**IEEE P802.15**

**Wireless Personal Area Networks**

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| Re: | [TG4k LECIM PHY development, MAC support] | |
| Abstract | Working draft for MAC additions necessary to support the LECIM PHYs | |
| Purpose | Draft standard development | |
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**DO NOT USE FOR ANY OTHER PURPOSE**

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Draft for

NOTE: When preparing a draft amendment, the editors will include only the section headings where changes to the base standard are made. Amendments, when completed, will not contain any empty sub-clauses. In this outline all of the clauses and sub-clauses of the base standard are included for preliminary draft development (and because it is easier in Word). If there is no annotation in a section it is likely the amendment would not have contents for that section.

This outline is based on P8021.15.4-2011 taking into account (nearly) approved amendments 15.4e, 15.4f and 15.4g. By the time LECM balloting begins these will be completed approved amendments.

This is a working draft outline so it excludes the IEEE Boilerplate that will be added to the draft prior to balloting.

No additions Clause 1 are expected.

1. Overview
   1. General
   2. Scope
   3. Purpose
2. Normative references

No changes expected.

1. Definitions, Acronyms and Abbreviations
   1. Definitions
   2. Acronyms

***Insert in 3.2 in alphabetical order the following acronyms:***

HWSL hybrid wakeup sample listening

1. General Description

Clause 4 is informative “big picture” overview. Normative text does NOT go in clause 4. The specific behaviors, structures and formats of things go in the appropriate PHY and MAC clauses.

* 1. General

Will add overview clauses as needed.

* 1. Components of the WPAN

Add in this clause any new categories of “device” that LECM adds, for example, assumptions about LECM coordinator vs LECM end device.

* 1. Network topologies
     1. Star network formation

Insert before 4.3.2 the following paragraphs:

LECIM networks are primarily star topology, with data flowing primarily from the endpoint devices to the coordinator. The coordinator is not as limited with respect to energy and available resources as endpoints devices, in which energy consumption is critical and resources may be very limited. This asymmetry is a characteristic feature of the LICEM network.

* + 1. Peer to peer network formation
  1. Architecture
     1. PHY layer (PHY)
     2. MAC Sub-layer (General Characteristics)

The following MAC enhancements are included to support of Low Energy Critical Infrastructure Monitoring PHYs defied in clause 17:

* Enhanced timing and synchronization capabilities to support synchronous and asynchronous channel access in both beacon enabled and non-beacon enabled operation
* Enhanced low energy mechanisms
* MPDU fragmentation to support extremely low data rates and limited PSDU sizes
* Priority channel access
* MAC SAP and PIB extensions for PHY control and configuration
  1. Functional Overview
     1. Superframe Structure
        1. General

Insert text at into the enumerated list:

* Superframe structure described in 4.5.1.2 based on beacons defined in 5.2.2.1 with an Information Element (IE) defined in 5.2.4.3.4 (DSME PAN Descriptor) and priority channel access slots.
* Priority access enabling structure described in 4.5.1.5 supporting priority channel access in beacon-enabled CAP.
  + - 1. DSME multi-superframe structure
      2. Use of superframe structure for LECIM

Priority based contention channel access is provided in beacon-enabled mode by allocating the first two timeslots during the CAP of each superframe (see Figure 8). When the multi-superframe multi-superframe structure (Figure 4a) is in use, first two time slots in each CAP in the multi-superframe are allocated for high priority access.

When configured to support priority access, the priority access slots are used by devices with critical events to report, as defined by the higher layer via [PIB attribute and/or MLME or MCPS data service parameters], using the currently configured CAA mode (8.2.7). Transmission of messages with other than critical event priority will commence following the priority access timeslots.

* + 1. Data transfer model

May describe synchronized channel access (how MAC and PHY are used together). Refer to appropriate sub-clauses for normative descriptions.

* + - 1. Data transfer to a coordinator

A general overview of the uplink communication.

* + - 1. Data transfer from a coordinator

A general overview of downlink communication.

* + - 1. Peer-to-peer data transfers

No changes expected.

* + 1. Frame Structure

***Insert at the end of 4.5.3:***

When MPDU fragmentation is used (Add the following text and figure Add a figure for ‘Schematic view of the PPDU with MPDU Fragmentation’.

* + 1. Improving probability of successful delivery

Description of MPDU fragmentation as a reliability enhancing mechanism.

Insert new subclause between 4.5.4.1 and 4.5.4.2:

* + - 1. a CSMA-CA used with priority channel access

When using a LECIM PHY in a Nonbeacon-enabled PAN, where unslotted CSMA-CA channel access mechanism is applied, priority channel access is achieved by an use of the alternate backoff mechanism (see 5.1.1.4). The alternate mechanism will, uses a fixed backoff window instead of an exponential backoff and will on average, provide less backoff duration for priority access than for normal access. In addition, the priority channel access continues to follow the channel, even if it is assessed busy, to gain immediate access to the channel once it is assessed idle.

Beacon-enabled PANs using a LECIM PHY dedicate CAP time slots in the beginning of a superframe for priority channel access. Priority frames may commence in the priority slot(s) and continue through the duration of the CAP. Priority frames in the priority access slots utilize persistent CSMA-CA with reduced CW and an alternate backoff mechanism for channel access, as described in [xref]. Priority frames during the non-priority slots of the CAP utilize CSMA-CA as described in 5.1.1.4 with an alternate backoff mechanism.

* + - 1. ALOHA mechanism

***Insert following after the last paragraph of 4.5.4.2:***

When priority channel access is enabled, priority the alternate (fixed window) backoff mechanism is used (see xref). When operating in a Beacon-enabled PAN, slotted ALOHA improves efficiency of channel access. When slotted ALOHA with priority access, the first two time slots after the beacon are dedicated for priority channel access traffic. The backoff slot length is PHY dependent and must be able to accommodate at minimum the transmission of a single MPDU fragment.

***Insert******new subclause between 4.5.4.2 and 4.5.4.3***

* + - 1. a MPDU Fragmentation

With the addition of very low data rate PHY operating modes the resulting increase in duration over the air of the MAC frame can lead to increased interference potential, susceptibility to channel conditions changing during the duration of a MAC frame transmission, and other effects that may reduce reliable transfer in some environments typical of LECIM applications. In some PHY modes the PSDU size available may be smaller than the size of a full MAC frame. To preserve the functionality and proven reliability of the MAC defined in this standard and to make these PHY characteristics transparent to the majority of MAC functional capability, optional MPDU fragmentation is provided.

MPDU fragmentation operates on the complete MPDU and adapts it to the specific PHY and PHY operating mode. To reduce over the air overhead, some MAC header information is compressed or suppressed in the over the air exchange, by establishing a fragement sequence (transaction) context. The MPDU content is distributed into fragments, each packaged into an PPDU for transmission. Information in the fragment, combined with the fragment sequence context, provides identification of the individual fragment, what sequence it belongs to and where the fragment fits into the sequence. Each fragment carries an incremental validity check sequence to detect errors in each fragment. A schematic view of fragmenting the MPDU in to a fragment sequence is shown in Figure 1. In this standard the term “fragment” refers to an individual MPDU fragment, the term “fragment sequence” refers to the collection of fragments transmitted that comprise together the original MPDU, “fragment number” is the position, in the sequence, of an individual fragment, and the “fragment sequence ID” identifies the fragment sequence.



Figure Schematic View of MPDU Fragmentation

Each fragment may be individually acknowledged and retransmitted. Retransmission of only missed fragments and reduce air time and improve reliability. The complete MPDU transaction may be acknowledged.

* + - 1. Frame acknowledge

Insert new subclauses at the end of 4.5.4.3:

* + - * 1. Fragment Incremental acknowledge (I-ACK)

The incremental acknowledgement (I-ACK) is used during the fragment sequence transfer to determine which fragments have been received successfully and which need to be retransmitted. An I-ACK may aggregate the status of one or more fragments. The number of fragment status reports grouped into an I-ACK is controlled by the higher layer. The format of the I-ACK is given in 5.1.6.4.2a.

* + - * 1. MPDU completion acknowledge

The MPDU acknowledgement mechanism may be used to report status of a fragment sequence transaction upon reconstruction of the MPDU at the recipient. The reassembly and validation process may require processing time in the MAC sublayer or higher layers prior to transmitting the final acknowledgement. A method is provided to coordinate the acknowledgement. Because fragment failures may due to conditions on a specific frequency channel, itt may also be desired to be able to transmit the acknowledgement and subsequent retransmissions on a different channel. A coordination mechanism is provided to support this capability (xref). Means is also provided to include feedback to the initiator of the transaction, such as link quality information (xref to IE definitions), which is made available to the higher layer and may be used for adjusting fragmentation parameters or PHY configuration based on performance.

* + - 1. Data verification

To accommodate individual fragment acknowledgement, a fragment validation sequence (FVS) is included with each fragment. The recipient uses the FVS and fragment number to determine which fragments of the sequence have been received correctly and which are missing. The I-ACK reports the status of 1 or more received fragments. The FVS is described in (xref).

The reassembled MPDU also carries a frame check sequence (FCS). The MAC may apply this FCS as a validity check of the reassembled MPDU.

* + 1. Power consumption considerations

A good place to give overview of the “Low Energy” part of LECM.

* + 1. Security

No changes expected

* 1. Concept of primitives

No changes expected.

1. MAC protocol
   1. MAC functional description
      1. Channel Access
         1. Superframe structure

When priority access is enabled and the superframe shown in Figure 8 is in use, the two first time slots in the CAP as shown in Figure 8 shall be dedicated for priority channel access. When priority access is enabled and the multi-superframe shown in Figure 34g is in use, the first two time slots in each CAP shall be dedicated for priority channel access. See 5.1.1.4.

* + - 1. Incoming and outgoing superframe timing
      2. Interframe spacing (IFS)
      3. CSMA-CA Algorithm
         1. CSMA with priority channel access

This clause describes the alternate backoff used to support priority channel access for transmission of a critical event priority message. The backoff procedure shall be used when the CCA returns channel busy.

If the MAC sublayer cannot proceed, it it shall wait until the expiration of the two first time slots of the CAP in the next superframe and apply a further random backoff delay before evaluating whether it can proceed again.

Using a LECIM PHY, in the Nonbeacon-enabled PAN, where unslotted CSMA-CA is used, the critical event priority transmission may be initiated at any time. When CAA returns channel busy, the alternate backoff is used: BE remains constant for subsequent retransmissions. The first transmission attempt shall set the BE to the value of MACMinBE-1 (with default value of MACMinBE = 2). In addition, the priority channel access follows a persistent CSMA mechanism, where a device continues to monitor the channel and decrements the value of unit backoff periods any time the channel is sensed idle for duration of backoff slot in order to gain access to the channel as soon as possible.

In a beacon enabled PAN, a critical event priority message transmission may be initiated in any part of the CAP. When transmission is initiated in the priority time slots, and the CCA returns channel busy, the alternate backoff mechanism shall be used as follows: BE remains constant (tentatively 2, or MACMinBE) for retransmissions. The first transmission attempt shall set the BE to the value of MACMinBE-1.

When the critical event priority transmission is initiated in the CAP other than in the priority access timeslots, the primary CSMA-CA as defined in 5.1.1.4 with the above alternate backoff mechanism.

* + - * 1. LECIM Aloha Priority Channel Access

When critical event priority channel access is in use with CCA mode 4 (ALOHA), priority channel access is achieved by using an alternate backoff mechanism. Backoff is defined in *macLECIMAlohaBackoffSlot* durations. A *macLECIMAlohaBackoffSlot* duration is a PHY and deployment dependent parameter. It shall be sufficiently long to accommodate the transmission of a single MPDU fragment with associated IFSs and any ACK frames. The backoff window size shall stay constant during retransmissions

In Beacon-enabled PANs, slotted Aloha is applied for more efficient channel access. When critical event priority channel access is in use, the slot length equals to *macLECIMAlohaBackoffSlot* duration. In addition, the two first time slots after the beacon transmission are dedicated for priority channel access traffic. Priority frames may be transmitted in the entire CAP portion of the superframe.

* + - 1. TSCH-Slotframe structure
      2. LLDN Superframe structure
      3. LE-Functional description

Change text as indicated:

This subclause specifies functionalities of devices supporting the PIB attributes:

* macCSLPeriod
* macRITPeriod
* macCSLMaxPeriod
* macHWSLMaxPeriod
* macHWSLPeriod
* macLowEnergySuperframeSupported and
* macLowEnergySuperframeSyncInterval
  + - * 1. LE-Contention access period (LE-CAP)

Change the text of the first paragraph as shown:

When *macCSLPeriod* is non-zero, CSL is deployed in CAP, while HWSL is deployed in CAP when macHWSLPeriod is non-zere. CSL behavior is defined in 5.1.11.1, and HWSL behavior is defined in 5.1.11.3. The *macRITPeriod* shall be set to zero in a beacon-enabled PAN.

* + - * 1. LE-Superframe structure
        2. LE- incoming and outgoing superframe timing
        3. LE-Scan

Change the first paragraph of 5.1.1.7.4:

When macCSLPeriod is non-zero, CSL is deployed in channel scans. When macCSLMaxPeriod is non-zero, each coordinator broadcasts beacon frames with wakeup frame sequence. When macHWSLPeriod is non-zero, each endpoint device deploy HWSL in channel scans. When macHWSLMaxPeriod is non-zero, each coordinator send wakeup sequence. This both allows devices to perform channel scans with low duty cycles.

* + 1. Starting and maintaining PANs

New methods to support LECIM go here, additions to scan for example.

* + 1. Association and disassociation

Expect there may be some sort of abbreviated link context setup considerations.

* + 1. Synchronization

Probably some additional considerations for LECIM for both beacon and non beacon cases.

* + - 1. Synchronization with beacons
      2. Synchronization without beacons
      3. Orphaned device realignment
      4. LECIM Synchronization

Alternately we may just add a separate section, or fold in to beacon or non-beacon cases as appropriate.

* + 1. Transaction handling
    2. Transmission, reception, and acknowledgment

Expect all sub-clauses will have some changes related to MPDU fragmentation

* + - 1. Transmission
      2. Reception and rejection

Expect some additional filtering for MPDU fragmentation will be required based on context ID, sequence # or something like that.

* + - 1. Extracting pending data from a coordinator

No changes expected; MPDU fragmentation should run ‘below’ this function.

* + - 1. Use of acknowledgments and retransmissions

Add appropriate subclauses for incremental acknowledge and retransmission of fragments. Since these will be inserted between existing clauses they get the number of the preceding subclause with “a” appended.

* + - * 1. No acknowledgment
        2. a Incremental fragment acknowledgement
        3. a Incremental fragment retransmission
      1. Promiscuous mode

No changes expected for LECIM.

* + - 1. Transmission scenarios

Expect a few new ones to be needed.

* + 1. GTS allocation and management

Don’t’ expect changes in here.

* + 1. Ranging

No changes expected.

* + 1. LLDN Transmission states

No changes expected.

* + 1. Deterministic and synchronous multi-channel extension (DSME)
    2. LE-transmission, reception and acknowledgment
       1. Coordinated sampled listening (CSL)
       2. Receiver initiated transmission (RIT)

Insert new subclauses before 5.1.12:

* + - 1. LECIM Alternate/Hybrid LE scheme
         1. General

The Alternate/Hybrid LE mode is active when *macLEenabled* is TRUE while CSL and RIT are disabled, as indicated by *macCSLPeriod* and *macRITPeriod* set to zero.

The basic LECIM Hybrid LE mode is illustrated in figure 34sa.

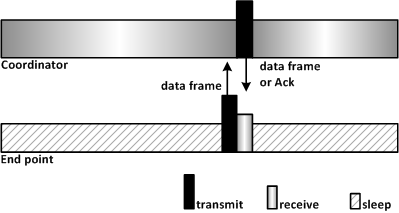


Figure 34sa Basic LECIM LE mode operations

* + - * 1. LECIM LE Transmission

In LECIM networks, transmissions are mainly from endpoint devices to coordinator. As described in 4, as power of the coordinator is not as limited as endpoint devices, in LECIM LE mode, the coordinator shall keep listening for the channel, except it has data frame to send, or need to send beacon frames when *macLowEnergySuperframeSupported* is TRUE.

Endpoint device shall keep sleeping for the normal time, when it has data frame to send, it will enable its transmitter, and send the data frame.

When *macLowEnergySuperframeSupported* is TRUE, endpoint device will send data frames by using slotted Aloha or slotted CSMA-CA. Otherwise, endpoint device will send data frames by using unslotted Aloha or unslotted CSMA-CA.

On receipt of data frame from endpoint device, if the coordinator has data frame need to send to the corresponding endpoint device, it will send the corresponding data frame as Acknowledgement for the received data frame. And if the coordinator has more than one data frame need to send to the same endpoint device, it can indicate it by setting the pending field in the frame. Otherwise, the coordicator will send Acknowledgement frame back.

After sending data frame to coordinator, the endpoint device shall wait for *macAckWaitDuration*. If an acknowledgement frame is received within *macAckWaitDuration* and contains the same DSN as the original transmission, or an new data frame is receive from the coordinator within *macAckWaitDuration*, the transmission is considered successful. Otherwise, the device shall conclude that the transmission has failed, and will retransmit the data frame as *macMaxFrameRetries* be set.

If the endpoint device received data frame from coordinator, it need the send acknowledgement as IEEE 802.15.4-2011 defined, and decided to turn off receiver or not by the pending field of the received data frame.

* + - * 1. Hybrid Wakeup Sample Listening (HWSL)

When the PIB attribute *macHWSLenabled* is TRUE, the Hybrid Wakeup Sample Listening (HWSL) mode is enabled, to guarantee timely transmission from coordinator to endpoint devices.

If PIB attribute *macHWSLenabled* is TRUE, the value of PIB attribute *macCSLPeriod* and *macRITPeriod* will be ignored.

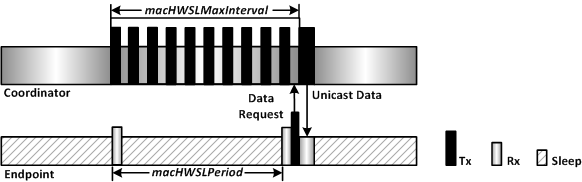


Figure 34sb unicast transmission of HWSL mode

As described in 5.1.11.3.2, for daily transmission from the coordinator to endpoint devices, the coordinator shall transmit the data the endpoint device until received data frames from the corresponding endpoint device. In some cases, the latency will be very long, HWSL mode is used for the emergency data frame from the coordinator to the endpoint device, and support broadcast data frame from the coordinator.

In HWSL mode, coordinator shall keep channel listening, and if it has emergency data frame to send, the transmission of the payload frame is preceded with a sequence HWSL wakeup frames.

The HWSL wakeup sequence is consist of a sequence of HWSL wakeup frames, and the interval of each HWSL wakeup frame is defined by the PIB attribute macHWSLWakeupInterval. Between sending the two HWSL wakeup frames, the coordinator will change to listen the channel. The maximum length of HWSL wakeup sequence is macHWSLMaxPeriod.

Endpoint devices performs a channel sample every macHWSLPeriod time. If the channel sample does not detect any HWSL wakeup frame from the coordinator on the channel, the endpoint device shall disable the receiver until the next channel sample time, and then performs the next channel sample.

If the coordinator has unicast frame to send, the destination address of HWSL wakeup frame shall be set to the address of corresponding endpoint device. On receipt of the unicast HWSL wakeup frame when the endpoint device performed channel sample, it shall first check the destination address. If the destination address is match, the endpoint device shall inform the higher layer, stop the periodly channel sample, send back HWSL data request frame to the coordinator, and wait for macDataWaitDuration for incoming unicast data frame.

If the coordinator received HWSL data request frame from the cooresponding endpoint device after sending an unicast HWSL wakeup frame, it shall stop sending the HWSL wakeup sequence, and send the corresponding unicast data frame to the endpoint immediately, and then wait for macAckWaitDuration, for the acknowledgement from endpoint device.

On receipt of the incoming unicast data frame, the endpoint device will send back corresponding acknowledgement to the coordinator.

If the next higher layer of the coordinator has multiple frames to transmit to the same destination, it can set the frame pending bit of frame control field to one in all but the last frame.

HWSL unicast transmission is performed in the following steps by the MAC layer of the coordinator:

a) Perform CSMA-CA to acquire the channel

b) If the previous acknowledged unicast data frame to the destination has the frame pending bit set and is within macHWSLFramePendingWaitT (defined in Table 52j), go to step d).

c) For the duration of wakeup sequence length, transmit HWSL wakeup frames by the interval of macHWSLWakeupInterval.

d) If the coordinator has pending unicast data frame to send, set the pending bit of the frame control field to one, then transmit unicast data frame.

e) Wait for up to macAckWaitDuration symbol time for the acknowledgment frame if the acknowledge request field in the unicast data frame is set to one.

f) If the acknowledgment frame is received, go to step g), otherwise, start retransmission process.

g) If the coordinator has pending unicast data to send, go to step b), otherwise turn off the HWSL mode, keep listening for the channel.

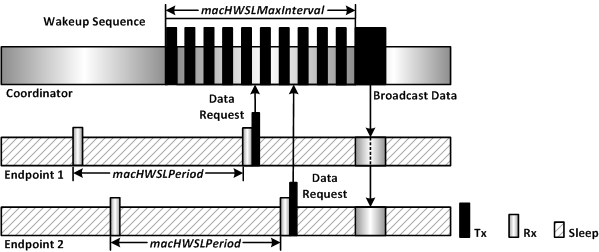


Figure (34sc) –broadcast transmission of HWSL mode

If the coordinator has broadcast frame to send, the destination address of HWSL wakeup frame shall be set to 0xffff, and include the remaining time of the broadcast data frame transmission.

On receipt of the broacast HWSL wakeup frame when the endpoint device performed channel sample, it shall inform the higher layer, stop the periodly channel sample, send back HWSL data request frame to the coordinator, back to sleep status until the remaining time indicated in the broadcast HWSL wakeup frame, then turn on the receiver, and waiting for the corresponding broadcast data frame.

If the coordinator received HWSL data request frame from the cooresponding endpoint device after sending a broadcast HWSL wakeup frame, it will keep sending the HWSL wakeup sequence, until received HWSL data request frames from all the endpoint devices or until macHWSLMaxPeriod. The coordinator will send corresponding broadcast data frame in the designed time.

* + - 1. Implicit receiver Initiated transmission (I-RIT)
         1. General

The implicit receiver initiated transmission (I-RIT) is an alternative low energy MAC for nonbeacon-enabled PANs. I-RIT is designed to be used for end devices, such as sensors, that primarily transmit information to a coordinator but have no way of determining when they should make use of conventional RIT. Instead of transmitting a RIT data request, when an end device has I-RIT enabled, the device turns its receiver on for a known period of time, at a known interval after each transmission, so that the end device makes itself available to receiver information from the coordinator. I-RIT mode is turned on when PIB attribute macIRITPeriod is non-zero and is turned off when macIRITPeriod is zero. The values of macCSLPeriod (in coordinated sample listening) and macRITPeriod, shall be set to zero when the value of macIRITPeriod is nonzero. Transmission and reception in I-RIT mode is illustrated in Figure 5 (34sd).



Figure (34sd) - I-RIT transmission

* + - * 1. I-RIT data request transmission and reception

In I-RIT mode, a device turns on its receive macIRITPeriod symbol periods after the last bit of its transmitted frame for a period of macIRITListenDuration symbol periods for incoming frame and goes back to idle state until the next frame is transmitted

Upon reception of frame during the I-RIT reception period, it notifies its arrival to the next higher layer by initiating corresponding indication primitive. The next higher layer will determine the successive operations based on the content of the received frame.

* + 1. Asynchronous multi-channel adaptation (AMCA)
  1. MAC frame formats

Expect to add new Information Elements to 5.2.4, which will require adding to table 4b and new subclauses starting at 5.2.4.23.

* + 1. General frame formats
       - 1. Frame pending field

Change the first paragraph of 5.2.1.1.3 as shown:

When operating in Low Energy (LE) CSL mode or HWSL mode, the frame pending bit may be set to one to indicate that the transmitting device has back-to-back frames to send to the same recipient and expects the recipient to keep the radio on until the frame pending bit is reset to zero.

* + 1. Format of individual frame types

Change the 3rd line of Table 3b as shown:

Table 3b – LE-specific MAC PIB attribute

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute Request Identifier | PIB attribute | IE Type | IEs to include |
| 3 | *macLEenabled* | Header | LE CSL, ~~or~~ LE RIT, HWSL LE (5.2.4.7, 5.2.4.8, 5.2.4.8a.) |

* + 1. Information Elements
       1. Header Information Elements

Insert the following row into Table 4b:

Table 4b—Element IDs, Header IEs

|  |  |  |  |
| --- | --- | --- | --- |
| Element ID | Content Length | Name | Description |
| 0x21 | 4 | LE HWSL | Defined in 5.2.4.8a |

Insert new subclause between 5.2.4.8 and 5.2.4.9:

* + - 1. a HWSL IE

The structure of HWSL IE is illustrated in Figure 48ua.

|  |  |
| --- | --- |
| Octets: 2 | 2 |
| HWSL Phase | HWSL Remain Time |

**Figure 48ua – HWSL IE**

The HWSL Phase field specifies the remaining time of the HWSL wakeup sequence, the range of the value of this filed is 0x0000 – 0xffff, by 10 symbols.

The HWSL Remain Time specifies the remaining time of the incoming data frame, the range of the value of this filed is 0x0000 – 0xffff, by 10 symbols.

* 1. MAC command frames

Insert the following rows into Table 5:

Table 5 – MAC command frames

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Command frame identifier** | **Command name** | **RFD** | | **Subclause** |
| **TX** | **RX** |
| 0x21 | HWSL-data request | X |  | 5.3.12.2 |
| 0x22 | HWSL-wakeup |  |  | 5.3.12.1 |

Insert new subcluse after 5.3.12.1:

1. * 11. 1. HWSL data request command

TBD

* + - 1. HWSL wakeup command

TBD

* 1. MPDU Fragmentation

When MPDU fragmentation is enabled, the completed MPDU will be transformed into a sequence of fragment cells as described in this subclause. The context of the fragment sequence is established between the initiating device and the recipient device, certain MHR fields may be transformed or elided, a fragment check sequence, fragment descriptor, and fragment content are packaged into a PPDU for the PHY in use according to PHY specific parameters and parameters provided by the higher layer. Each fragment

* + 1. MPDU PHY adaptation, fragmentation and reassembly
       1. Fragment sequence context
       2. Fragment cell formats
       3. Fragmentation
       4. Reassembly
    2. Fragment Acknowledgement and retransmission

Two levels of fragment acknowledgement are provided, acknowledgement of fragments during the transfer process (incremental acknowledgment) which provide “progress reports” and acknowledgement of the reassembled MPDU. In each, the status of individual fragments is indicated and the initiating device can retransmit only those fragments which were not received and validated.

* + - 1. Incremental fragment Acknowledgement (I-ACK)

The I-ACK is generated incrementally during the fragment sequence transfer and report status indicating which fragments have been successfully received up to that point. The interval of I-ACK is determined by the IACK\_interval parameter of the MCPS-Data.request. Upon completion of transmission of each IACK\_interval fragment cells, the initiating device will suspend transfer and wait *macIACKtimeout* for the expected I-ACK. Upon reception of the I-ACK, fragments indicated as not received correctly shall be retransmitted. The number of retransmissions is limited by *macMPDUFragRetryMax*.

Options: IACK field of the fragment descriptor is set upon transmission of every IACK-interval packet, or the IACK\_interval value is transferred with the fragment sequence context only.

The I-ACK will include the fragment status field, constructed as shown in [ref].

* + - 1. Aggregated MPDU transfer acknowledgement

If the received MPDU has Acknowledgment requested indicated in the MHR, the generated acknowledgement (using the Enhanced Acknowledgement) will include an the Fragment Status IE, constructed and transmitted as described here. The MPDU acknowledgement may contain information to support the channel switching notification.

Between the reception of last fragment of the group and transmission of MPDU acknowledgment, because the recipient MAC sublayer needs some time to process received fragments and prepare acknowledgement. MPDU acknowledgement or channel switching notification (CSN) command, there is a possibility that other devices in the network may access and use the medium so that MPDU acknowledgement or CSN command is further delayed. If channel condition change significantly, the transmission of following groups will be impacted. The following subclauses provides fuctions that may be used to mitigate the impact.

* + - 1. Channel switching for fragment sequence exchange

1. MAC services
   1. Overview
   2. MAC management service
   3. MAC data service
   4. MAC constants and PIB attributes
      1. MAC constants
      2. MAC PIB attributes
      3. Calculating PHY dependent PIB values
         1. LE-specific MAC PIB attributes

Insert new row into Table 52j:

Table 52j – LE-specific MAC PIB attribute:

Table 52j

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Attribute** | **Type** | **Range** | **Description** | **Defaul** |
| *macHWSLPeriod* | Integer | 0 - 65535 | HWSL sampled listening period in unit of 10 symbols. | 0 |
| *macHWSLMaxPeriod* | Integer | 0 - 65535 | Maximum length of HWSL wakeup sequence of 10 symbols. | *macHWSLPeriod* |
| *macHWSLFramePendingWaitT* | Integer | (*macMinLIFSPeriod* + max number of symbols per PPDU) - 65535 | Number of symbols to keep the receiver on after receiving a data frame with frame pending bit of control field set to one. | - |
| *macIRITPeriod* | Integer | 0x00000–0xffff | The interval (in symbol periods) from the end of the transmitted frame to the beginning of the I-RIT listening period.    0 means I-RIT is off | 0x00 |
| *macIRITListenDuration* | Integer | 0x00-0xff | The duration of listening time (in symbol periods) where the receiver is listening for the beginning of a frame to receive. | 0x64 |

1. Security

No changes expected at this time.

1. General PHY requirements
2. PHY services
3. O-QPSK PHY
4. Binary phase-shift keying (BPSK) PHY
5. Amplitude shift keying (ASK) PHY
6. Chirp spread spectrum (CSS) PHY
7. UWB PHY
8. GFSK PHY
9. SUN PHYs

Added by 15.4g TG.

1. MSK PHY

Added by 15.4f RFID TG.

1. LRP UWB PHY

Added by 15.4f RFID TG.

1. LECIM PHYs