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Determination of available PRACH and AICH access slots

1. Introduction

This paper proposes a method by which the allowed access slots of PRACH and AICH can be defined and signalled to MSs. It will be beneficial that there is a method how to define that there are less than 8 access slots available, since in this way the hardware resources can be saved and optimised in the base station.

At the moment S1.14 defines that BCH contains information about the available access slots. It should be however specified clearly how it is done, since the signaling should contain both possibilities of having either 3 or 4 access slots between two preambles, or preamble and message. The non-trivial case is the one where the AICH transmission value is 0, since then there are 3 access slots between two preambles. Since there are at maximum 8 access slots per frame, and 8 is not dividable by 3, it means that 3 access slot period will have a cycle of 3 frames.

2. Parameters sent on BCH

We propose that UE defines the next available access slot with the help of three parameters sent on BCH:

- AICH transmission timing parameter
- SFN of the present frame
- Parameter A, which defines the available access slots

3. Basic idea of the method

Parameter A contains four bits. The A parameter values 0000≤A≤0111 are used with AICH transmission timing parameter value 0, and values 0000≤A≤1111 with AICH transmission timing parameter value 1. If a certain bit position in parameter A has value 1, it means that corresponding sub-RACH channel is available. Sub-RACH channel_# can have a value among {0,1,2,3}. The LSB of parameter A corresponds to sub-RACH channel_# = 0, and the MSB of parameter A corresponds to sub-RACH_channel_# = 3.

For transmitting the first preamble, UE randomly selects the sub RACH channel from the available ones, with the help of A parameter and AICH transmission timing parameter.

After selecting randomly the sub RACH channel, UE derives the next available access slot with the help of SFN and AICH transmission timing parameter value:

- If AICH transmission timing parameter value is 0, the available access slots of frame SFN are defined by Access= 3*N +(SFN modulo3) + sub RACH channel_#, where N has values of the range 0 ≤N≤ 2, and the allowed values of sub RACH channel_# are indicated by parameter A, with the condition that only the values between 0 ≤ Access ≤ 7 are valid. The available access slot to which there is smallest distance is selected.

- If AICH transmission timing parameter value is 1, the available access slots of frame SFN are defined by Access= 4*N + sub RACH channel_#, where N has values 0 ≤N≤ 1. The available access slot to which there is smallest distance is selected.

Example 1) AICH transmission timing parameter value is 0

This is the case of 3 access slot period between preambles, or between preamble and message. This has the cycle of 3 frames.

With AICH transmission timing=0, only the first three LSB are used from A parameter. The access slots are divided into three so-called sub RACH channels. A=001 means that the first sub-RACH channel is available, A=010, that second sub-RACH channel is available and A=100 is that the third sub-RACH channel is available. If both first and second sub RACH channels are available then A=011. And if all sub-RACH channels are available then A=111.

UE defines the available access slots of frame SFN with the help of SFN modulo 3. Some examples given below. The idea is that the available access slot to which there is smallest distance is selected.

For A=001: Access =3*N + SFN modulo 3+ 0 , where N=0…2

For A=010: Access =3*N + SFN modulo 3+ 1 , where N=0…2

For A=100: Access =3*N + SFN modulo 3+ 2 , where N=0…2

Frame number	Sub-RACH channel_#=0 (A=001) Access	Sub-RACH channel_#=1 (A=010) Access	Sub-RACH channel_#=2 (A=100) Access
SFN modulo 3 =0	0, 3, 6	1, 4, 7	2, 5
SFN modulo 3= 1	1, 4, 7	2, 5	0, 3, 6
SFN modulo 3= 2	2,5	0, 3, 6	1, 4, 7

Table 1. The available access slots, Access, for different sub-RACH channels, when AICH transmission timing parameter = 0.

Example 2) AICH transmission timing parameter value is 1

This is the case of 4 access slot period between preambles, or between preamble and message. This has the cycle of 1 frame.

Now all the four bits of Parameter A are in use. The access slots are divided into four so-called sub RACH channels. A=0001 means that the first sub-RACH channel is available, A=0010, that second sub-RACH channel is available, A=0100 is that the third sub-RACH channel is available and A=1000 that the fourth sub-RACH channel is available. If both first and second sub RACH channels are available then A=0011, and so on. If all sub-RACH channels are available then A=1111.

Now the SFN modulo 3 function is not needed. UE defines the available access slots in the frame in the following way described below. The idea is that the available access slot to which there is smallest distance is selected.

For A=0001: Access =4*N + 0 , where N=0…1

For A=0010: Access =4*N + 1 , where N=0…1

For A=0100: Access =4*N + 2 , where N=0…1

For A=1000: Access=4*N + 3 , where N=0…1

Frame number	Sub-RACH channel_#=0 (A=0001) Access	Sub-RACH channel_#=1 (A=0010) Access	Sub-RACH channel_#=2 (A=0100) Access	Sub-RACH channel_#=3 (A=1000) Access
All frames	0, 4	1, 5	2, 6	3, 7

Table 2. The available access slots, Access, for different sub-RACH channels, when AICH transmission timing parameter = 1.

4. Selecting the access slot for sending the consecutive preambles after the first one

There are two alternative methods how the access slots are selected for sending the consecutive preambles, after the first preamble: deterministically or randomly.

In both methods the idea of transmitting the first preamble is the same. MS randomly selects the sub RACH channel among the available ones. With e.g. transmission timing =0 and A=111 , then MS can choose randomly among values {0,1,2} to select the sub-RACH channel. If transmission timing =1 and A=1111, then MS can choose randomly among values {0,1,2,3} to select the sub-RACH channel. If A<111 or A<1111, there is of course smaller group from which the random selection is done.

<u>Method1: deterministic transmission of consecutive preambles</u>

In this method, after the first preamble, MS transmits consecutive preambles either three or four access slots apart, depending on the value of AICH transmission timing parameter value. So after the first random selection of the sub RACH channel, the consecutive preambles are transmitted in deterministic way without any additional randomness.

<u>Method 2: random transmission of consecutive preambles</u>

In this method every time UE wants to transmit a new preamble, UE selects randomly the sub RACH channel among available values {0,1,2} or {0,1,2,3}, depending on parameter A and the transmission timing parameter values, 0 or 1, respectively. After that UE selects the next available access slot in the selected sub-RACH channel. In this method, the AICH-to-preamble timing will be τ_{a-p} or larger (see S1.11) and preamble-to-preamble timing will be 3, 4 or 5 access slots with AICH transmission timing set to 0, and 4,5,6 or 7 access slots with AICH transmission timing set to 1. This means that preamble-to AICH timing t_{p-a} and AICH-to-message timing t_{a-m} would be strictly as specified now in S1.11, section 7, and only the AICH to preamble timing would vary.

<u>Evaluating pros and cons of Method 1 and Method 2</u>

With method 2 the first feeling could be that there might be some benefit of reducing the collision probability. But the improvement in the collision probability is difficult to calculate, since following things should be taken into account: transmitter power level of UEs, their location in the cell, number of preamble codes available etc. So our opinion is that the collision probability reduction might be negligible.

On the contrary, the method 2 means that the power ramping process delay is increased. Since with AICH transmission timing parameter value=0 the τ_{p-p} can then get values: 3, 4, 5 access slots. And with AICH transmission timing parameter value=1 the τ_{p-p} can then get values: 4, 5, 6, 7 access slots.

So based on this reasoning, we propose that method 1 is used, where UE makes the random selection between available sub-RACH channels only when transmitting the first preamble. After that, the timing of consecutive preambles is deterministic, using the values $\tau_{p-p,}$ $\tau_{p-m,}$ τ_{p-a} and τ_{a-p} as defined presently in S1.11.