b, | FD2:O |
| LL-Configuration Request command, | 7.5.11c, | FD3:O |
| Clear To Send (CTS) Shared Group command, | 7.5.11d, | FD4:O |
| Request To Send command, (RTS) | 7.5.11e, | FD5:O |
| Clear To Send command | 7.5.11f | FD6:O |
| MLF16a.3 | LL Channel Access | 6.2.5.3a | MLF16a:M |  |  |  |
| MLF16a.4 | LL Superframe structure | 6.2.6a | MLF16a:M |  |  |  |
| MLF16a.5 | LL Transmission States | 6.10a | MLF16a:M |  |  |  |

# Annex G

(normative)

# Low Latency Deterministic Networks (LLDN)

ToDo: Introductory paragraphs on LLDN

## LLDN Superframe

LLDN PANs (i.e., *macLLenabled* is TRUE) use the LLDN superframe structure as described in 6.2.6a. The superframe is divided into a beacon slot, 0 or 2 management timeslots (i.e., 2 if *macLLDNmgmtTS* is TRUE), and *macLLDNnum TimeSlots* number of timeslots of equal length as shown in Figure 4b.



Figure 4b—LLDN Superframe with dedicated timeslots

The first timeslot of each superframe contains an LL-Beacon frame. The LL-Beacon frame is used for synchronization with the superframe structure. It is also used for re-synchronization of devices that, for instance, went into power save or sleep mode.

The beacon timeslot may be followed by two management timeslots, one for downlink and one for uplink.

The remaining timeslots are assigned to the LLDN devices in the network; there is no explicit addressing necessary inside the frames provided that there is exactly one device assigned to a timeslot as per 6.2.6a.6. The determination of the sender is achieved through the indexing of timeslots. If there is more than one device assigned to a timeslot, the timeslot is referred to as shared group timeslot, and a simple addressing scheme with 8-bit addresses, macSimpleAddress, is used as described in 6.38.3.

**6.2.6a LLDN Superframe structure**

**6.2.6a.1 General structure of superframe**

The LLDN superframe is divided into a beacon slot, management timeslots if present, and *macLLDNnumTimeSlots* base timeslots of equal length as illustrated in Figure 11e.

Superframe

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  | Beacon |  |  | TN 1 |  |  | TN 2 |  |  | TN 3 |  |  | TN n |  |  | Beacon |  | TN 1 |  | TN 2 |  | TN 3 |  | TN n |  |
|  |  |  |  |  | time |

Slot

Beacon

TN 1

TN 2

TN 3

TN n

Beacon

TN 1

TN 2

TN 3

TN n

Figure 11e—Superframe with dedicated timeslots

The first timeslot of each superframe contains a beacon frame. The beacon frame is used for synchronization with the superframe structure. It is also used for re-synchronization of devices that went into power save or sleep mode.

The remaining timeslots are assigned to specific devices of the network. Each timeslot may have assigned a so-called slot owner. The slot owner has access privileges in the timeslot (dedicated timeslot). There is no explicit addressing necessary inside the frames if the slot owner transmits in its timeslot. The determination of the sender is achieved through the number of the timeslot. More than one device can be assigned to a timeslot (shared group timeslot). The devices use a contention-based access method (simplified CSMA-CA as specified in 6.2.5.3a) and a simple addressing scheme with 8-bit addresses in shared group timeslots.

Multiple adjacent base timeslots can be concatenated to a single, larger timeslot, as illustrated in Figure 11f.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | managementtime slots | retransmission time slots |  | uplinktime slots | bidirectionatime slots | l |  |
| Beacon |  | downlink |  | uplink |  | S1 |  | Sr |  | Sr+1 |  | ... |  | Sn |  | A1 |  | ... |  | Am |  |

present if

*macLLDNmgmtTS* = TRUE

Superframe

*macLLDNnumTimeSlots*

*macLLDNnumUplinkTS macLLDNnumBidirectionalTS macLLDNnumRetransmitTS*

time

Figure 11f—Usage and order of slots in a superframe

As shown in Figure 11f, there is a specific order in the meaning or usage of the timeslots, as follows:

* Beacon Timeslot: always present.
* Management Timeslots: one timeslot downlink, one timeslot uplink, presence is configurable in

*macLLDNmgmtTS* during the Configuration state.

* Uplink timeslots for LLDN devices: *macLLDNnumUplinkTS* timeslots uplink (unidirectional communication), *macLLDNnumRetransmitTS* timeslots at the beginning can be reserved for retransmissions according to the Group Acknowledgement field contained in the LL-beacon as described in 7.3.4a.2 and 6.10a.4.
* Bidirectional timeslots for LLDN devices: *macLLDNnumBidirectionalTS* timeslots uplink/downlink (bidirectional communication).

It is also possible to use a separate Group Acknowledgement (GACK) frame as described in 7.3.4a.4 in order to facilitate retransmissions of failed transmissions in the uplink timeslots within the same superframe. The use of a separate GACK is configurable during configuration mode. If the use of a separate GACK is configured, the structure of the superframe is as depicted in Figure 11g.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | managementtime slots | uplink time slotsGroup Ack time slot | retransmission time slots |  | bidirectionaltime slots |  |
| Beacon |  | downlink |  | uplink |  | S1 |  | ... |  | Sn-r-1 |  | GACK |  | Sn-r+1 |  | Sn |  | A1 |  | ... |  | Am |  |

present if

*macLLDNmgmtTS* = TRUE

*macLLDNnumTimeSlots*

*macLLDNnumUplinkTS macLLDNnumBidirectionalTS*

time

*macLLDNnumRetransmitTS*

Superframe

Figure 11g—Usage and order of slots in a superframe with configured use of separate GACK

Descriptions of the following configuration parameters and intervals for the superframe with a separate GACK are only different for the Uplink Timeslots:

* Beacon Timeslot
* Management Timeslots
* Uplink Timeslots: *macLLDNnumUplinkTS* denotes the total number of timeslots available for uplink (unidirectional) communication. Typically, one timeslot is allocated to each LLDN device. In this case, M denotes the number of LLDN devices, *macLLDNnumRetransmitTS* denotes the number of timeslots allocated for LLDN devices that failed their original transmissions prior to the GACK and need to retransmit their message, and N denotes the number of LLDN devices that are allowed to retransmit. One timeslot is allocated for each retransmitting LLDN device.
* GACK: It contains an M bit bitmap to indicate successful and failed uplink transmissions in the same order as the uplink transmissions.
* Bidirectional Timeslots

The LL Beacon frame in the LLDN mode always carries the GACK bitmap even if a separate GACK frame is used. The GACK bitmap is used for acknowledging the successful retransmissions in timeslots R1, R2, ..., RN since some of the retransmitted frames (in R1, R2, …, RN timeslots) may fail.

6.2.6a.2 Beacon timeslot

The beacon timeslot is reserved for the LLDN PAN coordinator to indicate the start of a superframe with the transmission of a beacon. The beacon is used to synchronize the devices and to indicate the current transmission mode. The beacon also contains acknowledgments for the data transmitted in the last superframe.

The beacon timeslot is available in every superframe.

6.2.6a.3 Management timeslots

The first portion of a superframe after the beacon timeslot is formed by the management timeslots, i.e., the downlink and uplink management timeslots.

The downlink direction is defined as sending data to the LLDN device. The uplink direction is defined as sending data from the LLDN device to the LLDN Coordinator.

Management timeslots provide a mechanism for bidirectional transmission of management data in downlink and uplink direction. Downlink and uplink timeslots are provided in equal number in a superframe. There are two management timeslots per superframe at maximum. Management timeslots are implemented as shared group access timeslots.

Management downlink and uplink timeslots are used in the Discovery state and the Configuration state and are optional in the Online state. These states are described in 6.10a.

6.2.6a.4 Uplink timeslots

After the management timeslots, timeslots for the transmission of data are contained in a superframe. Uplink timeslots allow for unidirectional communication (uplink) only.

The first *macLLDNnumRetransmitTS* of the *macLLDNnumUplinkTS* uplink timeslots are dedicated timeslots for retransmissions of failed uplink transmission attempts in dedicated timeslots of the previous superframe. The dynamic assignment of nodes to retransmission timeslots is described in 6.10a.4.

6.2.6a.5 Bidirectional timeslots

Bidirectional timeslots allow for bidirectional communication between the LLDN PAN coordinator and the LLDN device. The direction of the communication is signaled in the beacon as described in 7.3.4a.2. Bidirectional timeslots are used for the transmission of device data to the LLDN PAN coordinator (uplink) as well as of data from the LLDN PAN coordinator to the LLDN device (downlink).

6.2.6a.6 Channel access within timeslots

Each timeslot is described by four time attributes as illustrated in Figure 11h and described in Table 0a.

Shared Group Timeslot

tSlotStart

tSlotTxOwner

tSlotTxGW tSlotEnd

Figure 11h—Time attributes of timeslots

**Table 0a—Time attributes of timeslots**

|  |  |
| --- | --- |
| **Attribute** | **Description** |
| tSlotStart | Starting time of timeslot |
| tSlotTxOwner | End time of privileged access by device that owns the timeslot |
| tSlotTxGW | If timeslot is unused, LLDN PAN coordinator can use the timeslot |
| tSlotEnd | End time of timeslot |

From tSlotStart till tSlotTxOwner, the device that owns the slot, the slot owner, has exclusive access to the timeslot.

From tSlotTxOwner till tSlotTxGW, any device other than the LLDN PAN Coordinator may use the timeslot for data transmission with a modified CSMA-CA access scheme as described in 6.2.5.3a if the timeslot is not used by the slot owner. If the timeslot is not used by the slot owner, the LLDN PAN Coordinator shall indicate this by broadcasting a Clear To Send (CTS) Shared Group frame (7.5.11d). To reduce the chances of collisions from other LLDN devices trying to use this timeslot, an LLDN device should send a Request To Send (RTS) frame (7.5.11e) and wait for the receipt of the corresponding CTS frame (7.5.11f) that identifies this LLDN device, from the LLDN PAN Coordinator before it transmits its data with a modified CSMA-CA access scheme as described in 6.2.5.3a.

From tSlotTxGW till tSlotEnd, the LLDN PAN coordinator may use the timeslot, if the timeslot is still unused.

Dedicated timeslots are reserved for a single device (slot owner). This is achieved by setting tSlotTxOwner and tSlotTxGW to tSlotEnd. A dedicated timeslot allows the transmission of exactly one packet. Dedicated timeslots are only used during online mode as described in 6.10a.4.

Shared group timeslots with contention-based access for every allowed device can be achieved by setting tSlotTxOwner to tSlotStart.

# G.xxx Data Transfer Model

**5.7.2.2 Data transfer to a coordinator**

To Editor: Insert before 5.7.2.3 the following paragraph and figure at the end of 5.7.2.2:

When a device wishes to transfer data to a PAN coordinator in an LLDN, it first listens for the network beacon. When the beacon is found, the device synchronizes to the superframe structure. At its assigned timeslot, the device transmits its data frame to the LLDN PAN coordinator. If the device transmits its data frame in a dedicated timeslot or as slot owner of a shared group timeslot, the data frame is transmitted without using CSMA-CA. If the device transmits its data frame in a shared group timeslot and is not the slot owner, the data frame is transmitted using slotted CSMA-CA as described in 6.2.5.3a depending on the used PHY. The LLDN PAN coordinator may acknowledge the successful reception of the data by transmitting an optional acknowledgment frame. Successful data transmissions in dedicated timeslots or by the slot owner are acknowledged by the LLDN PAN coordinator with a Group Acknowledgment either in the next beacon or as a separate group acknowledgment (GACK) frame. This sequence is summarized in Figure 4c.

**LLDN PAN**

**Coordinator**

**LLDN Device**

Beacon

Data

Group Ack

(if configured)

Beacon

(with Group Ack if no

separate GACK configured)

**LLDN PAN**

**Coordinator**

**LLDN Device**

Beacon

CTS shared group Data

Acknow ledgm ent (if requested)

Beacon

Dedicated time slot Shared group time slot

Figure 4c—Communication to a PAN coordinator in an LLDN

**5.7.2.3 Data transfer from a coordinator**

Insert before 5.7.2.4 the following paragraphs and figure at the end of 5.7.2.3:

A data transfer from an LLDN PAN coordinator is only possible in the *macLLDNnumBidirectionalTS* timeslots described in 6.2.6a.5 and if the Transmission Direction field in the Flags field of the beacon indicates downlink direction.

When the LLDN PAN coordinator wishes to transfer data to an LLDN device assigned to a bidirectional timeslot in an LLDN, it indicates in the network beacon that the transmission direction is downlink. At the appropriate time, the LLDN PAN coordinator transmits its data frame to the device without using CSMA-CA. The device may acknowledge the successful reception of the data by transmitting an acknowledgment frame to the LLDN PAN coordinator in the same timeslot of the next superframe. In order to do so, the transmission direction has to be uplink in that superframe. This sequence is summarized in Figure 4d.

**LLDN PAN**

**Coordinator**

**LLDN Device bidirectional**

Beacon

transmission direction: downlink

Data

Beacon

transmission direction: uplink

Acknowledgment

(if requested)

Figure 4d—Communication from a PAN coordinator to a device in an LLDN

**6.7.4.2 Acknowledgment**

To Editor: Insert in 6.7.4.2 before the last paragraph the following text:

LLDNs use several methods for the acknowledgment of data transmissions. The timings of these mechanisms are defined by the superframe structure of the LLDN. The transmission of an LL- Acknowledgment frame in response to an LL-data frame in an LLDN shall commence in the same bidirectional timeslot in the next superframe. The LL-Acknowledgment frame shall only be used with bidirectional timeslots.

G.xxx LLDN functional description

**6.10a LLDN transmission states**

**6.10a.1 General**

The transitions between the different transmission states are illustrated in Figure 34a.

**Online state**

**Discovery state**

**Configuration state**

**Start**

Addition of new device

Reconfiguration

Reset Reset

Figure 34a—Transitions between transmission states

The discovery state is the first step during network setup: the new devices are discovered and configured in the second step, the configuration state. After the successful completion of the configuration state, the network can go into online state. Data and readings from the devices can only be transmitted during online state. In order to reconfigure a network, the configuration state can be started again.

6.10a.2 Discovery state

The Discovery state is the first step during network setup or for the addition of new devices to an existing network.

In the Discovery state, the superframe contains only the timeslot for the beacon described in 6.2.6a.2 and two management timeslots, one downlink and one uplink (6.2.6a.3).

A new device scans the different channels until it detects an LLDN PAN coordinator sending beacons that indicate Discovery state.

If a new device received a beacon indicating Discovery state, it attempts to access the medium in the uplink management timeslot in accordance with 6.2.5.3a in order to send a Discover Response frame to the LLDN PAN coordinator. The Discover Response frame is described in 7.5.11a. The Discover Response frame contains the current configuration of the device. The new device shall repeat sending the Discover Response frame until it receives an acknowledgment frame for it or the Discovery state is stopped by the LLDN PAN coordinator. The acknowledgment frame is described in 7.3.4a.4.

The LLDN coordinator changes from the Discovery state to the Configuration state if it did not receive any Discover Response frames within *macLLDNdiscoveryModeTimeout* seconds.

Figure 34b illustrates the Discovery state.

LLDN Coordinator LLDN Device

|  |  |
| --- | --- |
|  |  |
| Bea con |
| Mgmt Slot |
| Mgmt Slot |
| Bea con |
| Mgmt Slot |
| Mgmt Slot |
| ... |
|  |  |

Start Discovery state

Received a D iscover R esponse

Frame, pr ep ar e Ack

Be aco n

Discover Response Frame

Be aco n Ack Frame

prep ar e Respo nse

the current device configuration

Resynchr on izes

Figure 34b—Flow diagram of Discovery state

**6.10a.3 Configuration state**

The Configuration state is the second step during network setup. It is also used for network reconfiguration.

In the Configuration state, the superframe contains only the timeslot for the beacon described in 6.2.6a.2 and two management timeslots, one downlink and one uplink as described in 6.2.6a.3.

If a device received a beacon indicating configuration state, it tries to get access to the transmission medium in the uplink management timeslot in order to send a Configuration Status frame to the LLDN PAN coordinator. The Configuration Status frame is described in 7.5.11b. The Configuration Status frame contains the current configuration of the device. The new device shall repeat sending the Configuration Status frame until it receives a Configuration Request frame for it or the Configuration state is stopped by the LLDN PAN coordinator. The Configuration Request frame is described in 7.5.11c. The Configuration Request frame contains the new configuration for the receiving device. After successfully receiving the

Configuration Request frame, the device sends an acknowledgment frame to the LLDN PAN coordinator. The acknowledgment frame is described in 7.3.4a.4.

Figure 34c illustrates the Configuration state.

LLDN Coordinator LLDN Device

|  |  |
| --- | --- |
|  |  |
| Beacon |
| Mgmt Slot |
| Mgmt Slot |
| Beacon |
| Mgmt Slot |
| Mgmt Slot |
| ... |
|  |  |

Start Configuration state

Received a Configuration Status Frame,

Prepare Configuration Request Frame

Beacon

Configuration Status Frame Beacon

Configuration Request Frame Beacon

Ack Frame

Synchronize and prepare Status

Frame that contains

the current device configuration

Resynchronizes

Received the Configuration Request Frame with

the new configuration, prepare Ack Frame

Resynchronizes

Figure 34c—Flow diagram of Configuration state

**6.10a.4 Online state**

User data is only sent during Online state. The superframe starts with a beacon and is followed by several timeslots. The devices can send their data during the timeslots assigned to them during the Configuration state. The different types of timeslots are described in 6.2.6a.

The existence and length of management timeslots in the Online state are contained in the Configuration Request frame.

The successful reception of data frames by the LLDN PAN coordinator is acknowledged in the Group Acknowledgment bitmap of the beacon frame of the next superframe described in 7.3.4a.2 or in a separate Data Group Acknowledgment frame depicted in Figure 48h. This is the case for both uplink timeslots and bidirectional timeslots if the transmission direction is uplink. Figure 34d illustrates an example of the Online state for uplink transmissions. In this example, the network has three dedicated timeslots, and LLDN device 2 is assigned to timeslot 2.

If retransmission timeslots are configured (i.e., *macLLDNnumRetransmitTS* > 0), the retransmission slots are assigned to the owners of the first *macLLDNnumRetransmitTS* with the corresponding bit in the group acknowledgment bitmap set to zero. Each LLDN device shall execute the algorithm as illustrated in Figure 34e in order to determine its retransmission timeslot. The LLDN PAN coordinator has to execute a similar algorithm in order to determine the senders of the frames in the retransmission slots.

LLDN Coordinator LLDN Device 2 (uplink)

|  |  |
| --- | --- |
|  |  |
| Beacon |
| Time Slot 1 |
| Time Slot 2 |
| Time Slot 3 |
| Beacon |
| Time Slot 1 |
| Time Slot 2 |
| Time Slot 3 |
| Beacon |
| ... |
| e |  |

Tim

Start Online state

Received a Data Frame, set Ack

in Beacon

Received a Data Frame, set Ack

in Beacon

Beacon

*Data Frame to LLDN Device 1 (uplink)*

Data Frame

*Data Frame to LLDN Device 3 (uplink)*

Beacon (with acknowl edgements)

*Data Frame to LLD N Device 1 (uplink)*

Data Frame

*Data Frame to LLDN Device 3 (uplink)*

Beacon (with acknowledgements)

Synchronize and prepare a Data Frame

Resynchronize and prepare a Data Frame

Resynchronizes

Figure 34d—Flow diagram of Online state for LLDN devices (uplink)

Ack[i] represents the uplink success and maps to the bit b(i1) in the group acknowledgment bitmap as illustrated in Figure 48e. Assuming that the LLDN device has been assigned to uplink timeslottimeslot “s,” Ack[s] represents the uplink success of that LLDN device.

If the data transmission of the LLDN device has failed and has not been acknowledged, that is, ack[s] is zero (i.e., false), the LLDN device determines the number of failed transmissions in previous timeslots excluding retransmission timeslots. This number of failed transmissions, NFT, is the number of ack[i] equal to 0 (i.e., false) with (*macLLDNnumRetransmitTS*+1) i (s1).

A retransmission is possible if the number of failed transmissions NFT is less than *macLLDNnumRetransmitT*S. The LLDN device retransmits its data in retransmission timeslot (NFT+1).

If the number of failed transmissions NFT is equal or greater than *macLLDNnumRetransmitTS*, a retransmission is not possible.

The successful reception of data frames by LLDN devices assigned to bidirectional timeslots (transmission direction is downlink) is acknowledged by an explicit acknowledgment frame by the corresponding LLDN devices in the following superframe. This means that after setting the Transmission Direction bit in the beacon described in 7.3.4a to downlink and sending a data frame to one or more LLDN devices, the LLDN PAN coordinator shall set the Transmission Direction bit to uplink in the directly following superframe. LLDN devices assigned to bidirectional timeslots that have successfully received a data frame from the LLDN PAN coordinator during the previous superframe shall send an acknowledgment frame to the LLDN PAN coordinator. LLDN devices that did not receive a data frame from the LLDN PAN coordinator may send data frames to the LLDN PAN coordinator during this superframe with Transmission Direction bit set to uplink. Figure 34f illustrates the Online state with LLDN devices assigned to bidirectional timeslots. In this figure, the network has three dedicated bidirectional timeslots, and LLDN device 2 is assigned to timeslot 2.

number of failed transmissions

NFT := 0

i := *macLLDNnumRetransmitTS*+1

NFT:= NFT+1

i := i+1

ack[i] == 0

?

no

yes

NFT <

*macLLDNnumRetransmitTS*

?

no

yes

i <= (s-1)

?

no

retransmission in

retransmission timeslot [NFT+1]

no retransmission

possible

yes

Figure 34e—Retransmission Slot Algorithm

LLDN Device 2 (bidirectional)

|  |  |
| --- | --- |
| LLDN Coordinator |  |
|  | Beacon (transmission direction = downlink) |
| *Data Frame to LLDN Device 1 (bidirecti onal)* |
| Data Frame |  |
| Beacon (transmission direction = uplink |
| *Ack Frame by LLDN Device 1 (bi directional)*Ack Frame*Data Frame by LLDN Device 3 (bidirectional)*Beacon (with acknowledgements) |
|  |

|  |  |
| --- | --- |
|  |  |
| Beacon |
| Time Slot 1 |
| Time Slot 2 |
| Time Slot 3 |
| Beacon |
| Time Slot 1 |
| Time Slot 2 |
| Time Slot 3 |
|  |
| ... |
| e |  |

Start Online

Synchronize

Received Data Frame and

prepare Ack Frame Resynchronize

Tim

Recei ved a

set Ack in Beacon

Resynchronizes

ack[s] == 0

(data transmisison failed )

Figure 34f—Flow diagram of Online state for LLDN devices (bidirectional)

To Editor: Insert the following clause 6.2.5.3a before “6.2.5.4 CSMA-CA with PCA”

6.2.5.3a LLDN simplified CSMA-CA

A simplified CSMA-CA algorithm is used during Management timeslots and Shared Group timeslots in LLDNs.

The simplified CSMA-CA is a slotted CSMA-CA mechanism and follows the same algorithm as described in 6.2.5.1.

The backoff slots of *aUnitBackoffPeriod* symbols are aligned with the start of the beacon transmission in management timeslots and with tSlotTxOwner in shared group timeslots.

Each time a device wishes to transmit data frames with CSMA-CA at the appropriate places, it locates the boundary of the next backoff slot and then waits for a random number of backoff slots. If the channel is busy, following this random backoff, the device waits for another random number of backoff slots before trying to access the channel again. If the channel is idle, the device begins transmitting on the next available backoff slot boundary. Acknowledgment and beacon frames are sent without using a CSMA-CA mechanism.

**G.xxx LLDN Security**

LLDN cannot be secured in this standard. LLDN uses 1-octet addresses (simple addresses). Any mode using simple addresses including LLDN shall not use security.

**G.xxx PHY considerations**

The LLDN specification has been developed for the 2.4 GHz PHY. The LLDN specification is PHY-independent, in principle. For instance, it can be used with the IEEE 802.15.4a PHY. However, the use of LLDN with several PHYs of this standard is not advisable, for instance, with PHYs targetting a completely different application case than LLDN. There is no requirement that every PHY of this standard has to support LLDN.

## Low Latency Deterministic Network (LLDN) frame format

### **General LLDN frame format**

The general LLDN frame shall be formatted as illustrated in .

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |

|  |  |  |
| --- | --- | --- |
| **Octets: 1** | **variable** | **2** |
| LLDN Frame Control | LLDN Frame Payload | FCS |
| MHR | MAC payload | MFR |

Figure G.1—General LLDN frame format

The order of the fields of the LLDN frame shall conform to the order of the general MAC frame as illustrated in Figure 86 in 7.2.

Four LLDN frame subtypes are defined: LLDN Beacon, LLDN Data, LLDN Acknowledgment, and LLDN MAC Command. These LLDN frame subtypes are specified in , , , and , respectively.

The LLDN Frame Control field contains information defining the frame subtype of the LLDN frame. The LLDN Frame Control field shall be formatted as illustrated in .

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bits: 0–2** | **3** | **4** | **4** | **6–7** |
| Frame Type | Reserved | LLDNFrame Version | LLDNACK Request | LLDNFrame Subtype |

Figure G.2—Format of the LLDN Frame Control field (LLDN frame)

NOTE 1—The LLDN frame will be rejected by devices compliant to IEEE Std 802.15.4-2011 since the Frame Type value is listed as “reserved” by IEEE Std 802.15.4-2011. The position of the Frame Type should not be changed in future versions of the protocol.

The Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5 in 7.2.1.1.

NOTE 2—The Frame Type field corresponds to the Frame Type field of the general MAC frame format in 7.2 in meaning and position. The frame type for LLDN frames allows efficient recognition of LLDN frames with an LLDN Frame Control field of 1 octet, but allows the usage of all other MAC frames within the LLDN superframe structure.

Bit 3 of the LLDN Frame Control field is reserved and shall be set to zero. This field is reserved for future.

The LLDN Frame Version field specifies the LLDN version number corresponding to the frame. This field shall be set to zero to indicate a frame compatible with IEEE Std 802.15.4. A value of one shall be reserved for future use.

The LLDN ACK Request field specifies whether an acknowledgment is required from the recipient device on receipt of a data or MAC command frame. If this field is set to one, the recipient device shall send an acknowledgment frame only if, upon reception, the frame passes the third level of filtering as described in 6.7.2 If this field is set to zero, the recipient device shall not send an acknowledgment frame.

The LLDN Frame Subtype field indicates the subtype of the LLDN frame. It shall be set to one of the values listed in .

Table G.1—Values of LLDN Frame Subtype field (LLDN frame)

|  |  |
| --- | --- |
| **Frame Subtype value b7 b6** | **Description** |
| 00 | LLDN Beacon |
| 01 | LLDN Data |
| 10 | LLDN Acknowledgment |
| 11 | LLDN MAC Command |

The LLDN Frame Payload field has a variable length and contains information specific to individual subframe types of an LLDN frame.

### **LLDN Beacon frame format**

The LLDN Beacon frame is sent during the beacon slot in every LLDN superframe. The LLDN Beacon frame shall be formatted as illustrated in .

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Octets: 1** | **1** | **1** | **1** | **1** | **0/1** | **variable** | **2** |
| LLDN Frame Control | LLDN Beacon Flags | LLDN PAN coordinator ID field | Configuration Sequence Number | LLDN Base Timeslot Size | Number of LLDN Base Timeslots in LLDN Superframe | LLDN Group Acknow- ledgment | FCS |
| MHR | MAC Payload | MFR |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |

Figure G.3—Format of the LLDN Beacon frame

The order of the fields of the LLDN Beacon frame shall conform to the order of the general LLDN frame as illustrated in Figure G.1.

The LLDN Beacon frame has a short MHR containing the LLDN Frame Control field of one octet.

In the LLDN Frame Control field, the Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN Beacon frame, as shown in .

The LLDN Beacon Flags field contains control information. The structure of the LLDN Beacon Flags field is shown in Figure G.4.

|  |  |  |  |
| --- | --- | --- | --- |
| **Bits: 0–2** | **3** | **4** | **5–7** |
| Transmission State | Transmission Direction | Reserved | Number of LLDN Base Timeslots per LLDN Management Timeslot |

Figure G.4—Structure of LLDN Beacon Flags field of LLDN Beacon frame

The Transmission State field defines the transmission state. The values for the different transmission states are specified in .

Table G.2—Transmission State settings

|  |  |
| --- | --- |
| **Bits 0–2** | **Transmission State** |
| 000 | LLDN Online state (described in G.xxx) |
| 100 | LLDN Discovery state (described in G.xxx) |
| 110 | LLDN Configuration state (described in G.xxx) |
| 111 | LLDN State Reset: The LLDN devices reset their state of the LLDN discovery or LLDN configuration |

The Transmission Direction field indicates the transmission direction of all bidirectional LLDN timeslots during this LLDN superframe. If the Transmission Direction field is set to zero, the direction of all bidirectional LLDN timeslots is uplink (from LLDN device to LLDN PAN coordinator). If the Transmission Direction field is set to one, the direction of all bidirectional LLDN timeslots is downlink (from LLDN PAN coordinator to LLDN device). The Transmission Direction field is only used in LLDN Online state.

The Number of LLDN Base Timeslots per LLDN Management Timeslot field contains the number of LLDN base timeslots per LLDN management timeslot. This value applies to both the downlink and the uplink LLDN management timeslot. A value of zero indicates that there are no LLDN management timeslots available in the LLDN superframe. A non-zero value indicates that there are one downlink and one uplink LLDN management timeslot available in the LLDN superframe. Each of the LLDN management timeslots is of duration of the given number of LLDN Base Timeslots.

The LLDN PAN coordinator ID field contains the 8-bit simple address (i.e., *macSimpleAddress*) of the LLDN PAN coordinator.

The Configuration Sequence Number field contains an integer number that identifies, together with the LLDN PAN coordinator ID, the current configuration of the LLDN.

The Timeslot Size field defines the length of a base timeslot through the maximum expected number of octets of the data payload of an LL-data frame. The actual timeslot size in octets is calculated as

*tTS* : = (*p* *sp* + (*m* + *n*) *sm* + *macMinSIFSPeriod* symbols {if *m* + *n* *aMaxSIFSFrameSize*

octets} or *macMinLIFSPeriod* symbols {if *m* + *n* > *aMaxSIFSFrameSize* octets}) / *v*

with the description and values for the 2 450 MHz PHY as an example as shown in .

Table G.3—Example of a set of parameter and values

|  |  |  |
| --- | --- | --- |
| **Variable** | **Description** | **Value for 2450 MHz PHY with no security enabled** |
| *p* | Number of octets of PHY header | 6 octets |
| *m* | Number of octets of MAC overhead (MHR + MFR) | 3 octets for LL-Data frames |
| *n* | Maximum expected number of octets of data payload | Value of Timeslot Size field of LL-Beacon frame |
| *sp* | Number of symbols per octet in PHY header | 2 symbols per octet |
| *sm* | Number of symbols per octet in PSDU | 2 symbols per octet |
| *v* | Symbol rate | 62 500 symbols/s |

The Number of Base Timeslots in Superframe field contains an integer number that represents the number of base timeslots for LLDN devices immediately following the management timeslots of the superframe (corresponds to *macLLDNnumTimeSlots*). The Number of Base Timeslots in the Superframe field is only present in the Online state.

The LLDN Group Acknowledgment field is a bitmap of length (*macLLDNnumTimeSlots* *macLLDNnumRetransmitTS*) bits, padded to a multiple of 8 bits, as shown in , to indicate successful transmissions by LLDN devices from the previous LLDN superframe. The size of the bitmap shall always be a multiple of 8 after padding with additional zeros at the end if necessary. In the separate LLDN group acknowledgment configuration, this field is not present in the LLDN Beacon. The LLDN Group Acknowledgment field is only present in LLDN Online mode. The LLDN Group Acknowledgment field contains a bit field where each bit corresponds to a LLDN base timeslot associated with an LLDN device excluding LLDN retransmission timeslots. Bit b0 of the LLDN Group Acknowledgement bitmap corresponds to the first LLDN base timeslot after the *macLLDNnumRetransmitTS* LLDN retransmission timeslots, bit b1 of the LLDN Group Acknowledgment bitmap corresponds to the second LLDN base timeslot, and so on. A bit value of one means the corresponding uplink transmission in the previous LLDN superframe was successful, and a bit value of zero means the corresponding uplink transmission in the previous LLDN superframe failed or there was no uplink transmission. In the case of a bit value of zero, the LLDN device is allocated an LLDN timeslot for retransmission in the current LLDN superframe. Because concatenated LLDN timeslots are multiples of LLDN base timeslots, a concatenated LLDN timeslot of length of *n* LLDN base timeslots shall have *n* bits in the LLDN Group Acknowledgment bitmap at the corresponding positions. If the data frame has been received during an LLDN shared group timeslot, all corresponding bits of this LLDN shared group timeslot shall be set accordingly in the LLDN Group Acknowledgment bitmap.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bits: 0** | **1** | **...** | **(*macLLDNnumTimeSlots* –*****macLLDNnumRetransmitTS*****– 1)** | **... n\* 8–1** |
| Acknowledgment of trans­mission in LLDN base timeslot *macLLDNnumRetransmitTS* + 1 | Acknowledgment of trans­mission in LLDN base timeslot *macLLDNnumRetransmitTS* + 2 | ... | Acknowledgment of trans­mission in LLDN base timeslot *macLLDNnumTimeSlots* | Padding |

Figure G.5—Structure of LLDN Group Acknowledgment bitmap

### **LLDN Data frame format**

The LLDN Data frame is sent during LLDN Online mode in LLDN device timeslots. The LLDN Data frame shall be formatted as illustrated in .

|  |  |  |
| --- | --- | --- |
| **Octets: 1** | **variable** | **2** |
| LLDNFrame Control | Data Payload | FCS |
| MHR | MAC Payload | MFR |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |

Figure G.6—Format of LLDN Data frame

The order of the fields of the LLDN Data frame shall conform to the order of the general MAC frame as illustrated in Figure 86.

The LLDN Data frame has a short MHR containing the LLDN Frame Control field of one octet.

In the LLDN Frame Control field, the Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN Data frame, as shown in .

The payload of an LLDN Data frame shall contain the sequence of octets that the next higher layer has requested the MAC sublayer to transmit.

### **LLDN Acknowledgment frame format**

The LLDN Acknowledgment frame is sent during Online mode in bidirectional timeslots. The LLDN Acknowledgment frame shall be formatted as illustrated in .

|  |  |  |  |
| --- | --- | --- | --- |
| **Octets: 1** | **1** | **variable** | **2** |
| LLDN Frame Control | LLDN Acknowledg­ment Type | Acknowledgment Payload | FCS |
| MHR | MAC payload | MFR |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |

Figure G.7—Format of the LLDN Acknowledgment frame

The order of the fields of the LLDN Acknowledgment frame shall conform to the order of the general LLDN frame as illustrated in Figure G.1.

The LLDN Acknowledgment frame has a short MHR containing the LLDN Frame Control field of one octet.

In the LLDN Frame Control field, the Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN Acknowledgment frame, as shown in .

The LLDN Acknowledgment Type field indicates the type of frame that is acknowledged or the type of LLDN acknowledgment. Possible values are listed in .

Table G.4—LLDN Acknowledgment types

|  |  |
| --- | --- |
| **Acknowledged frame typeLLDN Acknowledgment type** | **Acknowledgment payload** |
| LLDN Configuration Request frame | No |
| LLDN Data frame | No |
| LLDN Data Group ACK type | Yes |
| LLDN Discover Response frame | No |

The Acknowledgment Payload field is only available in certain LLDN acknowledgment types as depicted in . The structure and the length of the Acknowledgment Payload field depends on the value of the LLDN Acknowledgment Type field.

The structure of the Acknowledgment Payload field of the LLDN Data Group ACK frame is shown in Figure G.8.

LLDN Source ID

LLDN Group ACK Flags

|  |  |  |  |
| --- | --- | --- | --- |
| **b0** | **b1** | **...** | **bM – 1** |
| Acknowledgement of uplink trans­mission in LLDN base timeslot 1 | Acknowledgement of uplink trans­mission in LLDN base timeslot 2 | ... | Acknowledgement of uplink trans­mission in LLDN base timeslot M |

Figure G.8—Format of the LLDN Data Group ACK frame

The LLDN Source ID field shall be an 8-bit simple address that identifies the transmitting LLDN PAN coordinator.

The LLDN Group Ack Flags field is a bitmap of size equal to the smallest multiple of 8 that is greater than or equal to the number of uplink LLDN base timeslots. It indicates the states of transmissions of the LLDN devices in the uplink timeslots of the current LLDN superframe. A bit set to one indicates the fact that the LLDN PAN coordinator received the data frame successfully in the corresponding LLDN timeslot. A value of zero means, that the LLDN PAN coordinator failed in receiving a data frame in the corresponding LLDN timeslot from of the LLDN device.

### **LLDN MAC Command frame format**

There are different types of LLDN MAC Command frames sharing a common, general structure, differing only in the Command Payload. The LLDN MAC Command frame shall be formatted as illustrated in .

|  |  |  |  |
| --- | --- | --- | --- |
| **Octets: 1** | **1** | **variable** | **2** |
| LLDN Frame Control | CommandFrame Identifier | Command Payload | FCS |
| MHR | MAC payload | MFR |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |

Figure G.9—Format of the LLDN MAC Command frame

The order of the fields of the LLDN MAC Command frame shall conform to the order of the general LLDN frame as illustrated in .

The LLDN MAC Command frame has a short MHR containing the LLDN Frame Control field of one octet.

In the LLDN Frame Control field, the Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN MAC Command frame, as shown in .

The Command Frame Identifier field identifies the MAC command being used. This field shall be set to one of the non-reserved values listed in Table 50.

The Command Payload field contains the MAC command itself. The formats of the individual LLDN commands are described in G.3. The Command Payload field is of variable length and contains data specific to the different MAC Command frame types.

## LLDN commands

### **LLDN Discover Response command**

#### **General**

The LLDN Discover Response command contains the configuration parameters that have to be transmitted to the LLDN PAN coordinator as input for the configuration process in an LLDN.

This command shall only be sent by an LLDN device that has received an LLDN Beacon (refer to ) indicating LLDN Discovery mode as determined through the procedures of the Discovery state as described in G.xxx.

All LLDN devices shall be capable of transmitting this command, although an RFD is not required to be capable of receiving it.

The command payload of the LLDN Discover Response frame shall be formatted as illustrated in .

|  |  |
| --- | --- |
| **Octets: 1** | **variable** |
| Command Frame Identifier (defined in Table 50) | LLDN Discovery Parameters |

Figure G.10—LLDN Discover Response command MAC payload

#### **MHR fields**

The LLDN Discover Response command can be sent using both MAC Command frames described in 7.3.4 or LLDN MAC Command frames described in .

If sent in a MAC Command frame, the Frame Type field of the Frame Control field shall contain the value that indicates a MAC command frame, as shown in Table 5. The Source Addressing Mode field of the Frame Control field shall be set to three (64-bit extended addressing). The Source Address field shall contain the value of *aExtendedAddress*.

If sent in an LLDN MAC Command frame, the Frame Type field of the LLDN Frame Control field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN MAC Command frame, as shown in .

#### **Command Frame Identifier field**

The Command Frame Identifier field contains the value for the LLDN Discover Response command frame as defined in Table 50.

#### **LLDN Discovery Parameters field**

The LLDN Discovery Parameters field contains the configuration parameters that have to be transmitted to the LLDN PAN coordinator as input for the configuration process. The LLDN discovery parameters consist of the following:

Full MAC address

Required timeslot duration, this is defined by the application of the LLDN device (e.g., size of payload data)

Uplink/bidirectional type indicator

### **LLDN Configuration Status command**

#### **General**

The LLDN Configuration Status command contains the configuration parameters that are currently configured at the LLDN device as input for the configuration process in an LLDN.

This command shall only be sent by an LLDN device that has received an LLDN Beacon (described in ) indicating LLDN Configuration mode as determined through the procedures of the Configuration mode described in G.xxx.

All LLDN devices shall be capable of transmitting this command, although an RFD is not required to be capable of receiving it.

The command payload of the LLDN Configuration Status frame shall be formatted as illustrated in .

|  |  |
| --- | --- |
| **Octets: 1** | **variable** |
| Command Frame (defined in Table 50) | LLDN Configuration Parameters |

Figure G.11—Configuration Status command MAC payload

#### **MHR fields**

The LLDN Configuration Status command can be sent using both MAC Command frames described in 7.3.4 or LLDN MAC Command frames described in .

If sent in a MAC Command frame, the Frame Type field of the Frame Control field shall contain the value that indicates a MAC Command frame, as shown in Table 5. The Source Addressing Mode field of the Frame Control field shall be set to one (8-bit short addressing) or three (64-bit extended addressing). The Source Address field shall contain the value of *macSimpleAddress* if the Source Addressing Mode field is set to one or *aExtendedAddress* if the Source Addressing Mode field is set to three.

If sent in an LLDN MAC Command frame, the Frame Type field of the LLDN Frame Control field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN MAC Command frame, as shown in .

#### **Command Frame Identifier field**

The Command Frame Identifier field contains the value for the LLDN Configuration Status command frame as defined in Table 50.

#### **LLDN Configuration Parameters field**

The LLDN Configuration Parameters field contains the configuration parameters that are currently configured at the LLDN device. The LLDN configuration parameters consist of the following:

Full MAC address

Short MAC address

Required LLDN timeslot duration, this is defined by the application of the LLDN device (e.g., size of payload data)

Uplink/bidirectional data communication

Assigned LLDN timeslots

### **LLDN Configuration Request command**

#### **General**

The LLDN Configuration Request command contains the configuration parameters that the receiving LLDN device shall use during the Online state. This command shall only be sent by an LLDN PAN coordinator in response to a received LLDN Configuration Status frame of an LLDN device during the Configuration state. Only LLDN PAN coordinators are requested to be capable of transmitting this command; LLDN RFDs are required to be capable of receiving it.

The command payload of the LLDN Configuration Request frame shall be formatted as illustrated in .

|  |  |
| --- | --- |
| **Octet: 1** | **variable** |
| Command Frame Identifier (defined in Table 50) | LLDN Configuration Parameters |

Figure G.12—Configuration Request command MAC payload

#### **MHR fields**

The LLDN Configuration Request command can be sent using both MAC Command frames described in 7.3.4 or LLDN MAC Command frames described in .

If sent in a MAC Command frame, the Frame Type field of the Frame Control field shall contain the value that indicates a MAC Command frame, as shown in Table 5. The Source Addressing Mode field of the Frame Control field shall be set to one (8-bit short addressing) or three (64-bit extended addressing). The Destination Address field shall contain the value of the source address of the corresponding LLDN Configuration Status frame.

If sent in an LLDN MAC Command frame, the Frame Type field of the LLDN Frame Control field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN MAC Command frame, as shown in .

#### **Command Frame Identifier field**

The Command Frame Identifier field contains the value for the LLDN Configuration Request command frame as defined in Table 50.

#### **LLDN Configuration Parameters field**

The LLDN Configuration Parameters field contains the new configuration parameters that are sent to the LLDN device in order to either configure it or reconfigure it. The LLDN configuration parameters consist of the following:

Full MAC address

Short MAC address

Transmission channel

Existence of LLDN management timeslots

LLDN Timeslot duration

Assigned LLDN timeslots

### **LLDN Clear To Send (CTS) Shared Group command**

#### **General**

The LLDN Clear To Send (CTS) Shared Group command indicates to the LLDN devices of the star network that they now may use the timeslot for transmitting their own data with a simplified CSMA-CA.

This command shall only be sent by an LLDN PAN coordinator in a timeslot after tSlotTxOwner has been elapsed and the LLDN timeslot owner is not transmitting. For further information on channel access within LLDN timeslots refer to G.xxx

Only LLDN PAN coordinators shall be capable of transmitting this command, all other LLDN devices shall be capable of receiving it.

The command payload of the LLDN CTS Shared Group frame shall be formatted as illustrated in .

|  |  |
| --- | --- |
| **Octet: 1** | **1** |
| Command Frame Identifier (defined in Table 50) | LLD Network ID |

Figure G.13—Clear To Send (CTS) Shared Group command MAC payload

#### **MHR fields**

The LLDN CTS Shared Group command shall be sent using LLDN MAC Command frames.

In the LLDN Frame Control field of the LLDN MAC Command frame, the Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the Frame Subtype field shall contain the value that indicates an LLDN MAC Command frame, as shown in .

#### **Command Frame Identifier field**

The Command Frame Identifier field contains the value for the LLDN CTS Shared Group command frame as defined in Table 50.

#### **LLD Network ID field**

The LLD Network ID field contains an identifier specific to the LLDN PAN coordinator.

### **LLDN Request To Send (RTS) command**

#### **General**

The LLDN Request To Send (RTS) command may be used by an LLDN device to indicate to the LLDN PAN coordinator and to the other devices of the LLD star network that it wants to transmit data with a simplified CSMA-CA. The LLDN RTS frame is transmitted using a simplified CSMA-CA.

This command shall only be sent by an LLDN device in an LLDN timeslot after tSlotTxOwner has been elapsed and an LLDN CTS Shared Group frame has been received from the LLDN PAN coordinator.

LLDN devices shall be capable of transmitting and receiving this command.

The command payload of the LLDN RTS frame shall be formatted as illustrated in .

|  |  |  |
| --- | --- | --- |
| **Octet: 1** | **1** | **1** |
| Command Frame Identifier (defined in Table 50) | Short Originator Address | LLD Network ID |

Figure G.14—LLDN Request To Send (RTC) command MAC payload

#### **MHR fields**

The LLDN RTS command shall be sent using LLDN MAC Command frames.

In the LLDN Frame Control field of the LLDN MAC Command frame, the Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN MAC Command frame, as shown in .

#### **Command Frame Identifier field**

The Command Frame Identifier field contains the value for the LLDN RTS frame as defined in Table 50.

#### **Short Originator Address field**

The Short Originator Address field contains the 1-octet simple address of the LLDN device sending this LLDN RTS frame.

#### **LLD Network ID field**

The LLD Network ID field contains an identifier specific to the LLDN PAN coordinator. It has to be identical to the LLD Network ID of the corresponding received LLDN CTS Shared Group frame.

### **LLDN Clear To Send (CTS) command**

#### **General**

The LLDN Clear To Send (CTS) command indicates to a specific LLDN device of the LLD star network that it may now use the LLDN timeslot for transmitting its own data with a simplified CSMA-CA. The LLDN CTS command is broadcast by the LLDN PAN coordinator in response to a received LLDN RTS command.

LLDN PAN coordinators shall be capable of transmitting this command, other LLDN devices shall be capable of receiving it.

The command payload of the LLDN CTS frame shall be formatted as illustrated in .

|  |  |  |
| --- | --- | --- |
| **Octet: 1** | **1** | **1** |
| Command Frame Identifier (defined in Table 50) | Short Destination Address | LLD Network ID |

Figure G.15—LLDN Clear To Send (CTS) command MAC payload

#### **MHR fields**

The LLDN CTS command shall be sent using LLDN MAC Command frames.

In the LLDN Frame Control field of the LLDN MAC Command frame, the Frame Type field shall contain the value that indicates an LLDN frame, as shown in Table 5, and the LLDN Frame Subtype field shall contain the value that indicates an LLDN MAC Command frame, as shown in .

#### **Command Frame Identifier field**

The Command Frame Identifier field contains the value for the LLDN CTS frame as defined in Table 50.

#### **Short Destination Address field**

The Short Destination Address field contains the 1-octet simple address of the LLDN device to which this LLDN CTS frame is directed.

#### **LLD Network ID field**

The LLD Network ID field contains an identifier specific to the LLDN PAN coordinator that shall be identical to the LLD Network ID of the corresponding received LLDN RTS frame.

## LLDN primitives

### **General**

When the optional LLDN mode is implemented (i.e., *macLLenabled* = TRUE), the services shown in shall be implemented. These LLDN primitives control the different LLDN modes for the LLDN configuration and LLDN operation of the LLDN superframe in an LLDN.

Table G.5—LLDN primitives

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name** | **Request** | **Indication** | **Response** | **Confirm** |
| MLME-LLDN-DISCOVERY |  G.4.2 | — | — |  G.4.3 |
| MLME-LLDN-CONFIGURATION |  G.4.4 | — | — |  G.4.5 |
| MLME- LLDN-ONLINE |  G.4.6 |  G.4.7 | — | — |

### **MLME-LLDN-DISCOVERY.request**

This primitive switches the LLDN into the LLDN Discover state.

The semantics of this primitive are:

 MLME-LLDN-DISCOVERY.request (

 LowLatencyNetworkConfiguration

 )

The primitive parameters are defined in .

Table G.6—MLME-LLDN-DISCOVERY.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| LowLatencyNet- workConfiguration | Set of octets of variable length | ⎯ | Contains the necessary LLDN configuration parameters from the next higher layer for the LLDN in LLDN Discovery state |

The MLME-LLDN-DISCOVERY.request primitive is generated by the next higher layer of an LLDN PAN coordinator and issued to its MLME to switch the LLDN into the LLDN Discovery state as described in G.xxx.

When the MLME of an LLDN PAN coordinator receives the MLME-LLDN-DISCOVERY.request primitive, it sets the Transmission State field in the LLDN Beacon Flags field of the payload of the LLDN Beacons to the value for LLDN Discovery state as defined in G.2.2 and follows the procedures as defined for LLDN Discovery state in G.xxx.

### **MLME-LLDN-DISCOVERY.confirm**

This primitive indicates the end of the LLDN Discover state and gives the status of the LLDN Discovery state to a higher layer.

The semantics of this primitive are:

 MLME-LLDN-DISCOVERY.confirm (

 status,

 DiscoveredDevices,

 LowLatencyNetworkConfiguration

 )

The primitive parameters are defined in .

Table G.7—MLME-LLDN-DISCOVERY.confirm parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| status | Enumeration | SUCCESS, NO\_LLDN\_DEVICE, ABORTED | The status of the LLDN Discovery state when finished. |
| DiscoveredLLDN-Devices | Integer | 0 .. 128 | Number of discovered LLDN devices. |
| LowLatencyNetwork- Configuration | Set of octets of variable length | — | Discovered information of the discovered LLDN devices of the LLDN for the next higher layer |
| DiscoveryModeStatus | ? | ? | ? |

The MLME-LLDN-DISCOVERY.confirm primitive is generated by the MLME of the LLDN PAN coordinator and issued to its next higher layer to indicate the end of the LLDN Discovery state in the LLDN. It returns the number of discovered LLDN devices and the collected information about the discovered LLDN devices in the LLDN to the next higher layer. The MLME-LLDN-DISCOVERY.confirm primitive will either return a status SUCCESS, indicating that all LLDN devices with *macLLenabled* set to TRUE within range have been discovered, or an error code of NO\_LLDN\_DEVICE (expected to discover LLDN device, but none found) or ABORTED (LLDN Discovery state finished before all devices had been discovered).

When the next higher layer of an LLDN PAN coordinator receives the MLME-LLDN-DISCOVERY.confirm primitive, the LLDN PAN coordinator determines a configuration of the LLDN based on the status and the information about the discovered LLDN devices received in DiscoveredLLDNDevices and LowLatencyNetworkConfiguration DiscoveryModeStatus. It uses an algorithm outside the scope of this standard. The next higher layer of the LLDN coordinator should then issue the MLME-LLDN-CONFIGURATION.request primitive to its MLME.

### **MLME-LLDN-CONFIGURATION.request**

This primitive switches the LLDN into the LLDN Configuration state.

The semantics of this primitive are:

 MLME-LLDN-CONFIGURATION.request (

 LowLatencyNetworkConfiguration

 )

The primitive parameters are defined in .

Table G.8—MLME-LLDN-CONFIGURATION.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| LowLatencyNet- workConfiguration | Set of octets of variable length | — | Contains the necessary configuration parameters for the LLDN in the LLDN Configuration state |

The MLME-LLDN-CONFIGURATION.request primitive is generated by the next higher layer of an LLDN PAN coordinator and issued to its MLME to switch the LLDN into the LLDN Configuration state as described in G.xxx.

When the MLME of an LLDN PAN coordinator receives the MLME-LLDN-CONFIGURATION.request primitive, it sets the Transmission State field in the LLDN Beacon Flags field of the payload of the LLDN Beacons to the value for the LLDN Configuration state as indicated in G.2.2 and follows the procedures as defined for LLDN Configuration state in G.xxx.

### **MLME-LLDN-CONFIGURATION.confirm**

This primitive indicates the end of the LLDN Configuration state and gives the status of the LLDN Configuration state to the next higher layer.

The semantics of this primitive are:

 MLME-LLDN-CONFIGURATION.confirm (

 status,

 ConfiguredDevices,

 LowLatencyNetworkConfiguration

 )

The primitive parameters are defined in .

Table G.9—MLME-LLDN-CONFIGURATION.confirm parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| status | Enumeration | SUCCESS, NO\_LLDN\_DEVICE, ABORTED | The status of the LLDN Configuration state when finished. |
| ConfiguredLLDN-Devices | Integer | 0 .. 128 | Number of configured LLDN devices. |
| LowLatencyNetwork- Configuration | Set of octets of variable length | ⎯ | Configuration of the configured LLDN devices of the LLDN for the next higher layer. |

The MLME-LLDN-CONFIGURATION.confirm primitive is generated by the MLME of the LLDN PAN coordinator and issued to its next higher layer to indicate the end of the LLDN Configuration state in the LLDN. It returns the number of configured LLDN devices and the collected LLDN configuration information about the configured LLDN devices in the LLDN to the next higher layer. The MLME-LLDN-CONFIGURATION.confirm primitive will either return a status SUCCESS, indicating that all LLDN devices with *macLLenabled* set to TRUE within range have been configured, or an error code of NO\_LLDN\_DEVICE (expected to configure device, but none found) or ABORTED (LLDN Configuration state finished before all discovered LLDN devices had been configured).

When the next higher layer of an LLDN PAN coordinator receives the MLME-LLDN- CONFIRMATION.confirm primitive, the next higher layer of the LLDN PAN coordinator should issue the MLME-LLDN-ONLINE.request (status is SUCCESS), the MLME-LLDN-CONFIGURATION.request (status is ABORTED), or the MLME-LLDN-DISCOVERY.request (status is NO\_LLDN\_DEVICE) primitive to its MLME.

### **MLME-LLDN-ONLINE.request**

This primitive switches the LLDN into the LLDN Online state.

The semantics of this primitive are:

 MLME-LLDN-ONLINE.request (

 )

The MLME-LLDN-ONLINE.request primitive is generated by the next higher layer of an LLDN PAN coordinator and issued to its MLME to switch the LLDN into the LLDN Online state (G.xxx).

When the MLME of an LLDN PAN coordinator receives the MLME-LLDN-ONLINE.request primitive, the LLDN PAN coordinator shall switch over to LLDN Online state by setting appropriate flags in its LLDN Beacon payload, as described in G.2.2, and follows the procedures as defined for LLDN Online state in G.xxx.

### **MLME-LLDN-ONLINE.indication**

This primitive indicates any problems during the LLDN Online state to the next higher layer.

The semantics of this primitive are:

 MLME-LLDN-ONLINE.indication (

 status,

 AdditionalInformation

 )

The primitive parameters are defined in .

Table G.10—MLME-LLDN-ONLINE.indication parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| status | Enumeration | NONE, UNSPECIFIED | Contains the status in the LLDN including any discovered problems. |
| AdditionalInformation | Set of octets of variable length | ⎯ | Additional supporting information |

The MLME-LLDN-ONLINE.indication primitive is generated by the MLME of any LLDN device and issued to its next higher layer to indicate the status and any problems that occurred in the LLDN during the operation in LLDN online mode. It returns the indication of the problem (NONE or UNSPECIFIED) and the additional supporting information to the higher layer.

When the next higher layer of an LLDN device receives the MLME-LLDN-ONLINE.indication primitive, the LLDN device determines appropriate countermeasures using an algorithm outside the scope of this standard.

## LLDN specific MAC PIB attributes

In Low Latency Deterministic Networks (LLDNs), 8.4.2 applies. Additional MAC PIB attributes are required for LLDNs. These are stated in . Some MAC PIB attributes have a different default value in LLDNs as stated in .

Table G.11—LLDN specific MAC PIB attributes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Attribute** | **Type** | **Range** | **Description** | **Default** |
| *macLLDNnum- TimeSlots* | Integer | 0 … 254 | Number of LLDN base timeslots within LLDN superframe excluding LLDN timeslot for LLDN Beacon frame and LLDN management timeslots | 20 |
| *macLLDNnum- UplinkTS* | Integer | 0 … *macLLDNnum- TimeSlots* | Number of uplink LLDN base timeslots within LLDN superframe for unidirectional communication (uplink) as defined in G.xxx. | 20 |
| *macLLDNnum- RetransmitTS* | Integer | 0 … *macLLDNnum- UplinkTS/2* | Number of uplink LLDN base timeslots reserved for retransmission | 0 |
| *macLLDNnum- BidirectionalTS* | Integer | 0 … *macLLDNnum- TimeSlots* | Number of bidirectional LLDN base timeslots as defined in G.xxx within LLDN superframe for bidirectional communication | 0 |
| *macLLDNmgmtTS* | Boolean | TRUE or FALSE | Indicates presence of LLDN management timeslots in LLDN Online state | FALSE |
| *macLLDNlow- LatencyNWid* | Integer | 0x00–0xff | The 8-bit identifier of the LLDN on which the LLDN device is operating. If this value is 0xff, the LLDN device is not associated. | 0xff |
| *macLLDNtime- SlotInfo* | Imple- men- tation specific |  | Information related to a LLDN base timeslot, for instance, MAC addresses mapped to the LLDN base timeslot. For the LLDN PAN coordinator, there are *macLLDNnumTimeSlots* attributes of *macLLDNtimeSlotInfo*. | Set during LLDN Configu- ration state |
| *macLLDN- discoveryMode- Timeout* | Integer | 0…256 | The LLDN PAN coordinator switches from the LLDN Discovery state into the LLDN Configuration state after it did not receive an LLDN Discover Response Frame within the last *macLLDNdiscoveryModeTimeout* seconds. | 256 |
| *macLLDN- coordinator* | Boolean | TRUE or FALSE | Indicates whether the LLDN device is the LLDN PAN coordinator | FALSE |

Some MAC PIB attributes of Table 113 have a different default value in Low Latency Deterministic Networks (LLDNs). lists LLDN specific settings of these MAC PIB attributes of Table 133.

Table G.12—LLDN specific settings of MAC PIB attributes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Attribute** | **Type** | **Range** | **Description** | **Default** |
| macMaxBE | Integer | 3–8 | The maximum value of the backoff exponent, BE, in the CSMA-CA algorithm, as defined in G.xxx. | 3 |
| macMaxCSMABackoffs | Integer | 0–5 | The maximum number of backoffs the CSMA-CA algorithm will attempt before declaring a channel access failure. | 0 |

***To Editor: Not clear where to insert the text below (clause 6.4.3 and 6.4.3.1 [15.4e])***

**6.4.3 Calculating PHY dependent MAC PIB values**

***Insert after the heading of 6.4.3, the following new subclause header:***

**6.4.3.1 General**

***Insert the following paragraph as the last text paragraph of 6.4.3.1:***

If *macLLenabled* is TRUE, the attribute *macAckWaitDuration* is dependent on the acknowledgment method used and the timings of the superframe of the LLDN.