**IEEE P802.15**

**Wireless Specialty Networks**

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# Overview

## Not part of draft, but for background information

# References

… Not part of draft, but list related contributions

# Definitions, acronyms, and abbreviations

## Definitions

**anchor device** (which is already used in the 802.15.4 application nodes 14-0226): A device whose location in the network is known.

**mobile device** (already defined in 802.15.4): A device whose location in the network can change, also as known as a tag device in UWB terminology

**Uplink Time Difference of Arrival:** TDOA ranging process which is initiated by a mobile device.

**Downlink Time Difference of Arrival:** TDOA ranging using messages from anchor devices.

## Acronyms and abbreviations

UL-TDOA: Uplink Time Difference of Arrival.

DL-TDOA: Downlink Time Difference of Arrival.

# Format conventions

…

# General description

## …

## Special Application Spaces

### Downlink TDOA (DL-TDOA) based Location Service

DL-TDOA based location service usually include a number of anchor devices deployed at known locations in an indoor area. The anchor devices periodically transmit ranging messages so any mobile device in the area may overhear some of these messages and measure the time difference of arrival between messages to estimate its location. The location service uses DL-TDOA as the primary ranging mode for location service but may also include other ranging modes such as UL-TDOA and TWR for localization purpose. DL-TDOA based location service has several advantages in capacity, accuracy and privacy. First, it is able to support a large number of mobile devices if mobile device is not necessary to transmit. Second, the location accuracy is independent of number of mobile devices. Third, a mobile device may be anonymous to use this location service which protects user privacy.

## …

## …

## Network Topologies

### Peer-to-peer Network Formation

…

Anchor devices in DL-TDOA based location service form a peer-to-peer UWB network topology. Some or all anchor devices may support a second radio and/or Ethernet connection for out-of-band communication. The PAN coordinator could be an anchor device or an external device such as a server. If the PAN coordinator is an anchor device, it may control and communicate with other anchor devices in the network via in-band or out-of-band communications. If the PAN coordinator is an external device such as a local or cloud-based server, it may control and communicate with other anchor devices first via some gateways then via wireless (in-band or out-of-band) or wired communications. The UWB network could be a cluster tree network as shown in Figure 5-2, or other network topologies such as a mesh network in Figure 5-x.

Internet

Anchor device

Mobile device

UWB connectivity

Downlink ranging

Figure 5-x Example of mesh network

## …

## Functional Overview

### Superframe Structure

## 5.7.1.5 Flexible Superframe for Location Service

DL-TDOA based location service uses a flexible superframe structure which includes an optional beacon only period (BOP), a CFP for scheduled DL-TDOA ranging messages, and an optional CAP for supporting other ranging modes and/or in-band data/control communications. The superframe structure is illustrated in Figure 5-y. More information on this superframe structure can be found in 6.2.12.

BOP

CFP (for DL-TDOA)

CAP

time

 … …

Figure 5-y Flexible Superframe for location service

# MAC Functional Description

## …

## Channel Access

### Flexible Superframe Structure for Location Service

The flexible superframe structure for location service includes three periods – an optional BOP, a CFP for DL-TDOA ranging and an optional CAP for supporting other ranging, in-band data and/or control messages. The optional inclusion of BOP and CAP also provide capability for in-band service discovery and setup. Superframes repeat over time and the duration of periods could be modified over time, as long as the up-to-date superframe information is broadcasted in the network via in-band or out-of-band communications. A generic superframe structure for location service is illustrated in Figure 6-x.

The superframe duration is in the unit of *macBaseLSSuperframeSlotDuration*, where *macBaseLSSuperframeSlotDuration* is in the unit of RSTU, for example, *macBaseLSSuperframeSlotDuration* = 600\*RSTU = 0.5ms. The maximal value of *macBaseLSSuperframeSlotDuration* is denoted as another constant parameter *aMaxBaseLSSuperframeSlotDuration*.

In a superframe:

The BOP duration is *macLSSuperframeBOPDuration* =B\**macBaseLSSuperframeSlotDuration*, where B>=0, is the number of beacon slots.

The CFP duration is *macLSSuperframeDLTDOADuration* =N\*M\* *macBaseLSSuperframeSlotDuration*, where N is the number of ranging rounds in the ranging block, M is the number of ranging slots in a ranging round.

The CAP duration is *macLSSuperframeCAPDuration* = A\* *macBaseLSSuperframeSlotDuration*, where A>=0.

Therefore the overall duration of a superframe is *macLSSuperframeDuration* = (B+N\*M+A)\* *macBaseLSSuperframeSlotDuration*.

Enhanced beacons are transmitted in the BOP. A beacon may include information such as network identification, superframe configuration, timestamp for frame synchronization, etc. The corresponding IEs for containing the information are described in 7.4.x.x.

The CFP uses a ranging block structure. As described in 6.9.12, the ranging block structure can be configured in multiple ways to support different DL-TDOA ranging transmission schemes. In each ranging slot, one ranging frame (RFRAME) is transmitted.

 RFRAMEs for other ranging mode and data frames can be transmitted in the CAP.

BOP

CFP (for DL-TDOA)

CAP

time

Ranging round 0

Ranging round 1

Ranging round 2

Ranging round 3

Ranging round N-1

……

Ranging block

Ranging slot 0

Ranging slot 1

Ranging slot 2

Ranging slot M-1

……

RFRAME

Transmission offset

Figure 6-x Flexible Superframe structure for location service whose CFP is a ranging block

## Starting and Maintaining PANs

## Association and Disassociation

## …

## …

## …

## …

## Ranging

#### Overview

##### 6.9.1.2 Ranging and localization methods

##### 6.9.1.2.5 Time difference of arrival (TDOA)

TDOA is a technique to locate a mobile device, (e.g., a radio frequency identification (RFID) device), based on the relative arrival times of a single message or multiple messages. OWR is used for TDOA. There are two cases of TDOA. In one case a message is periodically broadcast by the mobile device to multiple fixed nodes (i.e., anchor devices) that are synchronized in some way so that the arrival times can be compared. Typically, the message sent by the mobile device is referred to as a blink. This is commonly known as uplink TDOA (UL-TDOA) approach where the mobile device initiates the range request by sending a single message (a.k.a. POLL message) received by all the neighboring anchor devices. In the other case, multiple synchronized anchor devices broadcast messages sequentially with known transmission time offsets with respect to each other. This is commonly known as downlink TDOA (DL-TDOA) approach where the ranging messages are from anchor devices. For any pair of fixed

synchronized anchor devices, the difference in arrival time of the blink in the first case, or the broadcast messages at the mobile device in the second case, places the mobile device on a hyperbolic surface. Combining the results from multiple such pairs will yield an intersection point between the sets of hyperbolic surfaces yielding the location of the mobile device. Note that in the second case, the transmission offset is taken into account when calculating the difference in arrival time of messages from synchronized nodes.

### Ranging Block Structure Options in the Superframe for DL-TDOA based Location Service

DL-TDOA RFRAMEs are organized and scheduled in the CFP of a superframe. The CFP uses a ranging block structure. Since the time difference of arrival values are derived from different RFRAMEs from different anchor devices, the ranging block structure provides flexibility in organizing the ranging procedure.

Even if the DL-TDOA ranging procedure is in general an OWR procedure from mobile device perspective, it is quite similar to traditional device-to-device ranging (e.g., one-to-one, one-to-many, many-to-many ranging, etc.) from anchor devices’ point of view.

#### One-to-One-like Ranging

In this case, anchor devices in the network are paired up to transmit RFRAMEs sequentially. For example, if anchor device A and anchor device B form an anchor pair, anchor device A sends out the first RFRAME (a.k.a., REQ or INIT) and anchor device B sends out the second RFRAME (a.k.a. RSP) as a response to the first RFRAME. Time difference of arrival is available at a mobile device when it overhears both RFRAMEs from this anchor pair. To support this setup, the ranging block in the CFP is configured as in Figure 6-y, where M=2, i.e., two ranging slots per ranging round.

Figure 6-y A ranging block to support anchor pair setup in DL-TDOA location service

CFP (for DL-TDOA)

Ranging round 0

Ranging round 1

Ranging round 2

Ranging round 3

Ranging round N-1

……

Ranging block

Ranging slot 0

Ranging slot 1

RFRAME

Transmission offset

#### One-to-Many-like Ranging

In this case, anchor devices in the network are organized into clusters to transmit RFRAMEs sequentially. For example, if anchor device A, B, C, D form a cluster, anchor device A sends out the first RFRAME (a.k.a., REQ or INIT) and anchor devices B to D sends out RFRAMEs (a.k.a. RSPs) sequentially as responses to the first RFRAME. Multiple time differences of arrival are available at a mobile device when it overhears all RFRAMEs from this anchor cluster. To support this setup, the ranging block in the CFP is configured as in Figure 6-z, where M is the number of anchor devices per cluster. The number of ranging slots per round can be different from round to round.

CFP (for DL-TDOA)

Ranging round 0

Ranging round 1

Ranging round 2

Ranging round 3

Ranging round N-1

……

Ranging block

Ranging slot 0

Ranging slot 1

Ranging slot 2

Ranging slot M-1

……

RFRAME

Transmission offset

Figure 6-z A ranging block to support anchor cluster setup in DL-TDOA location service

#### Many-to-Many-like Ranging

In this case, anchor devices in the network are not organized into pairs or clusters. If anchor devices are precisely synchronized, they broadcast RFRAMEs sequentially. Multiple time differences of arrival are available at a mobile device when it overhears some of RFRAMEs. To support this setup, the ranging block in the CFP is configured same as Figure 6-z, where a portion of ranging slots in a round are for anchor devices sending out RFRAMEs (a.k.a. Initiation Phase) and remaining ranging slots in a round may be used for other ranging modes (a.k.a. Response Phase).

Ranging slot J+1

Response

Ranging slot J+2

Initiation phase

CFP (for DL-TDOA)

Ranging round 0

Ranging round 1

Ranging round 2

Ranging round 3

Ranging round N-1

……

Ranging block

Ranging slot 0(RCM)

Ranging slot 1

Ranging slot 2

……

RFRAME

Transmission offset

……

Ranging slot M-1

 Figure 6-za A ranging block to support many-to-many setup in DL-TDOA location service

## 6.18 Device Discovery and Association in DL-TDOA based Location Service

The description in this section is for In-band discovery. Out-of-band (OoB) discovery is also available as a choice if OoB communication is supported. The option of In-band discovery is for devices to discover DL-TDOA based location service in case that a device does not support a compatible OoB communication mode provided by the network or even does not have a second radio for OoB communication.

### Scanning through channels

DL-TDOA anchors and mobile devices shall be able to perform passive scans. Some DL-TDOA anchors and mobile devices may be able to perform energy detection scans. DL-TDOA PAN coordinators (or FFD) may be able to perform energy detection scans.

#### Energy Detection channel scan

…, and then repeatedly perform an ED measurement for [*aMaxBaseLSSuperframeSlotDuration* *× (2^n + 1)*], where *n* is the value of the *ScanDuration* parameter in the MLME-SCAN.request primitive.

#### Active and passive channel scan

New anchors and mobile devices shall start with passive scans.

A new anchor may listen to and try to decode not only Beacon frames but also other frames. The MAC sublayer may accept frames received over the PHY data service that are not Beacon frames.

If a Beacon frame is received, and the anchor can extract information about the network and superframe structure, the MLME-SCAN.confirm (SUCCESS) shall be issued to the next higher layer of the anchor.

If a Beacon frame with the OOB/NB indicator is received, the anchor may switch to OOB/NB for getting further information.

The anchor may use the information extracted from the Beacon frame (in-band/OOB/NB) or non-beacon frame containing network timing information to perform network synchronization.

If non-Beacon frames containing any network or timing information (e.g., start and end of contention period) is received, the anchor may start active scan if it is allowed and necessary. The PAN coordinator and beacon devices (defined in 6.18.2) may send Beacon response during the contention period of the current superframe or continue to send Beacons during the BOP of the following superframes.

After channel scan, the anchor may update its network and superframe configurations and channel PIB attributes.

The anchor shall not transmit before they recognize the network and superframe structure. After network and superframe configurations are updated, the anchor shall transmit in the assigned slot during BOP and scheduled access period and may transmit during CAP.

### Conflict Resolution

If multiple Beacon frames are received with conflict network information such as PAN ID and sub-network ID, the anchor shall be able to detect conflict, issue an MLME-SYNC-LOSS.indication primitive with the LossReason parameter set to PAN\_ID\_CONFLICT, and issue an MLME-START.request with the CoordRealignment parameter set to TRUE to realign the PAN.

If multiple Beacon frames are received with the same network information but conflict superframe structure, the anchor may be able to issue MLME-SYNC-LOSS.indication primitive with the LossReason set to SF\_CONFLICT and issue an MLME-START.request to realign the PAN.

### Device discovery

In a DL-TDOA based location network, there may be multiple anchor devices, not necessarily only the PAN coordinator, transmitting beacons. An anchor device transmitting beacons is also known as a beacon device.

In addition to *macSNId* and *macExtendedAddress/macShortAddress* may be used as the identifier of a sub-network, *macPanId* may be the identifier of the DL-TDOA based location network.

### Association

The association procedure is required for any new anchor device, but optional for a mobile device if the mobile device prefers to keep anonymous while using DL-TDOA based location service.

The next higher layer of the anchor shall attempt to associate only after having performed a MAC sublayer reset, and then having completed channel scan. The results of the channel scan are used to choose a desired DL-TDOA based location network.

…, that the MLME configures the following PHY and MAC PIB attributes to the values necessary for association with the PAN coordinator:

* *phyCurrentChannel*
* *phyCurrentPage*
* *macPanId*
* *macCoordExtendedAddress or macCoordShortAddress*
* *macLSNetId*

Association request/response frames may travel through multiple hops along the path between the PAN coordinator and anchors. Routing is outside the scope of this specification.

The Association Request shall be sent to the PAN coordinator, and the higher layer of the PAN coordinator shall make the association decision and send the Association Response.

The next higher layer of the PAN coordinator makes the association decision based on the current resources available in the network. If association is allowed, the PAN coordinator shall send an Association Response containing the new address and the Association Status field indicating a successful association. If not, the next higher layer of the PAN coordinator should inform the MAC sublayer, and the MLME shall send an Association Response command containing the Association Status field indicating a failure.

After association, anchors may update some configurations (e.g., anchor location and scheduling information) by pull/push services from/to the PAN coordinator. Configurations could be confirmed by the PAN coordinator.

### Disassociation

Disassociation Notification frames could fail due to not only channel access failure but also other reasons such as routing failure and timeout. Disassociation Notification frames could be from/to not only the PAN coordinator but also other devices such as routers and neighbor devices.

### Beacon slot request

After the anchor is associated with the network, the anchor may send beacon command request BCMD\_BSLOT\_REQ (BCMD IE) during the contention period to request to be a beaconing device. After the BCMD\_BSLOT\_REQ is received by the PAN coordinator, the PAN coordinator sends BCMD\_BSLOT\_RESP during BOP. After the BCMD\_BSLOT\_RESP is received by the anchor, the anchor updates its role as a beacon device and sends BCMD\_BSLOT\_CONFIRM in the assigned beacon slot during BOP to confirm the Beacon slot assignment.

Beacon slots shall be assigned by the PAN coordinator that have the overall information about beaconing devices and the anchor to avoid beacon slot conflicts.

MLME-BEACON-SLOT-REQUEST/RESPONSE/NOTIFY/CONFIRM services shall be added to support the beacon slot request procedure.

Any message between the anchor and the PAN coordinator could be though multi-hop forwarding/routing, which is outside the scope of this specification.

# MAC frame formats

## IEs

### Header IEs

#### Header IE format

Insert row into Table 7-7 as indicated

Table 7-7—Element IDs for Header IEs

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Element ID | Name | Enhaned Beacon | Enhaned ACK | Data | Multipurpose | MAC Command | Format Description | Use Description | Used by | Created by |
| <ana> | DL-TDOA PAN descriptor | X |  | X | X |  | 7.4.2.21 |  | MAC | MAC |
| <ana> | DL- TDOA Ranging Info and Node ID IE |  |  | X | X |  | 7.4.2.22 |  | MAC | MAC |
|  |  |  |  |  |  |  |  |  |  |  |

Insert New Clauses 7.4.2.21 and 7.4.2.22:

#### DL-TDOA PAN Descriptor

The DL-TDOA PAN Descriptor IE conveys information used for synchronization and to describe the superframe structure for location service. The content field of the DL-TDOA PAN Descriptor IE shall be formatted as shown in Figure 7-zb.

Figure 7-zb DL-TDOA PAN Descriptor IE Content field format

|  |  |  |  |
| --- | --- | --- | --- |
| Octests: 1/7 | 2/12 | TBD | TBD |
| Frame Synchronization Specification | Superframe Specification | Other control information | Reserved |

Frame Synchornization Specification field shall be formatted as illustrated in Figure 7-zc

Figure 7-zc Frame Synchronization Specification field

|  |  |  |  |
| --- | --- | --- | --- |
| Octests: 1 | 0/4 | 0/1 | 0/1 |
| Bits: 0-1 | 2 | 3-7 |  |  |  |
| In-band/Out-of-band Control | Superframe Time Offset Unit | Reserved | Superframe Time Offset | Sync Hop | Reserved |

The In-band/Out-of-band Control field is an unsigned integer indicating that the Frame Synchronization information is transmitted in-band, out-of-band or both. The value of this field shall be set as described in Table 7-a1.

Table 7-a1 In-band/Out-of-band Control field values

|  |  |
| --- | --- |
| Value (b1b0) | Corresponding Field Present |
| 0b00 | Reserved |
| 0b01 | Frame Synchronization Specification sent in-band: The Superframe Time Offset Unit field is valid, the Superframe Time Offset field and Sync Hop field are present.  |
| 0b10 | Frame Synchronization Specification sent out-of-band. The Superframe Time Offset Unit field is set to invalid, the Superframe Time Offset field and Sync Hop field are not present. |
| 0b11 | Frame Synchronization Specification sent in-band and out of band: The Superframe Time Offset Unit field is valid, the Superframe Time Offset field and Sync Hop field are present |
|  |  |

Superframe Time Offset Unit field is a bit value and shall be set to indicate the units used for the Superframe Time Offset field as shown in Table 7-a2.

Table 7-a2 Superframe Time Offset Unit field values

|  |  |
| --- | --- |
| Value | Description |
| 0 | Ranging Scheduling Time Unit (RSTU) |
| 1 | Ranging Counter Time Unit (RCTU) |

Superframe Time Offset field, when present, is an unsigned integer shall be set to the offset between the time of transmission of the Enhanced Beacon frame containing the DL-TDOA PAN Descriptor IE and the start of the Superframe, in the units (RTSU or RCTU) indicated by the Superframe Time Offset Unit field.

The Sync Hop field, when present, is an unsigned integer and shall be set to the number of hops the generating node is from the first sync node. Shall be set to zero to when the generating node is the first sync node.

The Superframe specification field shall be formatted as shown in Figure 7-zd.

Figure 7-zd Frame Synchronization Specification field

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Octests: 2 | 0/3 | 0/2 | 0/2 | 0/2 |
| Bits: 0-1 | 2-13 | 14-15 |  |  |  |  |
| In-band/Out-of-band Control | Base Superframe Slot Duration | Slot Duration Scaling | Number of Superframe Slots | Number of BOP Slots | Number of DL-TDOA Slots | Number of CAP Slots |

The in-band/Out-of-band control field is an unsigned integer indicating that the Frame Synchronization Specification information is transmitted in-band, out-of-band or both. The value of this field shall be set as described in Table 7-a1.

The Base Superframe Slot Duration field is an unsigned integer which, combined with the Slot Duration scaling field value, indicates the duration of each Superframe slot. The value is expressed in units of SF\*RSTU where SF is determined from the Slot Duration Scaling value. Upon transmission this field is set to the value of the *macB*𝑎𝑠𝑒*LS*𝑆𝑢𝑝𝑒𝑟𝑓𝑟𝑎𝑚𝑒𝑆𝑙𝑜𝑡𝐷𝑢𝑟𝑎𝑡𝑖𝑜𝑛 attribute.

The Slot Duration Scaling field contains the exponent used to scale the Base Superframe Slot Duration field such that SF = 2(Slot Duration Scaling value). Upon transmission this field is set to the value of the *macB𝑎𝑠𝑒LS𝑆F𝑆𝑙𝑜𝑡Exponent* attribute.

The Number of Superframe Slots field is an unsigned integer and signals the total duration of the Superframe, expressed in units of the Base Superframe Slot Duration field value. Upon transmission this field shall be set to the value of *macLSSuperframeDuration* attribute.

The Number of BOP Slots field is an unsigned integer that signals the duration of the Beacon Only Period within the Superframe expressed in units of the Base Superframe Slot Duration field value. Upon transmission this field shall be set to the value of the *macLSSuperframeBOPDuration* attribute.

The Number of DL-TDOA Slots field is an unsigned integer that signals the duration of the dedicated DL-TDOA period within the Superframe expressed in units of the Base Superframe Slot Duration field value. Upon transmission this field shall be set to the value of the *macLSSuperframeDLTDOADuration* attribute.

The Number of CAP Slots field is an unsigned integer that signals the duration of the CAP period within the Superframe expressed in units of the Base Superframe Slot Duration field value. Upon transmission this field shall be set to the value of the *macLSSuperframeCAPDuration* attribute.

#### DL-TDOA Ranging Info and Node ID IE

The DL-TDOA Ranging Info and Node ID IE conveys information used for in DL-TDOA Ranging frame. The content field shall be formatted as shown in Figure 7-zd.

Figure 7-zd 7.4.2.22 DL-TDOA Ranging Info and Node ID IE

|  |  |  |
| --- | --- | --- |
| Octets: 2 | 0/2/8 | Variable |
| Bits: 0-1 | 2-3 | 4 | 5 | 6-13 | 14-15 |  | N\*(2/8) |
| Ranging Operation Type | Ranging Message Type | Source Node ID present | Node ID Format | Number of Dst Node IDs | Reserved | Source Node ID | Dst Node ID List |

The Ranging Operation Type field is an unsigned integer indicating the usage of the ranging frame. The value shall be set to a non-reserved value shown in table 7-a3. In DL-TDOA operation context, the SS-TWR and DS-TWR are the analogy of the RFAME exchange between anchors, not the purpose of the ranging operation itself.

Table 7-a3 Ranging Operation Type field values

|  |  |
| --- | --- |
| Value | Description |
| 0 | One-way ranging (OWR), see 6.9.1.2.5 |
| 1 | Single-sided two-way ranging (SS-TWR) -like, see 6.9.1.2.2. |
| 2 | Doube-sided two-way ranging (DS-TWR) -like, see 6.9.1.2.3. |
| 3 | Reserved |

The Ranging Message Type field indicates the role of the ranging message in the DL-TDOA ranging exchange sequence. The value shall be set a non-reserved value as shown in table 7-a4.

Table 7-a4 Ranging Message Type field values

|  |  |
| --- | --- |
| Value | Description |
| 0 | Poll  |
| 1 | Response  |
| 2 | Final  |
| 3 | Reserved |

The Source Node ID present field indicates if the Source Node ID field is present. The field shall be set to 1 when the Source Node ID is present and set to zero otherwise.

The Node ID Format field indicates the address type used for each node ID value. The value shall be set to 0 when short addresses are used and shall be set to 1 when extended addresses are used. All Node ID field values shall be the same format.

The Number of Dst Node IDs field is an unsigned integer and shall be set to the number of destination node IDs in the Dst Node ID list. When the Dst Node ID list is elided, this field shall be set to zero.

The Source Node ID field, when present, specifies the short or extended address of the originator of the IE content. The format is as indicated by the Node ID format field.

The Dst Node ID List field shall be present when the Number of Dst Node IDs field is not zero. Each list entry contains a short or extended address of a destination node, as specified by the Node ID Format field.

### Nested IEs

 Insert rows into Table 7-18 as shown

Table 7-18—Sub-ID allocation for short format

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sub-ID value | Name | Enhaned Beacon | Enhaned ACK | Data | Multipurpose | MAC Command | Format Description | Use Description | Used by | Created by |
| <ana> | DL-TDOA BCMD IE | X |  |  | X |  |  |  | MAC | MAC |
| <ana> | DL-TDOA Routing information IE | X |  |  | X |  |  |  | MAC | MAC |
| <ana> | DL-TDOA Anchor Ranging Information IE |  |  | X | X |  |  |  | UL | MAC |

Insert new clauses 7.4.4.56 through 7.4.4.58:

#### DL-TDOA BCMD IE

The DL-TDOA Beacon Command (BCMD) IE is contains control information used for managing beacon slot allocations (see 6.xxx F management). The content contains list of one or more BCMD elements, each element shall be formatted as shown in figure 7-ze. The number of elements is determined upon reception based on the IE content length and the length of each element, and each command shall be acted upon in the order it appears in the list.

Figure 7-ze DL-TDOA BCMD IE Format

|  |  |
| --- | --- |
| Octets: 1 | 2/3/8/9 |
| Bits: 0-3 | 4-7 |  |
| Command ID | Command Data Length | Command Data |

The Command ID field is an unsigned integer and shall be set to a non-reserved value in table 7-a5 to indicate the specific command.

Table 7-a4 Ranging Message Type field values

|  |  |
| --- | --- |
| Value | Description |
| 0 | Beacon Slot Request |
| 1 | Beacon Slot Response |
| 2 | Beacon Slot Confirm |
| 3 | Pending Packet Notification |
| 4-15 | Reserved |

The Command Data Length field is an unsigned integer that indicates the length in octets of the Command Data field. The value shall be determined as given in Table 7-a5.

Table 7-a5 Command Data Length values

|  |  |  |  |
| --- | --- | --- | --- |
| Command ID | Command Data Length Value | Node ID field | Slot Index field |
| 0 | 2 | Short Address | Not present |
| 1 | 3 | Short Address | Present |
| 2 | 3 | Short Address | Present |
| 3 | 2 | Short address | Not present |
| 0 | 8 | Extended Address | Not present |
| 1 | 9 | Extended Address | Present |
| 2 | 9 | Extended Address | Present |
| 3 | 8 | Extended Address | Not present |
| 4-15 | Not Applicable |

The format of the Command Data field is shown in Figure 7-zf and depends upon the command ID and the Command Data Length field values.

Figure 7-zf DL-TDOA BCMD Command Data field

|  |  |
| --- | --- |
| Octets: 2/8 | 1 |
| Node ID | Slot Index |

When the Command ID is set to Beacon Slot Request, Beacon Slot Response or Beacon Slot Firm, the Node ID field shall contain the ID of the anchor request the the beacon slot as either a short address or an extended address. When the Command ID is set to Pending Packet Notification, the Node ID field shall contain the ID of the destination for the pending packet (see 6.xx description of pending packets).

The slot index field is an unsigned integer and is present when the Command ID is either Beacon Slot Response or Beacon Slot Confirm, and not present otherwise, as shown in Table 7-a5. When present the value shall be set to the beacon slot assigned in response to the Beacon Slot Request.

#### DL-TDOA Routing Information IE

TBD

#### DL-TDOA Anchor Ranging Information IE

The DL-TDOA Anchor Ranging Information IE is used in DL-TDOA ranging frames exchanged between anchors as described in [6.xxx where the use of ranging frames is described]. The content shall be formatted as shown in Figure 7-zg

Figure 7-zg DL-TDOA Anchor Ranging Information IE

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 2 | 4/8 | 0/12/24 | 0/2 | Variable | Variable | Variable |
| Control | Ranging Block Index | Ranging Round Index | TX Timestamp | Node Location | Clock Frequency Offset | Dst Ranging Slot Index List | Reply Time List | ToF List |

The control field shall be formatted as in Figure 7-zh.

Figure 7-zh DL-TDOA Anchor Ranging Information Control Field

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bits: 0 | 1 | 2-3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11-15 |
| TX Timestanp Format | Node Location Present | Node Location Type | Node Location Format | CFO Present | Dst Ranging Slot Index Present | Reply Time Present | Reply Time Format | ToF Present | ToF Format | Reserved |

The TX Timestamp Format field shall be set to zero to indicate the TX Timestamp Field is 4 octets and shall be set to one to indicate the TX Timestamp field is 8 octets.

The Node Location Present field shall be set to one if the Node Location field is present and shall be set to zero otherwise. The Node Location field shall be present only if this field is set to one.

The Node Location field is an unsigned integer and shall be set to one of the non-reserved values shown in Table 7-a6. When the Node Location Present field is zero, this field shall be ignored. Absolute signals that the value in the Node Location field is absolute georeferenced position, and the value Relative signals that the position is referenced to [need reference point].

Table 7-6a Node Location Type

|  |  |
| --- | --- |
| Value | Description |
| 0 | Absolute Georeferenced Position |
| 1  | Relative position with reference to [reference point] |
| 2-3 | Reserved |

The Node Location Format field specifies the length and format of the Node Location field when present. This field shall set to one to indicate that the 10-octet format is used and shall be set to zero to indicate that the 12-octet format is used. When the Node Location Present field is zero, this field shall be ignored.

The CFO Present field shall be set to one when the Clock Frequency Offset field is present and shall be se to zero otherwise.

The Dst Ranging Slot Index Present field shall be set to one when the Dst Ranging Slot Index List is present and shall be set to zero otherwise.

The Reply Time Present field shall be set to one when the Reply Time List is present and shall be set to zero otherwise. If the Reply Time Present field is zero, the Reply Time Format field is ignored.

The Reply Time Format field indicates the length of each entry in the Reply Time List. This field shall be set to zero to indicate 4-octet length and shall be set to one to indicate 8-octet length.

The ToF Present field shall be set to one when the ToF list is present and shall be set to zero otherwise. If the ToF Present field is zero, the ToF Format field is ignored.

The ToF Format field indicates the length of each entry in the ToF List. This field shall be set to zero to indicate 2-octet length and shall be set to one to indicate 4-octet length.

The Ranging Block Index field specifies the index of the current ranging block (see 6.9.7.3.3).

Ranging Round Index field specifies the ranging round index for the ranging block (see 6.9.7.3.3).

The TX Timestamp is an unsigned integer in Ranging Counter Time Unit (RCTU) as specified in 6.9.1.4. This field value shall be set to the transmission time of the packet containing this IE.

The Node Location field, when present, contains an absolute or relative position as indicated by the Node Location Type field. The field shall be encoded as indicated below the Node Location Format field as indicated in table 7-7a.

|  |  |
| --- | --- |
| Length, octets | Format Description |
| 12 | WGS-84 coordinate system (x:33 bits, y:33 bits, z:30 bits) |
| 10 | A relative coordinate system (x: 28 bits, y: 28 bits, z:24 bits) |

The Clock Frequency Offset field, when present, contains the observed CFO for the sending device (e.g., a destination node) relative to the source node which sends the first RFRAME in a round.

The Dst Ranging Slot Index List contains the ranging slot assigned to each destination node in the Dst Node ID List of the DL-TDOA Ranging Info and Node ID IE included in the ranging frame (see 7.4.2.22). Each list element is an unsigned integer. Each element is 1 octet in length. The list elements correspond to the Node ID values in the order. The number of elements in the list shall be the same as the number of elements in the DL-TDOA Ranging Info and Node ID IE. If a DL-TDOA Ranging Info and Node ID IE included in the ranging frame, or the number of elements does not match, this field shall be ignored. Ranging slots are defined in 6.9.7.2.

Reply Time List, when present, contains a reply time value for each destination node in the Dst Node ID List of the DL-TDOA Ranging Info and Node ID IE included in the ranging frame (see 7.4.2.22). Each list element is an unsigned integer and shall be set to the time to generate the response in a ranging exchange for the associated node ID. Each element shall be of length 4 or 8 octets, as indicated in Reply Time Format field. This field shall be valid when contained in a RSP or FINAL message and shall be ignored otherwise. The list elements correspond to the Node ID values in the order. The number of elements in the list shall be the same as the number of elements in the DL-TDOA Ranging Info and Node ID IE. If a DL-TDOA Ranging Info and Node ID IE included in the ranging frame, or the number of elements does not match, this field shall be ignored.

The ToF List field contains a list of ToF values between one or more initiator-responder pairs. Each element is an unsigned integer of length 2 or 4 octets as indicated in the ToF Format field. The list elements correspond to the Dst Node ID List of the DL-TDOA Ranging Info and Node ID IE included in the ranging frame (see 7.4.2.22). Each value shall be set for a corresponding destination node. The number of elements in the list shall be the same as the number of elements in the DL-TDOA Ranging Info and Node ID IE. If a DL-TDOA Ranging Info and Node ID IE included in the ranging frame, or the number of elements does not match, this field shall be ignored.

# MAC Services

# Security

Minimal changes to the MAC security clause are anticipated based on the scope and project objectives.

# General PHY requirements

Project objectives likely to touch in this clause include:

* Additional channels and operating frequencies
* Interference mitigation techniques to support higher density and higher traffic use cases
* Other coexistence improvement
* Hybrid operation with narrowband signaling to assist UWB
* Sensing capabilities to support presence detection and environment mapping

# PHY services

Additional PHY PIB attributes will likely be added with PHY enhancements.

# O-QPSK PHY

Project objectives that might add features to this PHY clause:

* Hybrid operation with narrowband signaling to assist UWB

# HRP UWB PHY

# LRP UWB PHY

# SUN FSK PHY

# SUN OFDM PHY

# SUN O-QPSK

Project objectives that might add features to this PHY clause:

* Hybrid operation with narrowband signaling to assist UWB

# Annexes

We must not forget to add PICS for this amendment!