**IEEE P802.15**

**Wireless Personal Area Networks**

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| --- | --- |
| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | Proposed Resolution for LB#85 CID 284~287  |
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| Re: | [] |
| Abstract | LB #85 Comment Resolution for the Time-slot Relaying based Link Extension  |
| Purpose | Draft standard development |
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**CID 284-287:**

*Move TRLE into the main body and insert normative statements where required to yield an interoperable behavior.*

*Add the MAC functional description on time-slot relaying to clause 5.1: frame reception at the TRLE repeater and TRLE relaying function.*

*Add the MAC functional description on link establishment between the TRLE-enabled PAN coordinator and a TRLE repeater to clause 5.1. To support TRLE link establishment, add the MAC frame formats to clause 5.2, add the MAC command to clause 5.3, and add MAC management service to clause 6.2.*

*Add the MAC data service to support transmission on the TRLE path from the TRLE PAN coordinator to a TRLE enabled device to clause 6.3.*

**Resolution: Accept in Principle**

*See document 15-12-0565-00-004k*

*Insert the following to the draft*

**----------------------------------------------------------------------------------------------------------------------------**

1. Definitions, Acronyms and Abbreviations
	1. Definitions

***Insert the following definitions alphabetically into 3.1:***

**repeater:** A coordinator that relays IEEE Std 802.15.4 MAC frames either in the direction of the PAN coordinator or in the direction of a device.

* 1. Acronyms

***Insert the following acronyms alphabetically into 3.2:***

TRLE time-slot relaying based link extension

* + - 1. Low energy extension of networking coverage by synchronous relaying

***Insert the following sentence at the end of 4.5.5.3:***

A repeater may provide relaying of the frames inward or outward between the PAN coordinator and a device, in order to extend the coverage of a star network.

5.1.6.2 Reception and rejection

***Change the fourth paragraph of 5.1.6.2 as indicated:***

The second level of filtering shall be dependent on whether the MAC sublayer is currently operating in promiscuous mode or in relaying mode. In promiscuous mode, the MAC sublayer shall pass all frames received after the first filter directly to the upper layers without applying any more filtering or processing. The MAC sublayer shall be in promiscuous mode if *macPromiscuousMode* is set to TRUE.

***Insert the following paragraph after the end of the fourth paragraph of 5.1.6.2:***

In relaying mode (i.e., *macRelayingMode* is set to TRUE), the MAC sublayer shall process frames, which satisfy all of the following requirements, as described in 5.1.6.7:

— The Frame Type field shall not contain a reserved frame type.

— The Frame Version field shall not contain a reserved value.

— If a destination PAN identifier is included in the frame, it shall match macPANId or shall be the broadcast PAN identifier.

***Change the fifth paragraph of 5.1.6.2 as indicated:***

If the MAC sublayer is not in promiscuous mode (i.e., *macPromiscuousMode* is set to FALSE) or not in relaying mode (i.e., *macRelayingMode* is set to FALSE), it shall accept only frames that satisfy all of the following third-level filtering requirements:

***Insert the following new subclause (5.1.6.7) before 5.1.7:***

5.1.6.7 Relaying mode

When in relaying mode, the MAC sublayer either passes the frame to the next higher layer or relays the frame onward.

If a short destination address included in the frame matches *macShortAddress*, or if an extended destination address included in the frame matches *macExtendedAddress*, the frame shall be handled as per this standard for non-TRLE devices.

If a short destination address included in the frame doesn’t match *macShortAddress*, or if an extended destination address included in the frame doesn’t match *macExtendedAddress*, the frame shall be relayed at the MAC sublayer, as described in 5.1.13. The MLME shall perform the security process on the relayed frame, according to 7.2.1.

***Insert the following new subclauses (5.1.13) after 5.1.12.5:***

* + 1. Time-slot Relaying based Link Extension (TRLE)
			1. General

The TRLE repeater extends the link of a beacon-enabled star topology PAN by relaying frames inward or outward between the PAN coordinator and a device. The TRLE repeater in the IEEE 802.15.4 beacon-enabled PAN or the IEEE 802.15.4 DSME-enabled PAN provides one-hop relaying. The TRLE PAN coordinator may provide multi-hop relaying path with the TRLE repeaters. The TRLE repeater may be used in several beacon enabled PAN configurations, as shown in Figure x.1: (a) GTS/DSME PAN coordinator – TRLE repeater – GTS/DSME device, (b) TRLE PAN coordinator – TRLE repeater – GTS/DSME device, (c) TRLE PAN coordinator – TRLE repeater – TRLE device.

 

Figure x.1-Usage of a TRLE repeater

A FFD shall perform as a TRLE repeater, if PIB attribute *macRelayingMode* and *macTRLEenabled* are set to TRUE. A RFD shall perform as a TRLE device, if PIB attribute *macTRLEenabled* is set to TRUE.

* + - 1. Relaying frames

One or more repeaters may exist between the PAN coordinator and an end device. For any given repeater a neighboring repeater closer to the PAN coordinator is called an inner repeater and a repeater closer to the endpoint is called an outer repeater. Beacon frames from the PAN coordinator received by repeaters within the transmission range of the PAN coordinator form tier 1 of the TRLE-enabled PAN. The repeaters that are within a transmission range of the tier 1 repeaters, but not within PAN coordinator range, form tier 2 of the TRLE-enabled PAN, and so on, as illustrated in Figure x.2. The relaying of a TRLE-enabled PAN is limited to seven tiers.



Figure x.2-Hierarchy of relaying in the TRLE-enabled PAN

The TRLE repeater can identify the transmission direction of a received frame and retransmit the frame at a time slot that is delayed by a multiple of superframe durations, but aligned synchronously to the PAN coordinator, as shown in Figure x.3.

The beacon generated by the PAN coordinator is relayed outward after a unique repeater delay to avoid interfering with other beacons from neighboring repeaters. For a GTS-enabled PAN and DSME-enabled PAN, the delay duration for relaying is determined by the repeater. When a repeater associates with a TRLE-enabled PAN coordinator, the delay is assigned by the TRLE PAN coordinator. The algorithm for choosing the delay duration for relaying is outside the scope of this standard.

In a GTS-enabled PAN, frames that are received in the CAP of the superframe from the PAN coordinator are retransmitted in the CAP of the superframe generated by the TRLE repeater. The frames received in a CFP from the PAN coordinator are relayed in the CFP of the outward superframe that contains an outward beacon time slot.

In a DSME-enabled PAN, frames received from the PAN coordinator are retransmitted after a unique outward repeater delay, and frames received from the device are retransmitted after a unique inward repeater delay.

In a TREL-enabled PAN, frames are relayed as described in 5.1.13.3.



Figure x.3-Synchronous frame relaying (a) outward relaying (b) inward relaying

* + - 1. Cyclic-superframe for multi-hop relaying

The TRLE-enabled PAN coordinator and repeater use the cyclic-superframe structure. The cyclic-superframe structure is based on the DSME multi-superframe structure, as illustrated in Figure x.4. The CAP is divided into time slots for transmitting a frame to the PAN coordinator (i.e. the prioritized device time slot) and time slots for transmitting a frame to endpoint devices (i.e. the coordinator time slot). The prioritized device time slot starts after the beacon and continues for a preset number of time slots, *macNumPrioritizedDeviceSlot*. The coordinator time slot starts after the prioritized device time slot and continues for a preset number of time slots, *macNumCoordSlot*. The time slot in CFP is bidirectional (i.e the bidirectional device time slot).



Figure x.4-Time slots in a TRLE cyclic-superframe

At a TRLE repeater, frames in a cyclic-superframe are relayed either outward or inward. The beacon generated by the TRLE PAN coordinator is relayed outward after a unique outward repeater delay, which is the distance from incoming beacon slot to the outgoing beacon slot and measured with the number of superframe duration. The frame received in a prioritized device time slot is relayed inward within the prioritized device time slot or after one superframe duration delay, if transmission will not finished by the end of the prioritized device time slot. The frame received in a coordinator time slot is relayed outward within the coordinator time slot or after one superframe duration delay, if transmission will not finished by the end of the coordinator time slot. The frame received in a bidirectional device time slot from outer repeater is relayed inward after a unique inward repeater delay, as shown in Figure x.3.

* + - 1. Forming a TRLE path
				1. One-hop relaying for a GTS or DSME-enabled PAN

A FFD with PIB attribute *macRelayingMode* set to TRUE and *macTRLEcapable* set to TRUE, shall associate as a repeater with the GTS or DSME-enabled PAN, as described in 5.1.3.1.

After completing association, the next higher layer shall initiate the repeater by issuing the MLME-TRLE-MANAGEMENT.request primitive with ManagementType parameter set to RELAY\_ON and OutwardRepeaterDelay parameter. The next higher layer shall be notified of the result of initiating the repeater through the MLME-TRLE-MANAGEMENT.confirm primitive.

The repeater shall begin to relay frames, as described in 5.1.13.2. Frames received from the PAN coordinator are retransmitted after *superframe duration\*OutwardRepeaterDelay* delay. Frames received from the device are retransmitted after *superframe duration\*(2(BO-SO)-OutwardRepeaterDelay)* delay.

If the repeater wants to leave the PAN, the next higher layer shall halt the repeater by issuing the MLME-TRLE-MANAGEMENT.request primitive with ManagementType parameter set to RELAY\_OFF. The next higher layer shall be notified of the result of halting the repeater through the MLME-TRLE-MANAGEMENT.confirm primitive.

After halting the repeater, the repeater shall disassociate with the GTS or DSME-enabled PAN, as described in 5.1.3.2.

* + - * 1. Starting a TRLE-enabled PAN

A TRLE-enabled PAN should be started by an FFD with PIB attribute *macTRLEenabled* set to TRUE, only after having first performed a MAC sublayer reset, an active channel scan, and a suitable PAN identifier selection.

An FFD is instructed to begin operating as the TRLE-enabled PAN coordinator through the use of the MLME-START.request primitive, as described in 6.2.12.1, with the PANCoordinator parameter set to TRUE, the CoordRealignment parameter set to FALSE, and TRLESuperframeSpecification. On receipt of this primitive, the MAC sublayer shall update the cyclic-superframe configuration and channel parameters. After completing this, the MAC sublayer shall issue the MLME-START.confirm primitive, as described in 6.2.12.2, with a status of SUCCESS and begin operating as the TRLE-enabled PAN coordinator.

A TRLE-enabled PAN is formed when the PAN coordinator advertises the presence of the network by sending enhanced beacons in the cyclic-superframe beacon slot. The enhanced beacon contains the TRLE-enabled PAN descriptor IE:

* Cyclic-superframe specification, as defined in 5.2.4.30.1
* Time synchronization specification, as defined in 5.2.4.30.2
* Synchronous relaying information, as defined in 5.2.4.30.3
	+ - * 1. Multi-hop relaying for a TRLE-enabled PAN

A FFD with PIB attribute *macRelayingMode* set to TRUE and *macTRLEenabled* set to TRUE, shall associate as a TRLE repeater with the TRLE-enabled PAN.

The next higher layer instructs a FFD to perform a MAC sublayer reset and to complete either an active or a passive channel scan, as defined in 5.1.2.1.2. The results of the channel scan would have then been used to choose a suitable PAN and to select an inner coordinator, TRLE-enabled PAN coordinator or an inner TRLE repeater, through which it wishes to associate.

The next higher layer shall request through the MLME-ASSOCIATE.request primitive with tier identifier of the repeater, as described in 6.2.2.1:

* TRLE-enabled PAN information (*phyCurrentChannel, phyCurrentPage, macPANId*)
* Inner coordinator information (*macCoordExtendedAddress or macCoordShortAddress*)
* TRLE device information (*macRelayingTier*)

The repeater shall try to associate by sending a TRLE-Association request command, as described in 5.3.15.1. If the inner coordinator is an inner repeater on the TRLE path to the TRLE PAN coordinator, a TRLE-Association request command is relayed to the TRLE PAN coordinator.

The TRLE PAN coordinator indicates the reception of a TRLE-Association request command through the MLME-ASSOCIATE.indication primitive, as described in 6.2.2.2. The next higher layer of the TRLE PAN coordinator shall determine whether to accept or reject the device as a TRLE repeater and select outward repeater delay to transmit a cyclic-superframe of the device requesting association.

The next higher layer of the TRLE PAN coordinator initiates a response using an MLME-ASSOCIATE.response primitive with outward repeater delay and a bitmap on superframes in a cyclic-superframe occupied for transmitting a beacon from the neighboring devices around the inner coordinator, as described in 6.2.2.3.

When the MLME of the TRLE PAN coordinator receives the MLME-ASSOCIATE.response primitive, it generates a TRLE-Association response command, as described in 5.3.15.2, and attempts to send command to the repeater requesting association.

The TRLE-Association response command is relayed to the repeater. The repeater requesting association informs the next higher layer of the association response by using an MLME-ASSOCIATE.confirm primitive, as described in 6.2.2.4.

After completing association, the next higher layer shall initiate the repeater by issuing the MLME-TRLE-MANAGEMENT.request primitive with ManagementType parameter set to RELAY\_ON and OutwardRepeaterDelay parameter. The next higher layer shall be notified of the result of initiating the repeater through the MLME-TRLE-MANAGEMENT.confirm primitive.

The repeater shall begin to relay frames, as described in 5.1.13.3. The TRLE path is formed from the TRLE PAN coordinator to the TRLE repeater requesting association.

If the repeater wants to leave the PAN, the next higher layer shall halt the repeater by issuing the MLME-TRLE-MANAGEMENT.request primitive with ManagementType parameter set to RELAY\_OFF. The next higher layer shall be notified of the result of halting the repeater through the MLME-TRLE-MANAGEMENT.confirm primitive.

After halting the repeater, the repeater shall disassociate with the TRLE-enabled PAN, as described in 5.1.3.2. The disassociation notification command shall be relayed to the TRLE PAN coordinator.

* + - * 1. Time slot allocation for a TRLE-enabled device

A RFD with PIB attribute *macTRLEenabled* set to TRUE, shall associate as a TRLE device with the TRLE-enabled PAN. The bidirectional device time slots for the TRLE device may be pre-assigned or allocated during the association procedure.

For allocating device time slots during the association, the length of bidirectional device time slots shall be provided as a parameter of ASSOCIATE.request primitive by the next higher layer, addition to the TRLE-enabled PAN information, Inner coordinator information, and TRLE device information.

The MLME shall send a TRLE-Association request command, as described in 5.3.15.1. The TRLE-Association request command is relayed to the TRLE PAN coordinator.

The TRLE PAN coordinator indicates the reception of a TRLE-Association request command through the MLME-ASSOCIATE.indication primitive, as described in 6.2.2.2. The next higher layer of the TRLE PAN coordinator shall determine whether to accept or reject the device as a TRLE device and assign primary bidirectional time slots and supplementary time slots for the TRLE device.

The next higher layer of the TRLE PAN coordinator initiates a response using an MLME-ASSOCIATE.response primitive with the identifier of the allocated device time slot, as described in 6.2.2.3.

On reception the MLME-ASSOCIATE.response primitive, the MLME of the TRLE PAN coordinator generates a TRLE-Association response command, as described in 5.3.15.2, and attempts to send command to the device requesting association.

The TRLE-Association response command is relayed to the device. The device requesting association informs the next higher layer of the association response by using an MLME-ASSOCIATE.confirm primitive, as described in 6.2.2.4.

* + - 1. TRLE time slot usage

In a TRLE-enabled PAN, to accommodate various quality of service requirements for relaying frames between the PAN coordinator and a device, three grades of synchronous access are provided: grade 0 for transmitting delay sensitive data, grade 1 for the reliable transmission of data, and grade 2 for the best effort data transmission.

For grade 0 link access, a device first searches the earliest prioritized device time slot. If the device fails to transmit the data in the prioritized device time slot, the device will continue trying to transmit the data in either a bidirectional time slot or in another prioritized device time slot, whichever comes first.

A device using grade 1 link access waits for the primary bidirectional time slot in the cyclic-superframe and transmits the data. If the device fails to transmit the data in the primary bidirectional time slot, the device will keep searching supplementary bidirectional time slots for the duration of the cyclic-superframe or will search the coming cyclic-superframe for an opportunity to transmit the data.

A device using grade 2 link access waits for the primary bidirectional time slot in the cyclic-superframe and transmits the data without requiring an acknowledgment.

The next higher layer of a TRLE-enabled device begins data transmission by issuing the MCPS-DATA.request primitive with the TRLE Relaying specification IE ID and the grade of link access, as described in 6.3.1.

On receipt of the MCPS-DATA.request primitive, the MAC sublayer entity transmits data frame in the TRLE time slot selected according to the grade of link access.

The data frame shall be relayed in the TRLE time slot selected according to the grade of link access to the destination device.

* + - 1. TRLE path management

The repeaters and end points in a TRLE-enabled PAN shall be synchronized with the clock time of the PAN coordinator after joining the TRLE-enabled PAN. The TRLE-enabled PAN coordinator advertise the clock time of the TRLE-enabled PAN outward to the repeaters and end points via the Time Synchronization Specification field of the TRLE-enabled PAN descriptor IE in beacon frame (5.2.4.30). The clock time of the TRLE-enabled PAN is distributed by a repeater via the Time Synchronization Specification field of the TRLE acknowledgment descriptor IE in acknowledgment frame (5.2.4.32) and the TRLE-Management response command (5.3.15.4).

The repeaters and end points compensate for the clock drift based on the statistical variance of the difference in the real start time of a given slot and the expected start time. The selection of a slot to be measured for collecting statistical data depends on the frame type carrying the time synchronization specification and the grade of link access. In the beacon frame, the Time Synchronization Specification field contains the start time of the beacon slot. In the acknowledgment frame and the TRLE-Management response command frame with grade 0 link access, the Time Synchronization Specification field contains the start time of the coordinator slot. In the acknowledgment frame and the TRLE-Management response command frame with grade 1 link access, the Time Synchronization Specification field contains the start time of the primary bidirectional device slot.

After starting a TRLE-enabled PAN, the PAN coordinator may check the status of a device, collect information on the configuration of repeaters on the TRLE relaying paths, and control the transmission power of a device with the TRLE management procedure.

To search activated devices on the relaying path, the PAN coordinator issues the MLME-TRLE-MANAGEMENT primitives with the ManagementType attribute set to HELLO, as described in 6.2.23. The TRLE management request command with the Management Type field set to indicate HELLO is relayed to the destination device. The destination device reports the current configuration of all the devices on the relaying path beyond the destination device, as defined in 5.3.15.4.2.

To get information on the device configuration, the PAN coordinator issues the MLME-TRLE-MANAGEMENT primitives with the ManagementType attribute set to DEVICE, as described in 6.2.23. The TRLE management request command with the Management Type field set to indicate DEVICE is relayed to the destination device. The destination device reports the current configuration, as defined in 5.3.15.4.2.

To get information on the relaying path configuration, the PAN coordinator issues the MLME-TRLE-MANAGEMENT primitives with the ManagementType attribute set to PATH. The destination device reports the relaying path configuration identified at the device, as defined in 5.3.15.4.3.

To get information on the transmission power of a device, the PAN coordinator issues the MLME-TRLE-MANAGEMENT primitives with the ManagementType attribute set to POWER\_CONFIG. To control the transmission power of a device, the PAN coordinator issues the MLME-TRLE-MANAGEMENT primitives with the ManagementType attribute set to POWER\_CNTL. The requested transmission power is sent in PHY TX Power field of the Power Management Descriptor field, as defined in 5.3.15.4.4.

* 1. MAC frame formats
		1. Format of individual frame types
			1. Beacon frame format
				1. Information Elements fields

***Insert the following new row at the end of Table 3b:***

Table 3b-EBR IEs per enabled attribute

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute Request Identifier | PIB attribute | IE type | IEs to include |
| 5 | *macTRLEenabled* | Header | TRLE-enabled PAN Descriptor (5.2.4.30), TRLE Relaying Specification (5.2.4.31), TRLE ACK Descriptor (5.2.4.32) |

* + 1. Information element
			1. General
			2. Header Information Elements

***Insert the following new rows in Table 4b:***

Table 4b-Element IDs, Header IEs

|  |  |  |  |
| --- | --- | --- | --- |
| Element ID | Content length | Name | Description |
| TBD | Variable | TRLE-enabled PAN Descriptor | As defined in 5.2.4.30 |
| TBD | 2 | TRLE Relaying Specification | As defined in 5.2.4.31 |
| TBD | Variable | TRLE ACK Descriptor | As defined in 5.2.4.32 |

***Insert the following new subclauses (5.2.4.30-5.2.4.32) after 5.2.4.29:***

* + - 1. TRLE-enabled PAN descriptor IE

The TRLE-enabled PAN descriptor IE shall be included in enhanced beacons that are sent in a TRLE-enabled PAN.

The TRLE-enabled PAN descriptor IE shall be formatted as illustrated in Figure 48ns.

|  |  |  |
| --- | --- | --- |
| Octets: 2 | Octets: 6 | Variable |
| Cyclic-superframe Specification | Time Synchronization Specification | Synchronous Relaying Specification |

Figure 48ns- TRLE-enabled PAN Descriptor IE

* + - * 1. Cyclic-superframe Specification field

The cyclic-superframe Specification field shall be formatted as illustrated in Figure 48nt.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bits: 0-3 | 4-7 | 8-11 | 12-13 | 14-15 |
| Beacon Order | Superframe Order | Multi-superframe Order | Number of Prioritized device slot | Number of Coordinator slot |

Figure 48nt-Cyclic-superframe Specification field format

The Beacon Order field is described in 5.2.2.1.2.

The Superframe Order field is described in 5.2.2.1.2.

The Mulit-superframe Order field is described in 5.2.4.9.1.

The Number of Prioritized device time slot field shall specify the number of time slots in a superframe assigned to the devices for prioritized inward transmission as described in 5.1.13.3.

The Number of Coordinator time slot field shall specify the number of time slots in a superframe assigned to the coordinator for outward transmission as described in 5.1.13.3.

* + - * 1. Time Synchronization Specification field

The Time Synchronization Specification field is the timestamp in units of microseconds. It shall specify the start time of the slot in which the frame is transmitted.

* + - * 1. Synchronous Relaying Specification field

The Synchronous Relaying Specification field shall be formatted as illustrated in Figure 48nu.

|  |  |
| --- | --- |
| Octets: 2 | 1/2/4/8/16/32/64 |
| Relaying Specification | Beacon Bitmap |

Figure 48nu- Synchronous Relaying Specification field format

The Relaying Specification field has the same format as the content of the TRLE Relaying Specification IE described in 5.2.4.31.

The Beacon Bitmap field contains the bitmap indicating the beacon slot of the superframe reserved for transmitting a beacon from neighboring devices, which are the repeaters on the peer relaying tier, the repeaters on the one-hop inner relaying tier, and the repeaters on the one-hop outer relaying tier. Each corresponding bit in the bitmap shall be set to one if the beacon slot of the superframe is occupied, otherwise it is set to zero. The length of beacon bitmap will be 2(*macBeaconOrder* – *macSuperframeOrder* – 3) bits and is limited to 64 Octets (i.e. (*macBeaconOrder* – *macSuperframeOrder)≤* 9).

* + - 1. TRLE Relaying specification IE

The TRLE Relaying specification IE shall be included in data, acknowledgment, and MAC command frames that are sent in a TRLE-enabled PAN.

The TRLE Relaying specification IE shall be formatted as illustrated in Figure 48nw.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bits: 0-2 | 3 | 4-5 | 6 | 7-15 |
| Relaying Tier Identifier | Relaying Direction | Grade of Link access | Reference of Relaying Sync Indicator | Superframe Index |

Figure 48nw- TRLE Relaying specification IE

The Relaying Tier Identifier field contains the number of relaying tier that generated a frame. A value of zero shall indicate the PAN coordinator.

The Relaying Direction field shall be set to one if the frame is relayed outward, otherwise it is set to zero.

The Grade of Link access field is defined in Table 46.

The Reference of Relaying Sync Indicator field shall be set to one if a superframe is the first slotted-superaframe of a cyclic-superframe, otherwise it shall be set to zero.

The Superframe Index field contains the index of the superframe transmitting a frame. The index of the first superframe within a cyclic-superframe of the PAN coordinator shall be set to zero.

* + - 1. TRLE ACK descriptor IE

The TRLE ACK descriptor IE shall be included in acknowledgment frames that are sent in a TRLE-enabled PAN.

The TRLE ACK descriptor IE shall be formatted as illustrated in Figure 48nx.

|  |  |  |
| --- | --- | --- |
| Octets: 1 | 6 | Variable |
| ACK Control Specification | Time Synchronization Specification(refer to 5.2.4.30.2) | List of DSN of the acknowledged frame |

Figure 48nx- TRLE ACK Descriptor IE

The ACK Control Specification field shall be formatted as illustrated in Figure 48ny.

|  |  |  |
| --- | --- | --- |
| Bits: 0-1 | 2-5 | 6-7 |
| ACK Type | Number of Group ACK frames | Reserved |

Figure 48ny- ACK Control Specification field format

The ACK Type, shown in Table xx, identifies the acknowledgment modes for relaying frames.

 Table xx- Values of the ACK Type field

|  |  |
| --- | --- |
| ACK Type valueb1 b0 | Description |
|
| 00 | End-to-end ACK |
| 01 | Link ACK |
| 10 | Group end-to-end ACK |
| 11 | Reserved |

The Number of Group ACK frames field contains an integer that represents the number of group acknowledged frames.

The List of DSN of the acknowledged frame field shall contain the sequence number of the frame acknowledged in Group end-to-end acknowledgment mode.

* 1. MAC command frames

***Insert the following new rows in Table 5:***

Table 5-MAC Command frames

|  |  |  |  |
| --- | --- | --- | --- |
| Command frame idnetifier | Command name | RFD | Subclause |
| Tx | Rx |
| TBD | TRLE-Association request |  |  | 5.3.15.1 |
| TBD | TRLE-Association response |  |  | 5.3.15.2 |
| TBD | TRLE-Management request | X | X | 5.3.15.3 |
| TBD | TRLE-Management response | X | X | 5.3.15.4 |

***Insert the following subclause (5.3.15) after 5.3.14:***

* + 1. TRLE commands

A *macTRLEcapable* FFD device in a TRLE-enabled PAN shall be capable of transmitting and receiving all command frame types defined in 5.3.15.1 and 5.3.15.2.

* + - 1. TRLE-Association request command

The TRLE-Association request command allows a device to request association with a TRLE-enabled PAN as a repeater through the PAN coordinator or an inner coordinator.

The TRLE-Association request command shall be formatted as illustrated in Figure 59dda.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Octets: variable | 1 | 1 | Bits:0-2 | 3-4 | 5-7 |
| MHR fields(5.2.2.4.1) | Command Frame Identifier(Table 1) | Capability Information(5.3.1.2) | Relaying Tier Identifier(5.2.4.31) | Reserved | Length of Device Time slots |

Figure 59dda-TRLE-Association request command format

* + - 1. TRLE-Association response command

The TRLE-Association response command allows the PAN coordinator or an inner coordinator to communicate the results of an association attempt back to the device requesting association.

The TRLE-Association response command shall be formatted as illustrated in Figure 59di.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: variable | 1 | 2 | 1 | Bits:0-2 | 3-6 | Bits:7-15 | Octets:2 | 2 | variable |
| MHR fields(refer to 5.2.2.4.1) | Command Frame Identifier(Table 1) | Short Address(5.3.2.2) | Association Status(5.3.2.3) | Relaying Tier Identifier(5.2.4.31) | Reserved | RelayingDelay(5.2.4.31) | Primary Device Time slot Index | Supplemenatry Device Time slot Index | Relaying Bitmap(5.2.4.30.3) |

Figure 59ddb-TRLE-Association response command format

The Primary Device Time slot Index and the Supplemenatry Device Time slot Index shall be formatted as illustrated in Figure 59ddba.

|  |  |  |
| --- | --- | --- |
| Bits:0-8 | 9-12 | Bits:13-15 |
| Superframe Index | Reserved | Time slot Index |

Figure 59ddba- Device Time slot Index field format

* + - 1. TRLE-Management request command

The TRLE-Management request command request is used by a device or the PAN coordinator to request information on the clock time, the device configuration, and the relaying path configuration, or to control the transmission power of a device.

The TRLE-Management request command shall be formatted as illustrated in Figure 59ddc.

|  |  |  |
| --- | --- | --- |
| Octets: variable | 1 | 1 |
| MHR fields(5.2.2.4.1) | Command Frame Identifier(Table 1) | Management Type |

Figure 59ddc-TRLE-Management request command format

The Management Type field shall be set one of the values listed in Table xx.

 Table 7c- Values of the Management Type field

|  |  |
| --- | --- |
| Management Type value | Description |
|
| 0x00 | Hello |
| 0x01 | Time |
| 0x02 | Device configuration |
| 0x03 | Relaying path configuration |
| 0x04 | Link power configuration |
| 0x05 | Link power control |
| 0x06 | Relay-on |
| 0x07 | Relay-off |
| 0x08~0xff | Reserved |

* + - 1. TRLE-Management response command

The TRLE-Management response command is used by the PAN coordinator or a device to announce the result of a request to inform the clock time, the device configuration, and the relaying path configuration, or a request to control the transmission power of a device.

The TRLE-Management response command shall be formatted as illustrated in Figure xx.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: variable | 1 | 1 | 1 | 0/6 | 0/variable | 0/variable | 0/variable |
| MHR fields(refer to 5.2.2.4.1) | Command Frame Identifier(defined in Table 5) | Management Type(refer to 5.3.15.3) | Management Status | Time Synchronization Specification(refer to 5.2.4.30.2) | Device Descriptor | Relaying Path Descriptor | Power Management Descriptor |

Figure 59ddd-TRLE-Management response command format

* + - * 1. Management Status field

The Management Status field shall be set as defined in Table xx.

Table 7d- Values of the Management Status field

|  |  |
| --- | --- |
| Management Status value | Description |
|
| 0x00 | Management request successful. |
| 0x01 | Management request denied. |
| 0x02 | Management request not reached. |
| 0x03-0x7f | Reserved |
| 0x80~0xff | Reserved for MAC primitive enumeration values. |

* + - * 1. Device Descriptor field

The Device Descriptor field shall be formatted as illustrated in Figure xx.

|  |  |
| --- | --- |
| Octets: 1 | variable |
| Device Descriptor Count | Device List |

Figure 59dde- TRLE Device Descriptor field format

The Device Descriptor Count field specifies the number of the Device Descriptors in the Device List field.

The Device Descriptor shall be formatted as illustrated in Figure xx.

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 2 | 2 | 2 | 2 |
| Relaying Specification(5.2.4.31) | Primary Bidirectional device time slot Index(5.2.4.30.4) | Inner Repeater Short Address | Inner Repeater Link Status |

Figure 59ddf- TRLE Device Descriptor format

The Superframe Index of the Relaying Specification field contains the index of the superframe designated as the reference of synchronous relaying. (i.e., *macRelayingSyncReference*)

The Inner Repeater Short Address field contains the short address of the repeater connected to the device in the direction of the PAN coordinator.

The Inner Repeater Link Status field shall be formatted as illustrated in Figure xx.

|  |  |
| --- | --- |
| Octets: 1 | 1 |
| Channel | avgLQI |

Figure 59ddg- Inner Repeater Link Status format

The Channel field specifies the channel index reported by the device. The avgLQI field contains the average received LQI of the channel specified in Channel field within *macLinkStatusStatisticPeriod* symbols, as described in Table 52h..

* + - * 1. Relaying Path Descriptor field

The Relaying Path Descriptor field shall be formatted as illustrated in Figure xx.

|  |  |
| --- | --- |
| Octets: 1 | variable |
| Repeater Descriptor Count | Repeater List |

Figure 59ddh- TRLE Relaying Path Descriptor field format

The Repeater Descriptor Count field specifies the number of the Repeater Descriptors in the Repeater List field.

The Repeater Descriptor shall be formatted as illustrated in Figure xx.

|  |  |
| --- | --- |
| Octets: 2 | 2 |
| Repeater Short Address | Relaying Specification(5.2.4.31) |

Figure 59ddi- Repeater Descriptor field format

The Superframe Index of the Relaying Specification field contains index of the superframe designated as the reference of synchronous relaying. (i.e., *macRelayingSyncReference*)

* + - * 1. Power Management Descriptor field

The Power Management Descriptor field shall be formatted as illustrated in Figure xx.

|  |  |  |
| --- | --- | --- |
| Octets: 1 | 1 | variable |
| PHY TX Power(Table 71) | RX Link Status Descriptor Count | RX Link Status List |

Figure 59ddj- TRLE Power Descriptor format

The PHY TX Power field specifies the transmit power of the device in dBm.

The RX Link Status Descriptor Count field specifies the number of the RX Link Status Descriptors in the RX Link Status List field.

The RX Link Status Descriptor field shall be formatted as illustrated in Figure xx.

|  |  |  |
| --- | --- | --- |
| Octets: 2 | 1 | variable |
| Repeater Short Address | Repeater Link Count | Repeater Link Status List(5.3.15.4.2) |

Figure 59ddk- TRLE RX Link Descriptor format

The Repeater Short Address field contains the short address of the repeater neighbored to the device inward or outward.

The Repeater Link Count field specifies the number of channels activated in the neighbored repeater.

1. MAC services
	1. Overview
	2. MAC management service

Table 8— **Summary of the primitives accessed through the MLME-SAP**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Name | Request | Indication | Response | Confirm |
| MLME-TRLE-MANAGEMENT | 6.2.23.1 | 6.2.23.2 | 6.2.23.3 | 6.2.23.4 |

* + 1. Association primitives
			1. MLME-ASSOCIATE.request

***Insert the following new parameter at the end of the list in 6.2.2.1 (before the closing parenthesis):***

 RelayingTierIdentifier,

 DeviceTimeslotLength

***Insert the following new row at the end of Table 9:***

Table 9—MLME-ASSOCIATE.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| RelayingTierIdentifier | Integer  | 0x00-07 | Tier of TRLE-enabled PAN of the device requesting association.The TRLE PAN coordinator : 0The TRLE repeater: 1~6The TRLE device: 7 |
| DeviceTimeslotLength | Integer | 0x00-07 | Specifies the length of bidirectional device time slot to be allocated |

The RelayingTierIdentifier specifies the location of the repeater requesting association in a TRLE-enabled PAN or indicates that the device requesting association is a TRLE device.

The DeviceTimeslotLength specifies the length of bidirectional device time slots for a TRLE device. This parameter will be provided only when RelayingTierIdentifier parameter set to 7.

* + - 1. MLME-ASSOCIATE.indication

***Insert the following new parameter at the end of the list in 6.2.2.2 (before the closing parenthesis):***

 RelayingTierIdentifier,

 DeviceTimeslotLength

***Insert the following new row at the end of Table 9:***

Table 10—MLME-ASSOCIATE.indication parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| RelayingTierIdentifier | Integer  | 0x00-07 | Tier of TRLE-enabled PAN of the device requesting association, as defined in Table 9. |
| DeviceTimeslotLength | Integer | 0x00-07 | Specifies the length of bidirectional device time slot to be allocated |

The RelayingTierIdentifier specifies the location of the repeater requesting association in a TRLE-enabled PAN or indicates that the device requesting association is a TRLE device.

The DeviceTimeslotLength specifies the length of bidirectional device time slots for a TRLE device.

* + - 1. MLME-ASSOCIATE.response

***Insert the following new parameters at the end of the list in 6.2.2.3 (before the closing parenthesis):***

 RelayingDelay,

RelayingBitmap,

PrimaryDeviceSlot,

SupplementaryDeviceSlot

***Insert the following new rows at the end of Table 11:***

Table 11—MLME-ASSOCIATE.response parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| RelayingDelay | Integer | 0x0000-0x0fff | Specifies the assigned superframe in which to start the cyclic-superframe of the device requesting association. |
| RelayingBitmap | Beacon bitmap | As specified by 5.2.4.30.3 | Indicates the superframes reserved for transmitting a beacon from the neighboring devices around the inner coordinator. |
| PrimaryDeviceSlot | Time slot index | As specified by 5.3.15.1 | Specifies the time slot of primary bidirectional device time slots |
| SupplementaryDeviceSlot | Time slot index | As specified by 5.3.15.1 | Specifies the time slot of supplementary bidirectional device time slots |

The RelayingDelay specifies the assigned superframe index in which the repeater requesting association starts the cyclic-superframe.

The RelayingBitmap contains the bitmap indicating the beacon slot of the superframe reserved for transmitting a beacon from neighboring devices. Each corresponding bit in the bitmap shall be set to one if the beacon slot of the superframe is occupied, otherwise it is set to zero.

The PrimaryDeviceSlot specifies the assigned time slot index in which the device requesting association uses for primary bidirectional device time slots.

The SupplementaryDeviceSlot specifies the assigned time slot index in which the device requesting association uses for supplementary bidirectional device time slots.

* + - 1. MLME-ASSOCIATE.confirm

***Insert the following new parameters at the end of the list in 6.2.2.4 (before the closing parenthesis):***

 RelayingDelay,

RelayingBitmap,

PrimaryDeviceSlot,

SupplementaryDeviceSlot

***Insert the following new rows at the end of Table 12:***

Table 12—MLME-ASSOCIATE.confirm parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| RelayingDelay | Integer | 0x0000-0x0fff | Specifies the assigned superframe in which to start the cyclic-superframe of the device requesting association. |
| RelayingBitmap | Beacon bitmap | As specified by 5.2.4.30.3 | Indicates the superframes reserved for transmitting a beacon from the neighboring devices around the inner coordinator. |
| PrimaryDeviceSlot | Time slot index | As specified by 5.3.15.1 | Specifies the time slot of primary bidirectional device time slots |
| SupplementaryDeviceSlot | Time slot index | As specified by 5.3.15.1 | Specifies the time slot of supplementary bidirectional device time slots |

The RelayingDelay specifies the assigned superframe index in which the repeater requesting association starts the cyclic-superframe.

The RelayingBitmap contains the bitmap indicating the beacon slot of the superframe reserved for transmitting a beacon from neighboring devices. Each corresponding bit in the bitmap shall be set to one if the beacon slot of the superframe is occupied, otherwise it is set to zero.

The PrimaryDeviceSlot specifies the assigned time slot index in which the device requesting association uses for primary bidirectional device time slots.

The SupplementaryDeviceSlot specifies the assigned time slot index in which the device requesting association uses for supplementary bidirectional device time slots.

* + 1. Primitives for updating the superframe configuration
			1. MLME-START.request

***Insert the following new parameter at the end of the list in 6.2.12.1 (before the closing parenthesis):***

 TRLESuperframeSpecification

***Insert the following new row at the end of Table 34:***

Table 34-MLME-START.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| TRLESuperframeSpecification | Cyclic-superframe-Specification | As specified by 5.2.4.30.1 | Specifies the cyclic-superframe in the TRLE-enabled PAN, as defined in 5.2.4.30.1. |

***Insert the following new parameter before 6.2.12.2***

The TRLESuperframeSpecification parameter provides the Beacon Order (5.2.2.1.2), the Superframe Order (5.2.2.1.2), the Mulit-superframe Order (5.2.4.9.1), the Number of Prioritized Device Slot, and the Number of Coordinator Slot for specifying the cyclic-superframe in the TRLE-enabled PAN.

* + 1. MAC management service

***Insert the following new subclause (6.2.23) after 6.2.22:***

* + 1. Primitives for TRLE management
			1. MLME-TRLE-MANGEMENT.request

This primitive allows a TRLE-enabled device to request the device status, clock time, relaying-link information, relaying path information, and control of the transmission power of a peer device.

The semantics of this primitive are:

MLME-TRLE-MANAGEMENT.request (

 ManagementType,

 DstAddrMode,

 DstAddr,

TxGrade,

OutwardRepeaterDelay

 )

The primitive parameters are defined in Table 44za

Table 44dd- MLME-TRLE-MANAGEMENT.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| ManagementType | Enumeration | HELLO, TIME, DEVICE, PATH, POWER CONFIG, POWER CNTL,RELAY ON, RELAY OFF | The type of management for this primitive, as defined in Table 7c. |
| DstAddrMode | Enumeration | NO\_ADDRESS,SHORT\_ADDRESS,EXTENDED\_ADDRESS | The destination addressing mode for this primitive. |
| DstAddr  | Deviceaddress | As specified by theDstAddrMode parameter | The individual device address of the device for which the frame was intended. |
| TxGrade | Enumeration | GRADE\_0,GRADE\_1,GRADE\_2 | The grade of link access to be used |
| OuwardRepeaterDelay | Integer | 0x0000-0xffff | The outward relaying delay in the number of superframe duration |

The MLME-TRLE-MANAGEMENT.request primitive is generated by the higher layer of a device and issued to its MLME to request the device status, clock time, relaying-link information, relaying path information, and control of the transmission power of a device.

On receipt of the MLME-TRLE-MANAGEMENT.request primitive, the MLME shall send a TRLE Management request command frame as described in 5.3.15.3 to the DstAddr. The Management Type field of the TRLE Management Request command shall be set to the value of the ManagementType parameter. The TRLE Management request command frame is relayed to the DstAddr with the grade of link access specified in TxGrade.

* + - 1. MLME-TRLE-MANAGEMENT.indication

The MLME-TRLE-MANAGEMENT.indication is used to indicate the reception of a TRLE Management Request command.

The semantics of this primitive are:

MLME-TRLE-MANAGEMENT.indication (

 ManagementType,

 SrcAddrMode,

 SrcAddr,

TxGrade

 )

The primitive parameters are defined in Table 44ee.

Table 44ee- MLME-TRLE-MANAGEMENT.indication parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| managementType | Enumeration | HELLO, TIME, DEVICE, PATH, POWER CONFIG, POWER CNTL,RELAY ON, RELAY OFF | The type of management for this primitive, as defined in Table 7c. |
| SrcAddrMode  | Enumeration | NO\_ADDRESS,SHORT\_ADDRESS,EXTENDED\_ADDRESS | The source addressing mode for this primitive |
| SrcAddr  | Deviceaddress | As specified by theSrcAddrMode parameter | The individual device address of the device for which the frame was generated. |
| TxGrade | Enumeration | GRADE\_0,GRADE\_1,GRADE\_2 | The grade of link access to be used |

This primitive is generated by the MLME of a device and issued to its next higher layer upon the reception of a TRLE Management request command frame.

On receipt of the MLME-TRLE-MANAGEMENT.indication primitive, the higher layer is notified of the reception of a TRLE Management request command frame.

* + - 1. MLME-TRLE-MANGEMENT.response

This primitive allows the next higher layer of a device to respond to the MLME-TRLE-MANAGEMENT.indication primitive.

The semantics of this primitive are:

MLME-TRLE-MANAGEMENT.response (

 ManagementType,

 DstAddrMode,

 DstAddr,

TxGrade,

 status,

 TimeSync,

 DeviceDescriptor,

 PathDescriptor,

 PowerMangDescriptor

 )

The primitive parameters are defined in Table xx

Table 44ff- MLME-TRLE-MANAGEMENT.response parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| ManagementType | Enumeration | HELLO, TIME, DEVICE, PATH, POWER CONFIG, POWER CNTL,RELAY ON, RELAY OFF | The type of management for this primitive, as defined in Table 7c. |
| DstAddrMode  | Enumeration | NO\_ADDRESS,SHORT\_ADDRESS,EXTENDED\_ADDRESS | The destination addressing mode for this primitive |
| DstAddr  | Deviceaddress | As specified by theDstAddrMode parameter | The individual device address of the device for which the frame was intended. |
| TxGrade | Enumeration | GRADE\_0,GRADE\_1,GRADE\_2 | The grade of link access to be used |
| status | Enumeration | As defined in 5.3.15.4.1 | The status of the management attempt |
| TimeSync | Time Synchronization Specification | As defined in 5.2.4.30.2 | The start time of the slot in which the frame is transmitted. |
| DeviceDescriptor | Device Descriptor | As defined in 5.3.15.4.2 | The device configuration |
| PathDescriptor | Relaying Path Descriptor | As defined in 5.3.15.4.3 | The relaying path configuration |
| PowerMangDescriptor | Power Management Specification | As defined in 5.3.15.4.4 | The TX power configuration and RX link status |

On receipt of the MLME-TRLE-MANAGEMENT.response primitive, the MLME of the device shall generate a TRLE Management response command frame as described in 5.3.15.4. The ManagementType, Status, TimeSync, DeviceDescriptor, PathDescriptor, PowerMangDescriptor shall be contained in the Management Type field, Management Status field, Time Synchronization Specification field, Device Descriptor field, Relaying Path Descriptor field, and Power Management Descriptor field of the TRLE-Management response command frame.

* + - 1. MLME-TRLE-MANGEMENT.confirm

The MLME-TRLE-MANAGEMENT.confirm primitive reports the result of the TRLE management request.

The semantics of this primitive are:

MLME-TRLE-MANAGEMENT.confirm (

 ManagementType,

 SrcAddrMode,

 SrcAddr,

status,

 TimeSync,

 DeviceDescriptor,

 PathDescriptor,

 PowerMangDescriptor

 )

The primitive parameters are defined in Table xx

Table 44gg- MLME-TRLE-MANAGEMENT.confirm parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| managementType | Enumeration | HELLO, TIME, DEVICE, PATH, POWER CONFIG, POWER CNTL,RELAY ON, RELAY OFF | The type of management for this primitive, as defined in Table 7c. |
| SrcAddrMode  | Enumeration | NO\_ADDRESS,SHORT\_ADDRESS,EXTENDED\_ADDRESS | The source addressing mode for this primitive |
| SrcAddr  | Deviceaddress | As specified by theSrcAddrMode parameter | The individual device address of the device for which the frame was generated. |
| status | Enumeration | As defined in Table 7d | The status of the management attempt |
| TimeSync | Time Synchronization Specification | As defined in 5.2.4.30.2 | The start time of the slot in which the frame is transmitted. |
| DeviceDescriptor | Device Descriptor | As defined in 5.3.15.4.2 | The device configuration |
| PathDescriptor | Relaying Path Descriptor | As defined in 5.3.15.4.3 | The relaying path configuration |
| PowerMangDescriptor | Power Management Specification | As defined in 5.3.15.4.4 | The TX power configuration and RX link status |

On receipt of the MLME-TRLE-MANAGEMENT.confirm primitive, the higher layer is notified of the reception of a TRLE Management response command frame.

* 1. MAC data service
		1. MCPS-DATA.request

***Insert the following new parameter at the end of the list in 6.3.1 (before the closing parenthesis):***

 TxGrade

***Insert the following new row at the end of Table 46:***

Table 46-MCPS-DATA.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| TxGrade | Enumeration | GRADE\_0,GRADE\_1,GRADE\_2 | The grade of link access to be used |

***Insert the following paragraph at the end of 6.3.1:***

When the TRLE is enabled and the TxGrade parameter is within the valid range, the multiple grades of link access feature are enabled.

* 1. MAC constants and PIB attributes
		1. MAC constants
		2. MAC PIB attributes
		3. Calculating PHY dependent MAC PIB values
			1. General
			2. General MAC PIB attributes for functional organization

***Add the following rows to Table 52a:***

Attribute *macRelayingMode*, *macTRLEcapable,* and *macTRLEenabled* are read-only and set by the implementer.

Table 52a-General MAC PIB attributes for functional organization

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Attribute | Type | Range | Description | Default |
| *macRelayingMode* | Boolean | TRUE, FALSE | A value of TRUE indicates that the device is using relaying- mode frame filtering. A value FALSE indicates that it is not using relaying- mode frame filtering. | FALSE |
| *macTRLEcapable* | Boolean | TRUE, FALSE | A value of TRUE indicates that the device is capable of functionality specific to TRLE. A value FALSE indicates that it is not capable of TRLE functionality. | FALSE |
| *macTRLEenabled* | Boolean | TRUE, FALSE | A value of TRUE indicates that the device is using functionality specific to TRLE. A value of FALSE indicates that it is not using TRLE functionality. | FALSE |

***Insert the following new subclause after 6.4.3.11:***

* + - 1. TRLE specific MAC PIB attributes

Subclause 6.4.3.1 applies and additional attributes are required, as presented in Table 52o.

Table 52o-TRLE specific MAC PIB attributes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Attribute | Type | Range | Description | Default |
| *macNumPrioritizedDeviceSlot* | Integer | 1-3 | The number of time slots in a superframe assigned as the prioritized device slots. | 1 |
| *macNumCoordSlot* | Integer | 1-3 | The number of time slots in a superframe assigned as the coordinator slots. | 1 |
| *macNumBidirDeviceSlot* | Integer | 1-7 | The number of time slots in a cyclic-superframe assigned as the bidirectional device slots. | 2 |
| *macRelayingTier* | Integer | 0-7 | The identifier of the relaying tier in which a device is placed. The relaying tier of the PAN coordinator is zero. | 0 |
| *macRelayingSyncReference* | Integer | See 5.2.4.30.3 | The index of the superframe starting to transmit a cyclic-superframe. The reference of relaying synchronization of the PAN coordinator is zero. | Implementation specific |

**Annex P**

(informative)

**Low Energy, Critical Infrastructure Monitoring Systems**

**P.1 Introduction**

**P.2 Functionality added**

***Remove P.3 and insert the following new subclause after P.2.7:***

P.2.8 Coverage extension with the Time-slot Relaying based Link Extension (TRLE)

LECIM network deployments will typically use a star topology that provides a direct connection between the PAN coordinator acting as the concentrator and an endpoint. In a star topology, the range of the network is limited by the transmission and reception range of the devices forming a link. Even with the extended range possible with the LECIM PHYs, there are occasions when a further range extension of the LECIM network may be required. An example would be when supporting a very sparse dispersion of devices beyond the radio range of a PAN coordinator to endpoint. Another example may arise when maintaining connection with an endpoint where the RF environment degrades as a result of geographic change after the initial deployment.

To provide connectivity between the PAN coordinator and an endpoint beyond the PAN coordinator’s transmission and/or reception range is to use either routers or repeaters to extend the range the network.

In a beacon-enabled PAN, the endpoint associates with the PAN coordinator. In a router-enabled network the connection between the PAN coordinator and endpoint that is outside the radio range of the concentrator would associate with the coordinator acting as a router, and the path to the PAN coordinator becomes a routed connection of multiple links. Using a coordinator acting as router to extend the range of an LECIM network may require the installation mains-powered routers.

In a beacon-enabled PAN that uses routers for extending a link, the routers would get one or more GTS allocations from the PAN coordinator. The router may transmit to/from the PAN coordinator, or it may transmit to any other device in the assigned GTS. An endpoint(s) may request GTS allocation(s) from the router, and when allocated, use the GTS(s) to communicate with the router. If the router receives a frame that has as the destination the PAN coordinator with which it is associated, it will forward the frame inward to the PAN coordinator in the appropriate GTS. Likewise if receives a frame from the PAN coordinator directed at one of its associated endpoints, it will forward the frame outward to the device.

In a LECIM network, a repeater may be used for extending the network’s range. The repeater is transparent to the PAN coordinator and an endpoint. The repeater retransmits a frame, which it receives with the destination address of a device that is associated with the repeater, at an appropriate time so as to not interfere with neighboring devices.

When a TRLE repeater resides between a PAN coordinator and an endpoint, the TRLE repeater performs the following procedure to support the extension of a link:

* The TRLE repeater scans the channels and extracts information from the beacon frames sent from neighboring coordinators
* The TRLE repeater selects the coordinator to which it will connect and synchronizes to the beacon of that coordinator
* Acting upon the information from the beacon frame, the TRLE repeater chooses the time slot to relay the inner coordinator’s beacon and uses the time slot as the reference point for starting beacon interval of the repeater
* The TRLE repeater starts relaying frames received in a time slot from inner coordinator to the time slot aligned synchronously with the reference point of the repeater
* The TRLE repeater filters received frames, frames not destined to that repeater will be relayed

If the PAN coordinator is TRLE-enabled, a TRLE repeater cooperates with the TRLE PAN coordinator and neighbor TRLE repeaters as follows:

* The TRLE repeater scans the channels and extracts information on beacon frames from a neighboring TRLE PAN coordinator or TRLE repeater(s)
* The TRLE repeater selects the TRLE PAN coordinator or an inner TRLE repeater which is closer to the TRLE PAN coordinator, and synchronizes to the beacon of TRLE PAN coordinator or the inner TRLE repeater as appropriate
* The TRLE repeater requests to associate with the TRLE PAN coordinator and is notified the reference point for the starting beacon interval of the repeater
* The TRLE repeater starts to share the inward cyclic-superframe with its inner repeater and, if an outer repeater exists, shares the outward cyclic-superframe.
* The following information is transferred along the path from the outermost TRLE-enabled repeater to the TRLE PAN coordinator: TRLE PAN descriptor, relaying descriptor, and TRLE path management
* At the outermost TRLE repeater, the relaying descriptor is either inserted in an inward frame or dropped out from the outward frame

If the endpoint is TRLE-enabled, it may choose the grade of the link connections to the TRLE PAN coordinator as follows:

* Upon associating to the TRLE PAN coordinator, the TRLE-enabled endpoint will be assigned a bidirectional time slot
* The TRLE-enabled device can use inward prioritized device time slots and outward coordinator time slots
* The path to the TRLE-enabled device will be managed by the TRLE PAN coordinator

**----------------------------------------------------------------------------------------------------------------------------**