**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Wireless Specialty Networks (WSNs) | |
| Title | **Scheduled MAC resolutions** | |
| Date Submitted | 2 May 2022 | |
| Source | Bober, Kai Lennert Fraunhofer HHI | Voice: - Fax: - E-mail: bober@ieee.org |
| Re: |  | |
| Abstract | This document contains proposed updates to the scheduled medium access in D6 | |
| Purpose | Aid comment resolution | |
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**Legend:**

* Arial size 13 indicates subsections for individual comments
* Red underlined text needs to be adapted during the comment implementation (e.g. because it is a reference).
* Bold italic text is an instruction to the editor to implement the text

R2-8 R2-16 R2-18 R2-19 R2-20 R2-24 R2-46

*Rationale: The fixed structure with a Beacon, CAP and CFP is broken down so that there is a general notion of Time Slices, which are used to reserve resources for multiple purposes.*

Update 5.1

***Insert the following bullet after “Scheduled medium access”:***

* Flexible medium access schedules allowing for the support of isochronous traffic

Update 5.6.2.1

Place the following text at the end of the subclause 5.6.2.1:

The standard provides deterministic transmission for the support of real-time data streams through its channel access mechanism as described in 5.6.5. The configuration of data streams is out of scope of the standard and requires implementation-specific interfaces. Coordinators support registered streams by scheduling resources for transmissions accordingly.

The reliability of data transfers over the wireless medium is increased through multiple measures, such as forward error correction (FEC) and retransmissions.

Move 5.6.2.1 one level higher and delete 5.6.2.2 and 5.6.2.3.

Make 5.6.2.4 a new subclause under 5.6, e.g., 5.6.9.

Remove full acronym expansion of FEC in 5.7.

Update 5.6.5

Replace subclause 5.6.5 with:

IEEE Std 802.15.13 OWPANs make use of a scheduled medium access. The scheduled medium access relies on special frames to synchronize devices. The coordinator allocates channel time for different ways of channel access. Deterministic channel access is supported in guaranteed time slices (GTS) and random channel access is supported in random time slices (RTS).

NOTE—RTS are only used for certain purposes such as association and requesting additional channel time resources.

***Replace all occurrences of beacon-enabled with “scheduled”.***

Update 6.3.1

***Replace 6.3.1 with the following text***:

In scheduled channel access mode, channel time is divided into superframes. Superframes are further divided into continuous groups of one or more slots, called time slices.

Time slices can be unassigned, assigned to a device as guaranteed time slice (GTS) or designated as random time slice (RTS). Assigning time slices is done by an implementation specific scheduler that is part of the coordinator. The scheduler assigns time slices for transmissions to the coordinator and to members.

During a GTS, devices shall perform deterministic medium access according to the rules described in [REF to 6.3.5]. During an RTS, devices shall perform random medium access according to the rules described in [REF to 6.3.4].

When maintaining an OWPAN with scheduled medium access, the coordinator shall send frames containing the *Sync* elements as described in [REF to 6.3.3].

Update 6.3.2

***Replace the first two sentences in 6.3.2 with the following text:***

A superframe consists in total of *macNumSuperframeSlots* superframe slots. *macNumSuperframeSlots* is a variable determined by the OWPAN coordinator and announced to the devices in the *Sync* element.

The superframe slot with the number zero shall be the first slot in the superframe.

***Replace line 17 f. in 6.3.2 with the following text:***

The standard makes use of integer numbers of superframe slots to specify durations within the superframe, e.g., the duration of a GTS or RTS.

***Replace “allocation” with “assignment.***

*Rationale: “Allocation” is the process of giving the resource away in the scheduler. “Assignment” is the process of signaling the slice so the device. “Designation” is the process of determining the foreseen use during the scheduling process.*

***Replace line 21-25 in 6.3.2 with the following text:***

Each of these time slices in the superframe might be in one of the following states for the duration of the current superframe:

* Unassigned: No device shall transmit in these slots.
* Assigned as GTS: The time slice was assigned to a device by the coordinator using a GTS descriptor element as described in [REF to 6.3.6]. The corresponding device shall transmit during the GTS as described in [REF to 6.3.5].
* Assigned as RTS: These slots were assigned as RTS by the coordinator using a *RTS Descriptor* element. During the RTS, devices may access the channel randomly by means of slotted ALOHA, as defined in [REF to 6.3.4].

Devices shall refrain from transmissions in superframe slots that were not assigned to it.

***Replace figure 9 with the following graphic:***

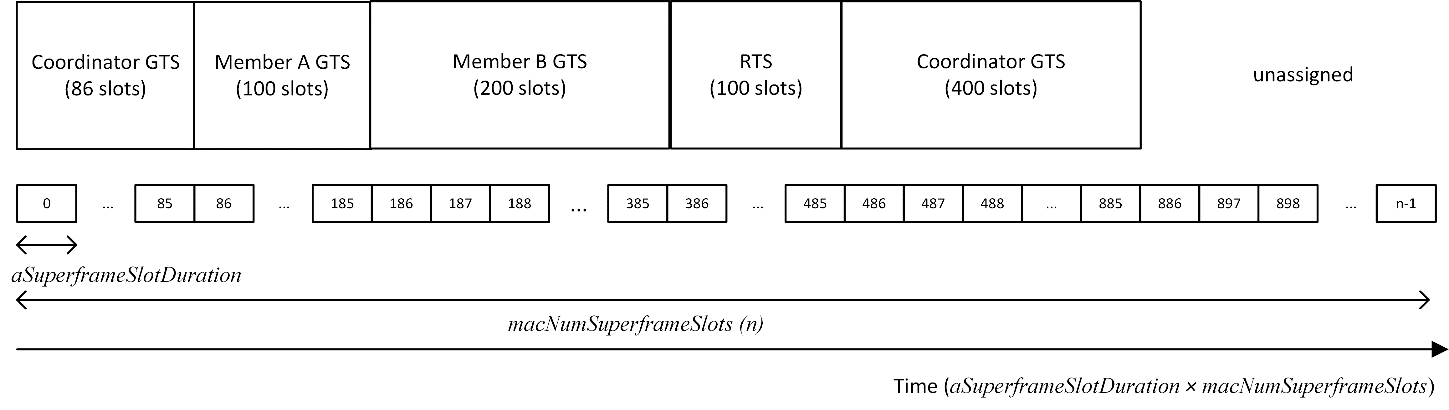


Figure X: Example of a superframe structure

Update 6.3.3

***Delete 6.3.3 (sync text is integrated in “Synchronization”)***

***Add the following text into subclause 6.3.7***:

All members shall be synchronized to a coordinator’s clock before they start transmission or reception. A *Sync* element transmitted by the coordinator enables synchronization of the members for scheduled medium access through time of arrival synchronization.

The coordinator shall maintain the value of *macSuperframeNumber* and increment it by one for every started superframe. The *macSuperframeNumber* value wraps to zero after reaching the maximum value given in [REF to Table 38].

The coordinator shall transmit a frame containing a *Sync* element via each OFE in a suitable time slice with an implementation specific rate but at least every *aMacMinSyncInterval*. The frame’s receiver address shall be the broadcast address. The frame shall contain the current *macSuperframeNumber,* the number of slots contained in the superframe,and the number of the slot in which the frame containing the *Sync* element was transmitted. The coordinator shall start transmitting the frame at the start of the superframe slot.

*NOTE – As defined for each PHY, the real transmit time does not deviate by more than aPhyOfeSyncAccuracy from the nominal transmit time.*

If the coordinator supports the *capExplicitMimoEstimation* capability, it shall embed an explicit MIMO pilot in the *Sync* frame, as detailed in [REF to 6.9].

Upon reception of a *Sync* element, members shall set their value of *macSuperframeNumber* and *macNumSuperframeSlots* to the value in the received *Sync* element. Moreover, members shall synchronize their clocks to the received *Sync* element by reducing the offset between their local clock and time indicated through the *Sync Slot* field within the *Sync* element to less than *aPhyOfeSyncAccuracy*.

If no *Sync* element is received during the duration of a superframe, devices shall assume that the value specified for *macNumSuperframeSlots* in the last received *Sync* element is still valid and increase *macSuperframeNumber* at the time the next expected superframe starts.

If a *Sync* element is not received within *aMacMinSyncInterval*, devices shall keep listening for the next *Sync* element in order to synchronize before attempting further transmissions. Devices are considered not synchronized after more than 2 \* *aMacMinSyncInterval* has passed without reception of a *Sync* element.

***In Figure 10, replace CAPOP with RANDOP, CAP with RTS.***

Update 6.3.4

***Replace 6.3.4, page 35 line 23 to line 37 with the following text***:

6.3.4 Medium access during an RTS

6.3.4.1 General channel access during an RTS

RTS shall only be used for transmissions from devices to the coordinator in the

1. Association procedure, described in [REF to 6.3.4.3]
2. GTS request procedure, described in [REF to 6.3.4.4]

The slotted Aloha scheme is used for contention-based access in RTS. Superframe slots in RTS are grouped in so-called RANDOPS, which comprise *RANDOP Length* superframe slots each. The number of superframe slots per RANDOP determines the slot size for the slotted Aloha scheme and hence the effectiveness of collision prevention. The value of *RANDOP Length* is advertised in the RANDOP Length field of the *RTS Descriptor* element, defined in [REF to new 7.6 subclause for RTS Descriptor].

RTS are signaled through RTS Descriptor elements, transmitted from the coordinator to members. For each received RTS Descriptor element, the corresponding RTS shall start with the superframe slot given in the RTS Descriptor element and end after the number of slots given in the *RTS Length* field has passed.

The number and duration of RTS might be varied by the coordinator in order to allow more or less random-access transmissions in a superframe.

*NOTE – The coordinator should transmit a frame containing a RTS Descriptor element regularly in order to allow associations and prevent members running out of transmit resources unnoticed.*

***In lines 1 to 23, on page 36, in figure 10, page 37, and in lines 3-13, page 37, replace “CAP” / “the CAP” with “RTS” / “the RTS” in the correct spelling. Replace CAPOP with RANDOP***

***Replace the heading and first two sentences in 6.3.4.4 with the following text:***

6.3.4.4 GTS request procedure in an RTS

Devices request additional resources during a GTS, as described in [REF to 6.3.6]. However, when a device does not have any or only insufficient GTS time allocated to perform a GTS request, it may make use of an RTS to transmit a *GTS Request* element to the coordinator.

***In P39L6, replace the CAP with an RTS.***

Update 6.3.5

***Change heading to 6.3.5 Medium access in a GTS***

***In line 12, change the first sentence to the following:***

GTS allow channel access based on the Time-Division Multiple Access (TDMA) principle.

***In lines 12, 13 and 14, change CFP to GTS.***

***Delete P38L19-22***

***Change P38L26-29 as follows:***

The coordinator may perform transmissions to a device at any point in the superframe, except when the device has a time slice assigned (half-duplex).

If the *capFullDuplex* was negotiated during association, the coordinator may also transmit to devices when they have a time slice assigned.

Update 6.3.6

In line P38L31 f., remove the sentence “Any allocated GTS shall be located within the CFP.”

Update lines 33-36 to the following text:

If the coordinator has control over multiple spatially distributed OFEs, it may allocate the same superframe slots in different GTS or RTS for multiple spatially distant devices in order to facilitate spatial reuse of superframe slots within the OWPAN’s coverage area. The coordinator should allocate GTS and RTS in a way that transmissions in RTS do not interfere with transmissions in GTS.

***Replace line 39 with “GTS for relay devices shall not overlap with GTS or RTS allocated to other devices.”***

***Insert the following text in 6.3.6 (in a suitable location):***

If the *capFullDuplex* capability was negotiated, superframe slots may be assigned to the coordinator and a member at the same time for transmission.

***Move P39L8-12 to the end of 6.3.5***

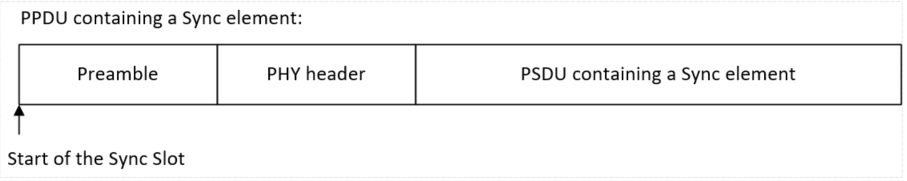
Update 6.3.7

***Replace lines 14-20 on page 39 with the following text:***

All members, whether they are associated with a scheduled OWPAN or attempting association, shall be synchronized to the coordinator’s clock before they start transmission or reception. The frame that contains a *Sync* elementenables synchronization of the devices in the scheduled OWPAN through time of arrival synchronization.

Members shall assume that the start of the preamble of the PPDU that carries a Sync element corresponds to the start time of the Sync Slot as specified in the Sync element. Therefore, the superframe starts Sync Slot slots before the start of the preamble. All superframe slots and hence timings within the superframe are relative to the calculated start of the superframe.

***Replace figure 11 with the following graphic and update the caption to “Timing relative to the PPDU reception.”***



Update 6.3.8

***In 6.3.8, replace “beacon-enabled” with “scheduled”.***

Update 6.3.9

***In 6.3.9, replace “Beacon (frame)” with “Sync element”.***

***On page 39, at the start of line 16, add the following half-sentence before the colon:***

With S*yncRate* being the implementation-specified sync-interval (see [REF to 6.3.7),

***On page 39, replace line 17-26 with:***

*MaxDrift = aClockAccuracy \* SyncInterval,*

Where *aClockAccuracy* is a MAC constant and *SyncInterval* is the interval between Sync element transmissions and hence the periodicity of the synchronizing event.

The coordinator shall allocate GTSs with the constraint that a guard time of at least

*2⋅(MaxDrift + aPhyOfeSyncAccuracy),*

lies between two subsequent GTS that are not orthogonal in space.

Update 6.3 generally

***In 6.3, reorder sections: insert 6.3.7 at the end of 6.3.3 and keep name “synchronization” and move 6.3.8 and 6.3.9 after Synchronization.***

Update 6.4.2

***In 6.4.2, replace “Beacon (frame)” with “frame containing an Announcement element”.***

Update 6.4.3

***In 6.4.3, replace “Beacon (frame)” with “frames containing Announcement elements”.***

***On page 42 after line 23, add the following paragraph:***

The coordinator shall start transmitting an *Announcement* element in a suitable time slice at least every *aMaxAnnouncementPeriod*.

The *Announcement* element shall contain the current values of the OWPAN name and OWPAN name length.

If the coordinator requires unassociated devices to set one or more PIB attributes to a specific value prior to association, it shall transmit one *Attribute Change Request* element for each of these PIB attributes in the same frame as the transmitted *Announcement* element.

If multiple OFEs are used by the coordinator, frames containing *Announcement* elements shall be transmitted over all OFEs.

Update 6.4.5

***In 6.4.5, replace “Beacon (frame)” with “frames containing Announcement and Sync elements”.***

Update 6.4.6.1

***In 6.4.6.1 replace “Beacon (frame)” with “Sync element”. Note: Make consistent when editing.***

***On page 43, after line 9, add the following paragraph:***

Before association is attempted, the device shall wait for the reception of an *Announcement* element. Upon reception of an *Announcement* element, devices shall update their value of OWPAN Name to the values in the received *Announcement* element. Furthermore, the device shall apply changed values from any attribute change request elements contained in the same frame as the *Announcement* element. The values contained in the A*nnouncement* element are required for association with the OWPAN.

Update 6.8.2

***In 6.8.2 replace “Beacon frames” with “Frames containing an Announcement element or a Sync element”.***

***In 6.8.2, add “Frames containing an RTS descriptor element”***

Update 7.6

***Insert the following new subclause under 7.6:***

7.X Sync element

The *Sync* element, depicted in Figure Y, is used to transmit synchronization information from the coordinator to members as part of the scheduled medium access, defined in X.

|  |  |  |
| --- | --- | --- |
| 2 Octets | 2 Octets | 2 Octets |
| Superframe Number | Total Superframe Slots | Sync Slot |

Figure Y: Sync element

**Superframe Number:** The number of the current superframe that the frame containing the Sync element was transmitted in.

**Total Superframe Slots:** The total number of slots contained in the current superframe.

**Sync Slot:** The slot in that the preamble of the frame that contained the *Sync* element was transmitted in.

***Insert the following new subclause under 7.6:***

7.X Announcement element

The *Announcement* element, depicted in Figure X, serves announcing the OWPAN as part of the OWPAN maintenance procedure.

|  |  |  |
| --- | --- | --- |
| 3 Bits | 5 Bits | 0-32 Octets |
| reserved | OWPAN Name Length | OWPAN Name |

Figure Y: Sync element

**OWPAN Name Length:** The length of the subsequent OWPAN Name field in octets.

**OWPAN Name:** A human-readable network name, encoded as UTF-8 string. The string shall include no null-byte at any location.

*NOTE - OWPAN IDs may be bitwise different but appear to be the same to humans due to possible homoglyphs in the UTF-8 encoding.*

7.X RTS Descriptor Element

The RTS Descriptor element, depicted in Figure X, describes a single RTS allocation in the beacon-enabled channel access mode.

|  |  |  |
| --- | --- | --- |
| 2 Octets | 2 Octets | 2 Octet |
| RTS Start Slot | RTS Length | RANDOP Length |

Figure Y: RTS Descriptor element

**RTS Start Slot**: This field specifies the first slot of the allocated RTS.

**RTS Length**: This field specifies the duration of the RTS in superframe slots.

**RANDOP Length**: This field specifies the number of slots in a RANDOP during the described RTS.

7.6.8 GTS Descriptor element

Replace “beacon-enabled" with “scheduled”.

Replace Figure 33 with the following graphic:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 Bits | 2 Bits | 0 / 1 Bit | 0 / 7 Bits | 0 / 2 Octets | 2 Octets | 2 Octets |
| reserved | Validity Information | Immediately Valid | reserved | Valid Superframe | GTS Start Slot | GTS Length |
| Element Control | | Relative Validity | |

**Validity Information:** This field indicates how the validity information for the GTS is signaled. See below for how to interpret the contained values.

**Immediately Valid:** If the field is set to one the GTS becomes effective in the same superframe, the GTS Descriptor element was received. Otherwise, the GTS becomes effective in the following superframe***.*** This field is only present if *Validity Information* equals zero.

**Valid Superframe:** This field specifies the superframe in that the GTS is valid. It is only present if *Validity Information* equals one.

**GTS Start Slot:** This field specifies the first slot of the allocated GTS.

**GTS Length:** This field specifies the duration of the GTS in superframe slots.

***On P65L6, remove phrase “the CFP of”.***

Update 7.6.16

***Rename GTS Request element to Queue State element***

Update 8.4

***Add constant aMaxAnnouncementPeriod with value of one second.***

***Add a new mac constant aMacMinSyncInterval with a value of 1 s.***

***Add macOWPANName as PIB attribute, with up to 32 octets / 256 bits.***

***Remove macBeaconNumber, replace with macSuperframeNumber***

***Rename macCapMaxRetries to macRTSMaxRetries and change CAP to RTS in description.***

***Rename macMaximumCapCw to macMaximumRTSCw and change CAP to RTS in description.***

***Remove macCapOpLength, macNumCapOps***

***Change aInitialCapCw to aInitialRtsCw and “the CAP” to “an RTS”.***

Update 10.1.4 and 11.1.3

***In tables 43 and 49, change description for “aPhyOfeSyncAccuracy”as follows:***

The maximum deviation of the real transmit time at the optical emitter from the nominal transmit time as intended by the MAC.