**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | IEEE 802.15.4z comment resolutions on multi-node ranging procedure and IEs |
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| Re: |  |
| Abstract | This contribution proposes updated text for the baseline draft P802.15.4z-D1 |
| Purpose | Provision of the text to facilitate its incorporation into the draft text of the IEEE 802.15.4z standard currently under development in TG4z. |
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| Release |  |
| Patent Policy | The contributor is familiar with the IEEE-SA Patent Policy and Procedures:<http://standards.ieee.org/guides/bylaws/sect6-7.html#6> and<http://standards.ieee.org/guides/opman/sect6.html#6.3>.Further information is located at <http://standards.ieee.org/board/pat/pat-material.html> and<http://standards.ieee.org/board/pat>. |

* **Page 12-18 (Figure 4, 6, 9, and 10)**

i-0669, i-0670, i-0671, i-0672, i-0673, i-0676, i-0677, i-0679, i-0683, i-0684, i-0685, i-0686, i-0687, i-0688, i-0689, i-0691, i-0692, i-0693, i-0694, i-0726, i-0727, i-0730, i-0731, i-0732, i-0733, i-0736, i-0737, i-0739, i-0744, i-0745, i-0746, i-0747, i-0749, i-1306, i-1307, i-1308, i-1309, i-1312, i-1313, i-1315, i-1319, i-1320, i-1321, i-1322, i-1323, i-1324, i-1325, i-1327, i-1328, i-1329, i-1330, i-1363, i-1364, i-1367, i-1368, i-1369, i-1370, i-1373, i-1374, i-1376, i-1381, i-1382, i-1383, i-1384, i-1386, i-1843, i-1848, i-1998, i-2000, i-2261, i-2326, i-2350, i-2355, i-2425, i-2471, i-2489, i-2490, i-2491, i-2557, i-2568, i-2582, i-2585, i-2588, i-2589, i-2590, i-2591, i-2592, i-2682, i-2683, i-2684, i-2685, i-2687, i-2780, i-2781, i-2782, i-2783, i-2784, i-2785, i-2786, i-2791, i-2792, i-2793, i-2794, i-2821, i-2822, i-2823, i-2824, i-2827, i-2828

*Replace the following sub-clauses*

6.9.7.3 Ranging procedure for SS-TWR with deferred reply time result

For a SS-TWR with a deferred reply time result, the ranging exchange is initiated by the next higher layer invoking the MCPS-DATA.request primitive to send a ranging frame including the Ranging Request Measurement and Control IE (RRMC IE), as described in 7.4.4.X1, requesting the ranging reply time information. The Ranging Control Information field is set according to Table TX.

The replying ranging frame completes the round trip measurement and the MCPS-DATA.confirm primitive gives the initiating side timestamps that define the round trip time. At the responding side, the MCPS-DATA.indication primitive supplies the responding side timestamps that define the reply time for the round trip measurement. This reply time is communicated to the initiating side in the Ranging Measurement Information IE (RMI IE), as described in 7.4.4.X2, carried by a subsequent message. Figure 4 shows the message sequence chart for this exchange, where RRMC(0) IE indicates the carried RRMC IE with the Ranging Control Information field value 0. At the point labelled (R) the initiating end has sufficient information to calculate the TOF between the two devices according to one of the formulas given in 6.9.5.2.



**Figure 4—Message sequence chart for SS-TWR with deferred reply time result**

* + - 1. Ranging procedure for SS-TWR with embedded reply time result

For an SS-TWR with an embedded reply time result, the ranging exchange is initiated by a ranging frame including the RRMC IE (as described in 7.4.4.X1) requesting the ranging reply time information, and the responding device completes the round trip measurement by sending a reply frame with embedded RRTI IE. The Ranging Control Information field of the RRMC IE is set according to Table TX. However, even though a device is capable of generating a Ranging Reply Time Instantaneous IE, it may take some time to calculate the timestamp of the received ranging message and prepare the RRTI IE value. While in some cases this time may be known a priori by an out-of-band means, the Ranging Preferred Reply Time IE (RPRT IE) provides a mechanism for a capable device to indicate how long it needs to prepare the frame with the RRTI IE. When this time is known, the ranging initiating device can expect the response message after the RPRT IE specified time. Figure 6 shows the message sequence chart for this exchange, where RRMC(0) IE indicates the carried RRMC IE with the Ranging Control Information field value 0. The communication of the RPRT IE, shown in the dashed box, may happen at any convenient time before the ranging exchange is initiated, or may be out-of-band. At the point labelled (R) the initiating end has sufficient information to calculate the range between the two devices according to one of the formulas given in 6.9.5.2.



**Figure 6—Message sequence chart for SS-TWR with embedded reply time**

* + - 1. Ranging procedure for DS-TWR with deferred timestamp information

DS-TWR essentially involves completing SS-TWR exchanges initiated at either end and combining the results. The DS-TWR exchange is initiated by the next higher layer sending a ranging data frame carrying the RRMC with the Ranging Control Information field set according to Table TX. This frame and its acknowledgement define the first round trip measurement, while the RRMC IE delivery in the MCPS-DATA.indication primitive tells the next higher layer to initiate the second round trip measurement of the exchange by the sending of a Data frame in the other direction. This Data frame includes the RRMC IE with the Ranging Control Information field set according to Table TX to indicate this is the continuation of the exchange. The fields of Reply Time Request and Round-trip Measurement Request have value one to request the reply time and the first round trip measurement. The acknowledgement to this message completes the second round trip measurement. A subsequent message from the initiator conveys the first round trip time measurement and the reply time for the second round trip time measurement in an RMI IE (7.4.4.X2). Figure 9 shows the message sequence chart for this exchange. At the point labelled (R) the responding end has sufficient information to calculate the range between the two devices according to the formula given in 6.9.5.3. The subsequent reporting of the ranging result to the initiating end, in the RMI IE, depends on the value of the TOF Request field in the initiating RRMC IE (as described in 7.4.4.X1).

 

**Figure 9—Message sequence chart for DS-TWR with deferred reply time result**

* + - 1. Ranging procedure for DS-TWR with embedded timestamp information

To embed the timestamp information in the RFRAME(s), the three message DS-TWR described in Figure 3 requires that the initiating end is able to embed the reply time as part of completing the second round trip measurement. With reference to the message sequence chart of Figure 10, the DS-TWR is initiated by an RFRAME carrying an RRMC IE (7.4.4.X1) with the Ranging Control Information field set according to Table TX. In this instance, the TOF Request field of initiating RRMC IE with value zero indicates that the initiating end does not require a report of the ranging result. The responding side completes the first round trip measurement and initiates the second measurement with an RFRAME carrying an RRMC IE with the Ranging Control Information field set according to Table TX to indicate this is the continuation of the exchange. The Reply Time Request and Round-trip Measurement Request fields of this RRMC IE are set to be one, indicating the requests of the first round trip measurement and the reply time for the second round trip measurement. The original initiator completes the exchange by sending a final RFRAME carrying the first round trip time measurement in an RMI IE (7.4.4.X2) and the reply time of this second round trip measurement in an RRTI IE.

 

**Figure 10—Message sequence chart for DS-TWR with three messages**

At the point labelled (R) the responding end has sufficient information to calculate the range between the two devices according to the formula given in 6.9.5.3. Where the initiator of the ranging exchange wants the result, this may be requested in the TOF Request field of initiating RRMC IE, to ask the responding end to convey the result in the RMI IE in a subsequent message at the end of the exchange as shown in Figure 9.

* **Page 30 Line 15 (Figure 22)**

i-0839, i-0840, i-1476, i-1477, i-2691, i-2692

*Replace line 4-16 on page 30, and line 1-9 on page 31 by the following texts and figure*

6.9.8.4 Ranging Procedure for One-to-Many SS-TWR

For one-to-many SS-TWR, the ranging exchange is started by the initiator, where the Ranging Request Measurement and Control IE (RRMC IE) as described in 7.4.4.X1 is embedded in the ranging initiation message broadcast to multiple responders. The Ranging Control Information field of the RRMC IE shall be set to zero according to the Table TX, which is indicated by the RRMC(0) IE in the Figure 22. The Reply Time Request field of the RRMC IE is set to be one, which requests the reply time of the responding ERDEV. At the responder side, the MCPS-DATA.indication delivering RRMC(0) IE tells its next higher layer to initiate the ranging response message. With the RequestRrti setting to insert the RRTI IE (7.4.4.32), the MCPS-DATA.request at the responder also conveys the RRMC IE to control ranging procedure and send request(s). The Ranging Control Information field of the RRMC IE in the response RFRAME shall be set to one according to the Table TX, which is indicated by the RRMC(1) IE in the Figure 22. The response RFRAME is sent to the initiator, where its destination address in the MAC header shall be the initiator’s address.

For the multi-node ranging based on scheduling (as described in 6.9.8.1), responders send the ranging response messages in their assigned time slots, while for the multi-node ranging based on contention, responders contend in the time slots of the ranging response phase. After acquisition of ranging response messages, the initiator has the full information to calculate the TOF to different responders.



**Figure 22-Message sequence chart for one-to-many SS-TWR**

Figure 22 illustrates the message sequence chart for one-to-many SS-TWR between one initiator and N responders, i.e., Responder-1, Responder-2, …, Responder-N, where ranging response messages from different responders are scheduled for transmission in a sequential order. At the point labeled (R), the initiator has the sufficient information to calculate the ranging result for the corresponding pair. Different responders can have different requests of ranging results. In Figure 22, for example, Responder-N requests the TX-to-RX round-trip time, i.e., the Roundtrip Time Request field value of the RRMC IE in the ranging response message is set to be one, while Responder-1 directly request the ranging result, i.e., the TOF Request field value of the RRMC IE in the ranging response message is set to be one. The final data message broadcast by the initiator conveying multiple RMI IEs to fulfill measurement report, where the destinations of the measurement reports can be distinguished by the Address field of the RMI IE. Note that if multiple responders request the same set of information, e.g., TOF, measurement report can be fulfilled by one RMI IE in the final data message (see 7.4.4.X2).

* **Page 32 Line 18 (Figure 24), Page 33 Line 4 (Figure 25), Page 34 Line 2 (Figure 26), Page 35 Line 2 (Figure 27)**

i-0851, i-0852, i-1488, i-1489, i-2699, i-2700, i-0854, i-0855, i-1491, i-1492, i-2701, i-2702, i-0856, i-0857, i-1493, i-1494, i-2703, i-2704

*Replace sub-clause 6.9.8.5 by following texts and figures*

6.9.8.5 Ranging Procedure for One-to-Many DS-TWR

For one-to-many DS-TWR, the three-way ranging method can be considered in order to reduce the number of transmissions. The ranging exchange is started by the initiator, where the RRMC IE (7.4.4.X1) is embedded in the ranging initiation message, and sent to multiple responders. The Ranging Control Information field value in the RRMC IE shall be two according to the Table TX, which is indicated by RRMC(2) IE in Figure 24.

Once the responder receives the ranging initiation message, it will form the ranging response message, containing the RRMC IE to initialize the second roundtrip measurement. The Ranging Control Information field value in the RRMC IE shall be three according to the Table TX, which is indicated by RRMC(3) IE in Figure 24. To request the first roundtrip time and the reply time of the final RFRAME from the initiator, the fields of Reply Time Request and Roundtrip Time Request in the RRMC IE of the ranging response message are set to be one. Similar to one-to-many SS-TWR in 6.9.8.4, ranging response messages of different responders can be scheduled, or contend for the time slots in the ranging response phase. Then, the initiator forms the final RFRAME, which incorporates the RMI IE (7.4.4.X2) reporting roundtrip times, and the RRTI IE (7.4.4.32) reporting reply times to different responders. The next higher layer of initiator sets RequestRrtiTx and RrtiNodeList (8.3.1) to request the MAC sublayer create and insert RRTI IE in the final RFRAME, which conveys the reply times to different responders.

Figure 24 illustrates the message sequence chart for one-to-many DS-TWR between one initiator and N responders, i.e., Responder-1, Responder-2, … Responder-N, where ranging response messages from different responders are scheduled for transmission in a sequential order. At the point labeled (R), responders have sufficient information to calculate the ranging result. If the fields of Reply Time Request, Round-trip Measurement Request, and TOF Request in the RRMC IE in the ranging initiation message are set to be zero, the responder will not send back the ranging result or relevant time measurement to the initiator.



**Figure 24-Message sequence chart for one-to-many DS-TWR: no request of ranging result from the initiator**

Figure 25 illustrates the message sequence chart for one-to-many DS-TWR when the Deferred Mode field value is set to be one in the ARC IE (7.4.4.38) of the RCM. Therefore, the initiator sends the 1st roundtrip time and 2nd reply time to the responders via the RMI IE (7.4.4.X2) in a deferred data frame, where the Deferred Mode field of the RMI IE is set to be one.



**Figure 25-Message sequence chart for one-to-many DS-TWR: no request of ranging result from the initiator with deferred mode**

In Figure 26, the initiator requests the 1st reply time and 2nd roundtrip time at the responder by setting the Reply Time Request and Roundtrip Time Request fields to be one in the RRMC IE of the ranging initiation message. Upon reception of the RRMC(2) IE by MCPS-DATA.indication, the next higher layer of the responder initializes the second roundtrip measurement via the MCPS-DATA.request with RRMC(3) IE. Meanwhile, the RequestRrtiTx in the MCPS-DATA.request is set to insert the RRTI IE in the response RFRAME. To send the final RFRAME, the next high layer of the initiator sets the RequestRrti and RrtiNodeList of MCPS-DATA.request to insert an RRTI IE, and also conveys the RMI IE reporting the first roundtrip time measurements to the MAC layer. Since initiator requests the second roundtrip time from the responder, a separate data frame after ranging transmissions is used by each responder to send this information back. Therefore, initiator is also able to calculate the TOF after the measurement report phase.



**Figure 26-Message sequence chart for one-to-many DS-TWR: request of 1st reply time and 2nd roundtrip time from the initiator**

In Figure 27, the initiator requests the ranging result, i.e., TOF, by setting the field value of the TOF Request to be one in the RRMC IE of the ranging initiation message. Therefore, the responders respectively send back the ranging result (RMI IE) in separate data frames based on either time-scheduling or contention.



**Figure 27-Message sequence chart for one-to-many DS-TWR: request of ranging result from the initiator**

* **Page 36 Line 5 (Figure 28)**

i-0860, i-0861, i-0862, i-0863, i-0864, i-1497, i-1498, i-1499, i-1500, i-1501, i-2705, i-2706, i-2707, i-2708, i-2709

*Replace sub-clause 6.9.8.6 by following texts and figures*

6.9.8.6 Ranging Procedure for Many-to-Many SS-TWR

For the scenario of many initiators-to-many responders (M2M), the controller sends the RCM with the ranging configuration to multiple initiators and responders. In the scenario of one-to-many ranging, there is only one ranging initiation message in the Ranging Initiation Phase (RIP) from a single initiator, while multiple initiators can send ranging initiation messages in the RIP through either scheduling or contention in the M2M ranging. The ranging initiation message contains the RRMC IE (7.4.4.X1), where the Ranging Control Information field value is set to be zero, and the Reply Time Request field value is set to be one. After collecting ranging initiation messages from different initiators, the next higher layer of the responders initiates the response RFRAME via the MCPS-DATA.request, where RequestRrtiTx and RrtiNodeList are set to insert an RRTI IE (7.4.4.32). The response RFRAMEs are sent to initiators in the ranging response phase based on the time-scheduling or contention determined via the ranging configuration.



**Figure 28-Message sequence chart for M2M SS-TWR**

Figure 28 illustrates the message sequence chart for M2M SS-TWR between M initiators and N responders, i.e., Initiator-1, Initiator-2, …, Initiator-M, and Responder-1, Responder-2, …, Responder-N, where transmissions of both ranging initiation and ranging response messages are scheduled in a sequential order. Contention-based transmissions for both ranging initiation phase and ranging response phase can also be performed. At the point labeled (R), the initiator has the sufficient information to calculate the ranging result for the corresponding pair. It is the responsibility of the higher layers to ensure that each required response is supplied in good time to allow the MAC to transmit it at the specified time, and similarly to have enabled the receiver in good time to receive any message it needs to receive. The controller can ascertain this using the ARC IE and RDM IE. In Figure 28, responders do not request the ranging results. However, similar to Figure 22, responders can also request the ranging results or relevant time measurement from initiators to calculate the ranging results, which need additional data frames transmitted from initiators.

* **Page 37 Line 2 (Figure 29)**

i-0865, i-0866, i-0867, i-0868, i-0869, i-1502, i-1503, i-1504, i-1505, i-1506, i-2710, i-2711, i-2712, i-2713, i-2714

*Replace sub-clause 6.9.8.7 by following texts and figures*

For the M2M DS-TWR, based on the ranging configuration, multiple initiators will contend or be time-scheduled for the time slots in the ranging initiation phase to send the ranging initiation messages, which convey RRMC IEs. The Ranging Control Information field value in the RRMC IE shall be two, which is indicated by the RRMC(2) IE in Figure 29.

After the ranging initiation phase, the responder forms the ranging response message, containing the RRMC IE to initialize the second roundtrip measurement. The Ranging Control Information field value shall be three, which is indicated by the RRMC(3) IE in Figure 29. The fields of Reply Time Request and Roundtrip Time Request in the RRMC IE are set to be one. Ranging response messages can also be transmitted through either time-scheduling or contention determined via ranging configuration. Then, the initiator forms the final RFRAME, which includes the RRTI IE (7.4.4.32) to report reply time, and RMI IE (7.4.4.X2) to report roundtrip time.



**Figure 29-Message sequence chart for M2M DS-TWR**

Figure 29 illustrates the message sequence chart for M2M DS-TWR between M initiators and N responders, where both ranging initiation messages and ranging response messages are scheduled for transmission in a sequential order. At the point labeled (R), responders have sufficient information to calculate the ranging results. If the fields of Reply Time Request, Round-trip Measurement Request, and TOF Request in the RRMC IE in the ranging initiation message are set to be zero, the responder will not send back the ranging result or relevant time measurement to the initiator.

* **Page 38 Line 3 (Figure 30)**

i-0470, i-0870, i-0871, i-0872, i-0873, i-0874, i-0875, i-0876, i-0877, i-0878, i-0879, i-0880, i-0881, i-0882, i-0883, i-0884, i-0886, i-0887, i-0888, i-1507, i-1508, i-1509, i-1510, i-1511, i-1512, i-1513, i-1514, i-1515, i-1516, i-1517, i-1518, i-1519, i-1520, i-1521, i-1523, i-1524, i-1525, i-2357, i-2715, i-2716, i-2717, i-2718, i-2719, i-2720, i-2721, i-2722, i-2723, i-2724, i-2725, i-2726, i-2727, i-2728, i-2729, i-2730, i-2731

*Replace Figure 30 on page 38 by the following one:*



**Figure 30-Message sequence chart for SP3 one-to-many SS-TWR**

*Replace the sentence at line 9-10 on page 38:*

For example, SRRR(R1|I) indicates that the responder-1 requests AOA and the roundtrip time at the initiator side, where the fields of RAOA and RRTM are set to be one in the SRRR IE (7.4.4.55).

*Add the following paragraph before the line 18 on page 38:*

Since multi-node SP3 ranging is based on the scheduling determined by the next higher layer of the controller, each time slot is allocated to a particular RDEV to use. With a fixed ranging procedure indicated by the Ranging Round Usage field of the ARC IE (7.4.4.38), the RDEV knows when the SP3 ranging phase will be completed, and can configure the packet format properly for the measurement report phase via the MLME-STS.request (8.2.26.1).

*Replace line 18-19 on page 38, and line 1-2 on page 39 by the following paragraph:*

After the SP3 ranging phase, ERDEVs are scheduled in the measurement report phase to send the requested information. For example, initiator conveys the AOA and roundtrip time to the Responder-1 via the RMI IE (7.4.4.X2). Responder-1 and Responder-N separately embed the requested reply time in the RMI IE to the initiators.

* **Page 39 Line 7 (Figure 31)**

i-0890, i-0891, i-0892, i-0893, i-0894, i-0895, i-0896, i-0897, i-0898, i-0899, i-0900, i-0901, i-0902, i-0903, i-0904, i-0905, i-0906, i-0907, i-1527, i-1528, i-1529, i-1530, i-1531, i-1532, i-1533, i-1534, i-1535, i-1536, i-1537, i-1538, i-1539, i-1540, i-1541, i-1542, i-1543, i-1544, i-2732, i-2733, i-2734, i-2735, i-2736, i-2737, i-2738, i-2739, i-2740, i-2741, i-2742, i-2743, i-2744, i-2745, i-2746, i-2747, i-2748, i-2749



**Figure 31-Message sequence chart for SP3 one-to-many DS-TWR**

Figure 31 illustrates an example of one-to-many DS-TWR with SP3 ranging, which is similar to Figure 30. The main difference is that there is a second SP3 RFRAME in the ranging phase from the initiator. At the beginning of the ranging round, the requests are broadcast from the controller to controlees. For example, initiator requests the AOA report from both Responder-1 and Responder-N by setting the RAOA field of the SRRR IE to be one. After the SP3 ranging phase, ERDEVs are scheduled to send their data reports with the requested information via the RMI IEs (7.4.4.X2). For example, the initiator sends its reply time and round-trip time to Responder-1, while Responder-1 and Responder-N send the AOA report back to the initiator, respectively. The controller assumes the role of a responder in this example. The controller may alternatively have been the initiator.

* **Page 53 Line 9 (7.4.4) ~ Page 72 Line 22**

i-0335, i-0342, i-0343, i-0344, i-0345, i-0346, i-0347, i-0348, i-0349, i-0488, i-0491, i-0497, i-0501, i-0502, i-0503, i-0564, i-0566, i-0964, i-0973, i-0975, i-1062, i-1096, i-1097, i-1110, i-1116, i-1601, i-1610, i-1612, i-1699, i-1733, i-1734, i-1747, i-1753, i-1978, i-2020, i-2028, i-2165, i-2191, i-2246, i-2453, i-2050, i-2519, i-2627, i-2638, i-2797

*Delete the sub-clause 7.4.4.32, 7.4.4.33, 7.4.4.34, 7.4.4.35, 7.4.4.36, 7.4.4.37, 7.4.4.46, 7.4.4.47, 7.4.4.48, 7.4.4.49, 7.4.4.50, 7.4.4.53, 7.4.4.54 in Section 7.4.4*

*Add the row of RRMC IE in Table 7-16 on page 54. Delete following IEs in this Table: 7.4.4.32, 7.4.4.33, 7.4.4.34, 7.4.4.35, 7.4.4.36, 7.4.4.37, 7.4.4.46, 7.4.4.47, 7.4.4.48, 7.4.4.49, 7.4.4.50, 7.4.4.53, 7.4.4.54.*

| Sub-ID Value | Name | Enhanced Beacon | Enhanced ACK | Data | Multipurpose | MAC command | Format sub-clause | Use description | Used by | Created by |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| <ANA> | Ranging Request Measurement and Control IE |  | X | X |  |  | 7.4.4.X1 | 6.9.7.3, 6.9.7.4, 6.9.7.6, 6.9.7.7, 6.9.8.4, 6.9.8.5, 6.9.8.6, 6.9.8.7 | UL | UL |

*Replace the following sub-clause 7.4.4.32 by following texts and Figures, increase the numbering of figures after Figure 42 here*

7.4.4.32 Ranging Reply Time Instantaneous IE

The Ranging Reply Time Instantaneous IE (RRTI IE) conveys the reply time(s) of the response frame containing the RRTI IE with respect to the frame(s) containing the RRMC IE (7.4.4.X1) with the Reply Time Request field being one that solicited this response. The content field of the RRTI IE shall be formatted as shown in Figure 41.

|  |  |  |
| --- | --- | --- |
| **Bit: 0** | **1-7** | **Variable** |
| Address Present | RRTI Table Length | RRTI Table |

**Figure 41—Ranging Reply Time Instantaneous IE content field format**

Each row element of the RRTI Table shall be formatted as shown in Figure 42.

|  |  |
| --- | --- |
| **Octets: 4** | **0/2/8** |
| RX-to-Tx –Reply-Time | Address |

**Figure 42—RRTI Table row element format**

The Address Present field in the Figure 4 is used to indicate the presence of the Address field in each row element of the RRTI Table as illustrated in Figure 42: if the Address Present field value is one, the Address field of each row element is present, otherwise it is not.

The RRTI Table Length field denotes the number of row elements in the RRTI Table. The RRTI Table stacks the reply times to different RDEVs.

The RX-to-TX-Reply-Time field is the time difference between the receive time of most recently received RFRAME, conveying an RRMC IE (7.4.4.X1) with the Reply Time Request field being one, from a particular source and the transmit time of the response RFRAME containing the RRTI IE. The reference for these time values is the RMARKER. The units of time are specified in 6.9.1.1. The general procedures for using the RRTI IE are specified in 6.9.7.

The RRTI IE can be used to report reply times in the RFRAME in response to multiple RDEVs, which request the reply time via the RRMC IE with the Reply Time Request field being one. The Address field in Figure 42 can be used to specify the identity of the RDEV(s). For the ranging between one initiator and one responder, the Address field shall be omitted since it is specified by the destination address field of the MAC header. For multi-node ranging, the Address field may not be present if reply times to different RDEVs are stacked in a pre-negotiated order.

The use of the RRTI IE is only appropriate where the sending device is able to accurately pre-determine the transmission time of the frame containing the IE, complete the calculations of time duration between the upcoming transmission and the frame being responded to, and insert the RRTI IE into the transmitted frame.

*Add the following sub-clause in Section 7.4.4*

* + - 1. Format of Nested IE
			2. TSCH Synchronization IE
			3. TSCH Slotframe and Link IE
			4. TSCH Timeslot IE
			5. Hopping timing IE
			6. Enhanced Beacon Filter IE
			7. MAC Metrics IE
			8. All MAC Metrics IE
			9. Coexistence Specification IE
			10. SUN Device Capabilities IE
			11. SUN FSK Generic PHY IE
			12. Mode Switch Parameter IE
			13. PHY Parameter Change IE
			14. O-QPSK PHY Mode IE
			15. PCA Allocation IE
			16. LECIM DSSS Operating Mode IE
			17. LECIM FSK Operating Mode IE
			18. TVWS PHY Operating Mode Description IE
			19. TVWS Device Capabilities IE
			20. TVWS Device Category IE
			21. TVWS Device Identification IE
			22. TVWS Device Location IE
			23. TVWS Channel Information Query IE
			24. TVWS Channel Information Source IE
			25. CTM IE
			26. Timestamp IE
			27. Timestamp Difference IE
			28. TMCTP Specification IE
			29. RCC PHY Operating Mode IE
			30. Vendor Specific Nested IE
			31. Channel hopping IE

***Insert the following new sub-clauses (7.4.4.32 to 7.4.4.66) after 7.4.4.31:***

7.4.4.X1 Ranging Request Measurement and Control IE

The Ranging Request Measurement and Control IE (RRMC IE) can be used to send ranging requests to different devices, and control ranging procedures. Figure FX illustrates the content field format for the RRMC IE, where its row element is shown in Figure FY.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Bit: 0** | **1** | **2** | **3** | **4** | **5-6** | **7** | **Octets: 0/1** | **0/Variable** |
| Reply Time Request | Round-trip Measurement Request | TOF Request | AOA Azimuth Request | AOA Elevation Request | Ranging Control Information | Reserved | RRMC Table Length | RRMC Table |

**Figure FX—Ranging Request Measurement and Control IE content field format**

|  |
| --- |
| **Octets : 0/2/8** |
| Address |

**Figure FY—RRMC Table row element format**

As shown in the Figure FX, the length of the RRMC IE content field determines the presence of the RRMC Table Length and RRMC Table fields: if its length is one octet, the RRMC Table Length and RRCM Table are not present; if the length is more than one octet, the RRMC Table Length and RRCM Table are present. RRMC Table length equals the number of row elements in the RRMC Table, which is the same as the number of devices receiving requests.

If the RRMC IE is conveyed in a unicast frame, the destination address has been specified by the MHR. Therefore, the RRMC Table Length and RRMC Table fields are not needed. When the RRMC IE is conveyed in a broadcast message, the device sending this IE intends to request all devices receiving it, then RRMC Table Length and RRMC Table fields are not needed either. However, if the requesting device expects responses from a specified set of devices, RRMC Table Length and RRMC Table fields are present to list addresses of those devices.

Reply Time Request (RTR) field denotes whether the reply time of ERDEV sending response to the message with this RRMC IE is requested: if RTR field value is one, the reply time is requested, otherwise it is not.

Round-trip Measurement Request (RMR) field indicates whether the round-trip measurement of ERDEV upon receiving the message with this RRMC IE is requested: if RMR field value is one, the round-trip measurement is requested, otherwise it is not.

TOF Request (TOFR) field denotes whether the ranging result, i.e., time-of-flight, is requested: if TOFR field value is one, the ranging result is requested, otherwise it is not. For the SS-TWR, the initiator is able to calculate the TOF after the ranging transmissions as shown in the Figure 22. The responder can request the TOF by setting the TOFR field to be one in the RRMC IE of the ranging response message. For the DS-TWR, the responder is able to calculate the TOF after the ranging transmissions as shown in the Figure 24-27. The initiator can request the TOF by setting the TOFR field to be one in the RRMC IE of the ranging initiation message.

Fields of AOA Azimuth Request (AAR) and AOA Elevation Request (AER) denote whether azimuth AOA, elevation AOA are requested or not: if the field value is one, the corresponding information is requested, otherwise it is not.

With the content field format as shown in the Figure FX, if a device requests different sets of information from different destinations, multiple RRMC IEs can be used in a broadcast message, where different RRMC IEs are used to exchange different sets of requests.

In the Figure FY, the address type, i.e., 2-octet or 8-octet address, can be specified by the DstAddrMode of MCPS-DATA.request.

The value of the Ranging Control Information field is illustrated in the following Table TX, which is used to indicate the usage of the RFRAME.

**Table TX—Values of the Ranging Control Information field in the RRMC IE**

|  |  |
| --- | --- |
| **Control Info value** | **Meaning** |
| 0 | This RFRAME is the ranging initiation message for the SS-TWR |
| 1 | This RFRAME is responding to the ranging initiation message of SS-TWR |
| 2 | This RFRAME is the ranging initiation message for the DS-TWR. |
| 3 | This RFRAME transmitted from ranging responder is continuing the DS-TWR, and initiating the second roundtrip measurement. |

*Add the row of RMI IE in Table 7-16 on page 54*

| Sub-ID Value | Name | Enhanced Beacon | Enhanced ACK | Data | Multipurpose | MAC command | Format sub-clause | Use description | Used by | Created by |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| <ANA> | Ranging Measurement Information IE |  |  | X |  |  | 7.4.4.X2 | 6.9.7.3, 6.9.7.4, 6.9.7.6, 6.9.7.7, 6.9.8.4, 6.9.8.5, 6.9.8.7 6.9.8.8.1, 6.9.8.8.2 | UL | UL |

*Add the following sub-clause in Section 7.4.4*

7.4.4.X2 Ranging Measurement Information IE

The Ranging Measurement Info IE (RMI IE) can be used to send ranging-related measurements to one or more devices. Figure FX illustrates the content field format for the RMI IE, where its row element is shown in the Figure FY.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Bits : 0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **Octets: 1** | **Variable** |
| Address Present | Reply Time Present | Round-trip Time Present  | TOF Present | AOA Azimuth Preset | AOA Elevation Present | Deferred Mode | Reserved | RMI Table Length | RMI Table |

**Figure FX—Ranging Measurement Information IE content field format**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Octets: 0/4** | **0/4** | **0/4** | **0/2** | **0/2** | **0/2/8** |
| RX-to-Tx Reply Time | TX-to-RX Round-trip Time | TOF | AOA Azimuth | AOA Elevation | Address |

**Figure FY—RMI Table row element format**

The first bit of the control octet, i.e., Address Present field, in the Figure FX is used to indicate whether the Address field is present in each row element of the RMI Table as shown in the Figure FY: if the Address Present field value is one, the Address field of RMI Table row element is present, otherwise it is not. For multi-node ranging, an ERDEV can report measurements via an RMI IE, which lists measurement reports to different destinations in the RMI Table. The Address field of the RMI Table row element is used to distinguish ERDEV that requested certain information. For the unicast ranging, the Address field shall be omitted.

Bit 1-5 are used to denote whether certain information is present in the row element of the RMI Table: if the field value is one, the corresponding information is presented in each row element of the RMI Table, otherwise it is not.

Bit 6 of the control octet is used to indicate whether this RMI IE is conveyed in the RFRAME, or in a deferred data message: if its value is zero, this RMI IE is embedded in the RFRAME, otherwise it is conveyed in a deferred data message.

In the Figure FY, the RX-to-TX Reply Time field is the time difference between the receive time of most recently received RFRAME with the RRMC IE (7.4.4.X1) from a particular source to request reply time, and the transmit time of the response RFRAME. If the Deferred Mode field value is zero, the RMI IE reporting the reply time is embedded in the responding RFRAME. If the Deferred Mode filed value is one, the RMI IE is embedded in a deferred data message, while the conveyed reply time is associated with the most recently transmitted RFRAME before this data message. The TX-to-RX Round-trip Time field is the time difference between the transmit time of the RFRAME initiating a roundtrip measurement and the receive time of the response RFRAME that completes a roundtrip measurement. The TOF field contains the time-of-flight estimate.

The reference for these time values, i.e., reply time, roundtrip time, and TOF, is the RMARKER. They are all unsigned integer time values, whose time units are specified in 6.9.1.1. The general procedures for using the RMI IE are specified in 6.9.8.

The AOA Azimuth field, if present, reports the estimated angle of arrival in the azimuth domain of the received RFRAME with the RRMC IE to request azimuth AOA. The AOA Elevation field, if present, reports the estimated angle of arrival in the elevation domain of the received RFRAME with the RRMC IE to request elevation AOA. These fields to report AOA contain unsigned integers. The unit of AOA Azimuth is $2^{-16}$ multiplying 360 degree, while the unit of AOA Elevation is $2^{-16}$ multiplying 180 degree.

If Address field is present in each row element of the RMI Table, the address type, i.e., 2-octet or 8-octet address, shall be specified by the DstAddrMode of MCPS-DATA.request.

* **Page 73, 7.4.4.55, Line 27**

i-0505, i-1115, i-1752, i-2601

*Replace the line 27 by the following sentence.*

If Address field is present, i.e., Requestor Address and/or Provider Address, the address type, i.e., 2-octet or 8-octet address, shall be specified the DstAddrMode of MCPS-DATA.request, which initializes the exchange of this SRRR IE.

* **Page 80-86, 8.3 (MAC Data Service)**

8.3.1 MCPS-DATA.request

*Change the rows in Table 8-75 by the following table:*

**Table 8-75—MCPS-DATA.request parameters**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| RequestRrtiTx | Unsigned Integer | 0x00-0xff | This parameter indicates whether to request the MAC sublayer insert an RRTI IE in the response RFRAME: if its values is 0, RRTI IE is not requested; if its value is non-zero, this parameter give the number of nodes that MAC sublayer needs to calculate reply times and create the RRTI IE for.  |
| RrtiNodeList | Short address or extended address,Unsigned Integer | Address type is specified by the DstAddrMode, the range of ranging counter value: 0x0000000000-0xffffffffff | This parameter gives a list (of length=RequestRrtiTx) of short (or extended) addresses and the associated ranging counter values corresponding to the arrival time of the message from each node (address supplied) for which this current MCPS-DATA.request is including RRTI IE replies. This parameter is used along with RequestRrtiTx with non-zero value.  |
| TxTimeSpecfied | Enumeration | NONE, RCTU\_TIME, RSTU\_TIME | This parameter specifies whether the RangingTxTime parameter is used to control the time of transmission the frame. If TxTimeSpecfied is NONE, the transmission time is not specified by the RangingTxTime.  |
| RangingTxTime | Unsigned Integer | 0x0000000000-0xffffffffff | When TxTimeSpecified = RCTU\_TIME, the transmit time is specified by RangingTxTime in the time unit of the running ranging counter (6.9.1.1) to give precise response time of the RMARKER. When TxTimeSpecified = RSTU\_TIME, the transmit time is specified by RangingTxTime is in RSTU (6.9.1.2) to specify the start of the packet (preamble), which would be referenced to the time parameter of the most recent RCM as reported by the MCPS-DATA.indication that delivered it (or for a controller the MCPS-DATA.confirm that sent it). |

8.3.1 MCPS-DATA.confirm

*Add the following counters in the unit of RSTU to the primitive of MCPS-DATA.confirm on page 82*

MCPS-DATA.confirm (

 TxRstuCounter,

 RxRstuCounter,

 )

*Add the definitions of new counters in the Table 8-76*

**Table 8-76—MCPS-DATA.confirm parameters**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| TxRstuCounter | Unsigned Integer | 0x0000000000-0xffffffffff | A count of the time units corresponding to the start of the transmitted packet (preamble), which would be referenced to the time parameter of the most recent RCM as reported by the MCPS-DATA.indication that delivered it (or for a controller the MCPS-DATA.confirm that sent it). The units of time are specified in 6.9.1.2.  |
| RxRstuCounter | Unsigned Integer | 0x0000000000-0xffffffffff | A count of the time units corresponding to the start of the received packet (preamble), which would be referenced to the time parameter of the most recent RCM as reported by the MCPS-DATA.indication that delivered it (or for a controller the MCPS-DATA.confirm that sent it). The units of time are specified in 6.9.1.2. |

*Delete TxRrti, and its row in the Table 8-76. Since next higher layer can use the ranging counters to calculate the reply time anyway, this parameter is redundant.*

8.3.1 MCPS-DATA.indication

*Add the following counters in the unit of RSTU to the primitive of MCPS-DATA.indication on page 85*

MCPS-DATA.indication (

 TxRstuCounter,

 RxRstuCounter,

 )

*Add the definitions of new counters in the Table 8-77*

**Table 8-76—MCPS-DATA.indication parameters**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| TxRstuCounter | Unsigned Integer | 0x0000000000-0xffffffffff | A count of the time units corresponding to the start of the transmitted packet (preamble), which would be referenced to the time parameter of the most recent RCM as reported by the MCPS-DATA.indication that delivered it (or for a controller the MCPS-DATA.confirm that sent it). The units of time are specified in 6.9.1.2.  |
| RxRstuCounter | Unsigned Integer | 0x0000000000-0xffffffffff | A count of the time units corresponding to the start of the received packet (preamble), which would be referenced to the time parameter of the most recent RCM as reported by the MCPS-DATA.indication that delivered it (or for a controller the MCPS-DATA.confirm that sent it). The units of time are specified in 6.9.1.2. |

8.4.2 MAC PIB attributes

*Delete macRngAckRrtiSupport, macRngAckRrtiEnable, macRngMinRrtiTime, macRngRrtiTime in Table 8-81 on page 87. These attributes are used to support the ACK RFRAME with embedded reply time. Since this feature is not considered, these attributes should be removed.*