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Title: Synchronisation of Node B's in TDD via Selected PRACH Time Slots
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1 Introduction

In order to minimise interference and optimise capacity in a TDD system, slot, frame, and multi-frame synchronisation of the transmissions from Node B's is necessary.

Synchronisation may be achieved by use of the fixed network or specialised satellite receivers like GPS. Use of the GPS-like methods requires separate radio receivers to detect the time reference signals, which may not be economical for use in each radio port. Furthermore GPS signals may not be received at all base station sites.

As an alternative, synchronisation can be achieved via the air-interface. Reference TSGR3#6(99)905 proposes a method for synchronisation that uses the already existing synchronisation signals on the physical synchronisation channel (PSCH). Therefore, this method doesn't require any special air interface waveform defined in the physical layer, but does use new messages between the RNC and Node B only. In Liaison TSGR3#6(99)A43 WG3 has asked WG1 and WG4 on their opinion about the feasibility of this method.

To show also a different appropriate alternative and to start the discussion on this topic in WG1 this contribution proposes a synchronisation technique that uses a special synchronisation signal that is sent in selected PRACH time slots.

2 Synchronisation Using the PRACH Time Slot

2.1 Basic Mechanism

The proposed approach suggests the use of a synchronisation signal transmitted by a base station in the PRACH time slot. This will inevitably cause some additional interference at other base stations. The level of this interference and its effect on UL access capacity needs to be studied. Typically the synchronisation signal is transmitted in one PRACH time slot every second, which will then result in an acceptable 1% capacity loss. An illustration of the basic mechanism is shown in the diagram below.

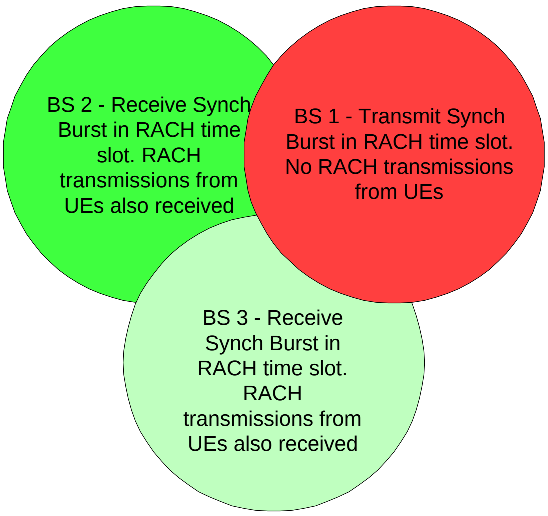

Figure 1 Node B Synchronisation Using the RACH Time Slot

In the illustration above the situation is depicted where BS1 transmits a synchronisation signal that is received in the PRACH time slots of BS2 and BS3. PRACH transmissions from UE's affiliated to BS1 are prevented using broadcast signalling.

Other configurations are possible: RACH transmissions in all Node B's adjacent to BS1 could be disabled in order to avoid any interference in the reception of the synchronisation signal. The disadvantage of this is primarily the reduction in RACH capacity. Disabling RACH transmissions in neighbouring Node B's when a synchronisation signal is being sent need not always be applied. It can be applied at some Node B's where the synchronisation signal is received with insufficient strength and interference caused by RACH transmissions means that a poor timing estimate is obtained. Alternatively no mechanism for broadcast signalling of the availability of the PRACH time slot is performed and RACH transmissions from UE's affiliated to BS1 are not prevented. This can lead to an increased delay for RACH transmissions where the Node B makes the synchronisation signal transmission.

Surrounding Node B's will be capable of receiving this transmission in their RACH time slot. The transmission from the Node B will be a special type of burst for the purpose of synchronisation. The structure of the burst, labelled synch burst is described later. Time of arrival measurements of the synch burst are made by all Node B's depending upon each Node B applying some detection criterion to the reception of the synch burst. The time of arrival measurements can then be reported to the RNC or used by the Node B to calculate a timing correction.

2.2 Broadcast Signalling

The availability of the PRACH time slot can be signalled in the BCH. If BCH transmissions occur every N frames, then a field can indicate which PRACH time slots are not available in the upcoming N frames. If the UE is in an idle mode and only occasionally listening to the CCPCH (which contains the BCH), then before making a RACH transmission, the UE must wait up to N frames to decode the BCH, and incur this additional delay.

A simpler, but less flexible signalling arrangement can be to fix which frame or frames in a superframe the synch burst is to be transmitted in and include this in a field in the BCH. The advantage of this approach is that the UE does not need to have read the previous BCH transmission prior to making a RACH transmission.

2.3 Synchronisation Burst

The synchronisation burst is an unmodulated transmission of a sequence of 2400 chips. It provides an additional 6.7dB processing gain over the midamble used in burst type 1 or the PSCH transmission, that could alternatively be used to measure timing when received by other base stations. Furthermore being the only transmission in that time slot it can be transmitted at higher power than say the CCPCH (normally the transmission with highest power), because other DPCH transmissions may be present in the time slot in which the CCPCH is transmitted. If the base station is dimensioned so that 8 codes in a time slot can reach the cell boundary, then it is possible for the synchronisation signal to be transmitted at least 9dB higher than any other signal. Consequently an additional path loss of at least 16dB can be tolerated by this transmission. The structure of the transmission is shown below in figure 2.

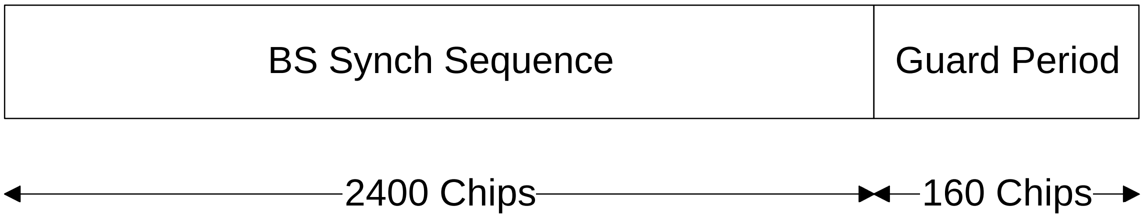

Figure 2 Synchronisation Burst

The sequence could be constructed from 2 sequences one of length 16, the other of length 150 following the hierarchical approach used in the construction of the Primary and Secondary SCH codes. This may reduce the complexity of the correlator.

An extended guard period is necessary to allow for the additional propagation delay that this signal will experience. The normal guard period of 96 chips has been extended by 64 chips. This should more than compensate for the additional propagation delay experienced by this signal.

The synchronisation sequence should possess good auto-correlation properties over its entire length, but the time period equal to the channel impulse response length is the most critical. Good cross-correlation properties against the RACH burst should be sought. Ideally only one such sequence is required in the system (or one per RNC), and given the length of sequence it would probably be sufficient to set the upper limit on non time-aligned auto-correlation values to the Walsh lower bound (0.02 for this sequence length). Consequently a limited search should yield a sequence with adequate auto-correlation properties. Where one sequence per RNC is required then good cross-correlation properties between sequences are also desired.

The timing measurement obtained from the synchronisation burst enables the Node B to synchronise its transmissions to the 10ms frame structure. By ensuring that synchronisation bursts are only ever transmitted in the first RACH time slot of a super-frame, then synchronisation to the super-frame structure can be obtained. This does limit the minimum time interval between Node B synchronisation transmissions to 720ms, but this is not thought to be a significant limitation (assuming references with a 0.05ppm stability, then the timing drift is 0.14 chips per super-frame).

3 Hidden Node B’s

The problem of the hidden Node B’s where one or more Node B cannot receive transmissions from any surrounding Node B’s is common to all on-air synchronisation schemes. Although two Node B’s may not be able to receive each other, a UE within the cell of either Node B may be able to receive both Node B’s transmissions. As a consequence although Node B to Node B reception is not possible, synchronisation is still required. There are a number of possible solutions to the problem and these are listed below:

a) Hidden Node B’s should use an accurate common timing reference such as GPS. Timing corrections for all other Node B’s are made relative to this.

b) Remote synch burst transmitter/receiver that can be received by two or more Node B’s, the location of which is known. The remote synch burst transmitter/receiver has no connection to the fixed network and control messages are sent by Node B’s instructing it to transmit.

c) As differential timing is used to calculating the timing corrections, the actual path traversed by the timing signal is irrelevant provided it has the same time delay in both directions. Consequently where a Hidden Node B exists a dedicated link via the RNC to another Node B is made within the network, so that the path traversed by signals from each pair of Node B’s is the same.

d) Node B’s are equipped with directional antennas specifically to transmit/receive the synch burst.

e) A network planning requirement is that Node B’s must be able to receive a synch burst from at least one other Node B.

Each of the possible solutions to the problem has its drawback and none can unreservedly be recommended. Use of a GPS reference assumes that the hidden Node B can receive GPS signals, which may not be the case in dense urban environments. Having a remote synch burst transmitter/receiver deployed is also not desirable because a site has to be found for it, even though the amount of equipment may be minimal. Using the network connections to send timing signals along is possible, but variable queuing and processing delays could render the differential timing measurement useless. A dedicated network path for timing signals would have to be provided. Equipping Node B’s with directional antennas may overcome the problem in a number of cases, but not all cases. Imposing a network planning requirement that Node B’s must be able to receive a synch burst from another Node B may be too restrictive in some circumstances.

The solution is perhaps to design the Node B synchronisation scheme so that any one of the above techniques can be used to overcome the Hidden Node B problem. Under specific circumstances one of the five techniques outlined above will be more appropriate than others.

4 Summary of the Proposed Scheme

In the previous sections many ways of operating a Node B synchronisation scheme using on-air transmission have been discussed. Below a summary of the simplest scheme that could be adopted is given.

Each Node B is assigned a frame within a super-frame in which the PRACH time slot will not be available and instead it transmits a synchronisation burst. The frame number in which the PRACH is unavailable is included in a field in the BCH information. Consequently on decoding the BCH a UE knows which PRACH time slot not to transmit in. The frame number is planned so that as many neighbour Node B's as possible can receive this transmission, and that the planning extends beyond an RNC area. Also there is the possibility of collision, and this needs to be avoided. In practice determining which frame number the Node B uses for synch burst transmission will be part of the commissioning process.

The synchronisation burst comprises a single sequence of 2400 chips. The sequence is unique to an RNC. In every PRACH time slot the Node B attempts to receive the synchronisation burst for its own RNC and for at least one neighbouring RNC. If the presence of a synchronisation burst is detected the Node B sends a timing measurement to the RNC indicating the timing measurement, the frame and super-frame number in which it was detected and which sequence was received.

The timing correction can be calculated either by the RNC (based upon measurements collected from all Node B's affiliated to it) or calculated directly by the Node B.

Compared with the method in TSGR3#6(99)905 (synchronisation via the synchronisation signals in PSCH), we see at least the following advantages:

- The processing gain of the PRACH synch burst is about 6.7 dB higher than that of the existing synchronisation sequences. Additionally, taking into account the higher transmit power a better reception quality/larger cell sizes can be achieved with the proposed scheme.
- No hearing pauses have to be introduced which means that no reshuffling or stopping of the SCH, CCPCH or traffic transmission is needed.