IEEE P802.15

**Wireless Personal Area Networks**

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| Re: | [] | |
| Abstract | [This document contains proposed changes to the IEEE P802.15.4e Draft to address required changes for Low Energy.] | |
| Purpose | [] | |
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1. Summary of Changes

* **3. Definitions** – add Coordinated Sampled Listening concepts
* **7. MAC sublayer specification**
  + 7.1. MAC sublayer service specification – no change
  + 7.2. MAC frame formats – add two new frame types and a new optional MHR field
  + 7.3. MAC command frames – no change
  + 7.4. MAC constants and PIB attributes – add five PIB attributes
  + 7.5. MAC functional specification – add Coordinated Sampled Listening
  + 7.6. Security suite specifications – no change
  + 7.7. Message sequence charts illustrating MAC-PHY iteraction – no change

1. Definitions

* Coordinated Sampled Listening (CSL): A low-energy mode to the MAC which allows receiving devices to periodically sample the channel(s) for incoming transmissions at low duty cycles. The receiving device and the transmitting device are coordinated to reduce transmit overhead.
* CSL Period: The period in which receiving devices sample the channel(s) for incoming transmissions.
* CSL Phase: The length of time between now and the next channel sample.
* CSL Payload Frame: a beacon, data or command frame.
* CSL Wakeup Frame: a special short frame transmitted back-to-back before the payload frame to ensure its reception by CSL receiving device.
* CSL Wakeup Frame Sequence: a sequence of back-to-back wakeup frames up to the duration of the CSL Period.
* CSL Rendezvous Time (RZTime): 2-octet timestamp in wakeup frame payload indicating the expected length of time in milliseconds between the end of the wakeup frame transmission and the beginning of the payload frame transmission.
* CSL Channel Sample: The operation to perform ED on a channel and attempt to receive wakeup frame when energy is detected.

1. New MAC frames
   1. Existing Frames

Figure 41 shows the general MAC frame format of IEEE802.15.4-2006.

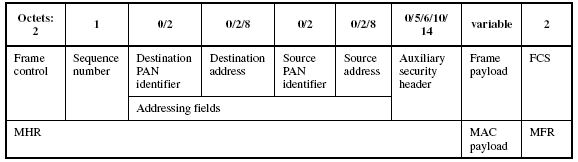
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Figure 41 -- General MAC Frame Format

Figure 42 shows the 2-octet frame control field (FCF) in IEEE802.15.4-2006.

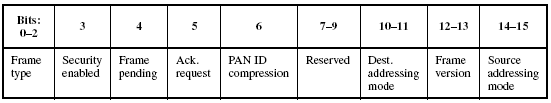
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Figure 42 -- Format of the Frame Control Field

Table 79 contains the frame type values of the existing frames with two new frame types added.

Table 79―Values of the frame type subfield

|  |  |
| --- | --- |
| ***b*2 *b*1 *b*0** | **Description** |
| 000 | Beacon |
| 001 | Data |
| 010 | Acknowledgment |
| 011 | MAC command |
| XXX | CSL Wakeup |
| YYY | Secure Acknowledgment |
| ZZZ-111 | Reserved |

* 1. Wakeup Frame

The following figure illustrates the format of wakeup frame.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Octets: 2**  **FCF** | **1**  **DSN** | **2**  **Dest PAN** | **2**  **Dest Addr** | **2**  **RZTime** | **2**  **FCS** |

The FCF is set as follows :

* Frame type = XXX
* Security enabled = 0
* Frame pending = 0
* Ack request = 0
* PAN ID compression = 0
* Dest addressing mode = 0x2
* Frame version = 0x1
* Source addressing mode = 0x0

The payload of this frame contains a 2-octet Rendezvous Time (RZTime) which is the expected length of time in milliseconds between the end of the transmission of the wakeup frame and the beginning of the transmission of the payload frame. This number is automatically filled in by the MAC layer when wakeup frames are constructed. The last wakeup frame in a wakeup sequence must have RZTime = 0.

* 1. New optional MHR field

The reserved FCF reserved bit 7 is renamed to the CSL sync bit. When the bit is set to 1, a 4-octet optional CSL sync field is added to the end of the current MHR. The following figure illustrates the format of the CSL sync field.

|  |  |
| --- | --- |
| **Octets: 2**  **CSL Phase** | **2**  **CSL Period** |

They represent the CSL phase and period of the transmitting device of the frame. This informmation helps eliminate or reduce the wakeup sequence for subsequent transmissions from the receiving device.

* 1. Secure Acknowledgement Frame (to be combined with other proposals)

The following figure illustrates the format of an secure acknowledgement frame.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Octets: 2**  **FCF** | **1**  **DSN** | **2**  **Dest PAN** | **2**  **Dest Addr** | **0/5/6/10/14**  **Auxiliary security header** | **2**  **CSL Phase** | **2**  **CSL Period** | **2**  **FCS** |

The FCF is set as follows :

* Frame type = YYY
* Security enabled = 0 or 1
* Frame pending = 0
* Ack request = 0
* PAN ID compression = 0
* CSL sync = 1
* Dest addressing mode = 0x2
* Frame version = 0x1
* Source addressing mode = 0x0

The payload of this frame contains 2-octet CSL Phase and 2-octet CSL Period. They represent the CSL phase and period of the receiving device. This information helps the transmitting device eliminate or reduce the wakeup sequence for subsequent transmissions to the same destination.

1. New MAC PIBs

**Table 86—MAC PIB attributes**

| **Attribute** | **Identifier** | **Type** | **Range** | **Description** | **Default** |
| --- | --- | --- | --- | --- | --- |
| cslPeriod |  | Integer | 0 … 1023 | CSL sampled listening period in milliseconds. 0 means always listening, i.e., CSL off. | 0 |
| cslMaxPeriod |  | Integer | 0 … 1023 | Maximum CSL sampled listening period in the entire PAN. 0 means cslMaxPeriod is the same as cslPeriod. | 0 |
| cslChannelMask |  | Integer |  | 32-bit bitmap relative to phyCurrentPage of channels. It represents the list of channels CSL operates on. 0 means CSL operates on phyCurrentChannel of phyCurrentPage. | 0 |
| cslFramePendingWaitT |  | Integer |  | Number of milliseconds to keep the receiver on after receiving a payload frame with FCF frame pending bit set to 1. |  |
| macSecAckWaitDuration |  | Integer |  | The maximum number of symbols to wait for a secure acknowledgement frame to arrive following a transmitted data frame. |  |

1. New Functional Description

7.5.1.1.1 Contention access period (CAP)

When cslPeriod is set to non-zero, CSL will be deployed in CAP.

7.5.6 Transmission, reception and acknowledgement

7.5.6.7 <New Section>Coordinated Sampled Listening (CSL)

The coordinated sampled listening (CSL) mode is turned on when the PIB attribute cslPeriod is set to non-zero and turned off when cslPeriod is set to zero. In CSL mode, transmission, reception and acknowledgement work as follows. Figure X illustrates the basic CSL operations.

Figure X. Basic CSL operations

7.5.6.7.1 CSL idle listening

During idle listening, CSL performs a channel sample every cslPeriod milliseconds. If the channel sample does not detect energy on the channel, CSL disables receiver for cslPeriod milliseconds and then perform the next channel sample. If the channel sample receives a wakeup frame, CSL checks the destination address in the wakeup frame. If it matches macShortAddress, CSL disables receiver until the Rendezvous Time (RZTime) in the wakeup frame from now and then enables receiver to receive the payload frame. Otherwise, CSL disables receiver until RZTime from now plus the transmission time of the payload frame and the secure acknowledgment frame and then resume channel sampling.

7.5.6.7.2 CSL transmission

Each CSL transmission of a payload frame is preceded with a sequence of back-to-back wakeup frames (wakeup sequence).

7.5.6.7.2.1 Unicast transmission

In unicast transmissions, the wakeup sequence length can be long or short based on the following two cases:

* Unsynchronized transmission: This is the case when the MAC layer does not know the CSL phase and period of the destination device. In this case, the wakeup sequence length is cslMaxPeriod or cslPeriod if cslMaxPeriod is zero.
* Synchronized transmission: This is the case when the MAC layer knows the CSL phase and period of the destination device. In this case, the wakeup sequence length is only the guard time against clock drift based on the last time when CSL phase and period updated about the destination device.

If the next higher layer has multiple frames to transmit to the same destination, it can set the FCF frame pending bit to 1 in all but the last frame to maximize the throughput.

CSL unicast transmission is performed in the following steps by the MAC layer:

1. Perform CSMA-CA to acquire the channel
2. If the previous acknowledged payload frame to the destination has the frame pending bit set and is within cslFramePendingWaitT milliseconds, go to step 5.
3. If it is a synchronized transmission, wait until the destination device’s next channel sample.
4. For the duration of wakeup sequence length (short or long)
   1. Construct wakeup frame with the destination short address and remaing time to payload frame transmission (at the end of wakeup sequence)
   2. Transmit wakeup frame
5. Transmit payload frame
6. Wait for up to macSecAckWaitDuration symbol time for the secure acknowledgement frame if the ack request subfield in the payload frame is set to 1.
7. If the secure acknowledgment frame is received, update CSL phase and period information about the destination device from the acknowledgment CSL sync field.
8. If the secure acknowledgement frame is not received, start retransmission process.

7.5.6.7.2.2 Multicast transmission

Multicast transmission is the same as as unicast transmission except the following:

* It is always unsynchronized transmission.
* The destination address in wakeup frames is set to 0xffff.

7.5.6.7.2.3 Utilizing the optional CSL sync field

Selectively the next higher layer may set the CSL sync bit in FCF in a frame to propogate CSL phase and period information among the neighboring devices. When the bit is set, the MAC layer automatically appends the CSL sync fields to the end of MHR.

7.5.6.7.3 CSL reception

When a payload frame is received, the MAC layer performs the following steps:

1. Immediately send back an secure acknowledgment frame with the destination address set as the transmitting device and its own CSL phase and period filled in the CSL sync field. The acknowledgment frame can be optionally authenticated and/or encrypted depending on the current security mode.
2. If CSL sync bit in the received payload frame is set to 1, the CSL phase and period information about the transmitting device is updated with the information in the CSL sync field.
3. If FCF frame pending bit in the received payload frame is set to 1, keep receiver on for cslFramePendingWaitT milliseconds before going back to CSL idle listening. Otherwise, start CSL idle listening.

7.5.6.7.4 CSL over multiple channels

When cslChannelMask is set to non-zero, the CSL operations are extended to all the channels selected in the bitmap. CSL idle listening performs channel sample on each channel from the lowest number to the highest in a round-robin fashion. In the unsynchronized case, CSL transmission transmits a wakeup sequence of the length *number\_of\_channels\*cslMaxPeriod* before each payload frame. In the synchronized case, CSL transmission calculates the next channel sample time and channel number and transmits at the next channel sample time on the right channel with a short wakeup sequence. In this case, CSL phase is the duration from now to the next channel sample on the first channel selected in cslChannelMask.