**IEEE P802.15**

**Wireless Personal Area Networks**

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| Title | Revision Text for Clock Drift and Guard Time Provisioning |
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| Re: | Sponsor ballot comments. |
| Abstract | This submission provides the normative text for the resolution of sponsor ballot recirculation 1 comment |
| 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. — Node Clock PPM field encoding

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

* 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.

The node may request the hub to include a timestamp in an acknowledgment (I-Ack, B-Ack, I-Ack+Poll, or B-Ack+Poll) frame by setting to one the Ack Timing field of a management or data type frame being sent with the Ack Policy field of the MAC header set to I-Ack or B-Ack. The timestamp encodes the start time of the acknowledgment frame transmission based on the hub’s clock. The hub shall include such a timestamp in the acknowledgment frame if and only if requested by the node.

The node shall synchronize to the hub through the beacons, T-Poll frames, acknowledgment frames containing a timestamp, or the first frames (on-time frames) in scheduled allocation intervals received from the hub. In particular, the node shall advance or delay its clock by a total amount of

 D = TS – TL, if TS > TL

or

 D = TL – TS, if TS < TL

respectively, where TS is the time when such a frame started to be transmitted on the transport medium (i.e., air), and TL is the time when the frame started to be received according to the local clock.

A node may rely on itself or a hub to track and set aside appropriate guard times in its allocation intervals, which include contended allocations, polled allocations, and scheduled uplink, bilink and downlink 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:

 GTa = 2 × Da, Da = SIa × HubClockPPM

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 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 at least GTn prior to 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 GTn – GT0 earlier than the nominal start of the interval to account for pertinent clock drifts.
* If the node’s last synchronization to the hub was less than SIn ago at the nominal end of its next scheduled uplink or polled allocation interval, the node shall commence its transmission in the interval at the nominal start of the interval, and the node shall end its transmission in the interval early enough such that the last transmission in the interval completes at least GTn prior to the nominal end of the interval.
* If the node’s last synchronization to the hub was less than SIn 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.
* If the node’s last synchronization to the hub was less than SIn ago at the nominal start of its next future poll or post, the node shall commence its reception of the poll or post up to GTn – GT0 earlier than the nominal start of the poll or post to account for pertinent clock drifts.
* If the node’s last synchronization to the hub was less than SIn ago at the nominal start of its next scheduled downlink or bilink allocation interval, the node shall commence its reception in the interval up to GTn – GT0 earlier than the nominal startof 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 SIn + SIa ago at the nominal end of its next scheduled uplink allocation interval, the node shall commence its transmission in the interval GTa later than that nominal start time, and shall end its transmission in the interval early enough such that the last transmission in the interval completes at least GTn + GTa prior to the nominal end of the interval.
* If the node’s last synchronization to the hub was SIn + SIa ago at the nominal end of its next polled allocation interval, the node shall commence its transmission in the 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 at least GTn + GTa prior to the nominal end of the interval.
* 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.
* If the node’s last synchronization to the hub was less than SIn + SIa ago at the nominal start of its next future poll or post, the node shall commence its reception of the poll or post up to GTn + GTa – GT0 earlier than the nominal start of the poll or post to account for pertinent clock drifts.
* If the node’s last synchronization to the hub was SIn + SIa ago at the nominal start of its next scheduled downlink or bilink allocation interval, the node shall commence its reception in the interval up to GTn + GTa – GT0 earlier the that nominal startof 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.



(a) Nominal guard time



(b) Nominal guard time and additional guard time

1. — Distributed provisioning of guard times 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. Clock 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 at the beginning and end of the allocation interval of the node requiring centralized guard time provisioning.

* + 1. Allocation Assignment for Centralized Guard time provisioning

When a hub sends to a node requiring centralized guard timing as indicated in its MAC Capability field an allocation in a connection assignment of S slots, the hub shall set aside a total of (S + 2SD) slots for the node to compensate for its clock drift, SD slots before and after the S slots respectively as illustrated in figure 6 below. SD is derived from the superframe slot time TSlot, node’s maximum synchronization interval SIn, the hub clock PPM PH­, and the node’s clock PPM PN, as follows:

 SD = ceiling ((SIn x (PH + PN))/TSlot)



1. — Centralized slot allocation for Node and Hub
	* + 1. Centralized guard time computation

A node shall compute a guard times GTC, to compensate for its clock drift when listening for a beacon or a future poll or post, as follows:

 GTC = GT0 + SIN × (PH + PN)

* + - 1. Centralized guard time compensation

With reference to Figure 3, and with GT0 given in Equation (4), GTn in Equation (3), and GTC in Equation (10), 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 no later than GTn after 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 at the nominal start of the interval.
* The node shall commence its transmission or reception in its next scheduled uplink, downlink or bilink allocation interval at the nominal start of the interval and shall end its transmission in an uplink allocation interval early enough such that the last transmission in the interval completes GT0 prior to 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 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. 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. The node shall ignore the first frame/on-time bit for purposes of synchronization.