**IEEE P802.15**

**Wireless Personal Area Networks**

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| Re: | 802.15.4 Revision Preparation: MAC Timing Discussion  |
| Abstract | Submission to Maintenance standing committee: Enumeration of timing parameters as defined in the current standard to support identification of issues and development of solutions.  |
| Purpose | Promote useful work |
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Enumeration of 15.4 MAC Timing Parameters

# Introduction

This document identifies the attributes and constants that specify or affect specified timing of MAC operations.

Section 2 lists the identified variables based on searching the standard. The search included the following documents:

* 802.15.4-2011
* 802.15.4e-2012
* 802.15.4f-2012
* 802.15.4g-2012
* 802.15.4j-2013.
* 802.15.4k-2013
* Draft P802.15.4m
* Draft P802-15-4p

The table indicates where the attribute is defined, provides a summary the attributes purpose and how it is affected by various amendments. The color coding to identify areas where it is known that attention is needed the revisions:

* RED identifies critical issues (where things may be broken)
* YELLOW are areas that need clarification or other less critical attention (may be broken or just misunderstood)
* BLUE indicates minor editorial issues associated with the attribute that may require care during the merge process
* Lack of color (white) indicates attributes that do not appear to have issues at this time.

Where there is a complex relationship between constants and attributes I have identified these as needing attention (RE or YELLOW). This would include things where changes in amendments may create unintended consequences, such as creating conflicting requirements. In some cases things are not so clearly ‘wrong’ but where the actual requirement may be difficult to understand (and thus test).

Section 3 provides some additional information to assist in the discussion of problems and solutions.

***This is not an exhaustive analysis. This serves as a starting point. RED and YELLOW are based on the issues we have already discussed and identified.***

# Summary of Timing Attributes, Constants and Parameters

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| **Constants** |
| **Name**  | **Type** | **Units** | **Description and Notes** | **Source** |
| aMaxSIFSFrameSize | MC | Octets | The maximum size of an MPDU, in octets, that can be followed by a SIFS period (18). Used many places. 4e: used in LLDN, 4m includes changes to figure 10 and links aTurnaroundTime to IFS.  | 2011 |
| aTurnaroundTime | PC | Mixed | Time to switch between transmit and receive modes in a half-duplex transceiver.12 Symbols in 2011; 1ms rounded up to symbol boundary 4g, 4k, 4m for specific PHYs.  | 20114g4k4m |
| aBaseSlotDuration | MC | Symbols | 60 symbols. Used in many places. Number of symbol durations in a Superframe slot when SF order =0; Used in 4g for timing of MPM beacons even without Superframes); 4m used in TMCP | 2011 |
| aBaseSuperframeDuration | MC | Symbols | 960 symbol durations. The number of symbols forming a Superframe when the Superframe order is equal to zero. Used in a lot of places independent of Superframe usage. 4e:used by RIT, DSME, AMCA; 4g: used in MPM, , 4m: used by TMCP. | 2011 |
| aCCATime | PC | Symbols | Introduced in 4g to replace a hard-coded value in 2011. For MR-O-QPSK PHY, 4 or 8 symbols depending in operating mode; For all other PHYs that don’t use phyCCADuration, 8 symbol periods. See 3.1. | 4g4p |
| aUnitBackoffPeriod | MC | Mixed | 2011: 20 symbol periods for all PHYs; 4e: TSCH uses different back off timing;4g: SUN PHYs in 950MHz or 920MHz: aTurnaroundTime + phyCCADurationFor all other PHYs: aTurnaroundTime + aCCATime.  | 20114e4g |
| aGTSDescPersistenceTime | MC | SFs | Number of Superframes in which a GTS descriptorappears in the beacon (4). | 2011 |
| aLeipDelayTime | MC | Time | The delay between the start of the SFD andthe location enhancing information postamble (0.815 ms). | 4f |
| aMinCAPLength | MC | Symbols | Minimum CAP length (440). Restrictions added in 4k for priority access. | 20114k |
| aNumSuperframeSlots | MC | None | Number of slots contained in any Superframe (16). | 2011 |
| aRCCNBaseSlotDuration | MC | Symbols | The number of symbols forming an RCCN superframe slot (60). | 4p |
| aMRFSKPHRLength | MC | Octets | The length of the MR-FSK PHR (2).  | 4g |
| aMRFSKSFDLength | MC | Octets | The length of the MR-FSK SFD (2). | 4g |
| aMROQPSKPHRLength | MC | Octets | The length of the MR-O-QPSK PHR (3). | 4g |
| aMROQPSKSFDLength | MC | Octets | The length of the MR-O-QPSK SFD (2). | 4g |

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| **MAC Attributes** |
| **Name**  | **Type** | **Units** | **Description and Notes** | **Source** |
| macAckWaitDuration | MA | Mixed | The maximum duration to wait for an acknowledgment frame. Value is PHY dependent and entangled with a number of other values which have changed in multiple amendments and in some cases mix units.  | 20114g4k |
| macLIFSPeriod | MA | Symbols | RO; in 2011 40 symbol durations for all PHYs; Has issues, See 3.3. Do we need for separate LIFS and SIFS  | 2011 |
| macSIFSPeriod | MA |  | RO; 12 symbol durations for all but 4p where it is set to 5 symbol durations for See 3.3.  | 2011 |
| macEnhAckWaitDuration | MA | Time | Deadline to send an enhanced acknowledgment and the maximum timeout period to wait. 4k: Tweaks usage in CSL; 4p: further tweaks language in CSL. | 4e |
| macMaxFrameTotalWaitTime | MA | Symbols | Timeout for response to a data request frame or for a broadcast frame to follow a beacon with the Frame Pending set. | 2011 |
| macMinLIFSPeriod | ?? | ?? | Used in 4e but not defined | 4e |
| macMinSIFSPeriod | ?? | ?? | Used in 4e but not defined | 4e |
| macResponseWaitTime | MA | Symbols | Response wait for MAC request commands. Multiples of *aBaseSuperframeDuration*.  | 2011 |
| macEnhancedBeaconOrder | MA | Symbols | Interval of EBs transmission when Multi-PHY-Management (MPM) is in use.  | 4g |
| macNBPANEnhancedBeaconOrder |  | Symbols | Interval to transmit EBs when MPM is in use in a non-beacon enabled PAN. | 4g |
| macOffsetTimeSlot | MA | SF Slots | When MPM is in use, offset the periodic beacon and the MPM EB transmission. | 4g |
| macSyncSymbolOffset | MA | symbols, | Implementation specific offset in the captured receive time stamp. 4g adds PHY specific “range” value for FSK and OFDM and removes extraneous text; Other PHY amendments don’t but probably should. Requires editorial cleanup and should consider if integer symbols is the right unit. | 20114g |
| macTxControlActiveDuration | MA |  | Duty cycle control, active duration | 2011 |
| macTxControlPauseDuration | MA |  | Duty cycle control, inactive duration | 2011 |
| macTxTotalDuration | MA |  | Number of symbols transmitted  | 2011 |
| macASN | MA |  | Absolute Slot Number. Used by TSCH | 4e |
| macBattLifeExtPeriods | MA | backoffperiods | 3+2+k for all PHYs except 950MHz in Japan;3+1+k for 950MHz in japan (and s/b 920MHz too)k = SHR duration rounded up to integer number of aUnitBackoffPeriods. | 2011 |
| macBeaconOrder | MA | Symbols | Exponent of beacon transmission interval BI = 960 \* 2^macBeaconOrder. Used extensively. | 2011 |
| macBeaconSlotLength | MA | Symbols | Duration of beacon slot (DSME) | 4e |
| macBeaconTxTime | MA | Symbols | The time that the device transmitted its last beacon frame, in symbol periods. READ ONLY. | 2011 |
| macCritMsgDelayTol | MA | Time | Maximum time (ms) between PCAs | 4k |
| macCSLInterval | MA | Time | Interval between two successive CSL wake-up frames (10 ms units) | 4k |
| macCSLMaxPeriod | MA | Symbols | Maximum CSL sampled listening period for the PAN (10 symbols) | 4e |
| macCSLPeriod | MA | Symbols | Sampled listening period (10 symbols) | 4e |
| macDisconnectTime   | MA | Timeslots | Duration to transmit disassociation notifications (TSCH). | 4e |
| macIRITListenDuration | MA | Symbols | Duration that the listens for the start of a frame to receive (IRIT).  | 4k |
| macIRITOffsetInterval | MA | Symbols | Interval from the end of the transmitted frame to the beginning of the I-RIT listening period. | 4k |
| macLECIMAlohaUnitBackoffPeriod | MA | Symbols | backoff increment when PCA backoff algorithm is in use. | 4k |
| macLECIMAlohaBE | MA | NA | Backoff exponent value for priority messagesusing CCA Mode 4 (ALOHA), | 4k |
| macLowEnergySuperframeSyncInterval | MA | Beacon Intervals | Beacon transmission interval when low energy superframe is enabled (how many BIs are skipped) | 4e |
| macMaxBE | MA | NA | The maximum value of the backoffExponent for CSMA; 4e changes the default value for LLDN and TSCH; 4k changes how minBE and maxBE are set when the alternate CSMA is used. | 20114e4k |
| macMaxCSMABackoffs | MA | NA | The maximum number of CSMA backoffs attempted. 4e changes default value for LLDN. | 2011 |
| macMaxCSMABackoffs |  | Backoff Periods | Max CSMA Backoffs. 4e changes default value for LLDN.  | 2011 |
| macMaxFrameRetries | MA | NA | Number of retransmission attempts.  | 2011 |
| macMinBE | MA |  | The minimum value of the backoff exponent(BE) for CSMA. 4e and 4k changes as described for macMaxBE.  | 20114e4k |
| macSuperframeOrder | MA | Symbols | Exponent for the Duration of the active part of the Supreframe (SD = 960 \* 2^macSuperframeOrder) | 2011 |
| macTransactionPersistenceTime | MA |  | Time an indirect transaction is stored.  | 2011 |
| macRITDataWaitDuration | MA | Symbols | The max time to wait for a data transmission after a RIT data request | 4e |
| macRITPeriod | MA | Symbols | The interval between RIT data requests. | 4e |
| macRITTxWaitDuration | MA | Symbols | The max time that an (indirect) transaction is stored by a device in RIT mode. | 4e |
| macTsAckWait | MA | Time | The minimum time to wait for start of an Acknowledgment in TSCH | 4e |
| macTsCCA | MA | Time | CCA duration for TSCH | 4e |
| macTsCCAOffset | MA | Time | Start of CCA offset from start of timeslot (TSCH) | 4e |
| macTsMaxAck | MA | Time | Transmission time to send Acknowledgment in TSCH | 4e |
| macTsMaxTx | MA | Time | Transmission time to send the maximum length frame | 4e |
| macTsRxAckDelay | MA | Time | When to listen for Acknowledgement in TSCH | 4e |
| macTsRxOffset | MA | Time | Beginging of the timeslot when receier listening | 4e |
| macTsRxWait | MA | Time | The time to wait for start of frame in TSCH | 4e |
| macTsTxAckDelay | MA | Time | When to start transmissino of Acknowldgement in TSCH | 4e |
| macTsTxOffset | MA | Time | The time between the beginning of the timeslot and the start of frame transmission in TSCH | 4e |

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| **PHY Attributes** |
| **Name**  | **Type** | **Units** | **Description and Notes** | **Source** |
| phyCCADuration | PA | Symbols |  For PHYs the 920MHz or 950MHz bands, and the RCC PHY, CCA duration is the value of phyCCADuration, with a range of 5-1000 symbol periods; For other PHYs, CCA duration is a constant (aCCATime) with a value of 8 or 4 symbol periods. See 3.1. | 20114g 4p |
| phyMaxFrameDuration | PA | Symbols | Duration of the PHY packet. Complicated definition for some PHYs. Different for most PHYs. | 20114g4k4m |
| phyCCATimeMethod | PA | NA | Controls how CCA duration is calculated (920MHz and 950MHz bands) | 4g |
| phyPHRDuration | PA | Symbols | Duration of PHY for the current PHY.  | 4g |
| phyRFRAMEProcessingTime | PA | Time | Minimum duration between RFRAMEs to assure the PHY processes all of them (2ms) | 2011 |
| phySHRDuration | PA | Symbols | Duration of the SHR for the active PHY (read only). | 2011 |
| phySymbolsPerOctet | PA | Symbols | Real number of symbols per octet. 2011: 0.4, 1.3, 1.6, 2, 5.3, 8).  | 2011 |
| phyPreambleSymbolLength | PA | NA | Indicates if the short or long preamble symbol is used (UWB PHY). | 2011 |
| phyTXRMARKEROffset | PA | Fraction of a chip | Propagation time from the ranging counter to the transmit antenna. Different fractions for different UWN PHYs. | 20114f |
| phyRXRMARKEROffset | PA | Fraction of a chip | Propagation time from the receive antenna to the ranging counter. Different fractions for different UWN PHYs. | 20114f |
| phyRFRAMEProcessingTime | PA | Time | processing time required by thePHY to handle an arriving RFRAME | 2011 |

# Details

## macMaxFrameTotalWaitTime

This is set by the next higher layer and is dependent upon other attributes and constants, giving a complex formula but no clear normative direction to the implementer of the standard or the higher layer protocol using the standard implementation. The formula depends on the following:

* aUnitBackoffPeriod
* macMaxBE
* macMaxCSMABackoffs
* macMaxFrameTotalWaitTime
* macMinBE
* phyMaxFrameDuration

Due to the complexity of the formula, the number of dependent attributes and constants and the fact that normative direction is not clear, there may be potential for unintended consequences.

## phyCCADuration

In 2011, for all PHYs except 950MHz FSK (Japan), CAA duration is 8 symbols and phyCCADuration for the 950MHz PHY. In 2011, phyCCADuration has a range of 0-1000 symbol periods. The 4g text introduces a new constant aCCATime which replaces the hard coded value 8 in the text for legacy PHYs, the MR-FSK PHY and the MR-OFDM PHY, extends the use of phyCCADuration to the 920MHz band, and specifies a value of 4 or 8 for the MR-O-QPSK PHY depending on operating mode.

15.4p added use of phyCCADuration for the RCC PHYs, and because a voter objected to a CCA duration of 0, 4p change the range to 5-1000 symbol periods.

It is unclear if aCCATime (or phyCCADuration) is applied to CCA Mode 4, i.e. is there a minimum delay before returning “clear”.

## LIFS and SIFS periods

These parameters were effectively unchanged for a long while, but since 2011 nearly every amendment has made a change. The LIFS and SIFS values are 12 and 40 symbols for all PHYs except RCC, and for the RCC PHY LIFS=SIFS=5 symbols. In discussion in the November meeting the following questions were raised:

* Do we still need separate LIFS and SIFS or can we replace both with a single IFS value?
* Are the values 12 and 40 really valid for all PHYs except RCCN?

## aUnitBackoffPeriod

From 2003 on it has been 20 symbols. This changed in 15.4g to be dependent on aTurnaroundTime and the CCA Duration (phyCCADuration or aCCATime). For PHYs prior to 4g, aTurnaroundTime = 12 symbol periods and aCCATime is 8 symbol periods, so it’s still 20 symbols. For PHYs added in 4g and 4k, aTurnAround time is 1ms. This may impact the CSMA algorithm.

## aTurnaroundTime

This value is entangled in the definition of several other critical values.

The value in 15.4-2011 is the same as provided in 2003 as 12 symbols. The value has been changed in 4g, 4k and 4m to be 1ms for some PHYs.

This is used in many places including computation of acknowledgement timing. It defines the maximum time that a transceiver can take to switch from transmitting to receiving modes. Thus it must be used by a receiver as a minimum time between reception of the frame being acknowledged and the acknowledgement being transmitted, to assure the initiator of the frame being acknowledged is prepared to receive the acknowledgment.

Prior to 4k, 5.1.6.4.2 specified that the transmission of an acknowledgment frame when using contention access shall commence *macSIFSPeriod* after the reception of the last symbol of the data or MAC command frame, not reflecting changes to aTurnaroundTime. An attempt to correct this is included in 4k.

## macAckWaitDuration

The definition is complex depending on a number of other timing values, and has been changed quite a bit. The complexity may lead to confusion.

## MPM specific attributes

The MAC attributes macEnhancedBeaconOrder, macNBPANEnhancedBeaconOrder, and macOffsetTimeSlot are used only by MPM, but this may not be clear from the attribute names, definitions and associated text when merged into the rest of the standard.

## Duty-cycle control attributes for the Japanese bands

It may not be clear from the attribute definitions that macTxControlActiveDuration, macTxControlPauseDuration, macTxTotalDuration are used only in Annex H which applies to the 950MHz band (and probably also the 920MHz band now).

## macMinLIFSPeriod and macMinSIFSPeriod

These appear in 4e but are not defined. Both are used in LLDN (5.2.2.5), and macMinLIFSPeriod is used in the definition of macCSLFramePendingWaitT (6.4.3.7 Table 52j).