



**5G;
NR;
Ambient IoT Medium Access Control (MAC) protocol
(3GPP TS 38.391 version 19.0.0 Release 19)**



ReferenceRTS/TSGR-0238391 vj00

Keywords5G

ETSI

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
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Important notice

The present document can be downloaded from the
[ETSI Search & Browse Standards application](#).

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format on [ETSI deliver repository](#).

Users should be aware that the present document may be revised or have its status changed,
this information is available in the [Milestones listing](#).

If you find errors in the present document, please send your comments to
the relevant service listed under [Committee Support Staff](#).

If you find a security vulnerability in the present document, please report it through our
[Coordinated Vulnerability Disclosure \(CVD\)](#) program.

Notice of disclaimer & limitation of liability

The information provided in the present deliverable is directed solely to professionals who have the appropriate degree of experience to understand and interpret its content in accordance with generally accepted engineering or other professional standard and applicable regulations.

No recommendation as to products and services or vendors is made or should be implied.

No representation or warranty is made that this deliverable is technically accurate or sufficient or conforms to any law and/or governmental rule and/or regulation and further, no representation or warranty is made of merchantability or fitness for any particular purpose or against infringement of intellectual property rights.

In no event shall ETSI be held liable for loss of profits or any other incidental or consequential damages.

Any software contained in this deliverable is provided "AS IS" with no warranties, express or implied, including but not limited to, the warranties of merchantability, fitness for a particular purpose and non-infringement of intellectual property rights and ETSI shall not be held liable in any event for any damages whatsoever (including, without limitation, damages for loss of profits, business interruption, loss of information, or any other pecuniary loss) arising out of or related to the use of or inability to use the software.

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2025.
All rights reserved.

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the [ETSI IPR online database](#).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™**, **LTE™** and **5G™** logo are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM®** and the GSM logo are trademarks registered and owned by the GSM Association.

Legal Notice

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

The present document may refer to technical specifications or reports using their 3GPP identities. These shall be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between 3GPP and ETSI identities can be found at [3GPP to ETSI numbering cross-referencing](#).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Contents

Intellectual Property Rights	2
Legal Notice	2
Modal verbs terminology.....	2
Foreword.....	4
1 Scope	6
2 References	6
3 Definitions, symbols and abbreviations	6
3.1 Definitions	6
3.2 Abbreviations	6
4 General	7
4.1 Introduction	7
4.2 A-IoT MAC architecture	7
4.3 Services	7
4.3.1 Services provided to upper layers	7
4.3.2 Services expected from physical layer.....	7
4.4 Functions	8
5 A-IoT MAC procedures	8
5.1 General	8
5.2 A-IoT paging	8
5.3 A-IoT access procedure.....	9
5.3.1 Contention-Based Random Access procedure.....	9
5.3.1.1 Selection of access occasion for D2R transmission of <i>Access Random ID</i> message	9
5.3.1.2 Transmission of <i>Access Random ID</i> message	10
5.3.1.3 Reception of <i>Random ID Response</i> message	10
5.3.2 Contention-Free Access procedure	11
5.4 A-IoT upper layer data procedure	11
5.4.1 General.....	11
5.4.2 D2R message transmission	11
5.4.3 R2D message reception	12
5.4.4 D2R segmentation	12
5.5 Failure detection.....	13
5.5.1 General.....	13
5.5.2 Detection of data transmission failure	13
5.5.3 Detection of failure related to access procedure	13
6 Protocol Data Units, formats and parameters.....	13
6.1 Protocol Data Units	13
6.1.1 General.....	13
6.2 A-IoT MAC messages.....	14
6.2.1 R2D messages.....	14
6.2.1.1 <i>A-IoT Paging</i> message	14
6.2.1.2 <i>Access Trigger</i> message	16
6.2.1.3 <i>Random ID Response</i> message (Msg2 in CBRA)	16
6.2.1.4 <i>R2D Upper Layer Data Transfer</i> message.....	17
6.2.1.5 <i>NACK Feedback</i> message	19
6.2.1.6 <i>D2R Scheduling Info</i> field description	20
6.2.2 D2R messages.....	23
6.2.2.1 <i>Access Random ID</i> message (Msg1 in CBRA)	23
6.2.2.2 <i>D2R Upper Layer Data Transfer</i> message.....	23
Annex A (informative): Change history	25
History	26

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].

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.

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
TrCH

Transport Block Size
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].

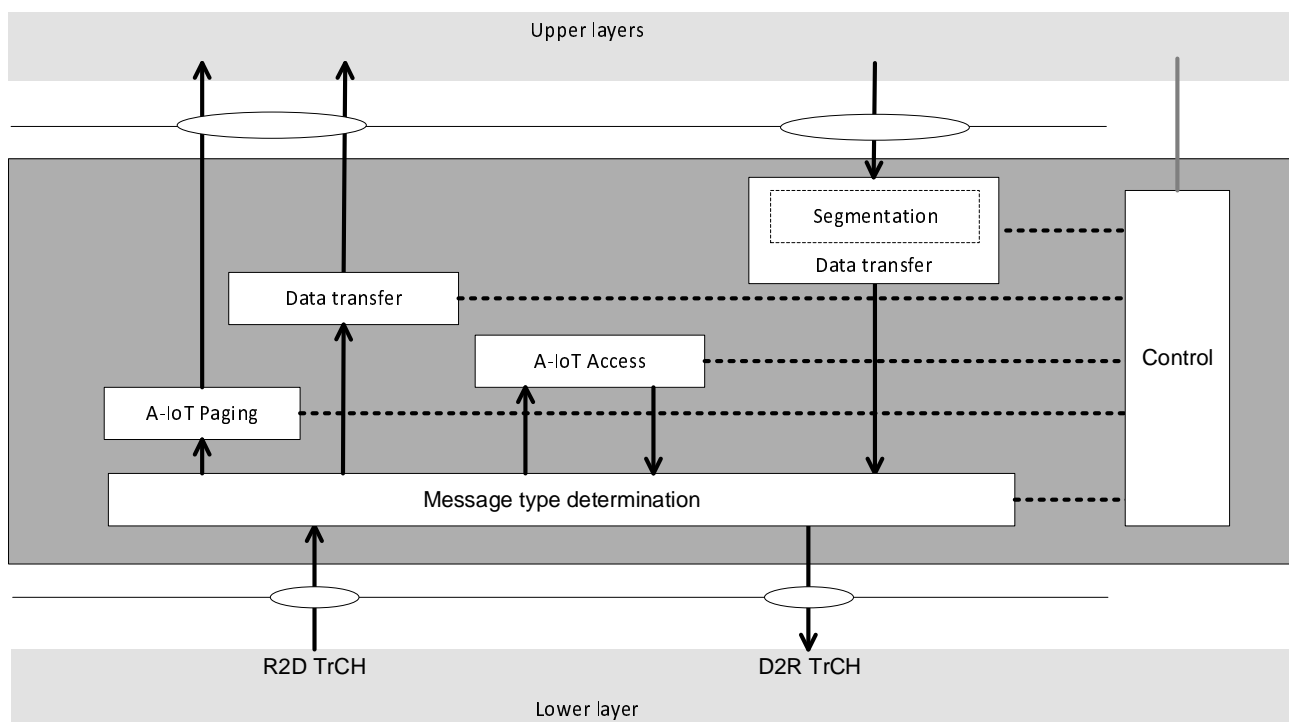


Figure 4.2-1: A-IoT MAC structure overview

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 always 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 *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 occasions configured in the *A-IoT Paging* message for D2R transmission of *Access Random ID* message, and the start of the access occasion may be provided by the *A-IoT Paging* message or a *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 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 behavior, which starts with the *A-IoT Paging* message, and continues with 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 $X \cdot N_{\text{SFS}}$ (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* $\geq m$):

- 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 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 *A-IoT Paging* message (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 5.4.1, 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 5.4.1, 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 5.4.1.

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 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*, 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 triggered the initiation of 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* 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> initiate the segmentation procedure for the upper layer data SDU as specified in 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> 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* in the *D2R Scheduling Info*:
 - 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:
 - 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.

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 not set to 0, as specified in clause 5.4.3, after this segmentation procedure is initiated, the A-IoT MAC entity shall:

- 1> apply the received *D2R Scheduling Info*, received in 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*, as follows:
 - 2> include the *SDU Length* field and set the *Data SDU* field to include the segment which starts from the $(x+1)^{\text{th}}$ 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* in 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

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 monitors 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 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 as specified in clause 5.3.1; and
- 1> upon reception of *A-IoT Paging* message; and
- 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 that is byte aligned (i.e., multiple of 8 bits) in length, except the *Access Trigger* message. 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 of D2R message if present. Presence and length of padding is determined 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 R2D message names and 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	<i>A-IoT Paging</i> message
010	<i>Access Trigger</i> message
011	<i>Random ID Response</i> message
100	<i>R2D Upper Layer Data Transfer</i> message
101	<i>NACK Feedback</i> 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.

Table 6.1-2: D2R Message type

D2R Message Type value	D2R message name
N/A	<i>Access Random ID</i> message
00	<i>D2R Upper Layer Data Transfer</i> 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*: This field indicates the message type. See the Table 6.1-1. The length of the field is 3 bits.
- *R2D TBS*: This field indicates the TBS of this message. The value can be {1, 2, ..., 124, 125} byte(s). The length of the field is 7 bits.
- *Access Type (AT)*: 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:

- *Transaction ID*: This field associates an inventory procedure or command procedure as specified in TS 38.300 [3]. The length of the field is 6 bits.
- *Paging ID Presence Indication (PIPI)*: This field indicates whether *Paging ID* and *Length of Paging ID* fields 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 bits when *Paging ID* field is present. If present, the length of the field is 8 bits.
- *Paging ID*: If present, this field contains A-IoT Identification Information (as defined in TS 23.369 [4], clause 5 and TS 23.003 [5]). This field is of variable length.

- *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 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*: This field contains the physical layer parameters used for D2R transmission. The child fields are defined in clause 6.2.1.6. The length of the field is 18 bits.
- *K*: 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. The length of the field is 1 bit.
- *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*: 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]). This field is of variable length.
- *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. The length of the field is 24 bits.
- *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.

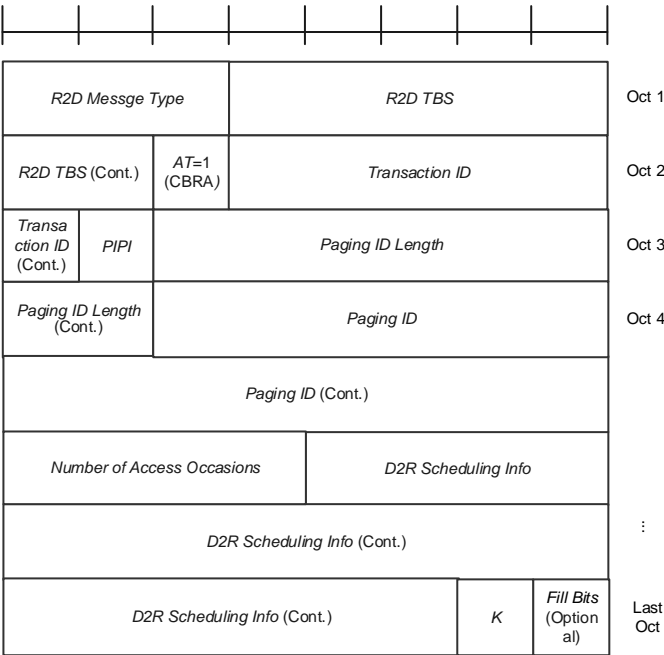


Figure 6.2.1.1-1: MAC PDU of A-IoT Paging message indicating CBRA

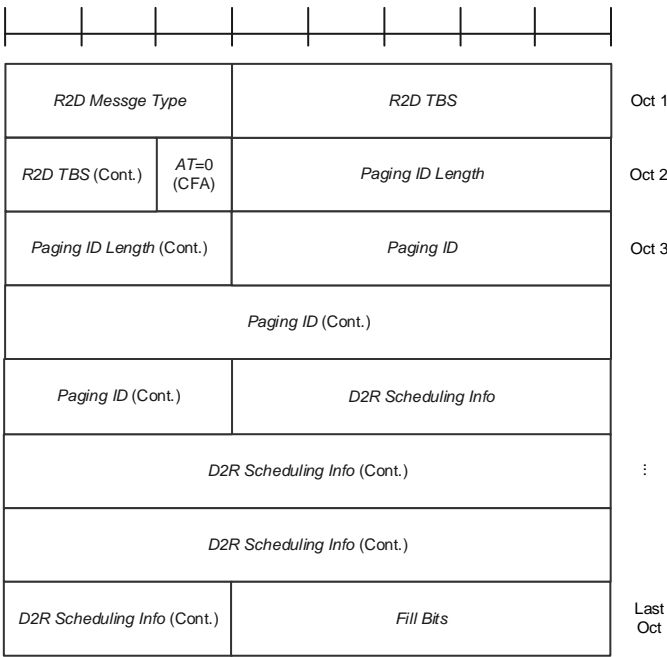


Figure 6.2.1.1-2: MAC PDU of A-IoT Paging message indicating CFA

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

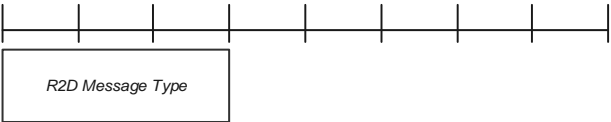


Figure 6.2.1.2-1: MAC PDU of Access Trigger message

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.
- R2D TBS: This field indicates the TBS of this message. The value can be {1, 2, ..., 124, 125} byte(s). The length of the field is 7 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. The length of the field is 24 bits.
- Frequency Index Present Indication (FIPI): 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). The length of the field is 1 bit.
- 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 indicates the small frequency shift factor value of the access occasion associated to the *Echoed Random ID*. The first codepoint (i.e., 000) presents the first value in {1, 2, 4, 8, 16, 32, 64, 128}, the second codepoint (i.e., 001) presents the second value in {1, 2, 4, 8, 16, 32, 64, 128}, and so on. The length of the field is 3 bits.
- *Echoed Random ID*: The length of the field is 16 bits.
- *AS ID Presence Indication (AIP)*: 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.
- *Fill Bits*: This field is of variable size and is optionally present. It can be used to pad for byte alignment (1-7 bits).

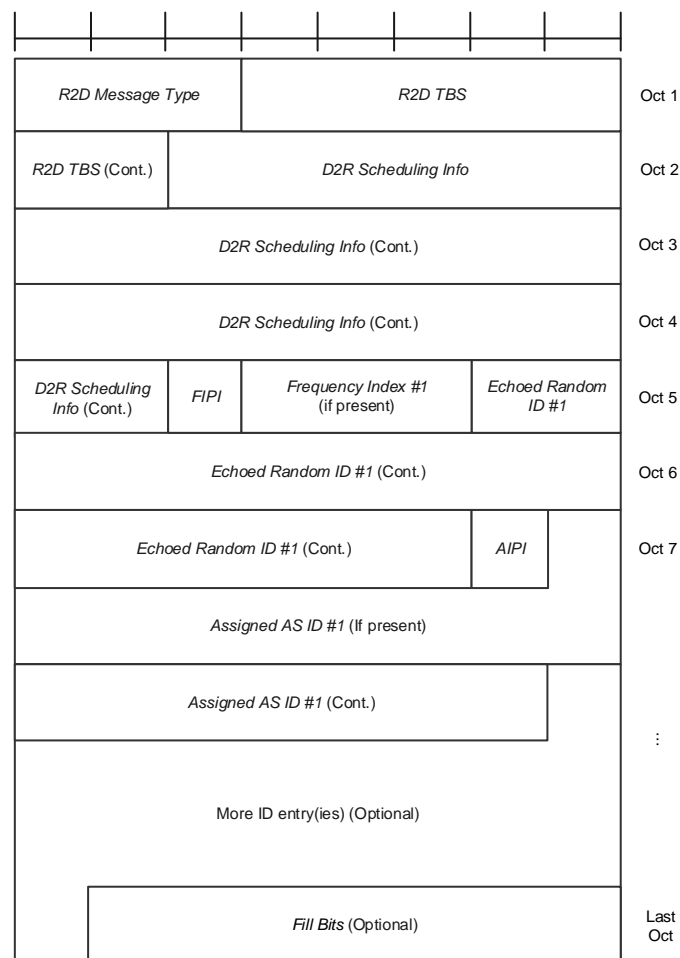


Figure 6.2.1.3-1: MAC PDU of *Random ID Response* message

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*: This field indicates the message type. See the Table 6.1-1. The length of the field is 3 bits.
- *R2D TBS*: This field indicates the TBS of this message. The value can be {1, 2, ..., 124, 125} byte(s). The length of the field is 7 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. The length of the field is 19 bits.
- *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 2 bits are set to 0, and the MAC entity ignores the value.
- *Data SDU*: This field contains the upper layer data. This field is of variable size.

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

- *R*: The 3 bits are set to 0, and the MAC entity ignores the value.
- *Received Data Size*: This field is to indicate the number of bytes successfully received by the reader. This field is 7 bits.

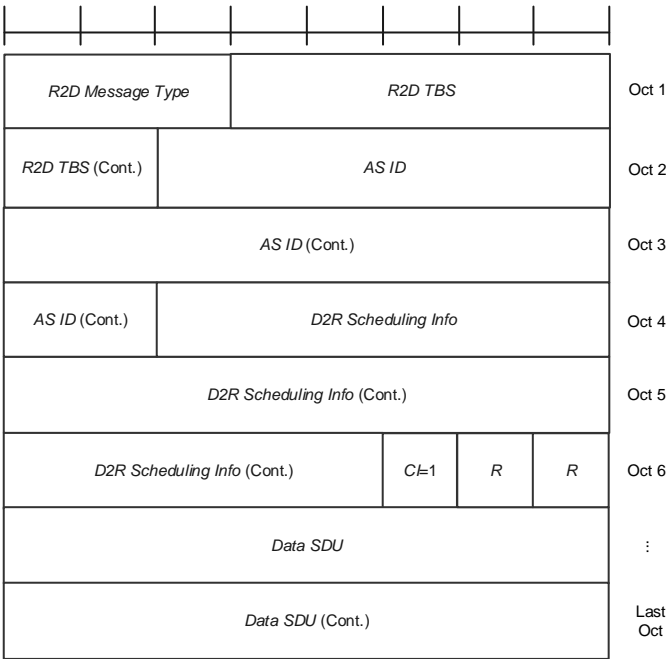


Figure 6.2.1.4-1: MAC PDU of *R2D Upper Layer Data Transfer* message containing *Data SDU*

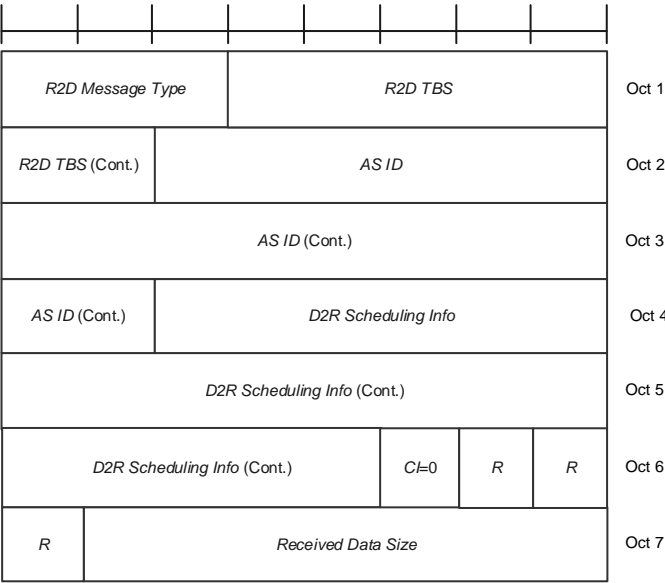


Figure 6.2.1.4-2: MAC PDU of *R2D Upper Layer Data Transfer* message containing *Received Data Size*

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.
- *R2D TBS*: This field indicates the TBS of this message. The value can be { 1, 2, ..., 124, 125 } byte(s). The length of the field is 7 bits.
- *R*: The 6 bits are set to 0, and the MAC entity ignores the value.
- This message include a 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*: This field indicates transmission failure for the device identified by this AS ID. The length of the field is 16 bits.

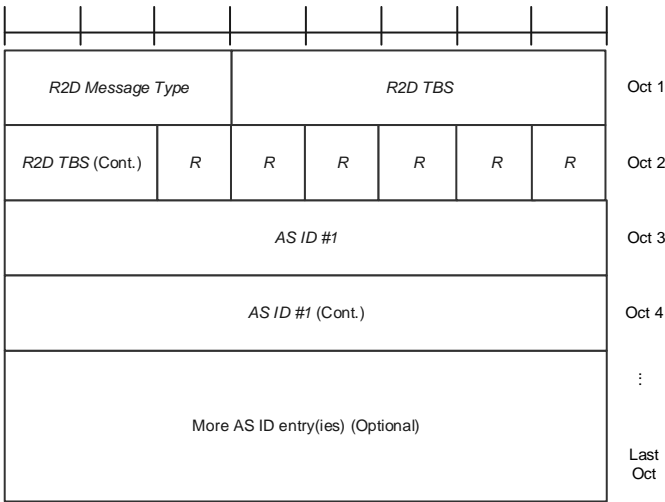


Figure 6.2.1.5-1: MAC PDU of *NACK Feedback* message

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 $(V+1)^{\text{th}}$ 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. 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. 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_{FS} , 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]
<i>Time Resource Indication</i>	1 bit	{1, 2}	The number of time domain resource of access occasions triggered by <i>A-LoT Paging</i> message or one <i>Access Trigger</i> message, i.e., X.	N/A
<i>Bit Duration</i>	3 bits	$\{2, 1, 1/2, 1/4, 1/8, 1/16, 1/32, 1/96\} \times \tau$, where $\tau = 2 \times 10^6 / 15000$	The duration in microseconds of each D2R bit.	$T_{\text{bit}}^{\text{D2R}}$
<i>Frequency Resource Indication</i> _{Broadcast}	8 bits	<p>An 8-bit bitmap.</p> <p>The values of small frequency shift factor are {1, 2, 4, 8, 16, 32, 64, 128}.</p> <p>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.</p>	<p>This field indicates:</p> <ul style="list-style-type: none"> - the set of N_{SFS} potential small frequency shift factors when present in <i>A-LoT Paging</i> 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 <i>A-LoT Paging</i> message or one <i>Access Trigger</i> message, i.e., the number of bits set to value 1. Or - one value of small frequency shift factor when present in <i>A-LoT Paging</i> message for CFA. Or - one or multiple values of small frequency shift factor when present in <i>Random ID Response</i> message. A device determines its small frequency shift factor value for the following D2R transmission based on its order of <i>Echoed Random ID</i> field in the <i>Random ID Response</i> message, i.e., the i-th device selects the i-th small frequency shift factor. <p>Regarding different Bit Duration, only the following values can be indicated to 1 in the bitmap:</p> <ul style="list-style-type: none"> - {1, 2, 4, 8, 16, 32, 64, 128}, when <i>Bit Duration</i> is configured to $2\tau\mu\text{s}$; - {1, 2, 4, 8, 16, 32, 64}, when <i>Bit Duration</i> is configured to $\tau\mu\text{s}$; - {1, 2, 4, 8, 16, 32}, when <i>Bit Duration</i> is configured to $\tau/2\mu\text{s}$; - {1, 2, 4, 8, 16}, when <i>Bit Duration</i> is configured to $\tau/4\mu\text{s}$; - {1, 2, 4, 8}, when <i>Bit Duration</i> is configured to $\tau/8\mu\text{s}$; - {1, 2, 4}, when <i>Bit Duration</i> is configured to $\tau/16\mu\text{s}$; - {1, 2}, when <i>Bit Duration</i> is configured to $\tau/32\mu\text{s}$; - {1}, when <i>Bit Duration</i> is configured to $\tau/96\mu\text{s}$. 	R_{SFS} associated to the selected access occasion or configured resource for D2R transmission

<i>Frequency Resource Indication</i> _{Unicast}	3 bits	{1, 2, 4, 8, 16, 32, 64, 128}	This field indicates a value of small frequency shift factor when present in <i>R2D Upper Layer Data Transfer</i> message.	R_{SFS} associated to the configured resource for D2R transmission
<i>Block Repetition number</i>	1 bit	{1, 2}	The block repetition number.	R_{block}
<i>Channel Coding Indicator</i>	1 bit	{FEC, no FEC}	The channel coding indicator.	R_{code}
<i>Interval Bits</i>	2 bits	{S*48, S*96, S*168, S*240}, S is a scale factor, and equals to: - 1, when <i>Bit Duration</i> is configured to 2τ μ s; - 2, when <i>Bit Duration</i> is configured to τ μ s; - 4, when <i>Bit Duration</i> is configured to $\tau/2$ μ s; - 8, when <i>Bit Duration</i> is configured to $\tau/4$ μ s; - 16, when <i>Bit Duration</i> is configured to $\tau/8$ μ s; - 32, when <i>Bit Duration</i> is configured to $\tau/16$ μ s; - 64, when <i>Bit Duration</i> is configured to $\tau/32$ μ s; - 192, when <i>Bit Duration</i> is configured to $\tau/96$ μ s.	The interval in bits for D2R midamble insertion.	I_{bit}
<i>Sequence Length Indicator</i>	1 bit	{short, long}	Sequence length indicator for D2R preamble/midamble.	L_{amble}
<i>Additional Midamble Indicator</i>	1 bit	{absent, present}	Additional D2R midamble insertion indicator.	I_{add}
<i>D2R TBS</i>	7 bits	{1, 2, ..., 124, 125}, i.e. integers from 1 to 125.	The D2R transport block size in bytes.	N_{TBS}^{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*: This field includes a 16-bit random number.

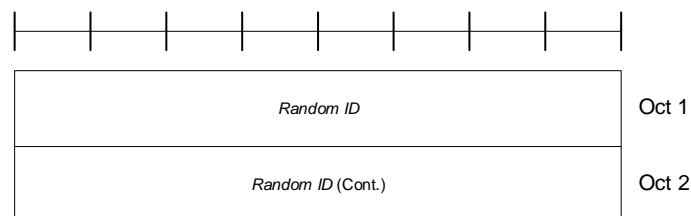


Figure 6.2.2.1-1: MAC PDU of *Access Random ID* message

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*: This field indicates the message type. See the Table 6.1-2. The length of the field is 2 bits.
- *R*: The 6 bits are set to 0.
- *More Data Indication (MDI)*: 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 is of variable length and includes the upper layer data.
- *MAC Padding*: This field includes padding bits. This field is optional.

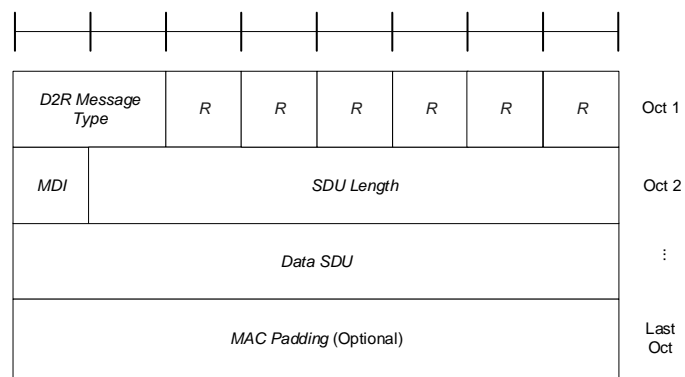


Figure 6.2.2.2-1: MAC PDU of *D2R Upper Layer Data Transfer* message

Annex 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

History

Document history		
V19.0.0	October 2025	Publication