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| 3rd Generation Partnership Project;Technical Specification Group Radio Access Network;Ambient IoT Medium Access Control Protocol specification(Release 19) |
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# Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

The present document specifies the Medium Access Control (MAC) protocol of Ambient IoT.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 38.291: "Ambient IoT Physical layer".

[3] 3GPP TS 38.300: "NR; Overall description; Stage 2".

[4] 3GPP TS 23.369: "Architecture support for Ambient power-enabled Internet of Things; Stage 2".

[5] 3GPP TS 23.003: "Numbering, addressing and identification".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**Device:** A device that supports A-IoT radio interface towards reader, as defined in TS 38.300 [3].

**Reader:** A reader providing A-IoT protocol terminations towards the A-IoT device, as defined in TS 38.300 [3].

**Access occasion:** A time-frequency resource for device(s) to transmit Msg1 (i.e., the *Access* *Random ID* message) during a CBRA procedure.

**AS ID:** The AS layer identifier to address the specific device for R2D reception and D2R scheduling.

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

A-IoT Ambient IoT

CBRA Contention-Based Random Access

CFA Contention-Free Access

D2R Device to reader

IoT Internet of Things

PDRCH Physical D2R channel

PRDCH Physical R2D channel

R2D Reader to device

TrCH Transport Channel

# 4 General

## 4.1 Introduction

This clause describes the A-IoT MAC architecture and the A-IoT MAC entity of the device from a functional point of view.

## 4.2 A-IoT MAC architecture

Figure 4.2-1 illustrates a model of the A-IoT MAC entity; and it does not restrict implementations.

The A-IoT MAC entity of the device handles the data received from R2D transport channel or to be transmitted via D2R transport channel, as specified in TS 38.291 [2].



Figure 4.2-1: A-IoT MAC structure overview

## 4.3 Services

### 4.3.1 Services provided to upper layers

The A-IoT MAC layer provides the following services to upper layers:

- data transfer;

### 4.3.2 Services expected from physical layer

The A-IoT MAC layer expects the following services from the physical layer:

- data transfer;

## 4.4 Functions

The A-IoT MAC layer supports the following A-IoT MAC functions:

- constructing MAC PDUs to be mapped onto transport blocks (TB) to be delivered to the physical layer on D2R transport channel;

- receiving MAC PDUs from transport blocks (TB) delivered from the physical layer on R2D transport channel;

- message type determination;

- paging;

- radio resource selection;

- access;

- transfer of upper layer data;

- D2R segmentation;

- failure detection.

# 5 A-IoT MAC procedures

## 5.1 General

The clause describes the A-IoT MAC procedures.

When the device is powered on, the device starts monitoring PRDCH for an R2D message, as specified in TS 38.291 [2], in order to perform the corresponding A-IoT MAC procedures.

## 5.2 A-IoT paging

The purpose of this procedure is to transmit *A-IoT Paging* message to one or more devices. The reader may include the *Paging ID* field to select a specific device or a group of devices, or may not include *Paging ID* field to select all devices.

The device monitors for the *A-IoT Paging* message, and determines whether the device is selected to initiate the access procedure.

Upon receiving the *A-IoT Paging* message, the A-IoT MAC entity shall:

1> if the *RA Type* field in the *A-IoT Paging* message indicates CBRA:

2> if the device has no stored Transaction ID; or

2> if the value of the *Transaction ID* field is different from the stored Transaction ID; or

2> if the value of the *Transaction ID* field is the same as the stored Transaction ID, and the previous procedure was determined as failed for this Transaction ID as specified in clause 5.5:

3> release the stored AS ID if any;

3> store the received value in *Transaction ID* field, if the device has no stored Transaction ID, or replace the previously stored Transaction ID with the current received value, if the value of the *Transaction ID* field is different from the stored Transaction ID;

3> if the *Paging ID Presence Indication* field indicates *Paging ID* field is absent::

4> consider the device is selected and indicate to the upper layers;

3> else:

4> forward the value of the *Paging ID* field to the upper layers;

4> if the upper layers indicate that the Paging ID is matched:

5> consider the device is selected;

3> if the device is selected:

4> initiate Contention-Based Random Access procedure as specified in clause 5.3.1;

1> else (i.e., the *RA Type* field in the *A-IoT Paging* message indicates CFA):

2> release the stored AS ID if any;

2> release the stored Transaction ID, if any

2> forward the value of the *Paging ID* field to the upper layers;

2> if the upper layers indicate that this Paging ID is matched:

3> consider the device is selected;

3> initiate Contention-Free Access procedure as specified in clause 5.3.2.

##

## 5.3 A-IoT access procedure

### 5.3.1 Contention-Based Random Access procedure

#### 5.3.1.1 Selection of access occasion for D2R transmission of *Access Random ID* message

If Contention-Based Random Access procedure is initiated according to clause 5.2, the device selects access occasion for D2R transmission of *Access Random ID* message based on *Paging* message or *Access Trigger* message. If needed, the device monitors for *Access Trigger* message until it has received a *A-IoT Paging* message.

The A-IoT MAC entity shall:

1> apply the *D2R Scheduling Info* received from the *A-IoT Paging* message;

1> generate a random number '*i*' in the range: 0 ≤ *i* ≤ *n*-1, where *n* is the number of access occasions configured in *A-IoT Paging* message;

The A-IoT MAC entity should:

1> set the *ACCESS\_OCCASION\_COUNTER* to'*i*';

1> if *ACCESS\_OCCASION\_COUNTER <* *m*, where *m* equals to X\* (where X and are defined in clause 6.2.1.6):

2> select the (*ACCESS\_OCCASION\_COUNTER+*1)th access occasion from the *m* access occasion(s) triggered by the *Paging* message;

2> initiate the transmission of *Access Random ID* message, as specified in clause 5.3.1.2.

1> else (i.e. *ACCESS\_OCCASION\_COUNTER >=* *m*):

2> perform the following procedure upon reception of *Access Trigger* message if *Access Random ID* message has not been transmitted:

3> decrement *ACCESS\_OCCASION\_COUNTER* by *m*;

3> if *ACCESS\_OCCASION\_COUNTER* < *m*:

4> select the (*ACCESS\_OCCASION\_COUNTER+*1)th access occasion from the *m* access occasion(s) triggered by this *Access Trigger* message;

4> initiate the transmission of *Access Random ID* message, as specified in clause 5.3.1.2.

NOTE: The count-down behaviour defined above does not preclude other device implementation alternatives of random selection of access occasion.

#### 5.3.1.2 Transmission of *Access Random ID* message

The A-IoT MAC entity shall:

1> generate a 16-bit random number 'j' in the range: 0 ≤ j < 216;

1> set the *Random ID* field to the ‘j’ in the *Access Random ID* message;

1> instruct the physical layer to transmit the *Access Random ID* message using the selected access occasion as specified in clause 5.3.1.1, and indicate the L1 parameters to the physical layer, as specified in clause 6.2.1.6.

###

#### 5.3.1.3 Reception of *Random ID Response* message

Once the *Access Random ID* message is transmitted, the device shall monitor for *Random ID Response* message until it has received [FFS one or *k*] Access Trigger message or one *A-IoT Paging* message (i.e., the device does not process the *Random ID Response* message after that).

Upon reception of *Random ID Response* message, the A-IoT MAC entity shall:

1> if the device has no stored AS ID (i.e., initial reception of *Random ID Response* message):

2> for each *Echoed Random ID* field in *Random ID Response* message:

3> if the value indicated by *Echoed Random ID* field is identical to the value of the *Random ID* field in the transmitted *Access Random ID* message:

4> consider this CBRA procedure is successful;

4> if the *Assigned AS ID* field corresponding to the *Echoed Random ID* field is included (i.e., *AS ID Present* *Indication* field is set to 1):

5> set AS ID to the value indicated by the *Assigned AS ID* field and store the AS ID;

4> else:

5> set AS ID to the value indicated by the *Random ID* field and store the AS ID;

4> initiate the D2R message transmission as specified in clause 5.4.1, upon which the procedure of processing this *Random ID Response* message ends;

1> else (i.e., reception of *Random ID Response* message retransmission):

2> for each *Echoed Random ID* field in the *Random ID Response* message:

3> if the *Assigned AS ID* field corresponding to the *Echoed Random ID* field is included, and the value indicated by *Assigned AS ID* field is identical to the stored AS ID; or

3> if the *Assigned AS ID* field corresponding to the *Echoed Random ID* field is not included, and the value indicated by *Echoed Random ID* field is identical to the stored AS ID:

4> initiate the D2R message transmission as specified in clause 5.4.1, upon which the procedure of processing this *Random ID Response* message ends.

###

### 5.3.2 Contention-Free Access procedure

If Contention-Free Access procedure is initiated according to clause 5.2, the A-IoT MAC entity shall:

1> initiate the D2R message transmission as specified in clause 5.4.1.

## 5.4 A-IoT upper layer data transmission

### 5.4.1 D2R message transmission

Upon initiation of the procedure, the A-IoT MAC entity shall:

1> apply the *D2R Scheduling Info*, received in the *A-IoT Paging* message with RA Type set to CFA or in the *Random ID Response* message or in the *R2D Upper Layer Data Transfer* message containing the *Data SDU* field;

1> if upper layer data is available to be transmitted:

2> if the size of the resulting MAC PDU including the total upper layer data is smaller than or equal to the resource size given by the D2R TBS in the D2R Scheduling Info:

3> generate the *D2R Upper Layer Data Transfer* message, as follows:

4> set the *More Data Indication* field to value 0;

4> include *SDU Length* field and *Data SDU* field;

4> if the size of the resulting MAC PDU including the total upper layer data is smaller than the resource size given by the D2R TBS in the D2R Scheduling Info:

5> include the *MAC Padding* field;

3> instruct the physical layer to transmit the *D2R Upper Layer Data Transfer* message and indicate the L1 parameters to the physical layer, as specified in clause 6.2.1.6;

2> else (the size of the resulting MAC PDU including the total upper layer data is larger than the resource size given by the D2R TBS in the D2R Scheduling Info):

3> the upper layer data SDU is to be segmented according to clause 5.4.3;

1> else (i.e., upper layer data is not available to be transmitted):

2> generate the *D2R Upper Layer Data Transfer* message, as follows:

3> set the *More Data Indication* field to [value ffs];

3> set the *SDU Length* field to 0;

3> include the *MAC Padding* field;

2> instruct the physical layer to transmit the *D2R Upper Layer Data Transfer* message and indicate the L1 parameters to the physical layer, as specified in clause 6.2.1.6.

NOTE: It is up to reader’s implementation to avoid segmentation for the D2R Upper Layer Data Transfer message for device ID reporting.

### 5.4.2 R2D message reception

Once a *R2D Upper Layer Data Transfer* message is received, the A-IoT MAC entity shall:

1> if the device has a stored AS ID and the R2D *Upper Layer Data Transfer* message is addressed to the device (i.e., the value of *AS ID* field is identical to the stored AS ID):

2> if the *Choice Indication* field indicates that the *Data SDU* field is included:

3> forward the upper layer data SDU to upper layers;

3> initiate the following D2R message transmission, as specified in clause 5.4.1;

2> else if the *Choice Indication* field indicates that the *Received Data Size* field is included:

3> perform the segmentation procedure using this information as specified in clause 5.4.3;

1> else if the device has no stored AS ID, and if CFA procedure has been performed in the current procedure:

2> if the *Choice Indication* field indicates that the *Data SDU* field is included:

3> set AS ID to the value indicated by the *AS ID* field and store the AS ID;

3> forward the upper layer data SDU to upper layers;

3> initiate the following D2R message transmission, as specified in clause 5.4.1.

###

### 5.4.3 Segmentation

Upon initiation of this segmentation procedure according to clause 5.4.1, or upon reception of *R2D Upper Layer Data Transfer* message containing the *Received Data Size* field, as specified in clause 5.4.2, after this segmentation procedure is initiated, the A-IoT MAC entity shall:

1> apply the received *D2R Scheduling Info*, if received from the *R2D Upper Layer Data Transfer* message containing the *Received Data Size* field;

1> generate the *D2R Upper Layer Data Transfer* message for this segment according to resource size given by the D2R TBS in the D2R Scheduling Info in the *R2D Upper Layer Data Transfer* as follows:

2> include the *SDU Length* field and set the *Data SDU* field to include the segment which starts from the (x+1)th byte of the original upper layer data SDU, where x=0 if the *Received Data Size* field is not included, otherwise x equals to the value indicated by the *Received Data Size* field;

2> if the segment is the last segment of the original upper layer data SDU:

3> set *More Data Indication* field to value 0;

3> if the size of the resulting MAC PDU including the segment is expected to be smaller than the resource size given by the D2R Scheduling Info:

4> include the *MAC Padding* field;

2> else:

3> set *More Data Indication* field to value 1;

1> instruct the physical layer to transmit the *D2R Upper Layer Data Transfer* message and indicate the L1 parameters to the physical layer as specified in clause 6.2.1.6.

## 5.5 Failure detection

Once the device transmitted the first *D2R Upper Layer Data Transfer* message after CBRA procedure, the A-IoT MAC entity shall monitor for *NACK Feedback* message until the device receives a *A-IoT Paging* message or *R2D Upper Layer Data Transfer* message addressed to the device (i.e., the device does not process *NACK Feedback* message after that).

Upon reception of *NACK Feedback* message, the A-IoT MAC entity shall:

1> for each *AS ID* field in the *NACK Feedback* message:

2> if the value indicated by the *AS ID* field is identical to the stored AS ID:

3> consider that the current procedure associated with the stored Transaction ID failed, upon which this procedure of processing *NACK Feedback* message ends.

Upon reception of *A-IoT Paging* message as specified in clause 5.2, the A-IoT MAC entity shall:

1> if CBRA procedure has not been considered as successful as specified in clause 5.3.1.3:

2> consider that the current procedure associated with the stored Transaction ID failed.

# 6 Protocol Data Units, formats and parameters

## 6.1 Protocol Data Units

### 6.1.1 General

An A-IoT MAC Protocol Data Unit (PDU) is the data unit format in which the A-IoT MAC message is encapsulated for transmission through the lower layer of the A-IoT protocol stack. An A-IoT MAC PDU is a bit string. The contents of each A-IoT MAC message are specified in clause 6.2 using tables to specify the fields in the message. In the tables, the most significant bit is the leftmost bit of the first line of the table, the least significant bit is the rightmost bit on the last line of the table, and more generally the bit string is to be read from left to right and then in the reading order of the lines. The bit order of each parameter field within a MAC PDU is represented with the first and most significant bit in the leftmost bit and the last and least significant bit in the rightmost bit.

An A-IoT MAC SDU is a bit string that is byte aligned (i.e., multiple of 8 bits) in length. A MAC SDU is included into a MAC PDU from the first bit onward.

A-IoT MAC Padding is placed at the end of the A-IoT MAC PDU if present. Presence and length of padding is implicitly based on TBS corresponding to the A-IoT MAC PDU.

The R2D message type represents the set of A-IoT MAC messages that are sent from the reader to the device on the R2D transport channel. The values of R2D message type are specified in Table 6.1-1.

Table 6.1-1: R2D Message Type

|  |  |
| --- | --- |
| R2D Message Type value | R2D message name |
| 000 | Reserved |
| 001 | *A-IoT Paging* message |
| 010 | *Access Trigger* message |
| 011 | *Random ID Response* message |
| 100 | *R2D Upper Layer Data Transfer* message |
| 101 | *NACK Feedback message* |
| 110 | Reserved |
| 111 | Reserved |

The D2R message type is the set of A-IoT MAC messages that are sent from the device to the reader on the D2R transport channel. The D2R message names are listed in Table 6.1-2.

Table 6.1-2: D2R Message type

|  |  |
| --- | --- |
| D2R Message Type value | D2R message name |
| N/A | *Access Random ID* message |
| N/A | *D2R Upper Layer Data Transfer* message |
|  |  |
|  |  |
|  |  |

*Editor’s Note: FFS D2R message type. Current running CR will capture no message type, but we can revisit this next meeting and also consider if any other bits are needed for the MAC header.* *.*

## 6.2 A-IoT MAC messages

### 6.2.1 R2D messages

#### 6.2.1.1 A-IoT Paging message

Figure 6.2.1.1-1 and 6.2.1.1-2 show the formats of the *A-IoT Paging* message.

The fields in this message are defined as follows:

- *R2D Message Type*: This field indicates the message type. See the Table 6.1-1. The length of the field is 3 bits.

- *R*: This field is a future extension indication. The length of the field is 1 bit, with the value set to 0 in this release.

- *RA Type* (*RT*): This field indicates CBRA (when set to 1) or CFA (when set to 0). The length of the field is 1 bit.

For CBRA, the following fields are further included:

- *Paging ID Presence Indication* (*PI*): This field indicates whether *Paging ID* and *Length of Paging ID* are present (when set to 1) or absent (when set to 0). The length of the field is 1 bit.

- *Paging ID Length*: This field indicates the length of the *Paging ID* field in unit of bit when *Paging ID* field is present. The length of the field is 8 bits.

- *Paging ID*: This field contains AIoT Identification Information (as defined in TS 23.369 [4], clause 5 and TS 23.003 [5]). .

- *Transaction ID*: This field associates an inventory procedure or command procedure as specified in TS 38.300 [3]. The length of the field is xxx bits.

- *Number of Access Occasions*: This field indicates the number of access occasions. The length of the field is 4 bits. The value 0 (i.e., 0000) indicates the number of access occasions is 20. The value 1 (i.e., 0001) indicates the number of access occasions is 21. The value 2 (i.e., 0010) indicates the number of access occasions is 22. And so on. The maximum number of access occasions is 215 when this field is set to 15 (i.e., 1111).

- *D2R Scheduling Info*: This field contains the physical layer parameters used for D2R transmission. The child fields are defined in clause 6.2.1.6.

- *Fill bits*: This field is of variable size, and can be used to pad for byte alignment (1-7 bits) and/or contain future extensions. In this release, the device shall ignore the values of this field.

For CFA, the following fields are further included:

- *Paging ID Length*: This field indicates the length of the *Paging ID* field in unit of bit. The length of the field is 8 bits.

- *Paging ID*: This field contains AIoT Identification Information (as defined in TS 23.369 [4], clause 5 and TS 23.003 [5]). .

- *D2R Scheduling Info*: This field contains the physical layer parameters used for D2R transmission. The child fields are defined in clause 6.2.1.6.

- *Fill bits*: This field is of variable size, and can be used to pad for byte alignment (1-7 bits) and/or contain future extensions. In this release, the device shall ignore the values of this field.

 ****

Figure 6.2.1.1-1: MAC PDU of *A-IoT Paging* message indicating CBRA

 ****

Figure 6.2.1.1-2: MAC PDU of *A-IoT Paging* message indicating CFA

*Editor’s Note: FFS the length of transaction ID.*

#### 6.2.1.2 *Access Trigger* message

Figure 6.2.1.2-1 shows the format of the *Access Trigger* message.

The field in this message is defined as follows:

- *R2D Message Type*: This field indicates the message type. See the Table 6.1-1. The length of the field is 3 bits.

 ****

Figure 6.2.1.2-1: MAC PDU of *Access Trigger* message

#### 6.2.1.3 *Random ID Response* message (Msg2 in CBRA)

Figure 6.2.1.3-1 shows the format of the *Random ID Response* message.

The fields in this message are defined as follows:

- *R2D Message Type*: This field indicates the message type. See the Table 6.1-1. The length of the field is 3 bits.

- *D2R Scheduling Info*: This field contains the physical layer parameters used for D2R transmission. The child fields are defined in clause 6.2.1.6.

- This message consists of one or multiple entries with the following fields included in each entry:

- *Echoed Random ID*: The length of the field is 16 bits.

- *AS ID Presence Indication* (*AI*): This field indicates whether a AS ID is assigned (when set to 1) for the corresponding *Echoed Random ID* or not (when set to 0). The length of the field is 1 bit.

- *Assigned AS ID*: This field provides the value of assigned AS ID which is 16 bits, when *AS ID Present* *Indication* field is set to 1.

*Editor’s Note: FFS how to include multiple echoed random ID(s) and D2R Scheduling Info (if also multiple).*

 ****

Figure 6.2.1.3-1: MAC PDU of *Random ID Response* message

#### 6.2.1.4 *R2D Upper Layer Data Transfer* message

Figure 6.2.1.4-1 and Figure 6.2.1.4-2 show the formats of the *R2D Upper Layer Data Transfer* message.

The fields in this message are defined as follows:

- *R2D Message Type*: This field indicates the message type. See the Table 6.1-1. The length of the field is 3 bits.

- *AS ID*: This field provides/indicates the value of AS ID. The length of the field is 16 bits.

- *D2R Scheduling Info*: This field contains the physical layer parameters used for D2R transmission. The child fields are defined in clause 6.2.1.6.

- *Choice Indication* (*CI*): This field indicates either *Data SDU* field is included (when set to 1) or *Received Data Size* field is included (when set to 0). The length of the field is 1 bit.

- *Data SDU*: This field contains the upper layer data. This field is of variable size.

- *Received Data Size*: This field is to indicate the number of bytes successfully received by the reader. This field is 7 bits.

 ****

Figure 6.2.1.4-1: MAC PDU of *R2D Upper Layer Data Transfer* message containing *Data SDU*

 ****

Figure 6.2.1.4-2: MAC PDU of *R2D Upper Layer Data Transfer* message containing *Received Data Size*

#### 6.2.1.5 *NACK Feedback* message

Figure 6.2.1.5-1 shows the format of the *NACK Feedback* message.

The field in this message is defined as follows:

- *R2D Message Type*: This field indicates the message type. See the Table 6.1-1. The length of the field is 3 bits.

- This message consists of one or multiple entries with the following field included in each entry:

- *AS ID*: This field indicates transmission failure for the device identified by this AS ID. The length of the field is 16 bits.

 ****

Figure 6.2.1.5-1: MAC PDU of *NACK Feedback* message

#### 6.2.1.6 *D2R Scheduling Info* field description

This clause defines the child fields contained in *D2R Scheduling Info* field. See the Table 6.2.1.6-1.

For the child fields except *Frequency Resource Indication*, the set of valid values is given in the table and configured in the form of an enumeration type. A field with *L* bits can provide 2*L* codepoints. For instance, if *L*=2, the first codepoint (i.e., 00) represents the first value within the value range. The second codepoint (i.e., 01) represents the second value within the value range. And so on. If the number *V* of valid values in the value range is less than 2*L*, the codepoints after the (*V*+1)th codepoint are not to be used in this release.

The *Time Resource Indication* field is only present in the *D2R Scheduling Info* field contained in *A-IoT Paging* message indicating CBRA. The *D2R TBS* field is absent in the *D2R Scheduling Info* field contained in *A-IoT Paging* message indicating CBRA, and present in the *D2R Scheduling Info* field contained in *A-IoT Paging* message indicating CFA, *Random ID Response* message, and *R2D Upper Layer Data Transfer* message. All other fields are present in the *D2R Scheduling Info* field contained in *A-IoT Paging* message, *Random ID Response* message, and *R2D Upper Layer Data Transfer* message.

After applying the *D2R Scheduling Info* field, the MAC entity derives the parameters (listed in the last column in Table 6.2.1.6-1) and indicates them to the physical layer. The MAC entity also derives some configurations to be used in MAC, e.g., X, , R2D TBS.

Table 6.2.1.6-1: Child fields of *D2R Scheduling Info* field

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Field name | Length | Value range | Description | Indicated L1 parameter in TS 38.291 [2] |
| *Time Resource Indication* | 1 bit | {1, 2} | The number of time domain resource of access occasions triggered by *A-IoT Paging* message or one *Access Trigger* message, i.e., X. | N/A |
| *Bit Duration* | 3 bits | {2, 1, 1/2, 1/4, 1/8, 1/16, 1/32, 1/96},where  | The duration in microseconds of each D2R bit. |  |
| *Frequency Resource Indication* | 8 bits | An 8-bit bitmap. The values of small frequency shift factor are {1, 2, 4, 8, 16, 32, 64, 128}.In the bitmap, the first/leftmost bit of the bitmap corresponds to the first value of small frequency shift factor, the second bit corresponds to the second value of small frequency shift factor, and so on. For each bit, value 0 indicates that the corresponding value is not allowed, while value 1 indicates that the corresponding value can be used. | This field indicates:* the set of potential small frequency shift factors when present in *A-IoT Paging* message for CBRA. Each small frequency shift factor corresponding to X access occasion(s). is the number of frequency domain resource of access occasions triggered by *A-IoT Paging* message or one *Access Trigger* message, i.e., the number of bits set to value 1. Or
* one value of small frequency shift factor when present in *A-IoT Paging* message for CFA, *R2D Upper Layer Data Transfer* message. Or
* one or multiple values of small frequency shift factor when present in *Random ID Response* message. A device determines its small frequency shift factor value for the following D2R transmission based on its order of *Echoed Random ID* field in the *Random ID Response* message.

Regarding different Bit Duration, only the following values can be indicated to 1 in the bitmap:* {1, 2, 4, 8, 16, 32, 64, 128}, when *Bit Duration* is configured to μs;
* {1, 2, 4, 8, 16, 32, 64}, when *Bit Duration* is configured to μs;
* {1, 2, 4, 8, 16, 32}, when *Bit Duration* is configured to μs;
* {1, 2, 4, 8, 16}, when *Bit Duration* is configured to μs;
* {1, 2, 4, 8}, when *Bit Duration* is configured to μs;
* {1, 2, 4}, when *Bit Duration* is configured to μs;
* {1, 2}, when *Bit Duration* is configured to μs;
* {1}, when *Bit Duration* is configured to μs.
 | associated to the selected access occasion or configured resource for D2R transmission |
| *Block Repetition number* | 1 bit | {1, 2} | The block repetition number. |  |
| *Channel Coding Indicator* | 1 bit | {*FEC*, *no FEC*} | The channel coding indicator. |  |
| *Interval Bits* | 2 bits | {S\*48, S\*96, S\*168, S\*240}S is a scale factor, and equals to:* 1, when *Bit Duration* is configured to μs;
* 2, when *Bit Duration* is configured to μs;
* 4, when *Bit Duration* is configured to μs;
* 8, when *Bit Duration* is configured to μs;
* 16, when *Bit Duration* is configured to μs;
* 32, when *Bit Duration* is configured to μs;
* 64, when *Bit Duration* is configured to μs;
* 192, when *Bit Duration* is configured to μs.
 | The interval in bits for D2R midamble insertion. |  |
| *Sequence Length Indicator* | 1 bit | {*short*, *long*} | Sequence length indicator for D2R preamble/midamble. |  |
| *Additional Midamble Indicator* | 1 bit | {*absent*, *present*} | Additional D2R midamble insertion indicator. |  |
| *D2R TBS* | 7 bits | {1, 2, …, 124, 125}, i.e. integers from 1 to 125. | The D2R transport block size in bytes. |  |

**Do you have any big concern on the implementation in 6.2.1.6, and provide comments if any.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Field name/L1 parameter** | **Comments** |
| CATT | Interval Bits | It’s better to change the field description by:for D2R-midamble insertionRapp1: ok. |
| OPPO | Time Resource Indication | It is unclear whether this field is still needed (e.g. 1 reserved bit when this field is not needed) for the *D2R Scheduling Info* included in *Random ID Response* message and *R2D Upper Layer Data Transfer* message, or is always set to “1”.Rapp1: I think it’s clear from RAN1 agreement “Use 1 bit to indicate the value of X (X=1 or X=2) time domain resource(s) for Msg1 transmission(s).”. So paging message for CBRA will have this indication, but for other R2D message, there is no such indication, which is clarified in the third paragraph above the table. |
| OPPO | Frequency Resource Indication | We can clarify that when the value of NSFS equals to the number of bits set to “1”.Rapp1: thanks for the good point.  |
| NEC | *Bit Duration**Frequency Resource Indication* | The total size of bits indicating *Bit Duration* and *Frequency Resource Indication* is 11 bits in the draft running CR. However, the total size of bits needed to indicate *Bit Duration* and *Frequency Resource Indication* is 9 bits. It is because there are totally = 502 different cases where **9 bits is enough** to indicate all of them. It’s benefit to reduce signalling overhead. Following is an example on how to indicate *Bit Duration* and *Frequency Resource Indication* by 9 bits. Device can distinguish the bits for “bit duration” and the bits “Frequency Resource Indication” by identifying where is the first “1” in the “bit duration”&” Frequency Resource Indication” joint bitmap; after the first “1”, the remaining bits are for “ Frequency Resource Indication”.

|  |  |  |  |
| --- | --- | --- | --- |
| *Bit Duration* | 1 to 8 bits | {266.67, 133.33, 66.67, 33.33, 16.67, 8.33, 4.17, 1.39} | The duration in microseconds of each D2R bit:* 1-bit of ‘1’ indicates bit duration 266.67μs;
* 2-bits of ‘01’ indicates bit duration 133.33μs;
* 3-bits of ‘001’ indicates bit duration 66.67μs;
* 4-bits of ‘0001’ indicates bit duration 33.33μs;
* 5-bits of ‘00001’ indicates bit duration 16.67μs;
* 6-bits of ‘000001’ indicates bit duration 8.33μs;
* 7-bits of ‘0000001’ indicates bit duration 4.17μs;
* 8-bits of ‘00000001’ indicates bit duration 1.39μs;
 |
| *Frequency Resource Indication* | 8 to 1 bits | An 8-bit to 1-bit bitmap where the size of bitmap depends on bit duration. ~~The values of small frequency shift factor are {1, 2, 4, 8, 16, 32, 64, 128}.~~In the bitmap, the first/leftmost bit of the bitmap corresponds to the first value of small frequency shift factor, the second bit corresponds to the second value of small frequency shift factor, and so on. For each bit, value 0 indicates that the corresponding value is not allowed, while value 1 indicates that the corresponding value can be used. | This field indicates:* the set of potential small frequency shift factors when present in *A-IoT Paging* message for CBRA. Each small frequency shift factor corresponding to X access occasion(s). is the number of frequency domain resource of access occasions triggered by *A-IoT Paging* message or one *Access Trigger* message. Or
* one value of small frequency shift factor when present in *A-IoT Paging* message for CFRA, *R2D Upper Layer Data Transfer* message. Or
* one or multiple values of small frequency shift factor when present in *Random ID Response* message. A device determines its small frequency shift factor value for the following D2R transmission based on its order of *Echoed Random ID* field in the *Random ID Response* message.

Regarding different Bit Duration, ~~only the following~~ the size of bitmap and corresponding values are ~~can be indicated to 1 in the bitmap~~:* 8-bits bitmap indicating values {1, 2, 4, 8, 16, 32, 64, 128}, when *Bit Duration* is configured to 266.67μs;
* 7-bits bitmap indicating values {1, 2, 4, 8, 16, 32, 64}, when *Bit Duration* is configured to 133.33μs;
* 6-bits bitmap indicating values {1, 2, 4, 8, 16, 32}, when *Bit Duration* is configured to 66.67μs;
* 5-bits bitmap indicating values {1, 2, 4, 8, 16}, when *Bit Duration* is configured to 33.33μs;
* 4-bits bitmap indicating values {1, 2, 4, 8}, when *Bit Duration* is configured to 16.67μs;
* 3-bits bitmap indicating values {1, 2, 4}, when *Bit Duration* is configured to 8.33μs;
* 2-bits bitmap indicating values {1, 2}, when *Bit Duration* is configured to 4.17μs;
* 1-bit bitmap indicating values {1}, when *Bit Duration* is configured to 1.39μs.
 |

Rapp1: Thanks for the discussion and suggestion.Regarding the signalling overhead, I understand RAN1 has discussed some optimizations to reduce the signalling size, but there was no consensus. So in this CR review, I suggest we first capture RAN1 agreements in direct terms, which is easier for companies to digest. Then we can discuss the optimization if there is a big interest. |
| Sharp | *Time Resource Indication* | It is unclear yet what the value of X (i.e. the number of time resources) is when the “*Time Resource Indication*” field is absent in paging, or for scheduling of other D2R transmissions.Note that X is relevant for scheduling of any D2R transmission. For example, X is also referred to in the current description of “*Frequency Resource Indication*” field, which is used for all cases of D2R transmission scheduling.Hence we think there should be a general definition of X, independent of the “Time Resource Indication” field which might not be present.Rapp1: please see the third paragraph above the table.Sharp2: thank you for pointing us to the 3rd paragraph of the text above Table 6.2.1.6-1 (where presence of the *Time Resource Indication* field in paging is described), but our original comment was not about the clarity of presence / absence of the “*Time Resource Indication*” field. Our comment was instead about the value of X for a D2R transmission when “*Time Resource Indication*” does not exist in a corresponding R2D transmission. For example, it doesn’t seem to have been made clear in the running CR what the value of X is for a D2R transmission in CFA, or one carrying “MSG3”. Our understanding is that for all these cases (actually in any case when there is no explicit time resource indication), X=1, and this should be clarified in TS 38.391. Note the following (in particular the yellow highlighted sentence) was agreed in RAN1#120bis,

|  |
| --- |
| AgreementFor Msg 1 transmission determined by one R2D transmission triggering random access, support X=1 and X=2 time domain resource(s) for D2R transmission(s) for Msg1 only, where each D2R transmission for Msg1 occurs in one time domain resource of the X time domain resource(s) in Rel-19.All devices support the aboveNote: the impact of specification support (at least including signalling overhead) for X=2 to a reader supporting only X=1 should be minimizedOnly support X=1 time domain resource for D2R transmission for Msg3 in response to a PRDCH for Msg2 transmission. |

  |
| Sharp | *Bit Duration* | The values of bit duration (and corresponding chip duration) that occurred in RAN1 agreements, e.g. 266.67μs, were just approximate values for discussion purpose. They were never intended to be captured in the specs “as is”. See Table 7.1.2-3 of TS 38.291 for an example of how chip duration values that occurred in RAN1 agreements were captured in RAN1 specs.The bit duration (*Tb*) is equal to 4/*Btx,D2R* where *Btx,D2R* is the D2R bandwidth (as can be seen e.g. in section 3 of the feature lead summary R1-2504751, where the RAN1 agreed table for *Tb*, *Tchip*, and *R* were originated from). As an example, 266.67 μs is actually 4/(15x103) seconds, i.e. corresponding to a D2R bandwidth of 15 kHz.Therefore, considering that “*Bit Duration*” is “in microseconds”, “266.67” should be replaced by “4x106/(15x103)”, or something equivalent (for example, , where is defined in clause 4.2 of TS 38.291 as ), and so on.Rapp1: Thanks for the comments. In this CR review, the goal is to capture RAN1 agreed L1 parameter according to the LS. But if RAN1 make further update, of course we will align accordingly.Rapp2: After checking with TS 38.291 editor, he confirmed it’s true that the agreed values are actually convenient approximations to the precise values, and the precise values are captured in the RAN1 spec using as unit, e.g., table 7.1.2-3 for chip length. So, I made some changes as suggested by Sharp. Companies are welcome to check internally with RAN1 colleagues.Sharp2: thank you. Just two editorial comments regarding those changes: 1. for the definition of , instead of repeating the definition of in TS 38.391, we think it may be better to just make a reference to TS 38.291, i.e. “where ” ==> “where is defined in clause 4.2 of TS 38.291 [2]”.
2. as defined in TS 38.291 (as well as the one currently defined in Table 6.2.1.6-1 of the running CR) is unitless, so we think the unit “μs” needs to be added back to each value.

Rapp3: I understand is just a value, so we can define it in MAC instead of referring to RAN1 spec. The reason we use the same alphabet is to avoid any confusion.Sharp3: OK. Thanks. In the latest update, in some cases a space between a value and “μs” is missing, e.g. the following yellow-highlighted ones:{S\*48, S\*96, S\*168, S\*240}S is a scale factor, and equals to:* 1, when *Bit Duration* is configured to μs;
* 2, when *Bit Duration* is configured to μs;
* 4, when *Bit Duration* is configured to μs;
 |
| Qualcomm | Bit DurationFrequency Resource Indication | We have similar view as NEC. The total size of Bit Duration and Frequency Resource Indication can be reduced to save signalling overhead. Further, for CFA case, the total size of Bit Duration and Frequency Resource Indication can be further reduced since only one device is indicated with the Frequency Resource Indication (bitmap is not needed) |
| Apple | Frequency resource indication | The current description is confusing. What is the relationship of the three sub-bullets and what items are the “OR” phrase concatenate? And how “A device determines its small frequency shift factor value for the following D2R transmission based on its order of *Echoed Random ID* field in the *Random ID Response* message”? it is better to further clarify.  |
| Sharp3 | *Time Resource Indication* | Sharp3: it seems our comment provided in v09 for “Time Resource Indication” (tagged “Sharp2”) was somehow corrupted since v10 and was not noticed by the Rapporteur when creating v16.We are now copying the full history of that comment (including original Sharp comment from v05, Rapporteur response tagged “Rapp1” from v06 , and our followed-up comment tagged “Sharp2” from v09), below. Sorry for any inconvenience caused.It would be much appreciated if the Rapporteur could respond to our comment tagged “Sharp2” below. Thanks!It is unclear yet what the value of X (i.e. the number of time resources) is when the “*Time Resource Indication*” field is absent in paging, or for scheduling of other D2R transmissions.Note that X is relevant for scheduling of any D2R transmission. For example, X is also referred to in the current description of “*Frequency Resource Indication*” field, which is used for all cases of D2R transmission scheduling.Hence we think there should be a general definition of X, independent of the “Time Resource Indication” field which might not be present.Rapp1: please see the third paragraph above the table.Sharp2: thank you for pointing us to the 3rd paragraph of the text above Table 6.2.1.6-1 (where presence of the *Time Resource Indication* field in paging is described), but our original comment was not about the clarity of presence / absence of the “*Time Resource Indication*” field. Our comment was instead about the value of X for a D2R transmission when “*Time Resource Indication*” does not exist in a corresponding R2D transmission. For example, it doesn’t seem to have been made clear in the running CR what the value of X is for a D2R transmission in CFA, or one carrying “MSG3”. Our understanding is that for all these cases (actually in any case when there is no explicit time resource indication), X=1, and this should be clarified in TS 38.391. Note the following (in particular the yellow highlighted sentence) was agreed in RAN1#120bis,

|  |
| --- |
| AgreementFor Msg 1 transmission determined by one R2D transmission triggering random access, support X=1 and X=2 time domain resource(s) for D2R transmission(s) for Msg1 only, where each D2R transmission for Msg1 occurs in one time domain resource of the X time domain resource(s) in Rel-19.All devices support the aboveNote: the impact of specification support (at least including signalling overhead) for X=2 to a reader supporting only X=1 should be minimizedOnly support X=1 time domain resource for D2R transmission for Msg3 in response to a PRDCH for Msg2 transmission. |

  |

### 6.2.2 D2R messages

#### 6.2.2.1 *Access* *Random ID* message (Msg1 in CBRA)

Figure 6.2.2.1-1 shows the format of the *Access Random ID* message.

The field in this message is defined as follows:

- *Random ID*: This field includes a 16-bit random number.



Figure 6.2.2.1-1: MAC PDU of *Access Random ID* message

#### 6.2.2.2 *D2R Upper Layer Data Transfer* message

Figure 6.2.2.2-1 shows the format of the *D2R Upper Layer Data Transfer* message.

The fields in this message are defined as follows:

- *More Data Indication*: This field indicates whether there are more upper layer data to be sent from the device (when set to 1) or not (when set to 0). This length of this field is 1 bit.

- *SDU* *Length*: This field indicates the length of the *Data SDU* field in the unit of byte. The length of this field is 7 bits.

- *Data SDU*: This field includes the upper layer data.

- *MAC Padding*: This field includes padding bits. This field is optional.



Figure 6.2.2.2-1: MAC PDU of *D2R Upper Layer Data Transfer* message

Annex <X> (informative):
Change history

|  |
| --- |
| Change history |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
|  |  |  |  |  |  |  |  |

Annex <X> (informative):

**Agreements**

Already captured

FFS parts/not captured

Stage2 related/not captured

``

1 Use as baseline the following message names, field names and definitions are to be used in A-IoT MAC:

− Message name: A-IoT Paging message, Access Trigger message, Random ID message, Random ID Response message, R2D Upper Layer Data Transfer message, D2R Upper Layer Data Transfer message.

− Field name: R2D Message Type, RA Type, Indication of Paging ID Presence, Length of Paging ID, Paging ID, Transaction ID, Number of Access Occasions, D2R Scheduling Info, Random ID, Echoed Random ID, AS ID, Assigned AS ID, More Data Indication, SDU Length, MAC Padding, Received Data Size.

− Definitions:

o Access occasion: A time-frequency resource for device(s) to transmit Msg1 (i.e., the Random ID message) during a CBRA procedure.

o AS ID: The AS layer identifier to address the specific device for R2D reception and D2R scheduling

2 One bit indication is needed for each echoed random ID in Msg2 to indicate whether AS ID is present (i.e., assigned by reader) for this random ID.

3 NACK feedback is defined as an explicit message (i.e. new message type). AS ID(s) is/are included to indicate the failure for given device(s). Multiplexing of NACK feedback is supported in one message

4 Assume two transport channels are introduced between A-IoT MAC and PHY. One is for R2D, and the other is for D2R. Neither logical channel concept nor SAP is defined for the interface between A-IoT MAC and upper layers.

**Agreements on parallel service request**

1. Rel-19 devices are not expected to receive parallel service request for overlapping reader scenario based on network implementation. Capture this in stage 2 specification.
2. The Rel-19 device always responds to the new service indicated by the received paging message applicable for that device. Capture this in stage 3 specification.
3. Send LS to RAN3 to notify them of agreements 1 and 2
4. Parallel service request for overlapping reader scenario can be addressed in Rel-20

**Agreements on paging**

1. For CFRA, as a baseline the fields related to the transaction ID, indication of paging ID present/absent and number of access occasions are absent. FFS on the need for the transaction ID for command case.
2. For CFRA, the device always responds to paging regardless of transaction ID (if we put a transaction ID) (i.e. as long as it is addressed to the corresponding device).
3. To ensure forward compatibility for paging with multiple identifiers, introduce at least one R field. FFS if more than one R bit is required.
4. Rel-19 devices would ignore the content of future release instead of ignoring the whole paging message.
5. Issue (1-4) For number of access occasions introduce exponential way, 4 bits, value range FFS

**Agreements**

1. For Msg1 resource selection procedure capture as guidance the countdown behaviour in the MAC specification (use TP in [R2-2503952](file:///C%3A%5CUsers%5Cpanidx%5COneDrive%20-%20InterDigital%20Communications%2C%20Inc%5CDocuments%5C3GPP%20RAN%5CTSGR2_130%5CDocs%5CR2-2503952.zip)). Capture a NOTE that other implementation are allowed. X, Y will be signalled by paging message
2. The start of the first set of MSG1 resources is indicated by Paging message directly instead of the new R2D trigger messages. R2D trigger message is not sent in CFRA procedure. Come back if RAN1/4 sees any issues. Send LS to RAN1/RAN4
3. FFS R2D byte alignment dependent on TBS size discussion

|  |
| --- |
| Agreements on RA1 Exclude the option of MSG2 transmission and any retransmission of MSG2 happens within a predefined time window (based on timer)2 A device expecting MSG2 assumes CBRA failure if its MSG2 is not received before a boundary, where the boundary can be further downselected between option B and C below. A device receiving MSG2 within this boundary transmits MSG3. The device does not process MSG2 (re)transmission received after the boundary. * Option B – the boundary is the reception of either the next R2D trigger message or the subsequent paging message
* Option C – the boundary is the reception of either the kth R2D trigger message or the subsequent paging message (K is FFS)
* Option A (the boundary being the subsequent paging only) is excluded.

 For option C, further discuss in terms of complexity at the device vs reader flexibility.3 Including frequency index along with RN16 in MSG2 to reduce collisions of MSG1 between different devices is feasible. FFS Discuss further whether to include it.**Agreements on NACK reception:**1. After MSG3 transmission, upon receiving NACK with its AS ID before subsequent paging or command addressed to this device from the reader, device determines it will perform re-access. FFS how to specify.

**Agreements on RN16/AS ID maintainance:**1. Confirm a device is not expected to maintain both AS ID and RN16. After msg2 reception, RN16 becomes AS ID, if new AS ID was not assigned by reader.

This implies that the reader cannot change AS ID and RN16 pair across message 2 retransmission. How to capture device behavior is FFS |

**Agreements**

1. R2D message scheduling non-first segment (re)transmission does not include upper layer command.
2. For the first segment and unsegmented packet (re)transmission, the “offset” indicator in R2D is not present.
3. This implies that the R2D message will either have command or offset (but not both). FFS whether we define two message types or one message type with optional fields.

**Agreements**

1. The device is expected to send a MAC response to the reader in the D2R occasion. The MAC response contains the NAS message if available at the D2R occasion. If there is no NAS message available to transmit at the D2R occasion then the response contains MAC with 0 SDU and padding as needed.
2. Send LS to CT1 to inform the agreement 1 to CT1 and explain that we have an issue with delayed NAS write success response. RAN2 would prefer that this is handled by CT1 (and give the example of sending NAS response upon successful reception of write command). Ask if this can be handled by CT1

**Agreement on MAC PDU format**

1. A mandatory length field directly indicates the length of D2R data MAC SDU to support varying lengths of D2R data. The size of length field is 7-bit in bytes.
2. The offset indication for transmission/retransmission of the segments after the first segment of a D2R message is 7-bit length in bytes. Segmented SDUs are also byte aligned.
3. FFS D2R message type. Current running CR will capture no message type, but we can revisit this next meeting and also consider if any other bits are needed for the MAC header
4. The length field inside MAC for SDU is not needed for R2D messages, assuming R2D MAC padding is not needed. FFS can come back if padding is needed depending on granularity of TBS (only if needed)

**Agreements**

- For CBRA, to avoid AS ID being occupied for unnecessary time and to keep alignment between reader and device on AS ID release, device can release AS ID upon receiving paging message with different transaction ID, no matter the paging message is for it or not. FFS for CFRA

- FFS for need for release message