**IEEE P802.15**

**Wireless Personal Area Networks**

|  |  |
| --- | --- |
| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | TG4k MAC Subgroup consolidated working draft contribution |
| Date Submitted | [13 Feb 2012] |
| Source | [][Blind Creek Associates][] | Voice: [ +1.408.395.7202 ]Fax: [ ]E-mail: [ ben @ blindcreek.com ] |
| Re: | [TG4k LECIM PHY development, MAC support] |
| Abstract | Working draft for MAC additions necessary to support the LECIM PHYs |
| Purpose | Draft standard development |
| Notice | This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein. |
| Release | The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15. |

IEEE 802.15.4k MAC Working Draft version: 2011-12-20

**WARNING: Incomplete Work Product**

**WORKING DRAFT ONLY: Contribution to TASK GROUP Draft Development Process.**

**DO NOT USE FOR ANY OTHER PURPOSE**

Contents

Contents

[1. Overview 1](#_Toc316893420)

[1.1 General 1](#_Toc316893421)

[1.2 Scope 1](#_Toc316893422)

[1.3 Purpose 1](#_Toc316893423)

[2. Normative references 2](#_Toc316893424)

[3. Definitions, Acronyms and Abbreviations 2](#_Toc316893425)

[3.1 Definitions 2](#_Toc316893426)

[3.2 Acronyms 2](#_Toc316893427)

[4. General Description 2](#_Toc316893428)

[4.1 General 2](#_Toc316893429)

[4.2 Components of the WPAN 2](#_Toc316893430)

[4.3 Network topologies 2](#_Toc316893431)

[4.3.1 Star network formation 2](#_Toc316893432)

[4.4 Architecture 2](#_Toc316893433)

[4.4.1 PHY layer (PHY) 2](#_Toc316893434)

[4.4.2 MAC Sub-layer (General Characteristics) 2](#_Toc316893435)

[4.5 Functional Overview 3](#_Toc316893436)

[4.5.1 Superframe Structure 3](#_Toc316893437)

[4.5.2 Data transfer model 4](#_Toc316893438)

[4.5.3 Frame Structure 4](#_Toc316893439)

[4.5.4 Improving probability of successful delivery 4](#_Toc316893440)

[4.5.5 Power consumption considerations 7](#_Toc316893441)

[4.5.6 Security 7](#_Toc316893442)

[4.6 Concept of primitives 7](#_Toc316893443)

[5. MAC protocol 8](#_Toc316893444)

[5.1 MAC functional description 8](#_Toc316893445)

[5.1.1 Channel Access 8](#_Toc316893446)

[5.1.2 Starting and maintaining PANs 11](#_Toc316893447)

[5.1.3 Association and disassociation 12](#_Toc316893448)

[5.1.4 Synchronization 13](#_Toc316893449)

[5.1.5 Transaction handling 14](#_Toc316893450)

[5.1.6 Transmission, reception, and acknowledgment 14](#_Toc316893451)

[5.1.7 GTS allocation and management 16](#_Toc316893452)

[5.1.8 Ranging 16](#_Toc316893453)

[5.1.9 LLDN Transmission states 16](#_Toc316893454)

[5.1.10 Deterministic and synchronous multi-channel extension (DSME) 16](#_Toc316893455)

[5.1.11 LE-transmission, reception and acknowledgment 16](#_Toc316893456)

[5.1.12 Asynchronous multi-channel adaptation (AMCA) 20](#_Toc316893457)

[5.2 MAC frame formats 20](#_Toc316893458)

[5.2.1 General frame formats 20](#_Toc316893459)

[5.2.2 Format of individual frame types 20](#_Toc316893460)

[5.2.4 Information Elements 21](#_Toc316893461)

[5.3 MAC command frames 23](#_Toc316893462)

[5.3.12 LE Commands 24](#_Toc316893463)

[**5.** 24](#_Toc316893464)

[**5.3.2** 24](#_Toc316893465)

[**5.3.3** 24](#_Toc316893466)

[**5.3.4** 24](#_Toc316893467)

[**5.3.5** 24](#_Toc316893468)

[**5.3.6** 24](#_Toc316893469)

[**5.3.7** 24](#_Toc316893470)

[**5.3.8** 24](#_Toc316893471)

[**5.3.9** 24](#_Toc316893472)

[**5.3.10** 24](#_Toc316893473)

[**5.3.11** 24](#_Toc316893474)

[**5.3.12** 24](#_Toc316893475)

[5.3.14 Channel switching notification command 24](#_Toc316893476)

[5.4 MPDU Fragmentation 24](#_Toc316893477)

[5.4.1 MPDU PHY adaptation, fragmentation and reassembly 24](#_Toc316893478)

[5.4.2 Fragment Acknowledgement and retransmission 26](#_Toc316893479)

[6. MAC services 27](#_Toc316893480)

[6.1 Overview 27](#_Toc316893481)

[6.2 MAC management service 27](#_Toc316893482)

[5.3.17 MLME-CALIBRATE 27](#_Toc316893483)

[6.2.1 MLME-CHAN-NOTIFY 28](#_Toc316893484)

[6.3 MAC data service 29](#_Toc316893485)

[6.3.1 MCPS-Data.request 29](#_Toc316893486)

[6.3.2 MCPS-Data.confirm 30](#_Toc316893487)

[6.3.3 MCPS-Data.indication 30](#_Toc316893488)

[6.3.4 MCPS-Merge.request 30](#_Toc316893489)

[6.3.5 MCPS-Merge.confirm 30](#_Toc316893490)

[6.4 MAC constants and PIB attributes 30](#_Toc316893491)

[6.4.1 MAC constants 30](#_Toc316893492)

[6.4.2 MAC PIB attributes 30](#_Toc316893493)

[6.4.3 Calculating PHY dependent PIB values 30](#_Toc316893494)

[7. Security 31](#_Toc316893495)

[8. General PHY requirements 31](#_Toc316893496)

[9. PHY services 31](#_Toc316893497)

[10. O-QPSK PHY 31](#_Toc316893498)

[11. Binary phase-shift keying (BPSK) PHY 31](#_Toc316893499)

[12. Amplitude shift keying (ASK) PHY 31](#_Toc316893500)

[13. Chirp spread spectrum (CSS) PHY 31](#_Toc316893501)

[14. UWB PHY 31](#_Toc316893502)

[15. GFSK PHY 31](#_Toc316893503)

[16. SUN PHYs 31](#_Toc316893504)

[17. MSK PHY 31](#_Toc316893505)

[18. LRP UWB PHY 31](#_Toc316893506)

[19. LECIM PHYs 31](#_Toc316893507)

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

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

HWSL hybrid wakeup sample listening

RSLN relayed slot-link network

1. General Description
	1. General
	2. Components of the WPAN

Insert before 4.3.2 the following paragraphs:

LECIM networks typically are asymmetric in power consumption and capability, with a coordinator that is mains powered (or otherwise provided a substantial power source), and energy constrained endpoints which must have minimum energy consumption.

* 1. Network topologies
		1. Star network formation

Insert before 4.3.2 the following paragraphs:

LECIM networks are primarily star topology. 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.

For extending networking coverage, a star network may include end points which may relay MAC frames synchronously inward to the PAN coordinator or outward to a device, to form a relayed link network operating as a virtual star network.

* 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.

Insert new subclause after 4.5.1.4:

* + - 1. 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.

In a relayed slot-link network (RSLN), the PAN coordinator generates a cyclic-superframe that periodically transmits slotted-superframes, which can be combined into multi-superframes. The slotted-superframe contains a beacon slot, prioritized device slots, coordinator slots, and bidirectional device slots as shown in Figure 4c. The prioritized device slot shall start immediately following the beacon and provide an up-link to the coordinator for transmitting delay sensitive data from devices. The coordinator slot shall provide a down-link to devices for broadcasting frames. The bidirectional device slots in a cyclic-superframe shall be assigned to each device in a RSLN and provide a bidirectional link between a certain device and the PAN coordinator.



Figure 4c - An example of the cyclic-superframe structure

* + 1. Data transfer model

* + - 1. Data transfer to a coordinator

Insert before 4.5.2.2 the following paragraph:

In a RSLN PAN, two types of data transfer methods to a coordinator exist. When a device wishes to transfer delay sensitive data to a coordinator, the device shall transmit the data frame on the earliest prioritized device slot of a slotted-superframe. If a device failed to transfer on a prioritized device slot and wishes to transfer data to a coordinator, the data frame shall be transmitted on the bidirectional device slot, which is allocated exclusively for the device in a RSLN.

* + - 1. Data transfer from a coordinator

Insert before 4.5.2.3 the following paragraph:

In a RSLN PAN, two types of data transfer link to a device exist. When the coordinator wants to broadcast data to devices in a RSLN, the coordinator may use the coordinator slot. When the coordinator wishes to transfer data to a device without notifying, the coordinator may transmit the data frame continuously on the bidirectional device slot assigned to the device of a cyclic-superframe until the device acknowledges the successful reception of the data.

* + - 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 the critical event priority access is in use 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 critical event priority access 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***

4.5.4.2a 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. Asynchronous multi-channel adaptation

Insert new subclause before 4.5.5:

* + - 1. Multiple grades of synchronous channel access

The times of occurrence of events are often crucial for the observer and maintaining synchronous channels can support an accurate time-stamping of measuring events. The synchronous channel access helps distributing the data transfers in time scale and can provide multiple grades of channel access. In a RSLN PAN, three grades of synchronous channel access are provided: the grade 0 for transmitting a delay sensitive data, the grade 1 for the reliable transmission of data, and the grade 2 for the best efforts on transmitting data.

As for the grade 0 channel access, a device searches the earliest prioritized device slot firstly. If fails to transmit the data on the prioritized device slot, a device keeps finding a chance to transmit the data on the bidirectional device slot or prioritized device slot which will come next. A device with the grade 1 channel access waits for the primary bidirectional device slot in the cyclic-superframe and transmits the data. If fails to transmit the data, a device keeps searching supplementary bidirectional device slots from the rest of duration of cyclic-superframe or from the coming cyclic-superframe for transmitting the data.

* + 1. Power consumption considerations
			1. General
			2. Low-energy mechanisms
			3. Low energy extension of networking coverage by synchronous relaying

In a star network, the coverage of networking will be limited by the transmission range of a device, and for low powered devices, transmit power may be limited to increasing the device’s life span in the network. Compared to the energy constrained end point device, the abundantly powered coordinator can have greater responsibility to extend the coverage of the star network with no burden to a device and preserving the topology. In a RSLN PAN, a cyclic-superframe repeater provides synchronous relaying of the frames inward or outward between the PAN coordinator and end device to extend the coverage of a star network.

* + 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

Insert the following paragraph before 5.1.1.1.1:

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.

The superframe structure used for RSLN applications is described in 5.1.1.8.

* + - 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. This backoff procedure shall be used when the CCA returns channel busy and priority access is enabled.

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. During transmission of a priority message, when CAA returns channel busy, the alternate backoff shall be used 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
* macIRITenabled
* 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.

Insert new subclausse before 5.1.2:

* + - 1. RSLN slot-link structure
				1. General

The relayed slot-link network has slot-links between the PAN coordinator and each device in the network. A slot-link is the pairwise assignment of a directed communication between the PAN coordinator and a device in a given timeslot. The PAN coordinator generates a sequence of timeslots and repeats the sequences, the cyclic-superframe. Timeslots in a cyclic-superframe are the link for PAN coordinator to a device, 1-to-1 link, or the link for the PAN coordinator to n devices, 1-to-n link.

The cyclic-superframe provides slot-links to devices, the slotted-superframe, in time scale. The slotted-superframe consists of a beacon slot, prioritized device slot, coordinator slot, and bidirectional device slot.



Figure 11j example of slot-links in a cyclic-superframe

* + - * 1. Beacon slot

The beacon slot provides a link for transmitting a beacon from the PAN coordinator to devices. The beacon slot is reserved for the RSLN PAN coordinator to indicate the start of every slotted-superframe with the transmission of a beacon.

The beacon provides the RSLN PAN information such as structure of cyclic-superframe and global time information.

* + - * 1. Prioritized device slot

The prioritized device slot provides a link for transmitting delay sensitive data from a device to the PAN coordinator. The number of the prioritized device slot is defined as macNumPrioritizedDeviceSlot.

A device shall use slotted ALOHA mechanism to access the prioritized device slot-link.

* + - * 1. Coordinator slot

The coordinator slot provides a link for transmitting data from the PAN coordinator to devices. The number of the coordinator slot is defined as macNumCoordSlot.

The PAN coordinator shall use slotted ALOHA mechanism to access the coordinator slot-link.

* + - * 1. Bidirectional device slot

The bidirectional device slot provides a link for transmitting data from a device to the PAN coordinator or from the PAN coordinator to a device. The bidirectional device slot-link is assigned to all the devices in a RSLN PAN. If the number of bidirectional device slots in a cyclic-superframe is larger than the number of devices in a RSLN PAN, each device has a preemptive bidirectional device slot-link. Otherwise, some devices might share the bidirectional device slot-link to the PAN coordinator.

The channel access mechanism of a bidirectional slot-link depends upon the direction of transmission. On the access of the bidirectional device slot-link, the device gives priority in use. A device transmits without sensing the medium at the start of the assigned bidirectional device slot. Each time the PAN coordinator wishes to transmit data on the bidirectional device slot-link assigned to a certain device, it waits for a random number of backoff periods at the start of the assigned bidirectional device slot. If the slot-link is found to be idle, the PAN coordinator begins transmitting.

One primary bidirectional device slot and multiple supplementary bidirectional device slots are allocated to each device in a RSLN PAN. The supplementary bidirectional device slot provides additional slots for the transmission or is used for retransmitting the frame which was failed to transmit in the primary bidirectional device slot. On the access of the supplementary bidirectional device slot-link, the device shall use a slotted CSMA-CA mechanism.

* + 1. Starting and maintaining PANs

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

Insert before 5.1.3 the following subclause:

* + - 1. RSLN PAN formation

A RSLN PAN is formed when the PAN coordinator is instructed to begin operating through the use of the MLME-RSLN-START.request primitive, as defined in 6.2.x.x, with the RSLN PAN configuration and starts to send Enhanced Beacon on every beacon slots of a cyclic-superframe. The Enhanced Beacons contain:

* Cyclic-superframe specification (BO, SO, MO, number of prioritized device slot, number of coordinator slot)
* Time synchronization specification (global clock timestamp, slotted-superframe ID)
* Synchronous relaying specification (current depth of relaying, beacon information about neighbor tiers’ repeaters)
* Indirect data transmission information



Figure xx- Relayed slot-link network PAN

* + 1. Association and disassociation

Insert the following subclauses before 5.1.4 :

* + - 1. Link context association when MPDU fragmentation is used

Describe the link context setup for mapping full addresss to coordinator and device short addresses.

* + - 1. RSLN repeater association

The next higher layer shall attempt to associate as a repeater after having completed channel scan. The result of channel scan would have been used to choose a repeater closer to the PAN coordinator or the PAN coordinator from the list of the RSLN PAN descriptors.

Following the selection of an inner coordinator to associate, the next higher layers shall request through the MLME-RSLN-ASSOCIATE.request primitive, as described in 6.2.x.x, that the MLME configures the following the values for repeater association to the RSLN PAN:

* RSLN PAN information (phyCurrentChannel, phyCurrentPage, macPANId)
* inner coordinator information (macCoordExtendedAddress or macCoordShortAddress)
* repeater information (current depth of relaying, slotted-superframe ID)

The PAN coordinator shall allow association only if relayed beacon slot is available.



Figure xx- Synchronous relaying of cyclic-superframe in a RSLN PAN

* + 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.

Insert before 5.1.5 the following subclause:

5.1.4.4.1 RSLN Synchronization

TBD

* + 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

Insesrt before 5.1.6.5:

* + - * 1. Incremental fragment acknowledgement
				2. Incremental fragment retransmission
			1. Promiscuous mode
			2. Transmission scenarios

Insert after 5.1.6.6:

* + - 1. Synchronous relaying

Each repeater relays the slot-link outward or inward. The selection of relayed slot-link depends on the direction of relaying and the type of the slot-link.

Only the beacon received on the beacon slot of an inner repeater or the PAN coordinator shall be relayed to the outward beacon slot of the inner repeater or the PAN coordinator. The relaying of the cyclic-superframe beacon slot-link of the PAN coordinator to the cyclic-superframe beacon slot-link of the repeater is synchronized by letting a cyclic-superframe beacon of the PAN coordinator relayed on the cyclic-superframe beacon slot of the repeater. The outward relaying beacon slot of the inner repeater is determined by relative beacon slot distance between the cyclic-superframe beacon slot of the repeater and the inner repeater.

Outward relaying of the coordinator slot is synchronized with the relaying of the cyclic-superframe beacon slot.

The frames received on the bidirectional device slot of the inner repeater are relayed to the bidirectional device slot of the next cyclic-superframe.

When relaying the beacon or command frames outward, the repeater updates the time synchronization specification and the synchronous relaying specification in the frames, if applicable.



Figure xx- Outward synchronous relaying in a RSLN PAN



Figure xx- Outward synchronous relaying in a RSLN PAN

The prioritized device slot of the outer repeater is relayed to the earliest available prioritized device slot of coming slotted-superframe.

The frames received on the bidirectional device slot of the outer repeater are relayed to the bidirectional device slot of the next cyclic-superframe.



Figure xx- Inward synchronous relaying in a RSLN PAN

* + 1. GTS allocation and management

TBD if additions are needed.

* + 1. Ranging
		2. LLDN Transmission states
		3. Deterministic and synchronous multi-channel extension (DSME)
		4. 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 a broadcast frame to send, the destination address of the HWSL wakeup frame shall be set to the broadcast address, 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

* + 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 Control field
				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 |
| TBD | 4 | LE HWSL | Defined in 5.2.4.8a |
| TBD |  | MPDU Fragment Sequence Context |  |

Editing Note: Element ID values are to be assigned by the 802.15 Numbering Authority (aka Gilb)

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.

Insert the following new subclause before 5.3:

* + - 1. MPDU Fragment Sequence Context Description IE

The MPDU Fragment Sequence Context IE contains a description of an MPDU being fragmented and associates this information with a unique fragmentation transaction context ID. The Context ID is transmitted with each fragment to identify it as part of the MPDU described by the IE. The IE is illustrated in figure 48ua.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octets: 2 | 1 | 2 | Variable | Variable |
| Bits: 10 | 5 | 1 |  | 10 | 6 |  |  |
| Transaction ID | I-ACK Interval | Reserved | Fragment Size | MPDU Size | Address Info | Addressing fields | PHY Dependent Parameters |

**Figure 48ub – MPDU Fragment Context Description IE**

* + - * 1. Transaction ID field

The transaction ID field contains a value that is locally unique in the PAN and identifies the fragment sequence transaction. It associates the context information with each fragment in the transaction. The specific method for generating the transaction ID is implementation dependent, and shall assure that the current value is different from the preceding value.

* + - * 1. I-ACK Interval field

The I-ACK interval field indicates the I-ACK policy to be employed. For values from 1 to the maximum number of fragments, an I-ACK is generated by the receiving device after it has detected a fragment cell with the fragment number greater than or equal to the (fragment # of last I-ACK + I-ACK interval).

* + - * 1. Fragment Size field
				2. Fragment Size field
				3. MPDU Size field
				4. Address Information field

The addressing information field describes the context of the addressing fields that follow. The fragment sequence description may contain any combination of source PAN ID, destination PAN ID, source address and designation address in any of the allowable addressing modes defined by this standard. Figure 48uc illustrates the format of this field.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bit Position:1 | 2 | 3:4 | 4:5 | 5 |
| Source PAN ID Present | Dest PAN ID Present | Source Address Mode | Destination Address Mode | Reserved |

**Figure 48uc – Address Information Field Format**

The source and destination PAN ID present fields shall be set respectively if a source and/or destination PAN ID is included in the Addressing field. The source address mode field indicates the presence and format of, a source address included in the Addressing field, and shall be set to one of the values given in Table 3. The Destination address mode field shall indicate the presence and format of a destination address included in the Addressing field, and shall be set to one of the values given in Table 3.

The setting of this field shall be determined by the PAN ID and addressing mode fields of the MPDU being fragmented.

* + - * 1. Addressing field

The addressing field contains source and/or destination addressing information associated with the MPDU being fragmented. The format is illustrated in Figure 48ud.

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 0/16 | 0/16 | 0/8/16/64 | 0/8/16/64 |
| Source PAN ID  | Dest PAN ID  | Source Address  | Destination Address  |

**Figure 48ud – Addressing field**

The content of this field shall be set according to the addresses contained in the MHR of the MPDU being fragmented.

* + - * 1. PHY dependent parameters

The value of this field depends upon the PHY being used. The possible values are implementation dependent. Table 4j shows the format for the LECIM FSK PHY defined in yyy1; Table 4k shows the format for the LECIM DSSS PHY defined in yyy2.

Table 4j – PHY dependent fragment context parameters for LECIM FSK PHY

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter**  | **Bit Position** | **Valid Range** | **Parameter Description** |
|
| Slot #/Chan # | TBD | S0/C3:S8/C1:S16/C7:S24/C2:S32/C5 | Where network sets slot durations at 50 ms and channel page to 9 |
| Sync Info | TBD | TBD | TBD |
| Time out perioid | TBD | 0 to 0x3C | >= 60 slots or 3 seconds (0xFF = no period defined) |

Table 4k – PHY dependent fragment context parameters for LECIM DSSS PHY

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter**  | **Bit Position** | **Valid Range** | **Parameter Description** |
|
| TBD | TBD | TBD | TBD |

* 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** |
| TBD | HWSL-data request | X |  | 5.3.12.2 |
| TBD | HWSL-wakeup |  |  | 5.3.12.1 |
| TBD | CSN |  |  | 5.3.14 |

* + 1. LE Commands

Insert new subcluse after 5.3.12.1):

* + - 1. RIT data request command
1. * 1.
		2.
		3.
		4.
		5.
		6.
		7.
		8.
		9.
		10.
		11. 1. HWSL data request command

TBD

* + - 1. HWSL wakeup command

TBD

Insert new subclause after 5.3.1:

* + 1. Channel switching notification command

The channel switching notification command is sent by a device to notify the other device to switch channel together during fragments transmission. All devices that support fragmentation shall be capable of transmitting this command. The channel switching notification command shall be formatted as illustrated in Figure 59de.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octets:  | 1 | 1 | 1 | 2/4 |
| Frame Control | Command ID | Sequence ID | Channel Offset | FCS |

Figure 59de Channel switching notification command format

* 1. MPDU Fragmentation

When MPDU fragmentation is enabled, the completed MPDU will be processed 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

The fragment sequence context is established by transmitting a fragment context command which contains a MPDU Fragment Sequence Context Description IE, as described in 5.2.4.23. The fragment context command is any directed MAC command or data frame which contains a MPDU Fragment Sequence Context Description IE, and the command shall contain exactly one such IE.

The context command imitates the transaction and establishes the initial state for the MPDU sequence transactionThe context command shall be transmitted with the Acknowledge Request field set. If acknowledgement is not received, the context command shall be retransmitted up to *macMaxTransactionInitRetry* times as needed.

Upon reception the context command, the information contained is associated with the transaction ID, which is used to identify each fragment in the sequence, and the context is acknowledged. If a fragmentation cell is not received within *aMPDUFragTimeout* the fragmentation transaction shall be terminated.

When the LECIM DSSS PHY is in use, a unique spreading code or codes may be used between the coordinator and end point, in which case the context of the transaction is established uniquely by code separation and the transaction ID may be elided from each fragment cell. The transaction ID value of zero (0) is allocated for this purpose. A transaction ID of 0 shall be used in the context information to indicate that fragment cells do not contain a transaction ID, and shall be used only with PHYs that support other means to establish point-to-point unique context.

* + - 1. Fragment cell formats

The fragment data cell contains a fragment descriptor, fragment data and fragment validation value, as depicted in Figure 59df.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bits: 0/10 | 5 | 1 | Variable | 16/24/32 |
| Transaction ID | Fragment Number | Extension | Fragment Data | Fragment validation  |

Figure 59df Fragment Cell General Form

The Transaction ID (TID), when present, shall contain the value assigned to the transaction context as indicated in the fragment sequence context command. When context is unambiguously known via other means provided by the PHY in use, the TID may be suppressed. Upon reception, if the TID contains a value other than the TID of a currently active transaction, the cell is ignored (not acknowledged, and not counted to reset the transaction timeout).

The Fragment number identifies which fragment in the sequence the data part contains. Fragment number of zero shall be used to indicate a terminated transaction, and upon reception of a cell with TID of zero the receiving devices will invalidate the transaction context; if subsequence cells are received with the same TID prior to a new transaction context command, they may be ignored. Upon MPDU reassembly the fragment data shall be placed in order according fragment number.

The extension field is used to indicate an extended cell descriptor and is reserved for future versions of this standard.

The Fragment Data field contains the part of the fragmented MPDU indicated by the fragment number. The size of the data field depends on the configuration of the PHY in use. For the LECIM DSSS the data field may be 15 to 23 octets; For the LECIM PHY the fragment data field may be from 19 to TBD octets.

The Fragment validation field is used to validate the received fragment cell. It shall be calculated as defined for the TBD length CRC according to 5.2.1.9.

* + - 1. Fragmentation

The MPDU is prepared for fragment transmission according to the following steps:

1. Determine fragment context using MHR fields depending on the source addressing, destination addressing and data request parameters
2. Construct the Fragment Sequence Context command as described in 5.4.1.1
3. Elide/compress the MHR fields that are effectively transmitted in the transaction context command.
4. Divide the remaining MPDU into fragment data cells of the size supported by the current PHY configuration. All fragments but the final fragment contain the maximum number of data octets; for PHY configurations that use a fixed PPDU size (no PPDU length field transmitted), the final fragment data is padded with *macMPDUFragPadValue* (which may be a PHY dependent value). The fragment validation field for the final fragment is calculated including the pad octets.
5. Transmit the fragment context command (retransmit as necessary)
6. Upon acknowledgement of the fragment context, transmit fragment cells. After I-ACK interval fragment cells have been transmitted, wait for the I-ACK. Retransmit the cell preceding the I-ACK if the acknowledge is not received with the I-ACK timeout.
7. Upon transmission of the final fragment cell and/or reception of the final I-ACK as appropriate, the MPDU level acknowledgement is performed as described in 5.1.6.

Fragments are transmitted in the order shown in (figure ref). The I-ACK is described in 5.4.2.1. If during the transaction an I-ACK retransmission count is exceeded the transaction is terminated and a fragment cell with the fragment number set to zero is transmitted to signal the receiving device.

* + - 1. Reassembly

Upon reception of the Fragment Sequence Context command, the transaction state is initialized for a new MPDU fragment sequence transaction and the context command is acknowledged. Each received fragment cell is placed into the reassembled MPDU based on the fragment number. I-ACKs are generated according to 5.4.2.1. When the final fragment is received and validated, MPDU validation proceeds according to 5.1.6.

* + 1. 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 IACKinterval parameter of the MCPS-Data.request, which is transmitted to the receiving device with the fragmentation sequence set-up message (xref). Upon completion of transmission of each IACKinterval 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*. If, following macIACKtimeout an I-ACK has not been received, the initiator will retransmit the last fragment sent and wait for the I-ACK again, repeating this process up to *macMaxFragRetries* times.

The I-ACK will include the fragment status field, constructed as shown in [ref]. Upon receipt of the I-ACK, the initiator of the fragment sequence will examine the fragment status field, and shall retransmit the fragments that are not indicated as successfully received (retry fragments) following the I-ACK, the fragments to be retransmitted shall be transmitted in the order of initial transmission, followed by the next k fragments in sequence, where k = (IACKinterval – number of retry fragments).

* + - 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 a Fragment Status IE, constructed and transmitted as described here. The MPDU acknowledgement may contain information to support the channel switching notification.

If *macFragmentSequExtAck* is FALSE, and MPDU acknowledgement is generated when the reassembly of the MPDU is completed and address filtering, if enabled has been completed. The fragmentation transaction status IE is populated with the status if each fragment in the sequence and the final FCS.

When *macFragmentSequExtAck* is TRUE, the MPDU higher layer may become involved in the acknowledgement processing. The recipient device will, upon receiving the final fragment, generate an simple acknowldgement to the originator with the frame pending field set, and generates an MCPS\_Data indication with the reassembled MPDU with the fragment sequence status information as described in 6.3.3, Upon completion of higher layer processing (which is out of scope of this standard), the higher layer uses the MCPS-ExtAck.request, which imitates generation of the MPDU acknowledgment frame containing the status and feedback information provided with the service parameters.

* + - 1. Channel switching for fragment sequence exchange

Given the potentially long duration of the MPDU transaction in time, there is a possibility that channel conditions may change significantly. The higher layer may decide that the channel is becoming unusable, and desire to change to another channel for subsequent transactions. The channel switch notification process provides this capability.

The Channel Switch Notification (CSN) is a directed command frame which facilitates changing channel or PHY parameters between the sending and receiving node. The CSN is sent by the recipient of a fragment sequence to the originator. To initiate the switch channel, the information of new channel will be included in the CSN command. The switch is initiated by the higher layer via the MLME-Chan-Notify service. When initiated, the CSN will be transmitted following the aggregated MPDU acknowledge. The AR field of CSN command is set to one. The originator shall acknowledge reception of the CSN command, and the originator and recipient shall switch to the new channel indicated in CSN command. [add MSCs and references]

The CSN will affect only the device sending it and the device receiving. The CSN command shall not be tranasmitted with the broadcast PANID anr/or broadcast destination address. The higher layer bnetwork management entity controls which channel and/or PHY configurations are used to communicate with which neighbors, the process by which this is done is outside the scope of this standard.

In the event that a CSN is not acknowledged, the channel switch is not performed. In the event that communication is not re-established after either a channel switch or aborted channel switch after the macCSNeffectTimeout, the device shall revert to the prior channel and PHY configuration. The originator should perform handshake with the recipient prior to transmission by sending the first fragment to recipient and receiving acknowledgment. This confirmation process is outside the scope of this standard.

1. MAC services
	1. Overview
	2. MAC management service
		1. MLME-CALIBRATE

Insert new subclause before 6.3:

* + 1. MLME-CHAN-NOTIFY

These primitives are used when a device notifies the other device to switch channel together during fragments transmission.

* + - 1. MLME-CHAN-NOTIFY.request

The MLME-CHAN-NOTIFY.request primitive is used by a device to notify the other device to switch channel together. On receipt of the MLME-CHAN-NOTIFY.request primitive, the MLME of the device generates a channel switching notification command.

The semantics of this primitive are:

MLME-CHAN-NOTIFY.request (

 ChannelOffset,

 SequenceID,

 CID or ShortAddr

 )

The primitive parameters are defined in Table 44a.

Table 44a - MLME-CHAN-NOTIFY.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| ChannelOffset | Integer | 0x00-0xff | The offset value of channel sequence of the PAN. |
| SequenceID | Integer | 0x00–0xff | The ID of the fragment sequence to switch channel. |
| CID or ShortAddr | Integer | 0x0000–0xffff | The CID or short address of the device transmitting the fragment sequence. |

* + - 1. MLME-CHAN-NOTIFY.confirm

The MLME-CHAN-NOTIFY.confirm primitive is used to inform the next higher layer of the originator whether the channel switching notification command is transmitted successfully.

The semantics of this primitive are:

MLME-CHAN-NOTIFY.confirm (

 Status

 )

The primitive parameters are defined in Table 44b.

Table 44b - MLME-CHAN-NOTIFY.confirm parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| Status | Enumeration | SUCCESS,CHANNEL\_ACCESS\_FAILURE,NO\_ACK,UNSUPPORTED\_LEGACY,INVALID\_PARAMETER | The status of transmission of channel switching notification command. |

* + - 1. MLME-CHAN-NOTIFY.indication

The MLME-CHAN-NOTIFY.indication primitive is used to indicate the reception of a channel switching notification command.

The semantics of this primitive are:

MLME-CHAN-NOTIFY.indication (

 ChannelOffset,

 SequenceID,

 CID or ShortAddr

 )

The primitive parameters are defined in Table 44c.

Table 44c – MLME-CHAN-NOTIFY.indication parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| ChannelOffset | Integer | 0x00-0xff | The offset value of channel sequence of the PAN. |
| SequenceID | Integer | 0x00–0xff | The ID of the fragment sequence to switch channel. |
| CID or ShortAddr | Integer | 0x0000–0xffff | The CID or short address of the device transmitting the fragment sequence. |

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

Add into the parameter list:

GroupTx,

The originator is instructed to transmit fragments in group through the MCPS-DATA.request primitive with GroupTx set to TRUE. After sending each group of fragments, the originator suspends transmission and waits for I-ACK.

Insert into Table 46:

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Valid range | Description |
| IACKinterval | Integer | - | Specifies that, if fragmentation of the MPDU is necessary, the maximum number of fragments to send prior to expecting an incremental acknowledgement. If set to zero, no incremental acknowledges request, only MPDU level acknowledgment will be used.  |

GroupTx

* + 1. MCPS-Data.confirm
		2. MCPS-Data.indication
		3. MCPS-Merge.request
		4. MCPS-Merge.confirm
	1. 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