**IEEE P802.15**

**Wireless Personal Area Networks**

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| Abstract |  | |
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1. NBA-MMS-UWB Ranging
   1. NBA-MMS-UWB range-measurement cycle
      1. Overview

The NBA-MMS-UWB ranging uses the following nomenclature to indicate ERDEV roles, as defined in 6.9.7.1 of IEEE 802.15.4z.

* Initiator
* Responder

Unless noted otherwise, the initiator acts as controller, and the responder acts as controlee during an NBA-MMS-UWB ranging cycle.

The NBA-MMS-UWB ranging also uses

* the ranging block and round structure, as specified in 6.9.7.2 of IEEE 802.15.4z, and
* the blocked-based mode, as specified in 6.9.7.3.3 of IEEE 802.15.4z.

Figure 6-48j and Figure 6-48r of IEEE 802.15.4z are quoted below as Figure 1.1.1.1 and Figure 1.1.1.2, respectively.

Diagram

Description automatically generated

**Figure 1.1.1.1 - Illustration of ranging block, ranging round, and ranging slot**

The ranging block structure can be setup for NBA-MMS-UWB by specifying:

* ranging block duration
* ranging round duration

Ranging slot duration is not used for NBA-MMS-UWB.

The time unit used in specifying the durations of ranging block, and ranging round is the RSTU as specified in 6.9.1.5 of IEEE 802.15.4z. Ranging devices shall realize this ranging block structure such that the tolerance in the ranging block duration with respect to the PHY clock shall be within ±100 ppm.

For a given block configuration, each ranging block is referenced by a ranging block index relative to the first block in that configuration (block number zero). Each ranging round in any ranging block is referenced by a ranging round index relative to the first ranging round in the current ranging block. Similarly, each ranging slot in a ranging round is referenced by a ranging slot index relative to the first ranging slot in the ranging round.

A ranging round is a period of sufficient duration to complete one entire range-measurement cycle. An initiator and a responder may use one or multiple ranging rounds from the first ranging block of a ranging session and repeat the same ranging round usage pattern in subsequent ranging blocks. The round hopping, as specified in 6.9.7.3.3 of IEEE 802.15.4z, may be optionally applied to an NBA-MMS-UWB ranging session, while the transmission offset does not apply to the NBA-MMS-UWB ranging.

Diagram, engineering drawing

Description automatically generated

**Figure 1.1.1.2 – Time diagram for an example of block-based mode**

A range-measurement cycle can be uniquely identified by a ranging block index and a ranging round index.

In the NBA-MMS-UWB ranging, a range-measurement cycle consists of following phases:

* Ranging control phase
* Ranging phase
* Measurement report phase (in-band/out-of-band)

The ranging control phase and ranging phase are mandatorily required in a range-measurement cycle. The measurement report phase is optionally supported in-band, or out-of-band. If provided in-band, the ranging round length shall be configured to include ranging control, ranging, and measurement report phases. If provided out-of-band, the ranging round length shall be configured to include ranging control, and ranging phase.

In contrast to non-MMS ranging modes defined in [3], MMS ranging mode supports non-uniform ranging slot duration for ranging control, ranging, and measurement report phases.

Figure 1.1.1.3 illustrates the NBA-MMS-UWB ranging round, range-measurement cycle, and phases.



**Figure 1.1.1.3 – NBA-MMS-UWB ranging round contents**

The following nomenclature is used for control and report messages:

* Poll message (e.g., POLL from 1.5.3): A NB message transmitted by an initiator at the beginning of the first ranging slot of a ranging round to initiate a range-measurement cycle within the ranging round.
* Response message (e.g., RESP from 1.5.3): A NB message transmitted by a responder at the beginning of a subsequent ranging slot after the first ranging slot, in response to a received poll message.
* Report message (e.g., RPRT from 1.5.3): a NB message transmitted by either an initiator or a responder to report the ranging measurement to the peer.

The NB O-QPSK 250k PHY is default for the transfer of control and report messages. Other NB and UWB PHYs [6] are supported optionally.

* + 1. NBA-MMS-UWB ranging control phase

An NBA-MMS-UWB ranging control phase starts at the beginning of an NBA-MMS-UWB range-measurement cycle and includes at least 2 ranging control slots.

An initiator starts an NBA-MMS-UWB ranging control phase by transmitting a poll message to a responder at the beginning of the first ranging slot of a ranging round. The initiator may extend transmission of the poll for up to the duration of *RcpPollSlot*. The responder that receives the poll message successfully shall transmit a response message back to the initiator in the ranging slot after *RcpPollSlot* from the beginning of the ranging control phase. The responder may extend transmission of the response for up to the duration of *RcpResponseSlot* in the ranging control phase. The responder that transmits the response message successfully shall continue the NBA-MMS-UWB range-measurement cycle and enter the ranging phase. The initiator that receives the response message successfully shall also continue the NBA-MMS-UWB range-measurement cycle and enter the ranging phase.

If LBT is enabled before a transmission in the corresponding operating band (referring to 1.3.2), a transmitter shall perform LBT in advance of the start of expected transmission. If the performed LBT cannot warrant the transmission at the beginning of the ranging slot, for the remainder of the ranging round the transmitter shall not commence further transmissions.

An initiator shall discontinue an NBA-MMS-UWB range-measurement cycle if at least one of following conditions is met:

* The LBT does not warrant the transmission of the poll message.
* The initiator fails to receive the response message at the expected ranging slot.
* All ERDEVs have requested to skip ranging for the current ranging block during ranging control phase

A responder shall discontinue an NBA-MMS-UWB range-measurement cycle if at least one of following conditions is met:

* The responder fails to receive the poll message at the beginning of the expected ranging round.
* The LBT does not warrant the transmission of the response message.
* All ERDEVs have requested to skip ranging for the current ranging block during ranging control phase

If a range-measurement cycle is terminated before its completion, the involved ERDEVs shall stop the NB and UWB transmissions until the next range-measurement cycle.

Figure 1.1.2.1 illustrates an example of the NBA-MMS-UWB ranging control phase.

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**Figure 1.1.2.1 - NBA-MMS-UWB ranging control phase**

* + 1. NBA-MMS-UWB ranging phase

An NBA-MMS-UWB ranging phase starts when the NBA-MMS-UWB ranging control phase ends.

An initiator may start transmitting a first UWB RSF fragment at *RpInitiatorRsfOffset* RSTUs into the ranging phase. The initiator may continue to send up to X UWB RSF fragments at regular intervals of *RpInitiatorRsfInterval* RSTUs (where X refers to [5]).

An initiator may start transmitting a first UWB RIF fragment at *RpInitiatorRifOffset* RSTUs into the ranging phase. The initiator may continue to send up to Y UWB RIF fragments at regular intervals of *RpInitiatorRifInterval* RSTUs (where Y refers to [5]).

A responder may start transmitting a first UWB RSF fragment at *RpResponderRsfOffset* RSTUs into the ranging phase. The responder may continue to send up to X UWB RSF fragments at regular intervals of *RpResponderRsfInterval* RSTUs (where X refers to [5]).

A responder may start transmitting a first UWB RIF fragment at *RpResponderRifOffset* RSTUs into the ranging phase. The responder may continue to send up to Y UWB RIF fragments at regular intervals of *RpInitiatorRifInterval* RSTUs (where Y refers to [5]).

The total duration of the ranging phase is *RpDuration* RSTUs.

After an ERDEV, being either an initiator or a responder, completes the reception of all UWB fragments for the ranging phase, it shall generate the ranging measurement report, if it is required to send the measurement report to a peer. The value of *RpDuration* may be set accordingly to allow sufficient pause to the following measurement report phase.

If in-band NBA-MMS-UWB measurement report phase is enabled for the range-measurement cycle, an ERDEV which completes its ranging phase shall enter the measurement report phase, if

* It is required to send the measurement report to a peer during the measurement report phase, and it generates the measurement report successfully; or
* It expects to receive the measurement report from a peer during the measurement report phase.

If an NBA-MMS-UWB measurement report phase is not included in an NBA-MMS-UWB range-measurement cycle, the involved ERDEVs conclude the range-measurement cycle after they complete the ranging phase. An ERDEV which is required to send the measurement report to a peer may either pass the measurement report to the next higher layer and request the next higher layer to transmit the measurement report to the peer.

Figure 1.1.3.1illustrates an example of the NBA-MMS-UWB ranging phase.



**Figure 1.1.3.1 - NBA-MMS-UWB ranging phase**

* + 1. NBA-MMS-UWB measurement report phase

In-band measurement reports may be transferred during an optional measurement report phase. If enabled, the in-band measurement report phase starts when the ranging phase ends. The in-band measurement report phase is referred to as report phase in the following.

The report phase consists of one, or more packet slots. The duration of the first slot in the report phase is of duration *MrpFirstSlot* RSTUs. The duration of the second slot in the report phase is of duration *MrpSecondSlot* RSTUs.

If the report phase only contains one packet slot, either the transmitter, or the responder shall transmit a measurement report packet in the slot. Whether the initiator, or the transponder transmit a report packet is configured by the report mode.

If the report phase contains two packet slots, the initiator shall transmit a report packet in the first slot, and the responder shall transmit a report packet in the second slot.



**Figure 1.1.4.1 - NBA-MMS-UWB measurement report phase**

The measure report phase may consist of a uni-, or bi-directional report exchange. The transmission of report packets shall be scheduled in the first two ranging slots of the measurement report phase according to the following configuration modes:

|  |  |  |
| --- | --- | --- |
| **Report mode** | **TX first report slot** | **TX second report slot** |
| Uni-directional, Responder only | Responder | - |
| Uni-directional, Initiator only | Initiator | - |
| Bi-directional, Initiator first | Initiator | Responder |

**Table 1.1.4.1 – NBA-MMS-UWB report modes**

For the bi-directional report, the transmission of reports shall be performed independently in the first and the second slot of the measurement report phase. In particular, the responder shall transmit its measurement report in the second slot, independent of whether it has received the initiator’s report in the first report slot, or not.

If an ERDEV fails to transmit its measurement report during its assigned slot in the measurement report phase, the ERDEV may defer and retry the transmission using higher layer, or out-of-band radio operation. If an ERDEV fails to receive a measurement report during its assigned slot in the measurement report phase, it may request retransmission using higher layer, or out-of-band radio operation.

* 1. NBA-MMS-UWB discovery and setup
     1. Overview

An NBA-MMS-UWB ranging session is configured by a set of parameters for PHY and MAC. The set of PHY parameters include NB and UWB channels, modulation, and data rate to be used for control, ranging, and measurement report phases. The MAC parameters include the slot, round, and block configuration for control, ranging, and measurement report phases.

To start an NBA-MMS-UWB ranging session, a pair of initiator and responder devices may engage in a discovery and setup phase to negotiate a ranging configuration different from the default set of parameters. Out-of-band communication may be used to setup session parameters, or change discovery channel and modulation, even prior to discovery and setup phase.

* + 1. Ranging session discovery
       1. Overview

Before entering the ranging control phase, ERDEVs may engage in a discovery and setup stage. The discovery and setup stage provides time synchronization of the first poll packet transmitted by the initiator during an upcoming ranging control phase. Furthermore, ranging session configuration may be altered by a two-way handshake packet exchange between the ERDEVs. Unless renegotiated during discovery and setup, the default ranging configuration parameters shall be used for the ranging session. Alternatively, the ranging session configuration may be setup by out-of-band radio.

To establish in-band discovery, ERDEVs shall opportunistically transmit and receive on the dedicated discovery channel and PHY modulation, as given by the ranging session configuration. The initiator may send advertising poll (ADV-POLL) packets opportunistically at times and intervals to its discretion as deemed suitable for the higher layer functionality to be supported. Similarly, the responder may opportunistically listen for incoming ADV-POLL packets.

After transmitting ADV-POLL on the discovery channel, the initiator shall listen for an incoming advertising response packet (ADV-RESP) in the subsequent ranging slot. Once a responder has received ADV-POLL, it may transmit ADV-RESP in the subsequent ranging slot. When the responder has transmitted ADV-RESP, it shall listen for a start of ranging (SOR) packet in the ranging slot following the ADV-RESP packet. Once the initiator has received an ADV-RESP packet, it may transmit a SOR packet in the ranging slot following the ADV-RESP packet.

After transmitting the SOR packet, the initiator shall enter the ranging control phase. After the initiator has confirmed receipt of the RESP from the responder during ranging control phase, and unless discovery of further ERDEVs is required, the initiator shall discontinue ranging discovery and cease transmission of ADV-POLL packets.

The discovery process is exemplified in the following figure:

****

**Figure 1.2.2.1.1 - An example of the NBA-MMS-UWB ranging phase**

* + - 1. Discovery setup handshake

The responder (controlee) requests ranging session configuration in ADV-RESP.

The initiator (controller) receives the request from the responder via ADV-RESP, sets the session configuration, and communicates the session configuration in SOR to the responder.

Protocol details tbd.

* + 1. Ranging session configuration

Before an NBA-MMS-UWB ranging session is started, the ranging block structure and the range-measurement cycle are configured. Unless set up by the next higher layer, the default parameters shall be applied to the ranging session configuration. During an NBA-MMS-UWB ranging session, some parameters of the ranging block structure and the range-measurement cycle may be updated by the next higher layer. For each parameter update, the next higher layer shall indicate the index of a future ranging block when the new parameters become effective. How the next higher layers of an initiator and a responder synchronize the parameters and the effective time is beyond the scope of this standard.

An initiator and a responder shall use the parameters which are set or updated by the next higher layers as the long-term operating parameters.

An initiator may overwrite the long-term operating parameters of a range-measurement cycle by indicating a new set of short-term parameters during the ranging control phase. The short-term parameters are only taking effect to the immediate range-measurement cycle. The long-term operating parameters resume effective in the next range-measurement cycle unless overwritten again during the ranging control phase.

A responder may request short-term operating parameters for the next range-measurement during the ranging control phase. The initiator may serve the responder’s request in the next ranging cycle, or ignore it.

Table 1.2.3.1, Table 1.2.3.2, and Table 1.2.3.3 illustrate the NBA-MMS-UWB ranging session general parameters, block structure parameters, and the range-measurement cycle parameters, respectively.

| Parameters | Value range/options | Default value | Description |
| --- | --- | --- | --- |
| Discovery channel | NB: 0-249  UWB: 250-254 | 2 | Values 250-254, refer to UWB channels 5, 6, 8, 9, 10 |
| Control and report channel allowlist (*NbaChannelAllowList*) | NB: {0-249} UWB: 250-254 | 3 | List only allowed for NB, otherwise one UWB |
| UWB ranging channel | 5, 6, 8, 9, 10, … | 9 |  |
| PHY rate | #1 - #5 [6]  6: UWB BPRF | #1: 250k uncoded |  |
| NB LBT Ch. 0-49 (UNII-3) | Yes/No | No |  |
| NB LBT Ch. 50-249 (UNII-5) | Yes/No | Yes |  |
| Round hopping | Yes/No | No |  |
| Channel switching | Per-block, per-round, Off | Per-block |  |

**Table 1.2.3.1 – NBA-MMS-UWB ranging session general parameters (example)**

| Parameters | Value range/options | Default value | Description |
| --- | --- | --- | --- |
| Ranging block duration |  | tbd |  |
| Ranging round duration |  | tbd |  |

**Table 1.2.3.2 – NBA-MMS-UWB block structure parameters (example)**

| Phases | Parameters | Value range/options | Default value | Description |
| --- | --- | --- | --- | --- |
| Ranging control phase | *RcpPollSlot* |  | 1200 (1ms) | RSTU |
| *RcpResponseSlot* |  | 1200 | RSTU |
| Ranging phase | Number of RSF fragments (X in [5]) | 0, 1, 2, 4, 8, … | 8 |  |
| Number of RIF fragments (Y in [5]) | 0, 1, 2, 4, 8, … | 0 |  |
| *RpDuration* |  | 9600 (8ms) | RSTU |
| *RpInitiatorRsfOffset* |  | 0 (0ms) | RSTU |
| *RpResponderRsfOffset* |  | 600 (0.5ms) |  |
| *RpInitiatorRsfInterval* |  | 1200 (1ms) |  |
| *RpResponderRsfInterval* |  | 1200 (1ms) |  |
| *RpInitiatorRifOffset* |  | 1200 |  |
| *RpResponderRifOffset* |  | 1200 |  |
| *RpInitiatorRifInterval* |  | 1200 |  |
| *RpResponderRifInterval* |  | 1200 |  |
| RSF code index | 33-48 |  |  |
| RSF complementary set zeros | 0-64 |  |  |
| RIF fragment length in 512-chip units | 32, 64, 128, 256 |  |  |
| RIF STS configuration |  |  | tbd |
| Measurement Report | In-band report | Yes/No | In-band |  |
| Report mode | Uni-directional initiator only, uni-directional responder only, bi-directional |  |  |
| *MrpFirstSlot* |  | 1200 | RSTU |
| *MrpSecondSlot* |  | 1200 | RSTU |

**Table 1.2.3.3 – NBA-MMS-UWB range-measurement cycle parameters (example)**

* 1. NBA-MMS-UWB bands and channels
     1. Overview

The spectrum for NB access is located in the UNII-3 and UNII-5 band at 5725-5850 MHz and 5925-6425 MHz. Both the UNII-3 and the UNII-5 band are used in coexistence with 802.11 and other radio technology. Since the occupied bandwidth of the O-QPSK NB radio is less than 2.5 MHz, up to 50 NB channels can be allocated for NBA-UWB in the UNII-3 band. Up to 200 NB channels can be allocated in the UNII-5 band. The arrangement of 802.11 channels and NB channels is shown in the following Figure 1.3.1.1.



**Figure 1.3.1.1 – NB channels UNII-3, UNII-5**

The center frequencies *fn* for the NB channels 0 <= n <= 249 are defined as

and

The ERDEVs may configure all channels 0-249, or an arbitrary subset of channels 0-249 to be included in the *NbaChannelAllowList* as described in 1.4.2. The ERDEVs may use the channel switching mechanisms described in 1.4.3 with the resulting list of allowed channels.

* + 1. NBA listen before talk (LBT)

If LBT is required before a transmission in the corresponding operating band (referring to [4]), a transmitter shall perform LBT in advance of the start of the expected transmission. If the performed LBT cannot warrant the transmission at the beginning of the ranging slot, the transmitter shall not commence the transmission.

NB radios according to 2.3. qualify as FBE according to [3] with a fixed frame period (FFP) equal to the NBA-MMS-UWB ranging slot length. In accordance with 4.3.6 [3], the NB radio shall perform a CCA for at least 9us before any attempt to transmit in the allocated NB channel and ranging slot. The EDT for CCA shall be considered as -75dBm/MHz in accordance with 4.4.6.3.3 [3]. After completing the CCA, if the channel is assessed clear, the NB radio shall start transmission no later than 16us after completing the CCA. If the channel is assessed occupied, the radio shall skip NB transmission for the current ranging block. The following figure shows the application of CCA for a two-sided packet exchange in two consecutive ranging slots between the initiator and responder, as needed during ranging control phase. The LBT scheme is depicted in Figure 1.3.2.1.



**Figure 1.3.2.1 – NB LBT**

LBT shall be applied to NB channels 50-249 according to regulatory constraints. LBT may be applied to all NB channels 0-249 in the absence of regulatory constraints, for example, to improve QoS and coexistence with other shared spectrum radio.

* 1. NBA-MMS-UWB channel switching
     1. Overview

NBA-UWB aggregates different properties of narrowband and UWB radio PHYs and application of the MAC protocols in shared spectrum in coexistence with 802.11 PHY and MAC. Since NB communication uses only a fraction of the available spectrum for transmission, a frequency diversity achieving method is defined here to assure robust NB access and mitigate the impact of NB fading.

1.4.2 defines a list-based mechanism to coordinate a set of NB channels that can be used by the initiator and the responder for NB channel access. 1.4.3 defines a mechanism to dynamically switch among the coordinated NB channels between successive ranging blocks.

Depending on the NB channel in use, band specific regulatory rules may apply. 1.3.2 defines the LBT protocol to be applied for NB channels 0-49 (UNII-3), and NB channels 50-249 (UNII-5). The LBT protocol shall be applied by initiator and responder independently in each transmission slot, even if the same channel is used consecutively.

* + 1. NBA channel lists

If a subset of the 250 NB channels is known to be unavailable, unusable, or deemed inefficient to be used, the initiator can mark the channels as blocked for the entire duration of an NBA-UWB session. E.g., the initiator may be additionally equipped with an 802.11.x radio and engaged in concurrent radio transmissions with other devices via a known WLAN channels. In this case the initiator may deem it favourable to exclude the conflicting set of channels being used for WLAN.

If the number of allowed channels is less than the number of blocked channels, the initiator can send the list of allowed channels *NbaChannelAllowList* to the responder.

The following table defines range and length of the necessary attributes:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Attribute** | **Type** | **Range** | **Description** | **Default** |
| *NbaChannelAllowList* | List | — | List of channels enabled for NB switching. | (f\_0,…,f\_249) |
| *NbaChannelAllowListLength* | Integer | 0-250 | Number of allowed channels. | tbd |
| *NbaUwbPrngFunction* | Integer | 0-tbd | 0: AES-128-CTR, tbd. | 0 |
| *NbaUwbPrngSeed* | Integer | 0-255 | Seed value for *NbaUwbPrngFunction* | 0 |

**Table 1.4.2.1 – NB channels UNII-3, UNII-5**

After receiving an allow list *NbaChannelAllowList* from the initiator, the responder shall employ this list to assign a NB channels to each ranging with the mechanism defined in 2.2.3.

* + 1. NBA channel switch protocol

To accommodate the requirements of synchronised network access, randomness of channel choice, and statistical dependence of interference between neighbouring channels the following switching protocol for NB channels is defined.

The switching protocol is based on the ranging configuration in terms of the allowed list of NB channels *NbaChannelAllowList*, the pseudo-random number generating function *NbaUwbPrngFunction,* and the corresponding seed value *NbaUwbPrngSeed*.

For *NbaUwbPrngFunction=*AES128(*key*, *data*) function in counter mode [7] shall be used as the PRNG, where *key*=*NbaUwbPrngSeed,* and *data=RangingBlockIndex*.

The least significant 32 bits of the output of the PRNG are then calculated and as

*PrngValue = NbaUwbPrngFunction*(*NbaUwbPrngSeed*, *RangingBlockIndex*) mod 232

and shall then be further mapped to the NB channel via the allowed list of channels as

*SelectedChannel = NbaChannelAllowList*[*PrngValue* mod *NbaChannelAllowListLength*],

where mod is the integer modulus operator.

The mapping function is calculated independently by initiator and responder without based on the ranging session configuration values established during setup phase.

* 1. NBA-MMS-UWB control channel messages
     1. Overview
     2. PSDU formats

For other but the PHYs specified in [6] the PSDU format specified for the respective PHY shall be used. When NB is used for control, report, and discovery messages, the compressed PSDU format shall be used.

* + 1. Compressed PSDU format

The compressed PSDU format only contains a 1-octet header that conveys the message ID. All remaining PSDU content is message specific to the message ID. The following table presents the messages used during discovery, setup, control, and report phases in compressed PSDU format.

Compressed PSDU messages may be encapsulated in the header IE type TBD data field.

* + - 1. Compressed PSDU messages

|  |  |  |  |
| --- | --- | --- | --- |
| **Message** | **Octet 0 (Message ID)** | **Octets 1-N** | **Description** |
| POLL | 0x00 | […, CRC16] | A qualifying poll message. More poll messages are tbd. |
| RESP | 0x01 | […, CRC16] | A qualifying response message. |
| RPRT (from responder) | 0x02 | […, CRC16] | A qualifying report message. |
| RPRT (from initiator) | 0x03 | […, CRC16] | A qualifying report message. |
|  | 0x04-0x1f |  | Reserved for in session control and report phases |
| ADV-POLL | 0x20 | […, CRC16] |  |
| ADV-RESP | 0x21 | […, CRC16] |  |
| SOR | 0x22 | […, CRC16] |  |
|  | 0x23-0x2f |  | Reserved for out of session |
|  |  |  |  |
|  |  |  |  |

* + - 1. Compressed PSDU message fields

|  |  |  |
| --- | --- | --- |
| **Field name** | **Length in bits** | **Description** |
| CRC16 | 16 | 2-octet FCS defined in 7.2.11 |
| ADDR |  |  |
| … |  |  |

* 1. References

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[3] 15-22-0080-00-04ab-nba-mms-uwb-mac-followup

[4] 15-22-0340-01-04ab-narrowband-channel-access-and-interference-mitigation-for-nba-mms-uwb

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[7] SP 800-38A Recommendation for Block Cipher Modes of Operation: Methods and Techniques”, National Institute of Standards and Technology (NIST), December 2001.