TSG-RAN Working Group 2 (Radio layer 2 and Radio layer 3)
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Title: **MAC Tasks in the Random Access Procedure**

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1 Introduction

This contribution addresses some open issues on MAC functions in the random access procedure. Especially MAC functionality for RACH load control is discussed in this paper. A replacement for present text in TS 25.321 related to the random access procedure is proposed.

This contribution considers the FDD random access procedure. The general principles however should be applicable also to TDD.

2 Discussion of MAC functions related to random access

2.1 Assumptions

Since the former MAC retransmission procedure has been removed, there is no inter-dependency between RACH and FACH transmissions on MAC anymore. Handling of RACH and FACH transmissions is completely independent of each other. The remaining task of MAC in the random access procedure is basically to control the load of the RACH. As an important new element of RACH load control, indication of negative acknowledgements on the AICH, which recently have been approved by RAN WG1, are taken into account here [3].

The following assumptions for RACH transmission are made (for completeness assumptions are made also for other layers than MAC):

UE side:

- PRACH transmissions are triggered by data indication from MAC to PHY (PHY-Data-IND). This implies that any desired backoff in PRACH transmissions is controlled by MAC (or higher layer).
- The physical layer uses the PHY-Status-IND primitive to indicate the following conditions to MAC:
  - Maximum preamble transmit power reached, no acknowledgement on AICH received,
  - Negative acknowledgement received on AICH (“
  - Positive acknowledgement received on AICH (“Ack”), RACH message has been transmitted,
- The following PRACH parameters are configured by RRC through C-SAP by means of CPHY-TrCH-Config-REQ primitive:
  - initial transmit power,
  - power ramping step size,
  - preamble-to-message transmit power offset,
  - PRACH maximum power
  - PRACH spreading code,
  - Access Service Class (ASC) parameters (ffs.).

- Configuration of AICH parameters by RRC (using CPHY-TrCH-Config primitive)
  - AICH spreading code
  - timing information for search of acquisition indicator (if needed)
- The following parameters are randomly selected by the physical layer (possibly within constraints defined by ASC parameters):
  - PRACH initial access slot,
  - PRACH signature

UTRAN side:

- Continuous monitoring of the PRACH is handled by layer 1 procedures. There is only a single primitive needed between PHY and MAC, indication of data (PHY-Data-IND).

2.2 Load control

In past WG2 contributions, two proposals for controlling the load on the RACH have been presented. The first algorithm, referred to as "dynamic persistence control" [1], controls the access probability *P* for the next available slot, which is broadcast on a common channel (e.g. on BCCH), and changed dynamically based on an estimate of congestion in the cell. The second algorithm [2] controls the backoff time between two RACH transmissions based on the number of transmission failures. The backoff time is randomly drawn from an interval which is exponentially increased with the number of failures.

In previous discussions of the second proposal it remained unclear which time interval should be controlled, the retransmission of preamble or the retransmission of the message.

With this contribution, we suggest that a similar approach as in GSM and GSM/GPRS shall be employed for load control, which includes "admission control" (i.e. an overall load control, handled by RRC) and "temporary" load control (with involvement of MAC).

For random access admission control, the users should be divided into access control classes (in GSM 16 classes, including 10 standard classes and 5 special classes, e.g. for emergency call), and access could be barred or admitted on access control class basis by broadcast of a respective access control class parameter. Admission control should be handled by RRC without involvement of MAC. It is therefore outside the scope of this contribution.

For control of the temporary load of the RACH a scheme as in GSM/GPRS should be employed which could comprise the following elements (cf. GSM 04.60, [6]):

- dynamic persistence control,
- control of the number of retransmissions and average time between them,
- access rejection (e.g. for specified time) by means of negative acknowledgements.

In UTRA, RACH transmissions are split into two phases, preamble power ramping and message transmission. The message is transmitted when acquisition of the preamble has been acknowledged, where a fixed timing between that last transmitted preamble, the acquisition indicator and the message needs to be maintained. Under certain conditions (see Sec. 2.3) it will be necessary to perform multiple attempts of preamble power ramping before the message can be sent. It seems most natural that temporary RACH load control includes control of the timing of preamble retransmissions. We therefore propose that above listed elements of load control are applied to the preamble transmission phase, and that this task shall be performed by the MAC sublayer (i.e. introduction of backoff delay based on transmission time interval units). Control of message retransmission should be handled by the RLC protocol.

It should be noted that the likelihood for collisions on the RACH is rather low due to signature and access slot diversity. When the overall uplink load is not very high, it is therefore not obvious that at all any further restriction on RACH usage should be imposed by the system. Introduction of random backoff time means that improved interference conditions due to spreading of transmission power over a larger time interval is traded off with additional delay. In this contribution we propose a basic MAC procedure for control of RACH transmissions similar as applied in GSM/GPRS for initial access. We however leave the concrete setting of its parameters for further study.

2.3 Example message sequences

An example sequence of random access is shown in Figure 1. In conclusion of the above discussion, RACH transmission is performed as follows:

The RACH (and AICH) is configured once via a CPHY-TrCH-Config-REQ primitive. This primitive needs to be issued only for initial configuration or when a parameter shall be changed, not for every RACH transmission.

The CMAC-Config-REQ primitive is used to configure MAC parameters required for the random access procedure. The parameters could include persistence value, maximum number of preamble retransmissions, and minimum and maximum backoff time in terms of number of transmission time intervals (i.e. radio frames) when transmission is allowed (how these parameters are obtained by RRC is outside the scope of this contribution).

When there is data to be transmitted on the RACH, i.e. reception of a MAC-Data-IND primitive, the RACH transmission control procedure is started. Firstly based on the persistence value it is decided whether or not transmission is allowed,

After some initial backoff time due to persistence control, a primitive PHY-Data-IND is sent to L1, which triggers the PRACH preamble transmission procedure, i.e. the physical layer selects a PRACH access slot without further backoff delay imposed on L1 (possibly within ASC constraints). In the example it is assumed that the preamble power ramping procedure is completed with one of the following conditions: (i) maximum permitted transmission power was reached without receiving an acknowledgement, or (ii) a negative acknowledgement has been received on AICH. The first condition can be due to following reasons:

1.) missed preamble in Node B at max power due to detection probability <1,

2.) collision with another user,

3.) an acknowledgement was sent but it was missed at the UE.

This condition should occur very rarely and would not necessarily require backoff for preamble retransmission (except case 1.) is due to overload, which however should be prevented by the system in some suitable way). However some backoff should be imposed to provide a better interference distribution over time.

The second condition, reception of "Nack" on AICH is used to prevent the user from sending his message in case of danger of a temporary congestion (it could be ignored by "special users"). In this case, a new access attempt could be started by MAC after some backoff delay which however is obtained differently as the one when no Ack is received, cf. Sec. 3.

This conditions could occur a number of consecutive times. The number of preamble retransmissions is counted on MAC. When the maximum number of retransmissions is exceeded an error condition is signalled to RRC (with CMAC-Status or CMAC-Error primitive, ffs.) and the MAC PDU is removed.

Upon successful transmission of a preamble, MAC receives an acknowledgement via PHY-Status-IND primitive that the acquisition indicator was received and the message sent.

At the UTRAN-side MAC the further processing of received RACH message depends on the MAC header. An acknowledgement that the message was received correctly could either be given by RRC procedure or by a RLC retransmission procedure, depending on the type of the message. The parameters of PRACH transmission are chosen such that retransmission of the messages is a very rare event. Incorrectly received messages should **not** be due to overload situations since this condition should have been signalled via the Nack on AICH after preamble acquisition. It is thus not needed to impose an additional outer backoff time for retransmission of the message. Message retransmission should be handled entirely on RLC, or RRC for CCCH messages, employing retransmission timers.

It should be noted that for transmission on common transport channels some parameters of the RLC retransmission protocol may need to be updated to cope with delays introduced by the MAC RACH transmission control function.

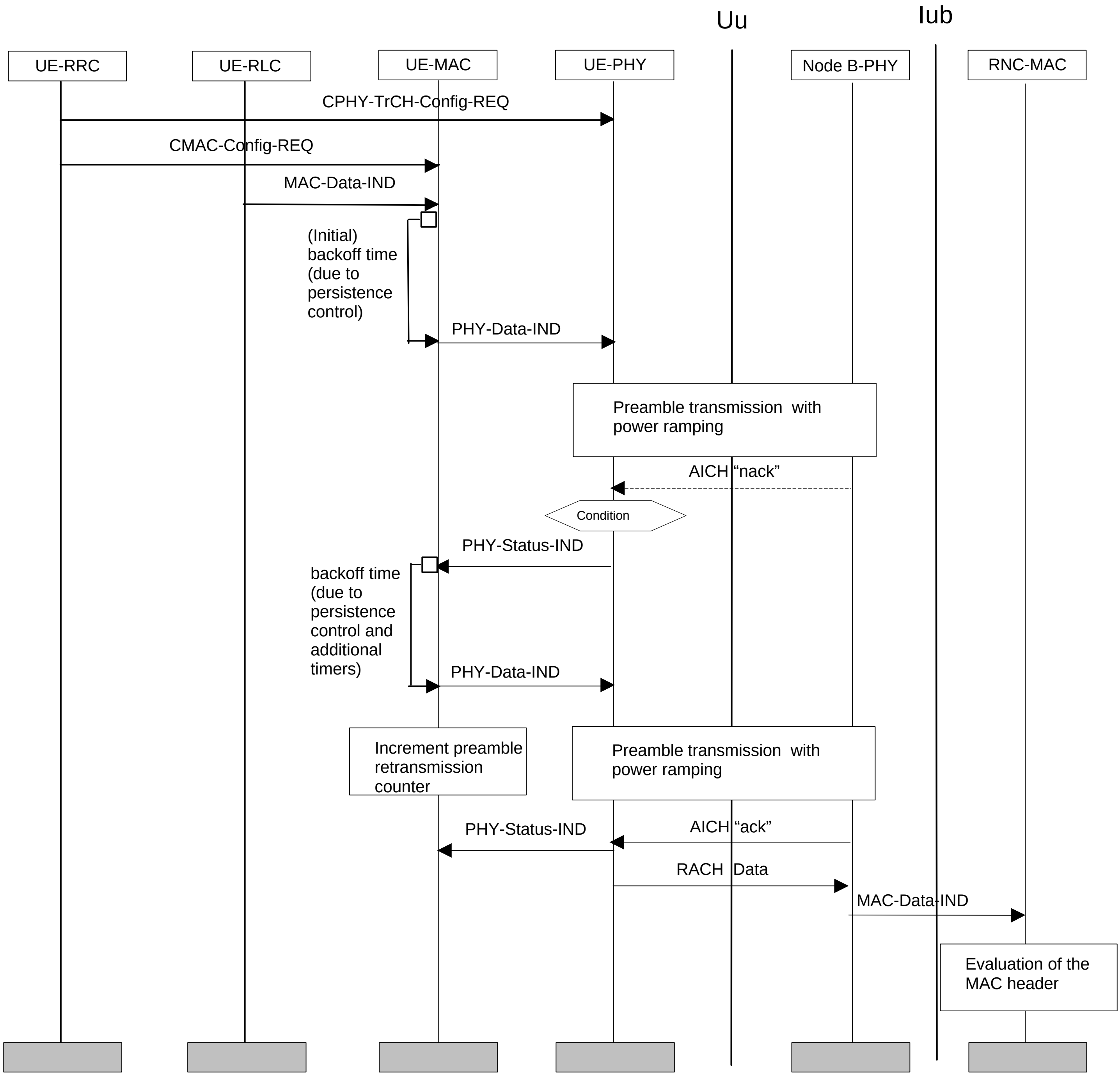

Figure 1: Example random access transmission sequence

3 CR to TS 25.321

The following changes in the MAC protocol specification TS 25.321 [5] are proposed:

- Remove in the Annex Secs. 14.2.4 “Control of RACH” and Sec. 15.1 “Random access procedure”.
- Include the message sequence example given in Sec. 2.3 above with explanatory text into an informative Annex (alternatively this could be included into TS 25.303).
- Include into the main text, Sec. 11 “Elementary procedures”, the following section:

11.1 Control of RACH transmissions

The MAC sublayer is in charge of controlling the timing of RACH transmissions on transmission time interval level (the timing on access slot level within a transmission time interval is controlled by L1). MAC controls the timing of each initial preamble transmission as well as preamble retransmissions in case that none or a negative acknowledgement is received. Note that retransmissions in case of erroneously received RACH message part are under control of higher layers (i.e. RLC, or RRC for CCCH data).

The RACH transmissions are performed by the UE as shown in Figure 2. MAC receives the following RACH transmission control parameters from RRC with the CMAC-Config-REQ primitive:

- persistence value P (transmission probability),
- maximum number of preamble retransmissions M_{max},
- others (ffs., e.g. minimum and maximum number of transmission time intervals between two preamble transmissions).

Based on the persistence value P, the UE decides whether to start the L1 power ramping procedure in the present transmission time interval or not. If transmission is allowed, the L1 preamble power ramping procedure is started. MAC then waits for status indication from L1. If transmission is not allowed, a backoff timer T_{BO1} is started and another attempt is performed after expiry of the timer.

When the preamble has been acknowledged on AICH, the RACH message part is transmitted according to L1 specifications. When no acknowledgement is received, a backoff timer T_{BO2} is started and a preamble retransmission attempt is performed. In case that a negative acknowledgement has been received on AICH a backoff timer T_{BO3} is started. After expiry of the timer persistence check is performed again.

The settings of the backoff timers T_{BO1}, T_{BO2}, T_{BO3} is ffs. The setting is an integer number (≥ 1) of transmission time intervals, either fixed or randomly drawn from an interval defined by RACH transmission control parameters received from RRC, which might be updated dynamically, together with update of persistence value.

[Note: The three timers are introduced at this stage mainly to keep the algorithm most general. Possibly T_{BO1} and T_{BO2} can simply be set to their minimum value, i.e. 1 transmission time interval. The introduction of random backoff with T_{BO3} could especially be useful when the update time for the persistence value is low, i.e. larger than a transmission time interval.]

Successive transmissions on the RACH, i.e. when the mobile station shall continue to transmit because the message is larger than one transmission time interval, shall be handled in the same way as the respective first transmission. This means that any RACH transmission is preceded with a L1 power ramping procedure.

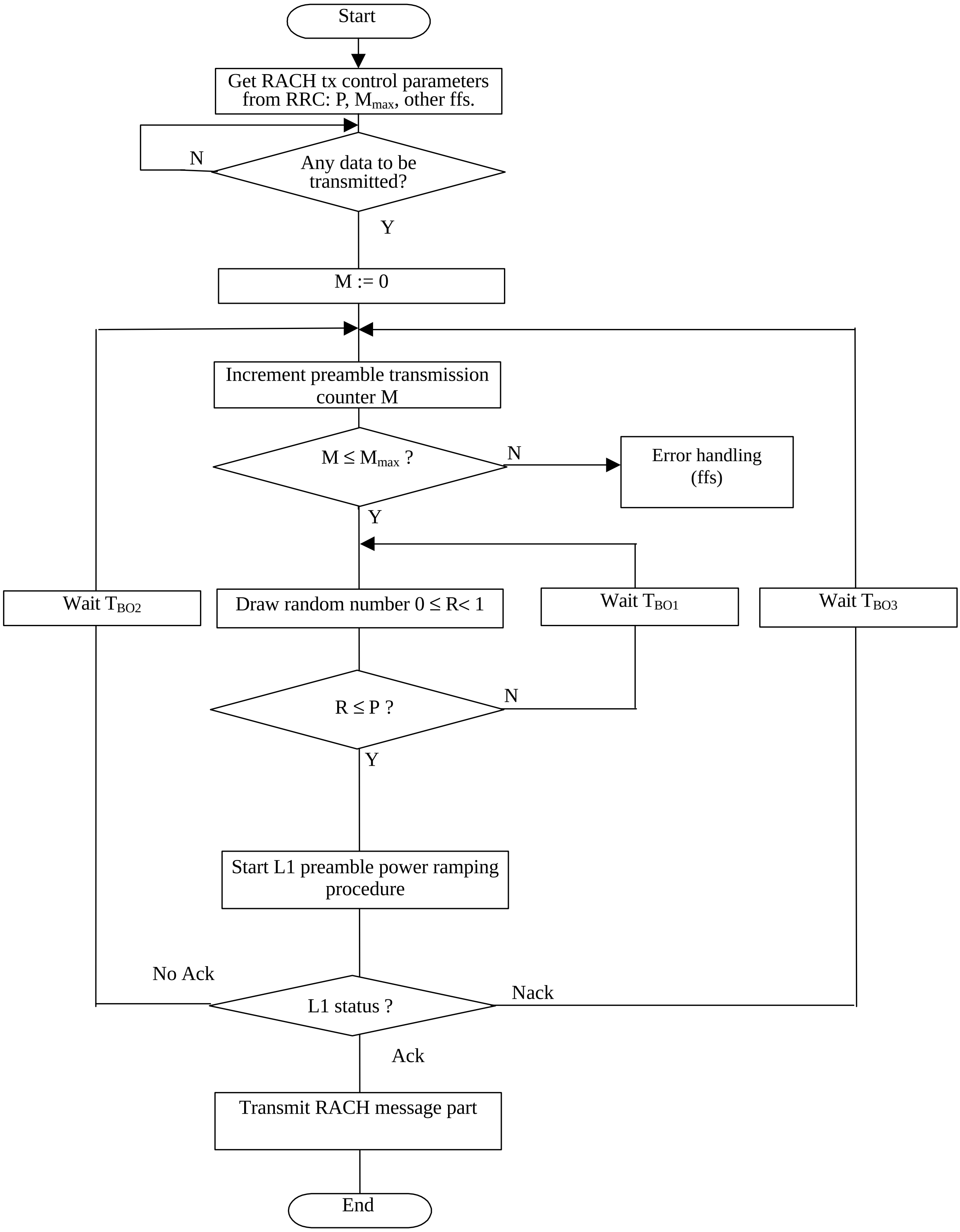

Figure 2: RACH transmission control procedure (UE side, informative)

4 CR to TS 25.301

We propose to **remove** the following MAC functions (currently regarded as further study items) in Sec. 5.3.1.2 of the Radio Interface Protocol Architecture TS 25.301 [4] (and accordingly also in Sec. 6.1 of TS 25.321 [5]):

Constrained execution of open loop power control algorithms. This function establishes layer 1 power levels within the constraints of open loop power control set by RRC.

Reason: There is no involvement of MAC in power control for RACH transmissions. The setting of tx power levels is handled directly between RRC and L1 by means of CPHY-TrCH-Config primitive. The same principle should be applicable to all other channels.

Successive Transmission on RACH. When the mobile station continues to transmit the succeeding (second or more) radio frames because the message length is longer than a radio frame, the transmission timing offset, the RACH spreading code and signature shall be determined as follows: The transmission timing offset (frame and/or slot) shall be determined pseudo-randomly. The RACH spreading code and the signature of the succeeding radio frame can be determined pseudo-randomly. The same RNTI shall be used as in the previous radio frame (for the radio frames belonging to the same higher layer PDU).

Reason: No specific functionality for successive transmission on RACH is needed on MAC. All RACH transmissions are equally handled.

5 Conclusions

In this contribution we have discussed the tasks of the MAC sublayer in the RACH transmission procedure, and we have proposed a procedure for controlling RACH transmissions which is based on dynamic persistence control as suggested in [1]. The proposed procedure is basically the same as employed for the packet-RACH in GSM/GPRS, here however applied to the transmission/retransmission of the RACH preamble part. Due to different characteristics especially with respect to collision probability, the details of exact parameter range and setting shall be left open for now, and be decided when more simulation results are available. We propose to include the described procedure into the MAC protocol specification [5] and use it as working assumption. The proposed procedure implies changes in the list of MAC functions in both TS 25.301 [4] and TS 25.321 [5]. The overall outlined random access procedure has the following features:

- MAC controls the backoff on preamble transmission and retransmissions,
- There is no involvement of MAC in PRACH power setting needed,
- RRC (for CCCH), or RLC (for DCCH and DTCH) control the RACH message retransmission (via retransmission timers).

6 References

[1] Motorola, Tdoc SMG2 UMTS-L23 535/98, Mechanisms for managing uplink interference and bandwidth.
[2] Sony, Tdoc TSGR2#3(99)229, Backoff algorithm with dependency on failed attempts.
[3] 3GPP TS 25.214, V1.0.0, UTRA FDD: Physical layer procedures.
[4] 3GPP TS 25.301,V3.0.1, Radio Interface Protocol Specification.
[5] 3GPP TS 25.321, V2.0.0, MAC Protocol Specification.
[6] ETSI GSM 04.60 V6.3.0, General Packet Radio Service (GPRS), RLC/MAC protocol.