TSG-RAN Working Group 1 (Radio Layer 1) meeting #3 ***RAN TSGW1#3(99)196***
Nynashamn, Sweden 22nd – 26th March 1999

Agenda Item: 9.1

Source: Motorola

Title: Macro-diversity for the PRACH

Document for: Discussion/Decision

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1 Introduction

Based on experience with CDMA systems, there can be problem when a mobile attempts to setup a connection whilst in an area where macro-diversity would normally be required for dedicated channel operation. The problem arises because macro-diversity is not available on the RACH and FACH channels that are used during the connection setup procedure. To address this problem, this paper describes a mechanism whereby a random access message can be directed to more than one basestation in order to exploit macro-diversity.

2 Benefits of macro-diversity on random access

According to the existing documentation, a UE that wishes make a connection must transmit a connection request message via the RACH to a single basestation. Following the initial access, the network will send a DCH allocation via the FACH. Once the DCH has been established the UE can be prepare to enter soft handover. When the UE is in an area of high intercell interference, where soft handover would normally required for DCH operation, it can be difficult to make the initial access to the system, thereby causing a failed connection attempt. The benefit of being able to directly set up a connection in soft handover has been recognised by ESTI SMG2 Layer2/3 Experts Group [1] and also by Nokia [2]. The Nokia contribution contains a proposal that the connection set up message should contain measurements from adjacent cells in order to enable the UE to enter soft handover directly, although the connection request message itself does not exploit macro-diversity. The mechanism described here addresses this problem by directing the initial RACH message to two basestations.

Directing RACH messages to more than one basestation, and soft combining those messages within the network, allows the RACH to exploit all the well recognised benefits of macro-diversity. This will improve successful detection probability, reduce the required transmission power, and therefore reduce the overall interference introduced into the system.

3 Description of Macro-diversity PRACH

Assume that a UE near the edge of two cells needs to access the network (this could be a control message such a connection request or it could be to transfer a small user packet). Based upon measurements of the downlink PCCPCH signal strength and other information the UE can select two basestations to which to direct the PRACH message. From the physical layer perspective, a number of issues must be considered in order to direct a PRACH transmission to two basestations:

- The basestations are asynchronous
- The power of the PRACH transmissions may need to be different for each cell
- The basestations have different PRACH scrambling codes
- It is very undesirable for a basestation to need extra preamble searchers or for the mobile to have multicode transmission.

These issues are addressed below, firstly for the preamble portion of the PRACH transmission, and then for the message portion.

3.1 Preamble Transmission

There are two options available for the transmission of PRACH preambles to two basestations. The first option is depicted in figure1 and shows the two preambles transmitted sequentially to the two basestations.

Figure 1 shows the two cells with a worst case timing offset of half a 1.25ms PRACH access slot. The mobile transmits a preamble to basestation 1 and then a preamble to basestation 2. The preambles are aligned with the access slot timing of the basestation to which they are being directed, but with a chip level timing offset that is discussed further in section 3.2. The preamble scrambling code, the initial transmission power, and the power ramping step size can be independent for the two cells. However, the signature is the same for both preambles and the choice of access slot is linked. Each basestation sends an independent physical layer acknowledgement, via the AICH, if it detects a preamble. The UE must be able to detect both the physical layer acknowledgements that can be transmitted by the two basestations, and must wait for both acknowledgements before deciding whether to transmit the message portion of the PRACH.

For cell 1, the time gap between the end of the preamble and the start of the message is three 1.25ms access slots plus 0.25ms, giving a total of 4ms. For cell 2, the gap is two access slots plus 0.25ms giving 2.75ms. For comparison, when the mobile is only sending the PRACH to a single basestation the gap is one slot plus 0.25ms giving 1.5ms.

The second option for transmitting the PRACH preambles to two basestations is depicted in figure 2, and shows that the two preambles, that are defined as BPSK sequences, are transmitted in quadrature. This means that the overlap between the two preambles does not require multicode transmission from the UE. In this case the gap between the preamble and the message is 2.75ms for both cells.

For both options there are three different outcomes depending on which acknowledgements are received:

1. No acknowledgement is received from either basestation. The UE should increase the preamble transmission power by the appropriate power ramping step size, and retransmit the preambles to both basestations.
2. When an acknowledgement is received from one basestation only, the UE sends the PRACH message to that basestation at the appropriate transmission power.
3. When acknowledgements are received from both basestations then the UE sends the message to both basestations with the transmission power chosen to be the greater of the two powers for the individual basestations. In this case, if both basestations successfully detect the message, then the UE can be assigned a dedicated channel in both cells simultaneously, and the UE can enter soft handover immediately.

There is a further option to soft combine the AICHs from both basestations. In this case, the UE will add the energy received from the two AICHs and then make a decision on whether to send the PRACH message to both basestations.

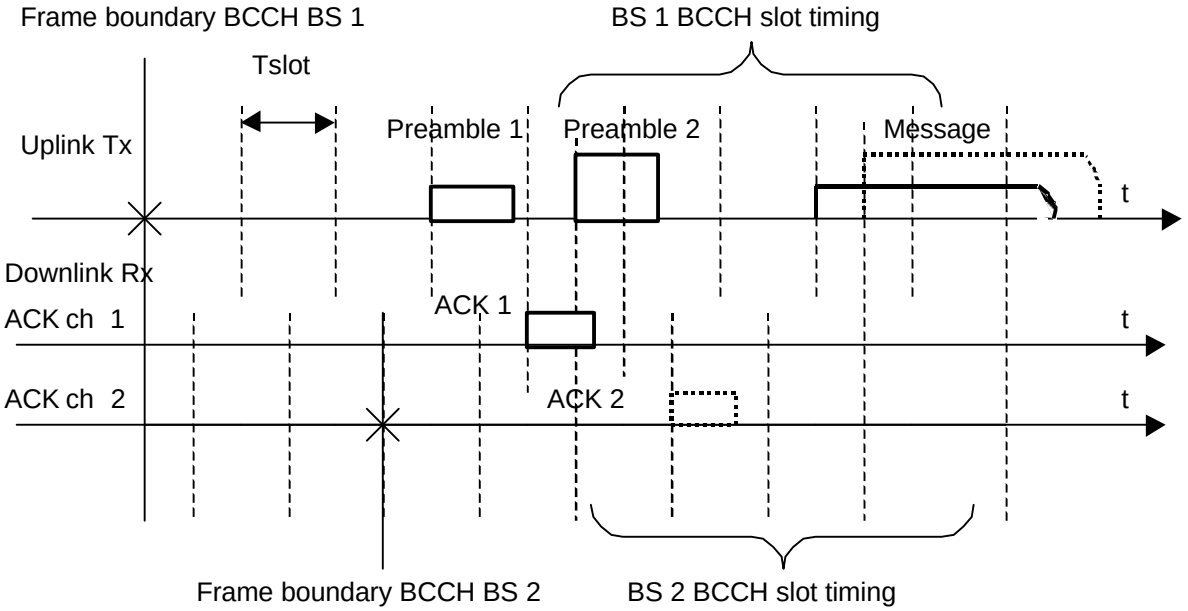

Figure 1: Preamble simualtaneous transmission to two basestations - option 1.

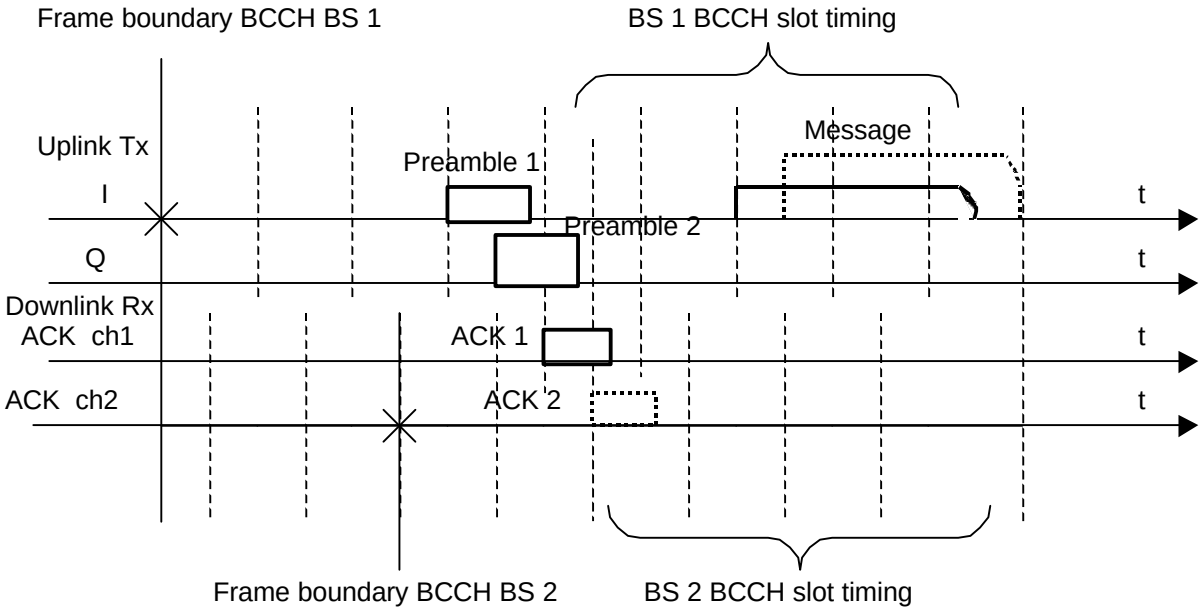

Figure 2: Simultaneous preamble transmission to two basestations - option 2

3.2 Message Transmission

If the UE receives acknowledgements from both basestations then it must transmit the PRACH message so that both basestations are able to detect it. To achieve this it is proposed that the transmission does not use a cell specific scrambling code but uses a common scrambling code that is reserved for this purpose. So that the basestation receiver knows that the UE will be using the common scrambling code, one or more of the preamble signatures should be set aside to indicate that the common scrambling code is to be used.

The maximum timing offset between the messages directed to the two basestations is half of a 1.25ms PRACH access slot. This corresponds to 10 symbols at a spreading factor of 256. The UE should start transmitting in the earliest of the two transmission slots but it should transmit dummy symbols until the latter of the two slots. At the latter slot boundary, the UE sends a sequence of known symbols (UW-1 to UW-N in the figure 3) to indicate the start of the message, and then transmits the message portion of the PRACH as defined in the current documentation. This is shown in figure 3.

A short scrambling code should be used to scramble the both dummy symbols and the known sequence. It is suggested that the first 256 chips of the message scrambling code could be used for as this short code.

The insertion of dummy symbols can only adjust the timing offset to the nearest symbol. There will still be a residual offset that can be up to half of a symbol (i.e. 128 chips). This residual will appear as an extra propagation delay in the PRACH message sent to one of the basestation receivers. So that the apparent propagation delay is the same for both the preamble and message parts, the UE must also insert this extra delay into its preamble transmission (this assumes that the basestation receiver uses the chip timing information obtained from the preamble portion when it receives the message portion). The window of the searcher in the PRACH detector should be wide enough to accommodate this extra delay.

The insertion of dummy symbols and the known sequence adds an overhead onto the 10ms PRACH message. The maximum overhead is 17 symbols (assuming a 7 symbol known sequence) which gives an overhead of 10%, with a mean overhead of 5% assuming that the basestation timing is random. Also, this overhead is only necessary when acknowledgements have been received from both basestations.

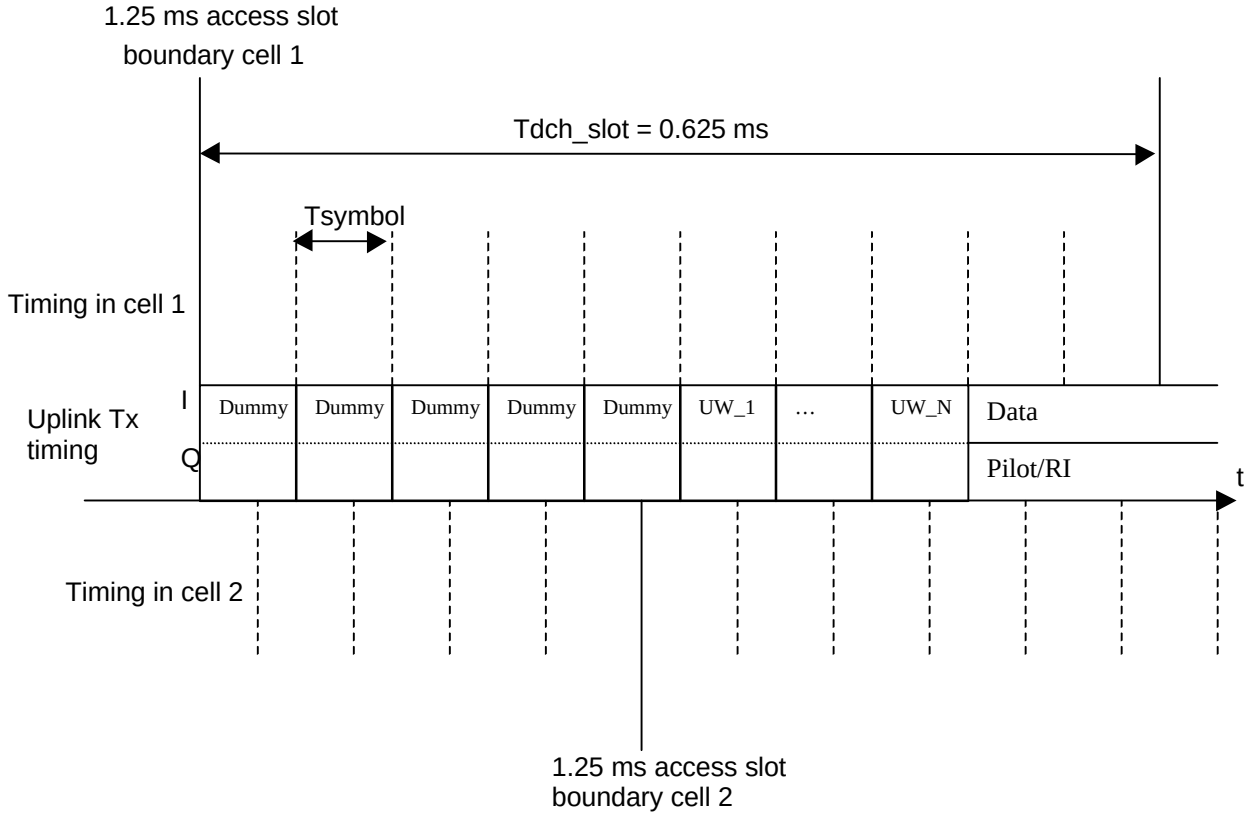

Figure 3: Transmission of a PRACH message to two asynchronous basestations

4 Conclusions

The paper has proposed a mechanism that allows the PRACH to exploit macro-diversity. The principal features of the scheme are:

- The macro-diversity PRACH facilitates the setting up of a connection in a soft handover area.
- The macro-diversity PRACH with soft combining in the network should improve detection probability, reduce the required transmission power, and reduced the interference introduced into the system. The scale of these benefits needs to be verified by simulation.
- The basestation does not require extra preamble searchers.
- The UE does need to support multicode transmission.
- The mean increase in overhead of a macro-diversity PRACH compared to a single basestation PRACH is 5%.
- The delay between the preamble and the message portion of the PRACH is increased by one 1.25ms PRACH access slot.

The potential impact of this mechanism is:

- In the window of the preamble searcher in the basestation should be able to handle delay spreads of up to one half of a symbol at a spreading factor of 256 – i.e. 128chips.
- The mobile should be able to detect AICH channels from two basestations simultaneously, and potentially soft combine those channels.

The macro-diversity RACH described in this paper can aid setting up a connection in soft handover. However, the procedure still needs to use the FACH, which doesn't support macro-diversity, in order to send the DCH allocation message. It is suggested that macro-diversity for these FACH messages could be considered further.

5 Proposal

TSG RAN WG1 should consider the proposed mechanism for a macro-diversity RACH for inclusion in the 3GPP documentation. It is recognised that the performance benefits of the proposed scheme have not yet been quantified by simulation and this needs to be addressed as soon as possible. It is also recognised that there are a number of layer 2/3 aspects that will need to be considered by RAN TSG WG2 and possibly RAN TSG WG3.

6 References

[1] SMG2 L1 Experts Group 602/98, 'Liaison from L2/3 Experts Group'

[2] Nokia, TSGR2#2(99)121, 'Contents of the RRC Connection Request, Connection Setup and Connection Reject Messages'