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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
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Contents

Foreword

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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".

[6] 3GPP TS 33.369: "Security aspects of Ambient Internet of Things (AIoT) services for isolated private networks".

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].

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, and to identify a specific device in the *NACK Feedback* message.

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].

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
TBS	Transport Block Size
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].

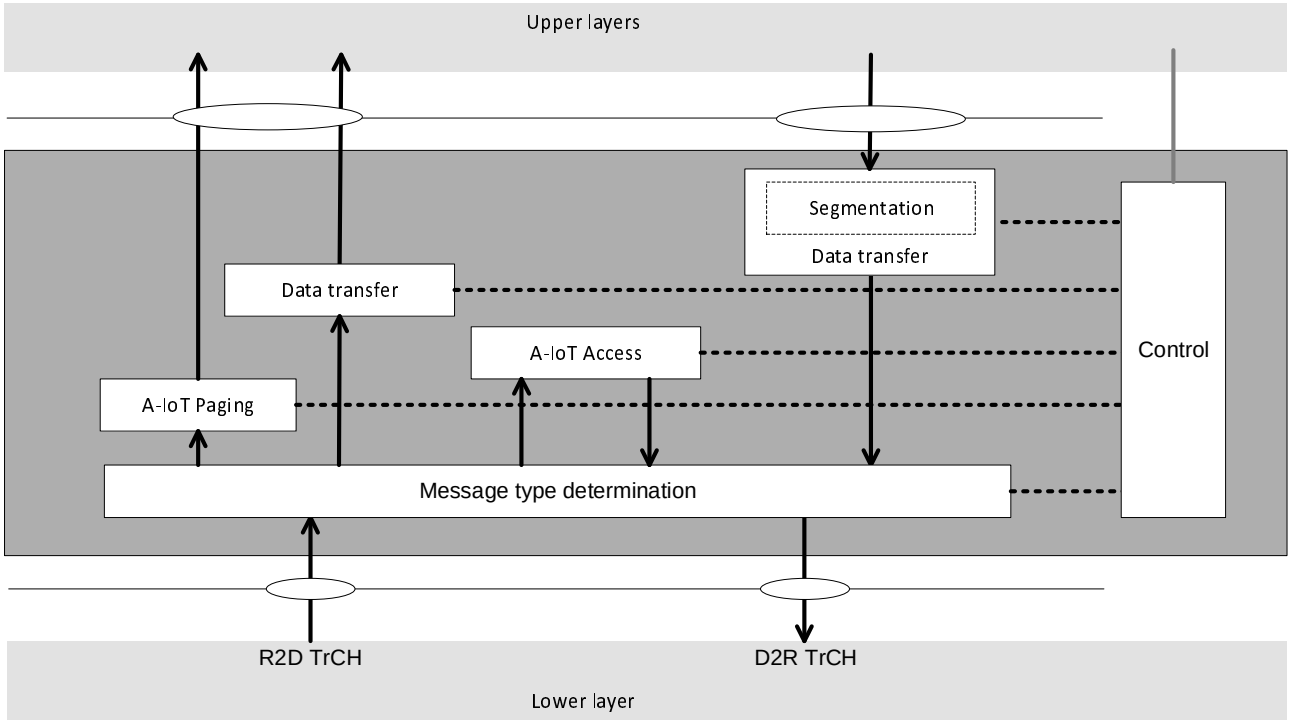

Figure 4.2-1: A-IoT MAC structure overview

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 and re-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 shall monitor 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 shall always monitor for the *A-IoT Paging* message, and determine whether the device is selected to initiate the access procedure.

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

1> if the *Access 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 it to the upper layers;

3> else:

4> forward the content 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 *Access 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 content 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 (CBRA) procedure is initiated due to a reception of *A-IoT Paging* message according to clause 5.2, the device shall randomly select an access occasion from the access occasion(s) configured in the *A-IoT Paging* message for D2R transmission of *Access Random ID* message, and the start of an access occasion set is indicated by the *A-IoT Paging* message or an *Access Trigger* message.

The A-IoT MAC entity shall:

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

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

1> select an access occasion corresponding to the random number *i*;

The access occasion can be selected according to a count-down behaviour. The count-down starts with the access occasion(s) triggered by the *A-IoT Paging* message, and continues with the access occasion(s) triggered by the subsequent *Access trigger* message(s), until *Access Random ID* message is transmitted or next *A-IoT Paging message* is received. For this, 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*N_{SFS} (where X and N_{SFS} 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 *A-IoT 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 each *Access Trigger* message:

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, upon which the procedure of processing any subsequent *Access Trigger* message for access occasion selection ends.

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: $0 \leq j < 2^{16}$;

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 *K* message(s) of the *Access Trigger* message or the next *A-IoT Paging* message or *R2D Upper Layer Data Transfer* message addressed to the device (i.e., the device shall not monitor for the *Random ID Response* message after that). The *K* is configured in the *A-IoT Paging* message.

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 ID entry 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; and

3> if the *Frequency Index* field is present (i.e., *Frequency Index Present Indication* is set to 1), and the small frequency shift factor indicated by the *Frequency Index* field matches the value of the small frequency shift factor used for the transmission of *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 *Echoed Random ID* field and store the AS ID;

4> initiate the D2R message transmission as specified in clause 5.4.2, upon which the procedure of processing this *Random ID Response* message ends;

1> else:

2> for each ID entry 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 5.4.2, upon which the procedure of processing this *Random ID Response* message ends.

5.3.2 Contention-Free Access procedure

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

1> initiate the D2R message transmission as specified in clause 5.4.2.

5.4 A-IoT upper layer data procedure

5.4.1 General

The purpose of this procedure is for a device to transmit or receive upper layer data.

5.4.2 D2R message transmission

Upon initiation of the procedure corresponding to the A-IoT access procedure as specified in clause 5.3 or reception of an *R2D Upper Layer Data Transfer* message which contains either the *Data SDU* field or the *Received Data Size* field set to 0, the A-IoT MAC entity shall:

1> apply the *D2R Scheduling Info* field, received in the *A-IoT Paging* message with *Access Type* set to CFA or in the *Random ID Response* message or in the *R2D Upper Layer Data Transfer* message containing either the *Data SDU* field or the *Received Data Size* field set to 0, whichever initiated the procedure;

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* field in the *D2R Scheduling Info* field:

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

4> include the *D2R Message Type* field;

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* field in the *D2R Scheduling Info* field:

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* field in the *D2R Scheduling Info* field):

3> initiate the segmentation procedure for the upper layer data SDU as specified in clause 5.4.4;

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> include the *D2R Message Type* field;

3> set the *More Data Indication* field as follows:

4> if the upper layer data is not available yet due to processing delay:

5> set the *More Data Indication* field to 1;

4> else (i.e., the upper layers indicate there is no upper layer data at all):

5> set the *More Data Indication* field to 0;

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

3> if the size of the resulting MAC PDU including no upper layer data is smaller than the resource size given by the *D2R TBS* field in the *D2R Scheduling Info* field:

4> 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 inventory response.

5.4.3 R2D message reception

Upon reception of an *R2D Upper Layer Data Transfer* message, 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 (i.e., *CI* field set to 1):

3> forward the upper layer data SDU in the *Data SDU* field to upper layers;

3> initiate the following D2R message transmission, as specified in clause 5.4.2;

2> else if the *Choice Indication* field indicates that the *Received Data Size* field is included (i.e., *CI* field set to 0):

3> if the *Received Data Size* field is set to 0:

4> initiate the D2R message transmission procedure as specified in clause 5.4.2;

3> else:

4> initiate the D2R segmentation procedure using this information as specified in clause 5.4.4;

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 (i.e., *CI* field set to 1):

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 in the *Data SDU* field to upper layers;

3> initiate the following D2R message transmission, as specified in clause 5.4.2;

2> else if the *Choice Indication* field indicates that the *Received Data Size* field is included (i.e., *CI* field set to 0), and the *Received Data Size* field is set to 0:

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

3> initiate the D2R message transmission procedure as specified in clause 5.4.2.

5.4.4 D2R segmentation

Upon initiation of this D2R segmentation procedure according to clause 5.4.2, or upon reception of *R2D Upper Layer Data Transfer* message containing the *Received Data Size* field set to a non-zero value, as specified in clause 5.4.3, after this segmentation procedure is initiated, the A-IoT MAC entity shall:

1> if the procedure is initiated upon the reception of *R2D Upper Layer Data Transfer* message containing the *Received Data Size* field set to a non-zero value:

2> apply the received *D2R Scheduling Info* field, received in the *R2D Upper Layer Data Transfer* message;

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

2> include the *D2R Message Type* field;

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 smaller than the resource size given by the *D2R TBS* field in the *D2R Scheduling Info* field:

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

5.5.1 General

The purpose of this procedure is to determine the failure cases.

5.5.2 Detection of data transmission failure

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 any *A-IoT Paging* message or *R2D Upper Layer Data Transfer* message addressed to the device's stored AS ID (i.e., after reception of those messages, the device does not process *NACK Feedback* message for current procedure associated with the stored Transaction ID).

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

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

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

3> release 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.

5.5.3 Detection of failure related to access procedure

The A-IoT MAC entity shall:

1> if CBRA procedure has been initiated but not considered as successful as specified in clause 5.3.1; and

1> upon reception of *A-IoT Paging* message, 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 rules

An A-IoT MAC Protocol Data Unit (PDU) is the data unit format in which an A-IoT MAC message is encapsulated for transmission through the lower layer of the A-IoT protocol stack. The structure of an A-IoT MAC message, which serves as the payload of the MAC PDU, is defined as a sequence of fields, each with strictly specified properties. The field used in text references is in the *italic font style* for distinction in this specification.

The presence of each field, whether it is optional or mandatory, shall be explicitly specified.

- If a field is optionally present, its presence or absence is typically indicated by a one-bit Optional Indicator Field. A single Optional Indicator Field may also apply to a group of optional fields. If a field is defined as the final element in a message, its presence or absence may be implicitly determined based on the remaining size after packing all prior fields, without an explicit Optional Indicator Field.
- A field that is mandatory shall always be present in the message. There is no associated indicator for its presence.

The length of each field shall be explicitly specified.

- A field of fixed length has a predefined, constant size, which is explicitly specified in the specification.
- If a field is of variable length, its length is typically determined by a separate Length Indicator Field. The Length Indicator Field is a fixed-length field that specifies the size, in bits or bytes, of the associated variable-length field. If a variable-length field is defined as the final element in a message, its length may be implicitly determined without an explicit Length Indicator Field, by calculating the difference between the total message length and the aggregate length of all preceding fields.

The value of a field is interpreted through a code point mapping, unless specified otherwise. A field with L bits can provide 2^L codepoints which are mapped sequentially to its candidate value range. 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 MAC PDU is assembled by concatenating all mandatory and conditionally present fields into the message, which is then delivered to the physical layer within a Transport Block of size TBS. For a D2R message, a MAC Padding Field may be present, if the total number of bytes used is less than the TBS after including all mandatory and indicated optional fields.

An A-IoT MAC PDU is a bit string that is byte aligned (i.e., multiple of 8 bits) in length, except the *Access Trigger* message. 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. The contents of each A-IoT MAC message are specified in clause 6.2. As shown in the figures illustrating MAC PDU format for each A-IoT MAC message, the fields are assembled into the MAC PDU in a strict sequential order. The field that appears first is placed at the leftmost position of the MAC PDU. For each field, the most significant bit is the leftmost bit. In the figures, bit strings are represented by tables in which 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 same rules also apply to the child fields if defined for a field, unless specified otherwise.

6.1.2 Message types

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 R2D message names and the values of R2D message type are specified in Table 6.1.2-1.

Table 6.1.2-1: 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 and the values of D2R message type are listed in Table 6.1.2-2.

Table 6.1.2-2: D2R Message type

D2R Message Type value	D2R message name
N/A	Access Random ID message
00	D2R Upper Layer Data Transfer message
01	Reserved
10	Reserved
11	Reserved

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*: The length of the field is 3 bits. This field indicates the message type. See the Table 6.1.2-1.
- *R2D TBS*: The length of the field is 7 bits. This field indicates the TBS of this message. The value range is {1, 2, …, 124, 125} byte(s).
- *Security Parameter Present Indication* (*SPPI*): The length of the field is 1 bit. This field indicates whether *Security Parameter* field is present (when set to 1) or absent (when set to 0). In this release, this field is set to 1 according to TS 33.369 [6].
- *Security Parameter*: The length of the field is 128 bits if present. This field contains the parameter $RAND_{AIOT\_n}$ as specified in TS 33.369 [6].
- *Access Type* (*AT*): The length of the field is 1 bit. This field indicates CBRA (when set to 1) or CFA (when set to 0).

For CBRA, the following fields are further included:

- *Transaction ID*: The length of the field is 6 bits. This field associates an inventory procedure or command procedure as specified in TS 38.300 [3].
- *Paging ID Presence Indication* (*PIPI*): The length of the field is 1 bit. This field indicates whether *Paging ID* and *Length of Paging ID* fields are present (when set to 1) or absent (when set to 0).

- *Paging ID Length*: This field is optionally present, as indicated by *Paging ID Presence Indication* field. If present, the length of the field is 10 bits. This field indicates the length of the *Paging ID* field in unit of bits when *Paging ID* field is present.

- *Paging ID*: This field is optionally present, as indicated by *Paging ID Presence Indication* field. If present, this field is of variable length which is indicated by *Paging ID Length* field. This field contains AIoT Identification Information (as defined in TS 23.369 [4], clause 5 and TS 23.003 [5]).

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

- *D2R Scheduling Info*: The length of the field is 18 bits. This field contains the physical layer parameters used for D2R transmission. The child fields are defined in clause 6.2.1.6.

- *K*: The length of the field is 1 bit. This field indicates that the value *K* is 1 (when set to 0) or 4 (when set to 1) used for determining monitor window for *Random ID Response* message.

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

For CFA, the following fields are further included:

- *Paging ID Length*: The length of the field is 10 bits. This field indicates the length of the *Paging ID* field in unit of bit.

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

- *D2R Scheduling Info*: The length of the field is 24 bits. 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 MAC entity shall ignore the values of this field.

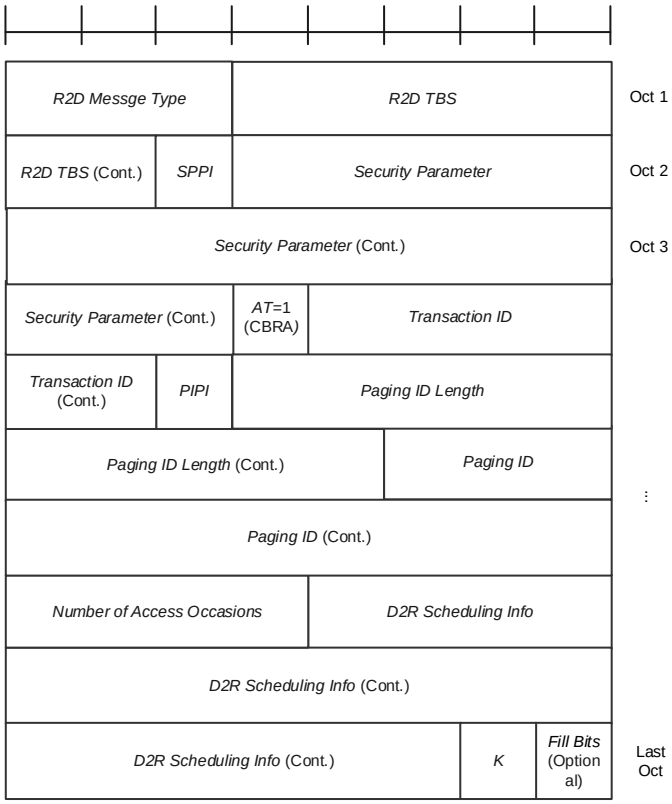

Figure 6.2.1.1-1: MAC PDU of *A-IoT Paging* message indicating CBRA

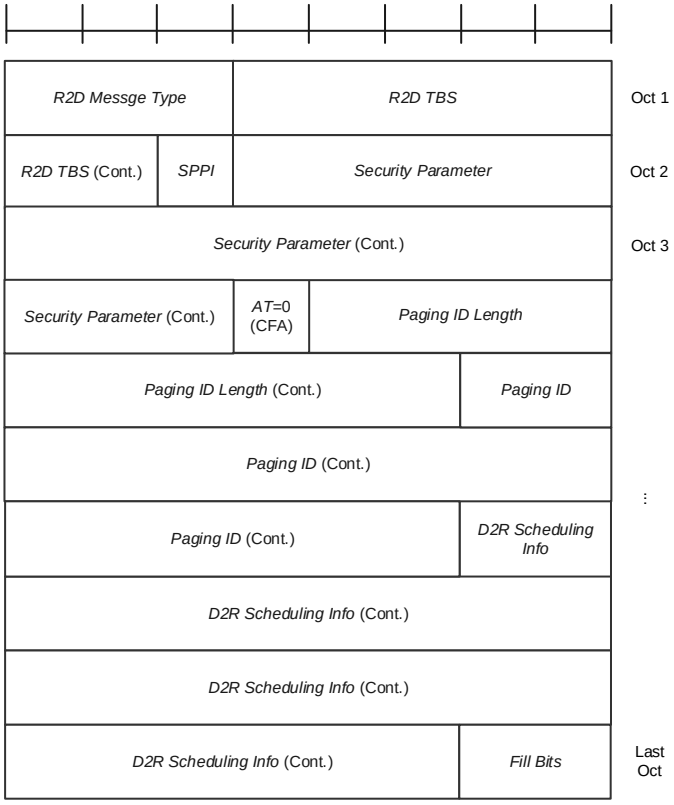

Figure 6.2.1.1-2: MAC PDU of *A-IoT Paging* message indicating CFA

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*: The length of the field is 3 bits. This field indicates the message type. See the Table 6.1.2-1.

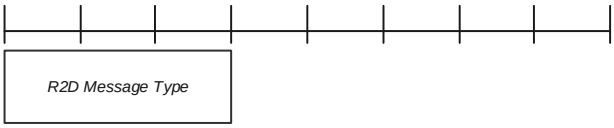

Figure 6.2.1.2-1: MAC PDU of Access Trigger message

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*: The length of the field is 3 bits. This field indicates the message type. See the Table 6.1.2-1.
- *R2D TBS*: The length of the field is 7 bits. This field indicates the TBS of this message. The value range is {1, 2, …, 124, 125} byte(s).
- *D2R Scheduling Info*: The length of the field is 24 bits. This field contains the physical layer parameters used for D2R transmission. The child fields are defined in clause 6.2.1.6.

- *Frequency Index Present Indication (FIPI)*: The length of the field is 1 bit. This field indicates whether the *Frequency Index* field is present (when set to 1) in each ID entry or not (when set to 0). This field applies to all ID entry(ies).
- This message includes an ID entry list, which consists of at most 8 ID entries with the following fields included in each ID entry:
  - *Frequency Index*: This field is optionally present, as indicated by *Frequency Index Present Indication* field. If present, the length of the field is 3 bits. This field indicates the small frequency shift factor value of the access occasion associated to the *Echoed Random ID* field. The value range is {1, 2, 4, 8, 16, 32, 64, 128}.
  - *Echoed Random ID*: The length of the field is 16 bits.
  - *AS ID Presence Indication* (*AIPI*): This field indicates whether an AS ID is assigned (when set to 1) for the corresponding *Echoed Random ID* field or not (when set to 0). The length of the field is 1 bit.
  - *Assigned AS ID*: This field is optionally present, as indicated by *AS ID Present Indication* field. The length of the field is 16 bits. If present, this field provides the value of assigned AS ID which is 16 bits.
- *Fill Bits*: This field is of variable size and is optionally present. It can be used to pad for byte alignment (1-7 bits).

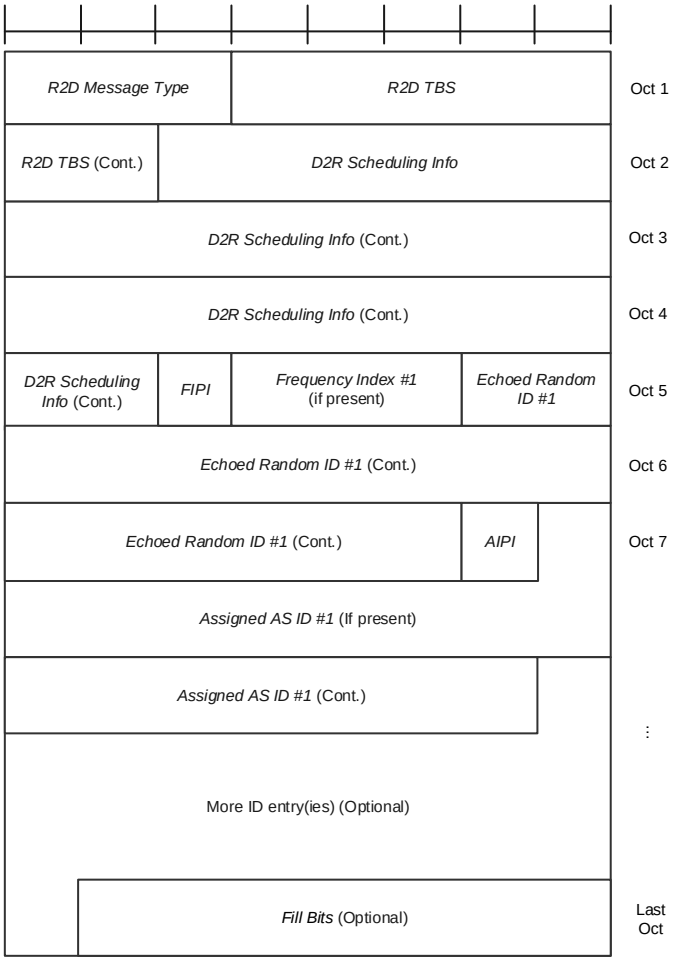

Figure 6.2.1.3-1: MAC PDU of *Random ID Response* message

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*: The length of the field is 3 bits. This field indicates the message type. See the Table 6.1.2-1.

- *R2D TBS*: The length of the field is 7 bits. This field indicates the TBS of this message. The value range is {1, 2, …, 124, 125} byte(s).
- *AS ID*: The length of the field is 16 bits. This field provides/indicates the value of AS ID.
- *D2R Scheduling Info*: The length of the field is 19 bits. 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.

When *Data SDU* field is included (when *CI* set to 1), the following fields are further included:

- *R*: The length of this field is 1 bit. There are 2 *R* fields. The 2 bits are set to 0, and the MAC entity ignores the value.
- *Data SDU*: This field is of variable size. This field contains the upper layer data.

When *Received Data Size* field is included (when *CI* set to 0), the following fields are further included:

- *R*: The length of this field is 1 bit. There are 3 *R* fields. The 3 bits are set to 0, and the MAC entity ignores the value.
- *Received Data Size*: This field is 7 bits. This field is to indicate the number of bytes successfully received by the reader. The value range is {0, 1, 2, …, 125} byte(s).

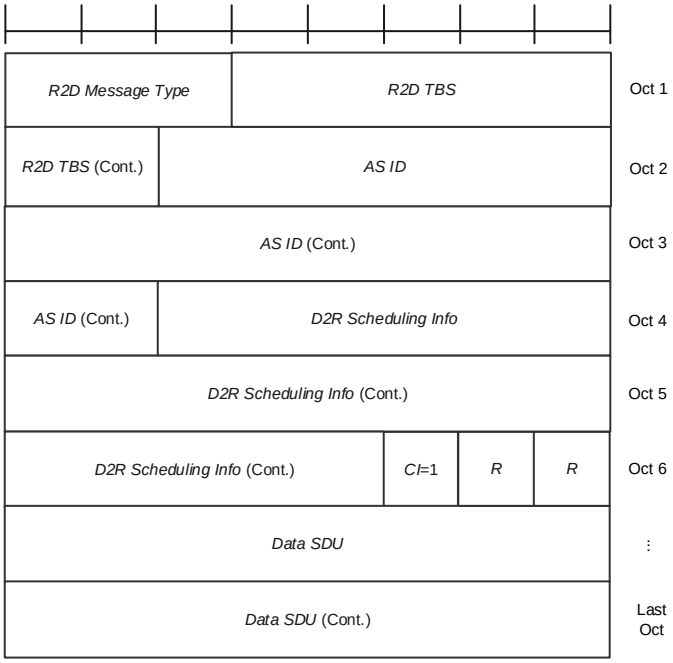

Figure 6.2.1.4-1: MAC PDU of *R2D Upper Layer Data Transfer* message containing *Data SDU*

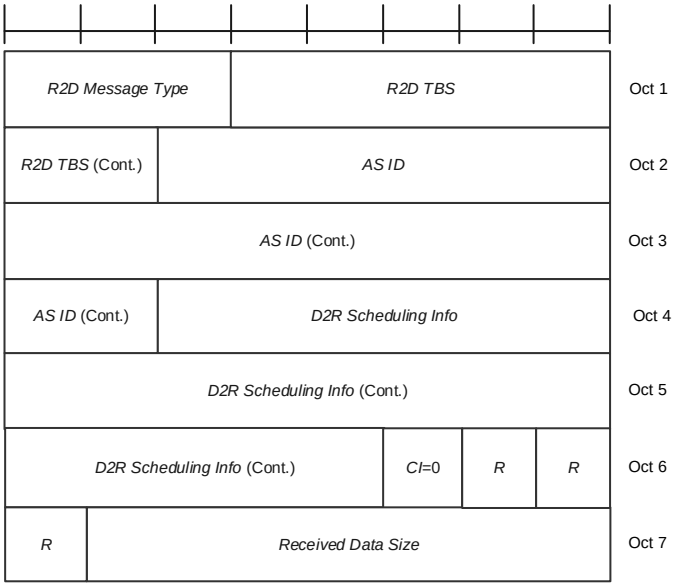

Figure 6.2.1.4-2: MAC PDU of *R2D Upper Layer Data Transfer* message containing *Received Data Size*

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*: The length of the field is 3 bits. This field indicates the message type. See the Table 6.1.2-1.
- *R2D TBS*: The length of the field is 7 bits. This field indicates the TBS of this message. The value range is {1, 2, …, 124, 125} byte(s).
- *R*: The length of this field is 1 bit. There are 6 *R* fields. The 6 bits are set to 0, and the MAC entity ignores the value.
- This message includes an AS ID entry list which consists of one or multiple AS ID entries with the following field included in each AS ID entry:
  - *AS ID*: The length of the field is 16 bits. This field indicates transmission failure for the device identified by this AS ID.

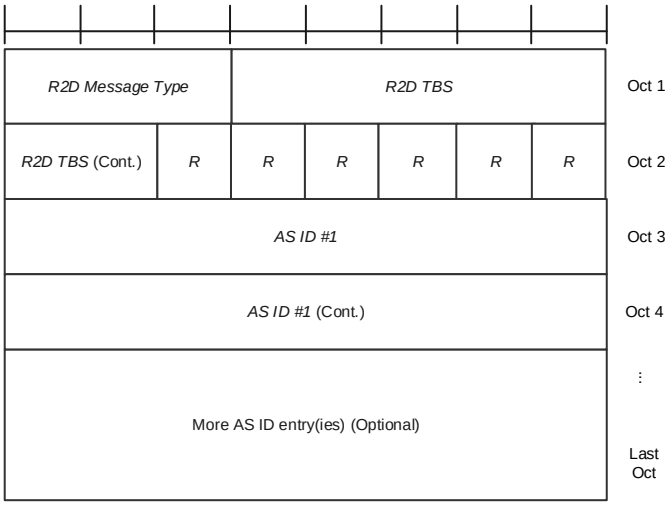

Figure 6.2.1.5-1: MAC PDU of *NACK Feedback* message

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.

The *Time Resource Indication* field is only present in the *D2R Scheduling Info* field contained in *A-IoT Paging* message indicating CBRA.

The *Frequency Resource Indication*$_{Broadcast}$ field is only present in the *D2R Scheduling Info* field contained in *A-IoT Paging* message and *Random ID Response* message. The *Frequency Resource Indication*$_{Unicast}$ field is only present in the *D2R Scheduling Info* field contained in *R2D Upper Layer Data Transfer* message.

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, N_{SFS}, D2R 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} × τ, where $\tau = 2 \times 10^6/15000$	The duration in microseconds of each D2R bit.	$T_{\text{bit}}^{\text{D2R}}$

Frequency Resource Indication$_{Broadcast}$	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 N_{SFS} 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). N_{SFS} 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. 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, i.e., the i-th device selects the i-th small frequency shift factor. 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 2τ μs; - {1, 2, 4, 8, 16, 32, 64}, when *Bit Duration* is configured to τ μs; - {1, 2, 4, 8, 16, 32}, when *Bit Duration* is configured to $\tau/2$ μs; - {1, 2, 4, 8, 16}, when *Bit Duration* is configured to $\tau/4$ μs; - {1, 2, 4, 8}, when *Bit Duration* is configured to $\tau/8$ μs; - {1, 2, 4}, when *Bit Duration* is configured to $\tau/16$ μs; - {1, 2}, when *Bit Duration* is configured to $\tau/32$ μs; - {1}, when *Bit Duration* is configured to $\tau/96$ μs.	R_{SFS} associated to the selected access occasion or configured resource for D2R transmission

Frequency Resource Indication$_{Unicast}$	3 bits	{1, 2, 4, 8, 16, 32, 64, 128}	This field indicates a value of small frequency shift factor when present in *R2D Upper Layer Data Transfer* 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 2τ µs - {1, 2, 4, 8, 16, 32, 64}, when *Bit Duration* is configured to τ µs; - {1, 2, 4, 8, 16, 32}, when *Bit Duration* is configured to $\tau/2$ µs; - {1, 2, 4, 8, 16}, when *Bit Duration* is configured to $\tau/4$ µs; - {1, 2, 4, 8}, when *Bit Duration* is configured to $\tau/8$ µs; - {1, 2, 4}, when *Bit Duration* is configured to $\tau/16$ µs - {1, 2}, when *Bit Duration* is configured to $\tau/32$ µs; - {1}, when *Bit Duration* is configured to $\tau/96$ µs	R_{SFS} associated to the configured resource for D2R transmission
Block Repetition Number	1 bit	{1, 2}	The block repetition number.	R_{block}
Channel Coding Indicator	1 bit	{*FEC*, *no FEC*}	The channel coding indicator.	R_{code}
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 2τ µs; - 2, when *Bit Duration* is configured to τ µs; - 4, when *Bit Duration* is configured to $\tau/2$ µs; - 8, when *Bit Duration* is configured to $\tau/4$ µs; - 16, when *Bit Duration* is configured to $\tau/8$ µs; - 32, when *Bit Duration* is configured to $\tau/16$ µs; - 64, when *Bit Duration* is configured to $\tau/32$ µs; - 192, when *Bit Duration* is configured to $\tau/96$ µs.	The interval in bits for D2R midamble insertion.	I_{bit}
Sequence Length Indicator	1 bit	{*short*, *long*}	Sequence length indicator for D2R preamble/midamble.	L_{amble}
Additional Midamble Indicator	1 bit	{*absent*, *present*}	Additional D2R midamble insertion indicator.	I_{add}
D2R TBS	7 bits	{1, 2, …, 124, 125}, i.e. integers from 1 to 125.	The D2R transport block size in bytes.	$N_{\text{TBS}}^{\text{D2R}}$

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*: The length of this field is 16 bits. This field includes a 16-bit random number.

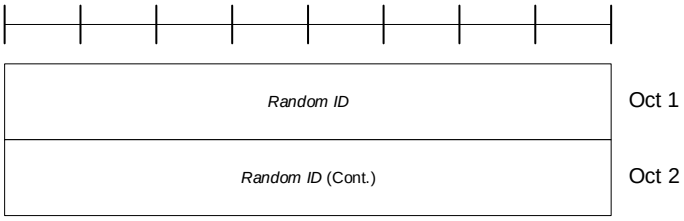

Figure 6.2.2.1-1: MAC PDU of *Access Random ID* message

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:

- *D2R Message Type*: The length of the field is 2 bits. This field indicates the message type. See the Table 6.1.2-2.
- *R*: The length of this field is 1 bit. There are 6 *R* fields. The 6 bits are set to 0.
- *More Data Indication (MDI)*: This length of this field is 1 bit. 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).
- *SDU Length*: The length of this field is 7 bits. This field indicates the length of the *Data SDU* field in the unit of byte. The value range is {0, 1, 2, …, 123} bytes.
- *Data SDU*: This field is of variable length as indicated by the *SDU Length* field. When the *SDU Length* field indicates 0, this field is absent. This field is to include the upper layer data.
- *MAC Padding*: This field is optional. If present, this field includes padding bits.

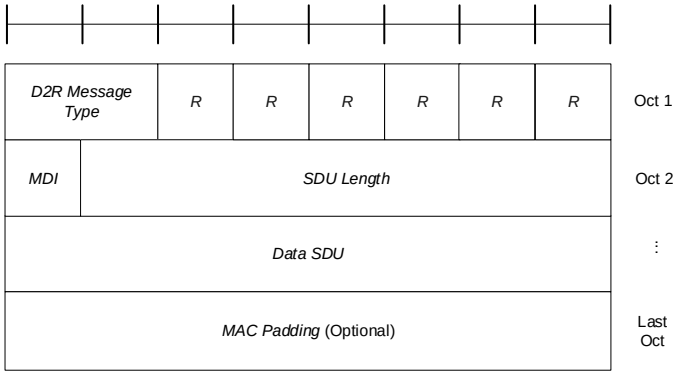

Figure 6.2.2.2-1: MAC PDU of *D2R Upper Layer Data Transfer* message

Annex A (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2025-03-28	RAN2#129 bis	R2-2502258	-	-	-	Skeleton of A-IoT MAC Protocol	0.01
2025-05-09	RAN2#130	R2-2503997	-	-	-	To capture the RAN2 agreements achieved before RAN2#130	0.0.2
2025-08-15	RAN2#131	R2-2505520	-	-	-	Updates based on the agreements achieved in RAN2#130	0.0.3
2025-09-05	RAN2#131	R2-2506559	-	-	-	Updates based on the agreements achieved in RAN2#131	0.1.0
2025-09-08	RAN2#131	R2-2506588	-	-	-	Clean version of R2-2506559	0.2.0
2025-09	RAN#109	RP-252530	-	-	-	Submitted to RAN for single-step approval	1.0.0
2025-09	RAN#109					Promoted to Rel-19	19.0.0
2025-12	RP-110	RP-253727	0001	2	F	Corrections to A-IoT MAC layer	19.1.0

History

Version	Date	Status
V19.0.0	October 2025	Publication
V19.1.0	February 2026	Publication