**IEEE P802.15**

**Wireless Personal Area Networks**

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| Source | Jinjing Jiang, Santhosh Kumar Mani, Alexander Krebs (Apple), Bin Qian, Lei Huang, Chenchen Liu, Rojan Chitrakar, David Xun Yang (Huawei), Mingyu Lee, Taeyoung Ha (Samsung Electronics), Hongwon Lee (LG Electronics) |
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| Abstract |  |
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1. Ranging Procedure for One-to-Many SS-TWR using NBA-MMS

## Introduction

In this document, we provide the texts for one-to-many SS-TWR ranging procedure using NBA-UWB MMS [1, 2] that will be incorporated into the draft-0 specification of IEEE 802.15.4ab.

## MAC

### 1.2.1 Basic Operation

In one-to-many SS-TWR using NBA-MMS, as shown in Figure 1, the ranging exchange is started by the initiator broadcasting to multiple responders the ranging initiation message on the narrow band.



Figure 1. Illustration of a ranging round of one-to-many SS-TWR using NBA-UWB

The configuration parameters of the one-to-many ranging round are embedded in the ranging initiation message. Such a configuration determines how the initiator ranges with multiple responders, divides the ranging slots in the ranging round into multiple *sub-rounds* and how the initiator completes the ranging control, ranging and optionally measurement report phase with one responder during each sub-round. Therefore, in the scheduled one-to-many ranging operation, the configuration shall include the list of responders that the initiator ranges with. The frame formats with signaling details are discussed in Section 1.2.3.

In each ranging sub-round, the ranging control, ranging, measurement report phases are the same as the one-to-one ranging using NBA-MMS. Particularly, in the first sub-round, the ranging initiation message allows CFO/SFO acquisition.

If the measurement report phase is not included in the ranging sub-round, the initiator shall reserve slots at the end of the ranging round to conduct measurement report phase for all the responders.

The examples in Figure 1 shows that the responder sends the measurement report back to the initiator and the initiator computes the range. It is also possible that the initiator sends the measurement report to the responder and then the responder calculates the range. These variations shall be part of the configuration parameters.

### 1.2.2 Other Configurations

In this section, further optimizations on the ranging configuration are described, which may be implemented to further improve the efficiency.

### 1.2.2.1 Contention-based Configuration

For contention-based one-to-many ranging, it is beneficial to switch the order of Poll and Response frame in a ranging sub-round. If no valid Response frame is received from a responder, the initiator should skip the sub-round without sending the UWB fragments as shown in Figure 2.



Figure 2. Illustration of a ranging round of contention based one-to-many SS-TWR using NBA-UWB, where Response message is sent first in a sub-round (excluding sub-round for Responder 1). In this example, the Response frame is not received correctly, the frames with dotted box are not sent accordingly.

### 1.2.2.2 Time Efficient Configuration

For some time-sensitive applications, e.g., VR/AR, it is useful to improve the time efficiency of the one-to-many ranging by allowing two responders to reply at different times within one ranging slot. The responders shall be capable of a fixed reply time of sufficient precision. The supported number of UWB MMS fragments (i.e., RSFs and/or RIFs) per ranging round is limited to 2.

As a ranging initialization message, the Poll frame with the MessageControl field set to 0x90 or 0xa0 serves to enable the time efficient one-to-many SS-TWR from an initiator to even number of responders. For two responders involved in each sub-round, the corresponding *StartSlotIndex* fields shall set to the same value; and the corresponding *TimeShiftIndication* fields shall set to 0 and 1, respectively. The *StartSlotIndex* field is used to indicate the slot index of the corresponding Poll frame.

In each sub-round as shown in Figure 3, the initiator may start transmitting the first UWB RSF fragment at *RpRsfOffset* slots into the ranging phase, and continue to send the second UWB RSF fragment at an interval of *1200* RSTUs. The responder with *TimeShiftIndication* field set to 0 may start transmitting the first UWB RSF fragment at *RpRsfOffset* slots plus *400* RSTUs into the ranging phase, and continue to send the second UWB RSF fragment at an interval of *1200* RSTUs. The responder with *TimeShiftIndication* field set to 1 may start transmitting the first UWB RSF fragment at *RpRsfOffset* slots plus *800* RSTUs into the ranging phase, and continue to send the second UWB RSF fragment at an interval of *1200* RSTUs.



Figure 3. Illustration of the time efficient one-to-many SS-TWR with different response time in a ranging slot using NBA-UWB RSF-only MMS ranging

For the time efficient one-to-many SS-TWR, the Report (from initiator in one-to-many ranging) frame with the MessageControl field set to 0x10 may serve to enable the transmission of the measurement report from the initiator to the two responders involved in the same sub-round. This message indicates the turnaround time of the two responders involved in the same sub-round in the TurnAroundTime1 and TurnAroundTime2 fields, respectively. Alternatively, two Report (from initiator in one-to-many ranging) frames with the MessageControl field set to 0x00 may be sent by the initiator individually to the two responders involved in the same sub-round.

## Multiple RSF Transmissions in a slot

## Introduction

As one of the PAR objectives provided by TG4ab, next generation UWB should improve link budget and/or reduced air-time. In this document we address the way to reduce air-time by allowing multiple transmitters to transmit ranging sequence fragments (RSFs) simultaneously.

There are two main sections: One focuses on MAC aspects of various features that rely on multiple RSF transmission in a slot, and the other one develops the message formats required to support the features introduced in the MAC section.

## Basic Operation

In order to support delay sensitive applications among the co-located devices at the same time, efficient use and scheduling of resources (i.e., slots) are required. The purpose of multiple RSF transmissions in a slot is to increase slot efficiency by allowing multiple RSF transmissions in a slot between devices. Support of multiple RSF transmissions in a slot is optional.

As presented in Figure 1, Multiple RSF transmissions can be applied to devices in a ranging area network (RAN). For example, as shown in Figure 1 Multiple RSF Transmission in a RANFigure 1, responders in a RAN can transmit RSFs simultaneously as scheduled by an initiator.



Figure 1 Multiple RSF Transmission in a RAN

Procedure of multiple RSF transmissions in a slot is divided into 3 phases, which are control, ranging phase, and measurement report phase. In control phase, RSF transmissions are scheduled to have the RSF transmission timing of each responder. In the ranging phase, an initiator sends (SYNC + SFD) packet of UWB or poll message of NB to trigger RSF transmission. After that, multiple RSF transmissions occur from the responders to the initiator in the slot. The measurement report phase delivers ranging results from the responders to the initiator. Responders may send Ranging report messages to the initiator to conduct this phase. Control and measurement report phase of multiple RSF transmissions can be omitted if unnecessary.

## Multiple RSF transmissions in a slot without NB assist

The operation of multiple RSF transmissions in a slot without NB assist is presented in Figure 2. Control phase is conducted by transmitting a control message in a UWB channel. This control message shall include the scheduling IE. In ranging phase, one (SYNC + SFD) only packet is transmitted to trigger multiple RSF transmissions. After RSF transmission occurs, measurement report phase is proceeded by sending ranging report messages in the UWB channel from the responders to the initiator. If there is no change in scheduling (tbd.), the control phase of RSF transmissions (i.e., control message in the UWB channel) can be omitted.

### The scheduling IE to be used for multiple transmissions in a slot it defined in [3].



Figure 2 Multiple RSF transmission in a slot without NB assist

## Multiple RSF transmissions in a slot with NB assist

The operation of multiple RSF transmissions in a slot with NB assist is shown in Figure 3. The control phase is conducted by sending a poll (one-to-many) message in the NB channel. After control phase, a poll (one-to-many) message is transmitted to trigger RSF transmissions. After the RSF transmission occurs, the measurement report phase is proceeded by sending ranging report messages in the NB channel from the responders to the initiator. If there is no change in scheduling (tbd.), the control phase of the RSF transmissions (i.e., a control message in the NB channel) can be omitted.



Figure 3 Multiple RSF transmission in a slot with NB assist

The REPORT message with message id 0x12 as defined in subsection 1.2.3 is used to transmit the ranging reports.

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### 1.2.3 Compressed PSDU messages

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| **Phase** | **Message Name** | **Octet 0 (Msg ID)** | **Octets 1-N [Len]** | **Description** |
| Initialization | POLL (one-to-many) | 0x10 | [RPA\_hash[3], RPA\_prand[3],MessageControl[1],MessageContent[],CRC16] | MessageControl=0x00:MessageContent={0x00, 0x00} This is the POLL message for ranging sub-rounds that are not the first one.MessageControl=0x10: MessageContent={Numberof Responders[1], SlotsPerResponder[1], List of Responder Address[3]}MessageControl = 0x20: MessageContent={Number of Responders[1], List of {Responder Address[3], StartSlotIndex[2], EndSlotIndex[2]}}MessageControl = 0x30: Same as Message Control = 0x10, but both Initiator and Responder send the measurement reportMessageControl = 0x40: Same as MessageControl = 0x20, but both Initiator and Responder send the measurement reportMessageControl = 0x50: MessageContent={NumberOfSubRounds[1], SizeOfSubRounds[1]}MessageControl = 0x60: Same as MessageControl = 0x50, but the Response frame and Poll frame in NB is switchedMessageControl = 0x70: MessageContent={Number of Responders[1], SlotsPerResponder[1], Request Bitmap[1],Presence Bitmap[1],List of {Responder Address[3],If Bit 0 of Presence Bitmap == 1 then {NB Channel Select[2]},If Bit 1 of Presence Bitmap == 1 then {NB PHY Config[1]},If Bit 2 of Presence Bitmap == 1 then {NB MAC Config[7]},If Bit 3 of Presence Bitmap == 1 then {UWB PHY Config[3]},If Bit 4 of Presence Bitmap == 1 then {UWB MAC Config[2]}}}MessageControl=0x80:MessageContent={Number of Responders[1],Request Bitmap[1],Presence Bitmap[1],List of {Responder Address[3],If Bit 0 of Presence Bitmap == 1 then {NbaChannelMap[6]},If Bit 1 of Presence Bitmap == 1 then {NB PHY Config[1]},If Bit 2 of Presence Bitmap == 1 then {NB MAC Config[7]},If Bit 3 of Presence Bitmap == 1 then {UWB PHY Config[3]},If Bit 4 of Presence Bitmap == 1 then {UWB MAC Config[2]},If Bit 5 of Presence Bitmap == 1 then {StartSlotIndex[2], EndSlotIndex[2]}}}MessageControl = 0x90: MessageContent={Number of Responders[1], List of {Responder Address, StartSlotIndex[2], TimeShiftIndication[1]}MessageControl = 0xa0: Same as Message Control = 0x90, but both Initiator and Responder send the measurement reportMessageControl = others: reserved |
| RESP (one-to-many) | 0x11 | [RPA\_hash[3],MessageControl[1],MessageContent[],CRC16] | A qualifying response message for one-to-many ranging.MessageControl=0x00:MessageContent={0x00, 0x00, 0x00, 0x00, 0x00}MessageControl=0x10:MessageContent={Presence Bitmap[1],If Bit 0 of Presence Bitmap == 1 then {NB Channel Select[2]},If Bit 1 of Presence Bitmap == 1 then {NB PHY Config[1]},If Bit 2 of Presence Bitmap == 1 then {NB MAC Config[7]},If Bit 3 of Presence Bitmap == 1 then {UWB PHY Config[3]},If Bit 4 of Presence Bitmap == 1 then {UWB MAC Config[2]},zero, one, two or three times 0x00}, where the number of padding bytes is determined so that the MessageContent field has a minimum size of 5 bytes; and at least one of NbaChannelMap, NB PHY Config, NB MAC Config, UWB PHY Config and UWB MAC Config fields shall be present. |
| Report | REPORT (from responder in one-to-many ranging) | 0x12 | [RPA\_hash[3],MessageControl[1],MessageContent[],CRC16] | A qualifying report message for one-to-many ranging.MessageControl=0x00:MessageContent={ReplyTime[5],PTDataLength[1],PTData[PTDataLength]}, where PTDataLength and PTData fields are optionally present and represent pass through data to higher layers.MessageControl=0x10:MessageContent={Presence Bitmap[1],ReplyTime[5],PTDataLength[1],PTData[PTDataLength],If Bit 0 of Presence Bitmap == 1 then {NB Channel Select[2]},If Bit 1 of Presence Bitmap == 1 then {NB PHY Config[1]},If Bit 2 of Presence Bitmap == 1 then {NB MAC Config[7]},If Bit 3 of Presence Bitmap == 1 then {UWB PHY Config[3]},If Bit 4 of Presence Bitmap == 1 then {UWB MAC Config[2]}}, where at least one of NbaChannelMap, NB PHY Config, NB MAC Config, UWB PHY Config and UWB MAC Config fields shall be present. |
| REPORT (from initiator in one-to-many ranging) | 0x13 | [RPA\_hash[3],MessageControl[1],MessageContent[],CRC16] | A qualifying report message for one-to-many ranging.MessageControl=0x00:MessageContent={TurnAroundTime[5],PTDataLength[1],PTData[PTDataLength]}, where PTDataLength and PTData fields are optionally present and represent pass through data to higher layers. |

References

[1] 15-23-0100-02-04ab-nba-uwb-technical-framework-for-draft0

[2] 15-22-0381-05-04ab-nba-uwb-ranging-text-proposal-for-15-4ab-tfd

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