**IEEE P802.15**

**Wireless Personal Area Networks**

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| Title | Revised Text for Clock Drift and Guard Time Provisioning |
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| Source | Jin-Meng HoTexas Instruments Incorporatedjinmengho@ieee.org 214-480-1994 |
| Re: | Sponsor ballot comments. |
| Abstract | This submission provides the normative text for the resolution of CID 115, incorporating the resolutions of CID 134-140. |
| Purpose | To facilitate sponsor ballot comment resolution. |
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*Editing Instructions: Incorporate the changes as given below into latest BAN draft, adjusting subclause, figure, and table numbers as appropriate.*

* + 1. Connection Request

A Connection Request frame contains a Frame Payload that is formatted as shown in Figure 1. It is transmitted by a node to request creation or modification of a connection with a hub.



1. — Frame Payload format for Connection Request frames
	* + 1. Recipient Address

The Recipient Address field is set to the EUI-48 of the recipient of the current frame, or is set to zero if such an EUI-48 is yet unknown.

* + - 1. Sender Address

The Sending Address field is set to the EUI-48 of the sender of the current frame.

* + - 1. MAC Capability

The MAC Capability is as defined in 6.6.1.

* + - 1. PHY Capability

The PHY Capability is as defined in 6.6.2.

* + - 1. Connection Change Indicator

The Connection Change Indicator is formatted as shown in Figure 28. It indicates certain fields that follow in the current frame have been changed in value since their last exchange between the sender and the recipient.



1. — Connection Change Indicator format
	* + - 1. Wakeup Phase Change

The Wakeup Phase Change field is set to one if the value of the Requested Wakeup Phase or Assigned Wakeup Phase field has been changed, or is set to zero otherwise.

* + - * 1. Wakeup Period Change

The Wakeup Period Change field is set to one if the value of the Requested Wakeup Period or Assigned Wakeup Period field has been changed, or is set to zero otherwise.

* + - * 1. Uplink Request / Assignment IE Change

The Uplink Request / Assignment IE Change field is set to one if the value of the Uplink Request IE or Uplink Assignment IE has been changed, or is set to zero otherwise.

* + - * 1. Downlink Request / Assignment IE Change

The Downlink Request / Assignment IE Change field is set to one if the value of the Downlink Request IE or Downlink Assignment IE has been changed, or is set to zero otherwise.

* + - * 1. Bilink Request / Assignment IE Change

The Bilink Request / Assignment IE Change field is set to one if the value of the Bilink Request IE or Bilink Assignment IE has been changed, or is set to zero otherwise.

* + - * 1. Unscheduled Bilink Request / Assignment IE Change

The Unscheduled Bilink Request / Assignment IE Change field is set to one if the value of the Type-I Unscheduled Bilink Request IE, Type-II Unscheduled Bilink Request IE, Type-I Unscheduled Bilink Assignment IE, or Type-II Unscheduled Bilink Assignment IE has been changed, or is set to zero otherwise.

* + - * 1. Channel Order IE Change

The Channel Order IE Change field in Connection Request frames is reserved.

The Channel Order IE Change field in Connection Assignment frames is set to one if the value of the Nibble Encoded Channel Order IE or Channel Hopping and Ordering IE has been changed, or is set to zero otherwise.

* + - * 1. Ack Data Rates Change

The Ack Data Rates Change field is set to one if the value of the Requested Ack Data Rates or Assigned Ack Data Rates field has been changed, or is set to zero otherwise.

* + - 1. Requested Wakeup Phase

The Requested Wakeup Phase field is set to the sequence number of the next beacon period (superframe) in which the sender (a node) plans to wake up for frame reception and transmission, with the sequence number of a beacon period (superframe) treated as incremented by one modulo 216, instead of modulo 28, from that of the previous beacon period (superframe). The value of this field is calculated as *S+D* modulo 216, where *S* is the one-octet sequence number of the current beacon period (superframe) and *D* is such that the node is to wake up *D* beacon periods (superframes) later after receiving a Connection Assignment frame. With a length of two octets, this field allows a node’s next wakeup to be scheduled up to 216 beacon periods (superframes) away from the current one.

The Requested Wakeup Phase field is reserved in non-beacon mode without superframes.

* + - 1. Requested Wakeup Period

The Requested Wakeup Period field is set to the length, in units of beacon periods (superframes), between the start of successive wakeup beacon periods (superframes) in which the sender (a node) plans to wake up for reception and transmission, starting from the one indicated in the preceding Requested Wakeup Phase field. It is set to zero to encode a value of 216 beacon periods (superframes). With a length of two octets, this field allows a node’s wakeup period to be up to 216beacon periods (superframes).

The value of this field determines whether the IEs in this frame denote 1-periodic or m-periodic allocations:

1. If Requested Wakeup Period = 1, these IEs denote 1-periodic allocations.
2. If Requested Wakeup Period ≠ 1, these IEs denote m-periodic allocations.

The Requested Wakeup Period field is reserved in non-beacon mode without superframes.

* + - 1. Requested Ack Data Rates

The Requested Ack Data Rates is formatted as shown in Figure 29. It defines the data rates requested for use to send I-Ack and B-Ack data frames between the sender and recipient of the current frame while they are exchanging data type frames.



1. — Requested Ack Data Rates and Assigned Ack Data Rates format
	* + - 1. Node Ack Data Rate Control

The Node Ack Data Rate Control field is set to one if the sender or recipient of this frame (a node) is to send its I-Ack and B-Ack frames at the same data rate as used to send the last frame it received, or is set to zero if the node is to send its I-Ack and B-Ack frames at a data rate indicated in the following Node Ack Data Rate field.

* + - * 1. Node Ack Data Rate

The Node Ack Data Rate field is set to *R* such that the sender or recipient of this frame (a node) is to send its I-Ack and B-Ack frames at the information data rate as encoded by *R* = *R2R1R0* of the Data Rate field defined in the corresponding physical layer (PHY) clause, if the preceding Node Ack Data Rate Control is set to zero, or is reserved otherwise. Here, bit *R0* denotes the least-significant bit of *R*, and bit *R2* denotes the most-significant bit.

* + - * 1. Hub Ack Data Rate Control

The Hub Ack Data Rate Control field is set to one if the sender or recipient of this frame (a hub) is to send its I-Ack and B-Ack frames at the same data rate as used to send the last frame it received, or is set to zero if the hub is to send its I-Ack and B-Ack frames at a data rate indicated in the following Hub Ack Data Rate field.

* + - * 1. Hub Ack Data Rate

The Hub Ack Data Rate field is set to *R* such that the sender or recipient of this frame (a hub) is to send its I-Ack and B-Ack frames at the information data rate as encoded by *R = R2R1R0* of the Data Rate field defined in the corresponding physical layer (PHY) clause, if the preceding Hub Ack Data Rate Control is set to zero, or is reserved otherwise. Here, bit *R0* denotes the least-significant bit of *R*, and bit *R2* denotes the most-significant bit.

* + - 1. Max Sync Interval / Clock PPM

The Max Sync Interval / Clock PPM is present only if this node is requiring centralized guard time provisioning as indicated in the MAC Capability field of the current frame. When present, it is formatted as shown in Figure 30.



1. — Max Sync Interval / Clock PPM format
	* + - 1. Node Max Sync Interval

The Node Max Sync Interval field is set to the length of this node’s maximum synchronization interval, in units of the Requested Wakeup Period field value in the current frame, over which this node is to synchronize with its hub at least once. It is set to zero to encode a value of 8 such units.

* + - * 1. Node Clock PPM

The Node Clock PPM field is set to the PPM of this node’s MAC clock encoded according to Table 10.

1. — Node Clock PPM field encoding

|  |  |
| --- | --- |
| Field valuein decimal  | Clock accuracy |
| 0 | 20 ppm |
| 1 | 40 ppm |
| 2 | 50 ppm |
| 3 | 100 ppm |
| 4 | 200 ppm |
| 5 | 300 ppm |
| 6 | 400 ppm |
| 7 | 500 ppm |

* + - 1. Uplink request IE

The Uplink Request IE is as defined in 6.7.2.

* + - 1. Downlink Request IE

The Downlink Request IE is as defined in 6.7.3.

* + - 1. Bilink Request IE

The Bilink Request IE is as defined in 6.7.4.

* + - 1. Unscheduled Bilink Request IE

The Unscheduled Bilink Request IE, when present, is either Type-I Unscheduled Bilink Request IE as defined in 6.7.5 or Type-II Unscheduled Bilink Request IE as defined in 6.7.6.

* + - 1. Group Connection IE

The Group Connection IE is as defined in 6.7.7

* + - 1. Former Hub Address IE

The Former Hub Address IE is as defined in 6.7.15.

* + - 1. Application Specific IE

The Application Specific IE is as defined in 6.7.16.

1. — Connection Status field encoding

|  |  |
| --- | --- |
| Field valuein decimal  | Status |
| 0 | Connection request accepted |
| 1 | Connection request rejected – due to access policy restrictions as imposed by the administrator/owner of this hub on the communications in its body area network (BAN)  |
| 2 | Connection request rejected – invalid or unsupported frame format  |
| 3 | Connection request rejected – no unsecured communication with this hub |
| 4 | Connection request rejected – no more channel bandwidth for a new connection |
| 5 | Connection request rejected – no more Connected\_NID for a new connection |
| 6 | Connection request rejected – no more internal resources for a new connection |
| 7 | Connection request rejected – node’s maximum synchronization interval too long |
| 8 | Connection request rejected – beacon shifting enabled but not supported by requestor |
| 9 | Connection request rejected – channel hopping enabled but not supported by requestor |
| 10-15 | Reserved |
| 16 | Connection assignment modified |
| 17-31 | Reserved |

* + 1. MAC Capability

The MAC Capability is formatted as shown in Figure 41.



1. — MAC Capability format
	* + 1. CSMA/CA

The CSMA/CA field is set to one if the sender supports contended allocations obtained by using CSMA/CA in exclusive access phase 1 (EAP1), random access phase 1 (RAP1), exclusive access phase 2 (EAP2), random access phase 2 (RAP2), and contention access phase (CAP), or is set to zero otherwise.

* + - 1. Slotted Aloha Access

The Slotted Aloha Access field is set to one if the sender supports contended allocations obtained by using slotted Aloha access in exclusive access phase 1 (EAP1), random access phase 1 (RAP1), exclusive access phase 2 (EAP2), random access phase 2 (RAP2), and contention access phase (CAP), or is set to zero otherwise.

* + - 1. Type-I Polling Access

The Type-I Polling Access field is set to one if the sender supports type-I polled allocations, or is set to zero otherwise.

* + - 1. Type-II Polling Access

The Type-II Polling Access field is set to one if the sender supports type-II polled allocations, or is set to zero otherwise.

* + - 1. Scheduled Access

The Scheduled Access field is set to one if the sender supports scheduled allocations, or is set to zero otherwise. The sender supports scheduled bilink allocations if and only if it supports both scheduled allocations and type-I polled allocations.

* + - 1. Unscheduled Access

The Unscheduled Access field is

1. set to one in beacon or non-beacon mode with superframes, if the sender supports unscheduled bilink allocations and type-I polled allocations and will be always in active state (abbreviated as always active) ready to receive and transmit frames during time intervals wherein polls and posts are allowed to be sent;
2. set to one in non-beacon mode without superframes, if the sender supports unscheduled bilink allocations and type-II polled allocations; or
3. is set to zero otherwise.
	* + 1. Fragmentation / Reassembly

The Fragmentation / Reassembly field is set to one if the sender supports fragmentation and reassembly, or is set to zero otherwise.

* + - 1. G-Ack

The G-Ack field is set to one if the sender supports group acknowledgment, or is set to zero otherwise.

* + - 1. L-Ack / B-Ack

The L-Ack / B-Ack field is set to one if the sender supports both L-Ack and B-Ack acknowledgment, or is set to zero otherwise.

* + - 1. Group Connection

The Group Connection field is set to one if the sender supports group connection, or is set to zero otherwise.

* + - 1. Guard Time Provisioning

The Guard Time Provisioning field is set as follows:

1. In frames sent by a node, it is set to one if the node supports and requires centralized guard time provisioning, or is set to zero if the node supports and requires distributed guard time provisioning.
2. In frames sent by a hub, it is reserved.
	* + 1. Relaying Node

The Relaying Node field is set to one if the sender is a node that supports the functionality required of a relaying node in a two-hop extended star body area network (BAN), or is set to zero if the sender is a node that does not support such a functionality. It is reserved if the sender is a hub.

* + - 1. Relayed Hub/Node

The Relayed Hub/Node field is set to one if the sender supports the functionality required of a relayed hub or node in a two-hop extended star body area network (BAN), or is set to zero otherwise.

* + - 1. Node Always Active / Hub Clock PPM

The Node Always Active / Hub Clock PPM field is set as follows:

1. In frames sent by a node, it is used as a Node Always Active field, which is set to one if the node will be always in active state (abbreviated as always active) ready to receive and transmit frames during time intervals wherein polls and posts are allowed to be sent, or is set to zero if the node will not be always in active state.
2. In frames sent by a hub, it is used as a Hub Clock PPM field, which is set to one if the hub has a clock with a minimum accuracy of ppm = mHubClockPPMLimit / 2, or is set to zero if the hub has a clock with a minimum accuracy of ppm = mHubClockPPMLimit.
	* + 1. Command Frames

The Command Frames field is set to one if the sender supports the processing and functionality of Command frames, or is set to zero otherwise.

* + - 1. Data Subtypes

The Data Subtypes field is set to the maximum number of data subtypes supported by the sender for data type frames received from the recipient of the current frame. It is set to zero to encode a value of 16.

* + - 1. Beacon Shifting

The Beacon Shifting field is set to one if the sender supports beacon shifting, or is set to zero otherwise.

* + - 1. Channel Hopping

The Channel Hopping field is set to one if the sender supports channel hopping, or is set to zero otherwise.

* 1. Random access

In exclusive access phase 1(EAP1), random access phase 1 (RAP1), exclusive access phase 2 (EAP2), random access phase 2 (RAP2), and contention access phase (CAP), as depicted in 7.3, allocations may only be contended allocations, which are non-reoccurring time intervals valid per instance of access. The access method for obtaining the contended allocations shall be

* CSMA/CA as specified in 7.5.1 if pRandomAccess is set to CSMA/CA, or
* slotted Aloha access as specified in 7.5.2 if pRandomAccess is set to Slotted Aloha.

A hub or a node may obtain contended allocations in EAP1 and EAP2, only if it needs to send data type frames of the highest user priority (i.e., containing an emergency or medical event report) as defined in Table 17. The hub may obtain such a contended allocation pSIFS after the start of EAP1 or EAP2 without actually performing the CSMA/CA or slotted Aloha access procedure. Only nodes may obtain contended allocations in RAP1, RAP2, and CAP, to send management or data type frames.

To obtain contended allocations in EAP1, RAP1, EAP2, or RAP2 of a beacon period in beacon mode with superframes, a node shall first receive the beacon that specifies the start and end times of these access phases.

* 1. Clock synchronization and guard time provisioning

A node or a hub shall maintain a MAC clock with a minimum resolution of mClockResolution and with a minimum accuracy of mHubClockPPMLimit to time its frame transmission and reception, except that a node may use a MAC clock with a PPM higher than mHubClockPPMLimit subject to certain restrictions as stated later in this subclause. The node or the hub shall time its transmission and reception in any of their allocation intervals according to its local clock.

ed to be transmittedstarted to be

A node may rely on itself or a hub to track and set aside appropriate guard times in its uplink allocation intervals, which include contended allocations, polled allocations, and scheduled uplink allocation intervals. A hub shall be ready to accommodate either choice, referred to as distributed or centralized guard time provisioning, respectively, as indicated in the node’s last transmitted MAC Capability field.

* + 1. Distributed guard time provisioning

For distributed guard time provisioning, the node and the hub shall include appropriate guard times in their scheduled allocation intervals they requested or assigned, respectively. The hub shall also include appropriate guard times in the polled allocation intervals granted to the node.

* + - 1. Distributed guard time computation

If the node and the hub have the same clock accuracy designated as HubClockPPM in terms of PPM, as shown in Figure 91, the node and the hub shall compute a nominal guard time GTn to compensate for their clock drifts over an interval not longer than a nominal synchronization interval SIn, as follows:

 GTn = GT0 + 2×Dn

 GT0 = pSIFS + pExtraIFS + mClockResolution

 Dn = SIn×HubClockPPM, SIn = mNominalSynchInterval

The parameter GT0 comprises the receive-to-transmit or transmit-to-receive turnaround time pSIFS, the synchronization error tolerance pExtraIFS, and the timing uncertainty mClockResolution, which are all of fixed values that are independent of clock drifts. The parameter Dn represents the maximum clock drift of the node or the hub relative to an ideal (nominal) clock over SIn. The parameter SIn delimits a nominal synchronization interval over which the clock drifts of the node and the hub are accounted for in the nominal guard time GTn.

The node shall further compute an additional guard time GTa to compensate for additional clock drifts of itself and the hub over an interval SIa beyond SIn, as follows:

 Hub

The parameter SIa denotes the the length of the time interval that has accrued in addition to SIn since the node’s last synchronization with the hub. The corresponding additional clock drift Da is a function of SIa and accounts for the required additional guard time GTa. The values of Da and SIa are specific to the node and time of concern.

A node may time its frame transmission and reception with a clock accuracy NodeClockPPM larger than HubClockPPM, provided it reduces its nominal synchronication interval to SIn such that

 SIn × NodeClockPPM = mNominalSynchInterval× HubClockPPM

If the time interval length SI since its last synchronization with the hub exceeds the reduced SIn by SIa, i.e., if SI = SIn + SIa, the node shall calculate the required additional guard time GTa as follows:

 GTa = SIa × NodeClockPPM + min[0, (SI – mNominalSynchInterval)× HubClockPPM]

An illustration of clock drifts and guard times for the case of a hub and nodes operating with the same clock accuracy is given in Figure 91, with the following legend:

Nf = fast node Ns = slow node H = slow hub in (a) and fast hub in (b)

tmH = position of ideal (nominal) clock when NH‘s local clock is at tm, m = 1, .., or 4

tmf = position of ideal (nominal) clock when Nf‘s local clock is at tm, m = 1, .., or 4

tms = position of ideal (nominal) clock when Ns‘s local clock is at tm, m = 1, .., or 4

SIn = nominal synchronization interval GTn = nominal guard dtime

Dn = maximum clock drift over SIn w.r.t. ideal clock

SIa = additional synchronization interval GTa = additional guard time

Da = maximum clock drift over SIa w.r.t. ideal clock

allocation interval of H = allocation interval in which H controls the timing for frame transactions

allocation interval of N = allocation interval in which N controls the timing for frame transactions



(a) Slow hub



(b) Fast hub

1. — Analysis of clock drifts and guard times for distributed provisioning

* + - 1. Distributed guard time compensation

With reference to Figure 91 and Figure 92, and with GTn given in Equation (6), GT0 in Equation (7), SIn in Equation (8) or (11) as appropriate, and GTa in Equation (12), the node and the hub shall account for in their frame transmission and receptionfollows

* the node’s nextscheduled or bilink
* The hub shall commence its transmission of the node’s next future poll or post at the nominal start of the poll or post.
* the node’s nextup toGT0 earlier than to account for pertinent clock drifts
* scheduled or polled
* up toGT0 earlier thanthe of the beacon to account for pertinent clock drifts
* up toGT0 earlier thanthe of the poll or post to account for pertinent clock drifts
* up toGT0 earlier thantheof the interval to account for pertinent clock drifts. The node may commence its reception up to GTn – GT0 earlier or later than the start of the interval in order to reduce its listening time for energy conservation, if the request and assignment of the interval accordingly accounted for a relative clock drift up to GTn – GT0
* If the node's last synchronization to the hub was less than SIn + SIa ago at the nominal start of the next beacon transmission, the node shall commence its reception of the beacon up to GTn – GT0 earlier than the nominal start of the beacon to account for pertinent clock drifts.
* up toGT0 earlier thanthe of the poll or post to account for pertinent clock drifts
* up toGT0theof the interval to account for pertinent clock drifts. The node may commence its reception up to GTn + GTa – GT0 earlier or later than the start of the interval in order to reduce its listening time for energy conservation, if the request and assignment of the interval accordingly accounted for a relative clock drift up to GTn – GT0





1. Distributed provisioning of for frame transmissions
	* + 1. Distributed guard time allocation

The node and the hug shall include a nominal guard time GTn as given in Equation (6) and, if applicable, twice an additional guard time GTa as given in Equation (12) in the scheduled allocation intervals they request or assign. The hub shall also include the nominal guard time GTn in the polled allocation intervals granted to the node.

* + - 1. Clcok synchronization for distributed guard time provisioning

The node shall synchronize with the hub at least once within the nominal synchronization interval SIn given in Equation (8) or (11) as appropriate, if only the nominal guard time GTn as given in Equation (6) is accounted for. The node shall synchronize with the hub at least once within the nominal synchronization interval SIn given in Equation (8) or (11) as appropriate, plus the additional synchronization interval SIa given in Equation (11), if both the nominal guard time GTn as given in Equation (6) and the additional guard time GTa as given in Equation (12) are accounted for.

* + 1. Centralized guard time provisioning

For centralized guard time provisioning, the node and the hub shall not include guard times in their scheduled allocation intervals they request or assign, respectively. The hub shall insert an appropriate guard time between two neighboring allocation intervals one or both of which are assigned to the node requiring centralized guard time provisioning.

* + - 1. Centralized guard time computation

As shown in Figure 93, the hub shall compute a centralized guard time GTc between two neighboring allocation intervals (with beacon treated as an allocation interval), both of which do not include a guard time, to compensate for pertinent clock drifts, as follows:

For case (a) where each of the two allocation intervals is a beacon or an allocation interval in which the hub controls the timing for frame transactions,

 GTc = GT0

For case (b) where one of the two allocation intervals is a beacon or an allocation interval in which the hub controls the timing for frame transactions, and the other is an allocation interval in which the node controls the timing for frame transactions, given the node’s maximum synchronization interval SIN and its clock accuracy PN in terms of PPM, and the hub’s clock accuracy PH in terms of PPM,

 GTc = GT0 + SIN ×(PH + PN)

For case (c) where one of the two allocation intervals is an allocation interval in which the node controls the timing for frame transactions, and the other is an allocation interval in which another node controls the timing for frame transactions, given the node’s maximum synchronization interval SIN1 and its clock accuracy PN1 in terms of PPM, the other node’s maximum synchronization interval SIN2 and its clock accuracy PN2 in terms of PPM, and the hub’s clock accuracy PH in terms of PPM, with the other node also requiring centralized guard time provisioning,

 GTc = GT0 + PN1×SIN1 + PN2×SIN2 + PH×|SIN1 – SIN2|

The parameter GT0 is a fixed value independent of clock drifts as given in Equation (7).

In Figure 93(a), there are no relative clock drifts since it is the same hub that controls the timing for frame transactions in both allocation intervals. In Figure 93(b), since the node last synchronized to the hub SIN ago, the hub’s clock has drifted by DH toward the other allocation interval, and the node’s clock has drifted by DN toward the other direction, both relative to an ideal clock. In Figure 93(c), since the two nodes last synchronized to the hub SIN1 and SIN2 ago, their clocks have drifted by DN1 and DN2 in oppsite directions, respectively; between the times of the nodes’ last synchronization, the hub’s clock has also drifted by DH in the same direction as the clock of the node that synchronized with the hub later, all relative to an ideal clock.

Of the two neighboring allocation intervals, in case the earlier one is provided for distributed guard time provisioning and thus includes a nominal guard time GTn as given in Equation (6) at the end, the hub may deduct GTn from GTc in inserting a centralized guard time between the two intervals. Further, if the earlier one is a scheduled uplink or polled allocation interval provided to a node for distributed guard time provisioning, the hub shall set SIN or SIN1 to SIn as given in Equation (8) in computing GTc according to Equation (14) or (15).

On the other hand, in case the later one is a scheduled downlink, bilink, or uplink allocation interval assigned to a node requiring distributed guard time provisioning, the hub shall treat such an interval as one assigned for centralized guard time provisioning in inserting a centralized guard time between the two intervals. Further, if such an interval is a scheduled uplink allocation interval, the hub shall set SIN or SIN2 to SIn as given in Equation (8) in computing GTc according to Equation (14) or (15), respectively.

An illustration of clock drifts and guard times for the case of both neighboring allocation intervals (with beacon treated as an allocation interval) not including guard times is given in Figure 91, with the following legend:

H = hub N = node N1 = node 1 N2 = node 2

PH = PPM of H’s clock PN = PPM of N’s clock PN1 = PPM of N1’s clock PN2 = PPM of N2’s clock

SIN = maximum synchronization interval of N

SIN1 = maximum synchronization interval of N1

SIN2 = maximum synchronization interval of N2

DH = clock drift of H w.r.t. ideal clock DN = clock drift of N w.r.t.. ideal clock

DN1 = clock drift of N1 w.r.t. ideal clock DN2 = clock drift of N2 w.r.t. ideal clock

GTc = centralized guard time

allocation interval of H = allocation interval in which H controls the timing for frame transactions

allocation interval of N = allocation interval in which N controls the timing for frame transactions



(a) Beacon or allocation interval of H – beacon or allocation interval of H



(b) Beacon or allocation interval of H – allocation interval of N or vice versa

 

(c) Allocation interval of N1 – allocation interval of N2

1. — Analysis of clock drifts and guard times for centralized provisioning
	* + 1. Centralized guard time compensation

With reference to Figure 93 and Figure 94, and with GT0 given in Equation (7), and GTc in Equation (13), (14), or (15) as appropriate, the node and the hub shall account for guard times in their frame transmission and reception as follows:

* The hub shall commence its beacon transmission at the nominal start of the beacon.
* The hub shall commence its transmission in the node’s next scheduled downlink or bilink allocation interval at the nominal start of the interval, and shall end its transmission in the interval early enough such that the last transmission in the interval completes by the nominal end of the interval.
* The hub shall commence its transmission of the node’s next future poll or post at the nominal start of the poll or post.
* The hub shall commence its reception in the node’s next scheduled uplink allocation interval up to GTc – GT0 earlier than the nominal start of the interval to account for pertinent clock drifts since the node last synchronized with it.
* The node shall commence its transmission in a scheduled uplink allocation interval at the nominal start of the interval, and shall end its transmission in the interval early enough such that the last transmission in the interval completes by the nominal end of the interval.
* The node shall commence its reception of the beacon up to GTc – GT0 earlier than the nominal start of the beacon to account for pertinent clock drifts since it last synchronized with the hub.
* The node shall commence its reception in its next scheduled downlink or bilink allocation interval up to GTc – GT0 earlier than the nominal start of the interval to account for pertinent clock drifts since it last synchronized with the hub. The node may commence its reception up to GTc – GT0 earlier or later than the start of the interval in order to reduce its listening time for energy conservation, if the request and assignment of the interval accordingly accounted for a relative clock drift up to GTc – GT0.
* The node shall commence its reception of its next poll or post up to GTc – GT0 earlier than the nominal start of the poll or post to account for pertinent clock drifts, where the node’s last synchronization interval is measured up to the nominal start of the poll or post.



1. — Centralized provisioning of of guard times for frame transmissions
	* + 1. Centralized guard time allocation

The node and the hub shall not include guard times in the scheduled allocation intervals they request or assign, respectively, other than indicating the node’s PPM number and maximum synchronization interval. The hub shall insert a centralized guard time GTc given in Equation (13), (14), or (15) as appropriate, between two neighboring allocation intervals, minus a nominal guard time GTn given in Equation (6) if the earlier one of the allocation intervals is provided to a node requiring distributed guard time provisioning and hence includes GTn in the end, treating a beacon as an allocation interval that does not include GTn.

* + - 1. Clock synchronization for centralized guard time provisioning

The node shall synchronize with the hub at least once within its maximum synchronization interval SIN as indicated in its last transmitted Connection Request frame.

1. — MAC sublayer parameters

|  |  |
| --- | --- |
| Parameter | Value |
| mBackLimit | 8 |
| mCSMATxLimit | 2 for UP ≤ 5 or 4 for UP ≥ 6 |
| mHubClockPPMLimit | 40 ppm |
| mClockResolution | 4 μs |
| mG-AckDataSubtype | 1111 (binary) |
|  |  |
| mMaxFragmentCount | 8 |
| mMaxBANSize | 64 |
| mNominalSynchInterval | 8 × Beacon Period (Superframe) Length |
| mScheduledAllocationAborted | 32 |
| mTimeOut | 30 μs |
| mUnscheduledAllocationAborted | 32 |
| mUnscheduledNoResponseLimit | 3 |

Table 26, Table 27, and Table 28 provide the values of the PHY dependent parameters used by the MAC sublayer.

1. — PHY-dependent MAC sublayer parameters pertaining to narrowband PHY

|  |  |
| --- | --- |
| Parameter | Value |
| pAllocationSlotMin | 500 μs |
| pAllocationSlotResolution | 500 μs |
| pCCATime  | 63 / Symbol Rate (See Table 30 to Table 36 for Symbol Rate) |
| pChannelSeparation | 2 |
| pChannelsTotal | See Table 46 |
| pChannelSwitchTime | 100 μs |
| pCSMAMACPHYTime | 40 μs |
| pCSMASlotLength | pCCATime + pCSMAMACPHYTime |
| pExtraIFS | 10 μs |
| pHybridARQ | FALSE |
| pMaxFrameBodyLength | 255 octets |
| pMICSChannelsTotal | 10 |
| pMICSChannelSwitchTime | 100 μs |
| pMICSHubMaxRetries | 10 |
| pMICSMcastPollRxTime | pMICSPollTxTime + pMIFS + pMICSPreambleTxTime = 1,567 μs |
| pMICSMcastPolls | ⎡pMICSChannelsTotal × (pMICSMcastPollRxTime + pMICSChannelSwitchTime ) / (pMICSPollTxTime + pMIFS)⎤ = 16 |
| pMICSNodeEmergencyRetries | 2 |
| pMICSPollRxTime | pMICSPollTxTime + pMICSPollSpace + pMICSPreambleTxTime = 2,157 μs |
| pMICSPollSpace | 2×pSIFS + pMICSPreambleTxTime + mTimeOut = 610 μs |
| pMICSPollTxTime | pMICSPreambleTxTime + pMICSPLCPHeaderTxTime + {(7+2)×8 +12×⎡(7+2)×8/51⎤ }/187.5 ms = 1,323 μs |
| pMICSPreambleTxTime | 90/187.5 ms = 480 μs |
| pMICSPLCPHeaderTxTime | 2×31/187.5 ms = 331 μs |
| pMICSUnconnectedPollPeriod | > (pMICSUnconnectedPollTxTime +pMICSPollSpace)×pMICSUnconnectedPolls = 25,130 μs  |
| pMICSUnconnectedPollRxTime | pMICSUnconnectedPollTxTime + pMICSPollSpace + pMICSPreambleTxTime = 2,275 μs |
| pMICSUnconnectedPolls | ⎡pMICSChannelsTotal × (pMICSUnconnectedPollRxTime + pMICSChannelSwitchTime ) / (pMICSUnconnectedPollTxTime + pMICSPollSpace)⎤ = 14 |
| pMICSUnconnectedPollTxTime | pMICSPreambleTxTime + pMICSPLCPHeaderTxTime + {(7+4+2)×8 +12×⎡(7+4+2)×8/51⎤ }/187.5 ms = 1,558 μs |
| pMIFS | 20 μs |
| pRandomAccess | CSMA/CA  |
| pSIFS | 75 μs |
| pUnconnectedPolledAllocationMin | ≥ transmission time of two PHY packets containing a MAC frame of 7+104+2 and 7+2 octets, respectively, both transmitted at the highest mandatory data rate of the operating frequency band specified in clause 9 |

1. — PHY-dependent MAC sublayer parameters pertaining to UWB PHY

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| pAllocationSlotMin | 16 μs |
| pAllocationSlotResolution | 16 μs |
| pAlohaSlotLength | pUnconnectedPolledAllocationMin  |
| pCCATime | 252 μs |
| pCSMAMACPHYTime | 40 μs |
| pCSMASlotLength | pCCATime + pCSMAMACPHYTime |
| pExtraIFS | 10 μs |
| pHybridARQ | TRUE |
| pMaxFrameBodyLength | 255 octets |
| pMIFS | 20 μs |
| pRandomAccess | CSMA/CA or Slotted Aloha |
| pSIFS | 75 μs |
| pUnconnectedPolledAllocationMin | ≥ transmission time of two PHY packets containing a MAC frame of 7+104+2 and 7+2 octets, respectively, both transmitted at the mandatory data rate of the operating frequency band specified in clause 10 |

1. — PHY-dependent MAC sublayer parameters pertaining to HBC PHY

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| pAllocationSlotMin | 500 μs |
| pAllocationSlotResolution | 500 μs |
| pAlohaSlotLength | pUnconnectedPolledAllocationMin |
| pExtraIFS | 10 μs |
| pHybridARQ | FALSE |
| pMaxFrameBodyLength | 255 octets |
| pMIFS | 20 μs |
| pRandomAccess | Slotted Aloha |
| pSIFS | 75 μs |
| pUnconnectedPolledAllocationMin | ≥ transmission time of two PHY packets containing a MAC frame of 7+104+2 and 7+2 octets, respectively, both transmitted at the highest mandatory data rate of the operating frequency band specified in clause 11 |