**IEEE P802.15**

**Wireless Personal Area Networks**

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| Re: | [TSCH, one more try to make everyone happy.] |
| Abstract | [Changed text to Sponsor Ballot draft.] |
| Purpose | [Description of what the author wants P802.15 to do with the information in the document.] |
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**6.2.6.3 Links**

Figure 22 illustrates an example of nodes communicating in a sample three-timeslot slotframe. Nodes A and B communicate during timeslot 0, nodes B and C communicate during timeslot 1, and timeslot 2 is not being used. Every three timeslots, the schedule repeats, but note that ASN increments continuously. The pairwise assignment of a directed communication between devices in a given timeslot on a given *macChannelOffset* is a link. Physical channel, CH, in a link is made according to the following formula:

CH = *macHoppingSequenceList* [(*macASN* + *macChannelOffset* ~~channelOffset~~) % *macHoppingSequenceLength*]



Use of a *macChannelOffset* allows for different channels to be used at a given *macASN* for a given *macHoppingSequenceList*. There are *macNumberOfChannels* channel~~Offsets~~ offsets that will result in a unique channel for that combination of *macASN* and *macHoppingSequenceList*.

**6.2.6.4 Multiple slotframes**

A given network using timeslot-based access may contain several concurrent slotframes of different sizes. Multiple slotframes may be used to define a different communication schedule for various groups of nodes or to run the entire network at different duty cycles by giving some devices many active timeslots in a slotframe, and others few or none.

A network device may participate in one or more slotframes simultaneously, and not all devices need to participate in all slotframes. By configuring a network device to participate in multiple overlapping slotframes of different sizes, it is possible to establish different communication schedules and connectivity matrices that all work at the same time.

Slotframes can be added, removed, and modified while the network is running. Even though this is the case, all slotframes are aligned to timeslot boundaries, and timeslot 0 of the first repetition of every slotframe is projected back to *macASN* = 0, which is determined by the PAN coordinator (or other network device that starts the network). Because of this, timeslots in different slotframes are always aligned, even though the beginning and end of a particular repetition of that slotframe may not be as illustrated in [Figure 23.](#bookmark2) When, for any given timeslot, a device has links in multiple slotframes, transmissions take precedence over receives, and lower *macSlotframeHandle* slotframes takes precedence over higher *macSlotframeHandle* slotframes.



**6.3.6 TSCH PAN formation**

A TSCH PAN is formed when a device, ~~usually the PAN coordinator~~, referred to as an advertising device, advertises the presence of the network by sending Enhanced Beacons upon receipt of a MLME-BEACON.request from a higher layer. In a TSCH PAN the Enhanced Beacons contain the following IEs:

* TSCH Synchronization IE, containing timing information so new devices can synchronize to the net- work, as described in 7.4.4.2.
* Channel hopping IE, containing channel hopping information, as described in 6.2.10 and 7.4.4.31.
* TSCH Timeslot IE, containing timeslot information describing when to expect a frame to be transmitted and when to send an acknowledgment, as described in 7.4.4.4.
* TSCH Slotframe and Link IE containing initial link and slotframe information so new devices know when to listen for transmissions from the advertising device and when they can transmit to the advertising device, as described in 7.4.4.3.

The device wishing to join a TSCH network begins passively (preferred) or actively scanning for the network as the result of receiving an MLME-SCAN.request from a higher layer. Once the listening device has heard a valid Enhanced Beacon, it generates an MLME-BEACON-NOTIFY.indication to a higher layer. The higher layer may ~~may~~ wait for additional MLME-BEACON-NOTIFY.indication primitives before selecting a TSCH network based upon the value of the Join Metric ~~Priority~~ field in the TSCH Synchronization IE. The higher layer may initialize the slotframe and links contained in the Enhanced Beacon from the preferred TSCH network and switch the device into TSCH mode with a MLME-TSCH-MODE.request.

NOTE: A lower value of join metric field ~~join priority~~ indicates that connection ~~to~~ of the beaconing device to a specific network device determined by a higher layer is a shorter route. ~~to the PAN coordinator.~~

At this point the device is synchronized to the network and may optionally send in an Association Request command. If the device uses association, it may request a short address. The sequence of messages exchanged to synchronize a device to the networks is shown in Figure 33, and the process of synchronization is described in 6.5.3.

Typically at this point the device will go through a procedure to allocate additional communication resources (slotframes and links) to the joining device. This procedure may include a security handshake to mutually authenticate the joining device, configure encryption keys, and configure routing information. The mechanism and rules for setting up these additional communication links ~~and configure other policies would normally~~ needs to be defined in a higher layer standard~~—the content of these messages is beyond the scope of this document.~~

Once synchronized and configured by a higher layer to do so, all FFDs that are already part of the network may send Enhanced Beacon frames announcing the presence of the network. The advertising rate and content is configured by a higher layer as appropriate to the density of devices, the desired rate of network formation, and the energy devoted to network formation.

Figure 33—Message sequence chart for TSCH procedure to find an advertising device

After joining, the device may receive additional slotframes and links from a higher layer management entity or peer ~~as required by the application~~, or the device may be instructed to remove certain slotframes and links

~~obtained from the Enhanced Beacon~~.

**7.4.4.2 TSCH Synchronization IE**

The TSCH Synchronization IE Content field shall be formatted as illustrated in Figure 134.

|  |  |
| --- | --- |
| Octets: 5 | 1 |
| ASN | Join Metric ~~Priority~~ |

Figure 134—TSCH Synchronization IE Content field format

The ASN field contains the ASN corresponding to the timeslot in which the enhanced beacon is sent. The ASN is used as the Frame Counter for security operations if enabled.

The Join ~~Priority~~ Metric field is an unsigned integer and shall be set to *macJoinMetric ~~macJoinPriority~~*.

**7.4.4.3 TSCH Slotframe and Link** **IE**

The TSCH Slotframe and Link IE is used in enhanced beacons to allow new devices to synchronize to a TSCH PAN.

The TSCH Slotframe and Link IE Content field shall be formatted as illustrated in Figure 135.

|  |  |  |  |
| --- | --- | --- | --- |
| Octets: 1 | variable | … | variable |
| Number of Slotframes | Slotframe Descriptor 1 | … | Slotframe Descriptor *n* |

Figure 135—TSCH Slotframe and Link IE Content field format

The Number of Slotframes field is set to the total number of Slotframe Descriptor fields IE.

The Slotframe Descriptor field(s) shall be formatted as illustrated in Figure 136.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Octets: 1 | 2 | 1 | 5 | … | 5 |
| Slotframe handle | Slotframe size | Number of Links | Link Information 1 | … | Link Information *m* |

Figure 136—Slotframe Descriptor field format

The Slotframe Handle field shall be set to the *macSlotframeHandle* from *macSlotframeTable* for this slotframe.

The Slotframe Size field is the size of the slotframe in number of timeslots and shall be set to the corresponding *macSlotframeSize* from *macSlotframeTable*.

The Number of Links field shall be set to the number of links that belong to the slotframe identified by the Slotframe Handle field.

The Link Information field shall be formatted as illustrated in Figure 137.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Octets: 2 | 2 | 1 |
| Timeslot | Channel Offset | Link Options |

Figure 137—Link Information field format

The Timeslot field shall be set to *macTimeslot*.

The Channel Offset Information field shall be set to *macChannelOffset*.

The Link Options field shall be formatted as illustrated in Figure 138.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bits: 0 | 1 | 2 | 3 | 4 | 5-7 |
| TX Link | RX Link | Shared Link | Timekeeping | Priority | Reserved |

Figure 138—Link Options field format

The TX Link field shall be set to one if ~~it~~ the link is a TX link and shall be set to zero otherwise. ~~If the TX Link field~~

~~is set to one, the RX Link field and Shared Link fields shall be set to zero.~~

TX Shared links, indicated by TX Link field and Shared Link field both set to one, may be used by a joining device to send an Association Request command or other higher layer message to the advertising device.

The RX Link field shall be set to one if ~~it~~ the link is an RX link and shall be set to zero otherwise. RX links are used for a joining device to receive an Association Response command or other higher layer message from an advertising device.

The Shared Link field shall be set to one if ~~it~~ the link is a Shared link and shall be set to zero otherwise. A Shared Link is one that uses contention to access the medium.

~~The Shared Link and RX Link fields may be both be set to one.~~

It is possible for one link to be used as both TX Shared and RX link.

The Timekeeping field shall be set to one if the link is to be used for clock synchronization and shall be set to zero otherwise. RX links shall have the Timekeeping field set to one.

The Priority Link field shall be set to one if the link uses priority channel access as defined in 6.2.5.2 and shall be set to zero otherwise.

**8.2.20.3 MLME-SET-LINK.request**

The MLME-SET-LINK.request primitive requests to add a new link, or delete or modify an existing link at the MAC sublayer. The SlotframeHandle and LinkHandle are supplied by a higher layer.

The semantics of this primitive are:

MLME-SET-LINK.request (

Operation,

LinkHandle,

SlotframeHandle, Timeslot,

ChannelOffset,

TxLink,

RxLink

SharedLink, TimekeepingLink, PriorityLink,

LinkType, NodeAddressMode,

NodeAddr

)

The primitive parameters are defined in Table 103.

Table 103—MLME-SET-LINK.request parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| Operation | Enumer-ation | ADD\_LINK, DELETE\_LINK, MODIFY\_LINK | Type of link management operation to be performed. |
| LinkHandle | Integer | 0x0000–0xffff | Unique identifier, local to specified slotframe, for the link, as described in Table 137. |
| Slotframe- Handle | Integer | 0x00–0xff | The slotframe handle of the slotframe to which the link is associated. |
| Timeslot | Integer | 0x0000–0xffff | Timeslot of the link to be added, as described in 6.2.6. |
| Channel- Offset | Integer | As defined in 6.2.6.3 | The Channel offset of the link  |

|  |  |  |  |
| --- | --- | --- | --- |
| TxLink | Boolean | TRUE, FALSE | Set to TRUE if it is a TX link ~~and set to FALSE otherwise~~ |
| RxLink | Boolean | TRUE, FALSE | Set to TRUE if it is an RX link, ~~otherwise set to FALSE as described in Table 137.~~ |
| SharedLink | Boolean | TRUE, FALSE | Set to TRUE if the link is a shared link. |
| TimekeepingLink | Boolean | TRUE, FALSE | I~~ndicates~~ Set to true if the link is to be used for clock synchronization as described in 6.5.3. ~~If the RxLink is TRUE TxLink is FALSE, then this shall be set to TRUE This parameter is ignored if TxLink is TRUE.~~  |
| PriorityLink | Boolean | TRUE, FALSE | Set to true if link is to be used for high priority traffic as described in 6.2.5.2 |
| LinkType | Enumera-tion | ADVERTISE, NORMAL | Set to ADVERTISE if it is an Advertising link, otherwise set to NORMAL. |
| NodeAddressMode | Enumera-tion | SHORT, EXTENDED | Addressing mode of the neighbor device connected to the link |
| NodeAddr | Short address or extended address | As specified by NodeAddressMode | Address of neighbor device connected by the link or the broadcast address  |

MLME-SET-LINK.request primitive may be used by the device management layer to add, delete, or modify a link in a slotframe.

When Operation is set to ADD\_LINK, the MAC layer shall attempt to add the link to a new *macLinkTable* associated with the indicated slotframe. When Operation is set to DELETE\_LINK, all parameters except LinkHandle and SlotframeHandle shall be ignored, and the indicated link shall be deleted from the associated *macLinkTable*. When Operation is set to MODIFY\_LINK, the MAC layer shall attempt to update the indicated link. If the link is currently in use, the delete or modify operation shall be postponed until the link operation completes, either through a successful unacknowledged transmission, time-out for receipt of an expected acknowledgment, receipt of an invalid or unacknowledged frame, or transmission of an acknowledgment upon receipt of a valid frame. Upon completion, the result of the operation shall be reported through the corresponding MLME-SET-LINK.confirm primitive.

If TxLink is TRUE and SharedLink is TRUE, then the device shall back off according to the method described in 6.2.5.2 ~~6.6~~. If TimekeepingLink is TRUE and RxLink is TRUE then a neighbor is to be used for timing synchronization.

If LinkType is set to ADVERTISE, the link~~s~~ may be used to send Enhanced Beacon frames as the result of the MAC receiving a MLME-BEACON.request.

**8.4.2.2.2 TSCH MAC PIB attributes for *macLinkTable***

The attributes contained in the MAC PIB for *macLinkTable* are presented in Table 137. Each link requires a *macLinkTable* to be stored.

**Table 137—TSCH MAC PIB attributes for *macLinkTable***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Attribute** | **Type** | **Range** | **Description** | **Default** |
| *macLinkHandle* | Integer | 0x0000–0xffff | Identifier of Link | — |
| *~~macLinkType~~**macTxLink* | ~~Enumeration~~Boolean | ~~TX, RX, SHARED, RX\_SHARED~~TRUE, FALSE | ~~Indicates the Link type~~Set to TRUE is the link is a TX link | — |
| *macRxLink* | Boolean | TRUE, FALSE | Set to TRUE if it is an RX link |  |
| *macSharedLink* | Boolean | TRUE, FALSE | Set to TRUE if the link is a shared link |  |
| *macLinkTimekeeping* | Boolean | TRUE, FALSE | Set to TRUE if the link is a timekeeping link~~, FALSE otherwise.~~ |  |
| *macPriorityLink* | Boolean | TRUE, FALSE | Set to true if link is to be used for high priority traffic as described in 6.2.5.2 |  |
| *macLinkType* | Enumeration | NORMAL, ADVERTISING | Type of link. | Normal |
| *macSlotframeHandle* | Integer | 0x00–0xff | Identifier of Slotframe to which this link belongs | — |
| *macNodeAddressMode* | Enumera-tion | SHORT, EXTENDED | Addressing mode of the neighbor device connected to the link |  |
| *macNodeAddress* | ~~Integer~~Short address or extended address | ~~0x0000–0xfffd,~~As specified by NodeAddressMode | ~~Short~~ ~~address of the node connected to this link~~ Address of neighbor device connected by the link or the broadcast address | — |
| *macTimeslot* | Integer | 0x0000–0xffff | Timeslot for this link | — |
| *macChannelOffset* | Integer | 0x0000–0xffff | Channel offset for this link | — |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bit Map dependencies | TxLink | RxLink | SharedLink | TimekeepingLink | PriorityLink |
| TxLink | — | Only if SharedLink is set | TX must backoff as per 6.2.5.3 | Not Defined |  |
| RxLink | Only if Shared-Link is set | — | Not Defined | Required if RxLink only |  |
| SharedLink | TX must backoff as per 6.2.5.3 | Not Defined | — | Not Defined |  |
| TimekeepingLink | Not Defined | Required if RxLink only | Not Defined | — |  |
| PriorityLink |  |  |  |  | — |
| Reserved |  |  |  |  |  |

TxLink=1, RxLink=0, SharedLink=0, TimekeepingLink=0, PriorityLink=Don’t Care

TxLink=1, RxLink=0, SharedLink=1, TimekeepingLink=0, PriorityLink=0

TxLink=1, RxLink=0, SharedLink=1, TimekeepingLink=0, PriorityLink=1

TxLink=1, RxLink=1, SharedLink=1, TimekeepingLink=0, PriorityLink=0

TxLink=1, RxLink=1, SharedLink=1, TimekeepingLink=0, PriorityLink=1

TxLink=0, RxLink=1, SharedLink=0, TimekeepingLink=1, PriorityLink=Don’t Care

Encrypt only mode – delete vs. deprecate

The use of security mode 4 (i.e. encryption w/o authenticity) is deprecated and shall not be used in implementations of this standard. The rationale for not using this mode is:

* Add Tero’s text here (DF5 page 320 first sentence of last paragraph)

No legacy mode – discard frames received that use mode 4 as described in 9.xxxx

Acknowledge

Send upon frame check or frame check and authentication check?

Many steps before MIC check such as frame version

Note: if an enhanced ack is received during the security mode

**6.7.2 Reception and rejection**

For the first level of filtering, the MAC sublayer shall discard all received frames that do not contain a

correct value in their FCS field in the MFR, as described in 7.2.10. The FCS field shall be verified on

reception by recalculating the purported FCS over the MHR and MAC payload of the received frame and by

subsequently comparing this value with the received FCS field. The FCS field of the received frame shall be considered to be correct if these values are the same and incorrect otherwise.

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If any of the third-level filtering requirements are not satisfied, the MAC sublayer shall discard the incoming

frame without processing it further. If all of the third-level filtering requirements are satisfied, the frame

shall be considered valid and processed further.

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For valid frames that are not broadcast, if the Frame Type field indicates one of a Multipurpose frame, a

Data frame with the Frame Version set to 0b10 or a MAC command with the Frame Version field set to

0b10, and the AR field is set to request an acknowledgment, the MAC sublayer shall send an Enh-Ack frame

~~as described in 6.7.4.2~~. unless the device performs the incoming frame security procedure as per 9.2.3. If the device performs the incoming frame security procedure and the Status is not SUCCESS the device is not required to send an Enh-Ack. If the Enh-ACK contains IEs and/or a Frame Payload and it is in response to a secured frame, then the Enh-ACK shall be secured. If the Enh-Ack is in response to a secured frame and does not contain either IEs or a Frame Payload, then the Enh-Ack may be secured.

**6.7.4.2 Acknowledgment**

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~~A frame transmitted with the AR field set to request an acknowledgment, as defined in 7.2.1.4, shall be~~

~~acknowledged by the recipient.~~ If the intended recipient has received a valid frame as defined in 6.7.2 ~~correctly receives the frame~~ with the AR set to request an acknowledgement, it shall generate and send an Ack frame as defined by 6.7.2. ~~containing the value of the same DSN from the Data frame or MAC command that is being acknowledged.~~

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The receiving device may include additional content in an Enh-Ack frame using IEs. If the originator does

not understand ~~the~~ a specific IE ~~content~~ of the Enh-Ack frame, ~~it~~ that IE is ignored, but the transmission is considered successful. The number and the content of the IEs included in the Enh-Ack should be limited to only those IEs with the minimal content that is required.

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The Time Correction IE shall be used in all Enh-Ack frames if *macTschEnabled* is TRUE. When returning

Time Correction IE, as described in 7.4.2.7, in the Enh-Ack frame the receiving device may indicate a negative acknowledgment to indicate that the frame successfully passed FCS check, but could not be transferred to a higher layer due to resource constraints (e.g., insufficient buffer space). This is treated as a failure from the sender’s perspective, and a notification of failure due to congestion is indicated to the higher layer through the MAC performance metrics. A higher layer may signal lack of buffers by setting

*macNoHLBuffers* to TRUE.

When in TSCH mode, incoming frames are acknowledged using the Enh-Ack frame as described in 7.3.3.

Security of the Enh-Ack frame shall match that of the incoming frame.

Instructions from 4e:

For enhanced acknowledgment frames (which are only sent after the incoming frame passes security filtering, if applicable), additional time may be required after aTurnaroundTime to complete incoming and outgoing security processing. If the enhanced acknowledgment is not sent before macEnhAckWaitDuration μs, the sender will assume the frame was not successful."

**7.2.1.4 AR field**

The AR field specifies whether an acknowledgment is required from the recipient device on receipt of a Data frame or MAC command. If this field is set to one, the recipient device shall send an Ack frame or only if, upon reception, the frame passes the filtering described in 6.7.2. If this field is set to zero, the recipient device shall not send an Ack frame.