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Title: Node B Synchronization over the Air:
Preliminary Comparison of Alternatives
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1 Introduction

This contribution compares two techniques for synchronizing Node Bs over the air. These two techniques were each originally introduced in references [1] through [4]. References [1] and [2] define the concept suggested by InterDigital and Siemens in WG3. References [3] and [4] define an approach suggested by Siemens in WG1. Reference [4] includes initial simulation results.

There are several small differences between the two proposed approaches, which can easily be reconciled. These include the grouping of NodeBs, the intervals between updates or the criteria for doing an update, whether or not the distance between NodeBs is known a priori, etc. We do not see these as inherent differences.

The primary difference between the two approaches is as follows. We will refer to them as the Passive Approach and the Active Approach.

Passive Approach
In the proposal of references [1] and [2], one Node B listens for, and detects the Synchronization Channel (SCH), of a second Node B, deriving the time of arrival of that burst. It uses functionality that is based on the UE's cell search function. Having performed the measurement, the Node B sends this information to the RNC. The RNC subtracts the predicted propagation delay (distance between NodeBs/speed of light). The result is a time value, which is ideally zero if the two NodeBs transmitted at the exactly same time. Deviations from zero are the basis for a time correction of one of the two NodeBs. The RNC may then elect to send a time correction to one of the Node Bs.

Active Approach
In the proposal of references [3] and [4], one Node B transmits a special burst in the RACH time slot of a second Node B. See figure 1, obtained from reference [4] The second Node B detects the special burst and derives the time of arrival of that burst. This would be sent to the RNC. The algorithm in the RNC subtracts the predicted propagation delay (distance between NodeBs/speed of light). The result is a time value, which is ideally zero if the two NodeBs transmitted at the exactly same time. Deviations from zero are the basis for a time correction of one of the two NodeBs. From the perspective of a time synchronization function/algorithm in the RNC, the two approached would provide measurements which are equivalent.

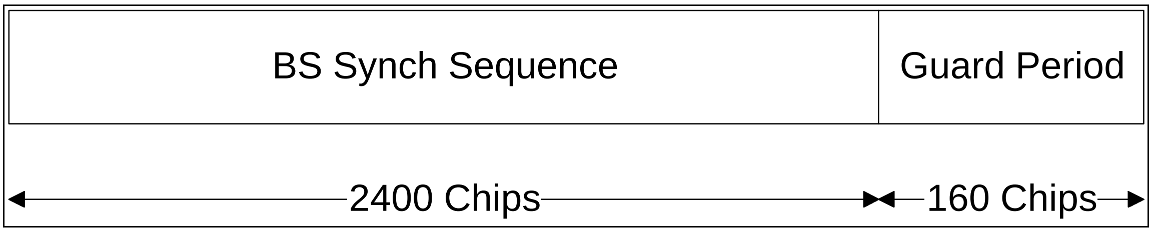


Figure 1 Special Sync Burst

2 Performance Comparison

Detailed performance comparisons have not yet been done. However the following statements can be made:

- The active approach, with its special waveform and option to use high power, should provide more accurate and reliable Time of Arrival measurements. The accuracy claims of reference [3] appear to be reasonable. See reference [5]

- However, it remains to be proven that this additional accuracy and reliability is necessary, or that it provides a measurable improvement in overall system performance. While measurement accuracies of a fraction of a chip may be achievable, such accuracies may not be required. Operationally it is only necessary that Node Synchronization be within a few microseconds.

Reference [3] by Siemens shows simulation results based on a typical scenario and suggests that the system will maintain very good synchronization with over-the-air updates on the order of 20 seconds. Steady state errors are on the order of 0.1 microseconds, worst case. InterDigital has started a similar simulation. Preliminary results are shown in reference [5]. These results show steady state timing errors that are not quite as small, but which will be, nevertheless, operationally acceptable.

3 Operational Comparison

For both approaches, in steady state, each NodeB must steal a resource (i.e. RACH time slot for Active Approach; Sync signal transmission for Passive Approach). Using the typical value of Reference [3], this occurs once per 20 seconds. For both approaches, the cycle stealing is insignificant; i.e. one slot per 2,000 slots, for a measurement once per 20 seconds. We do not believe that this loss is critical for either concept; however, it may be important to review this issue.

InterDigital believes that the real difference between the two approaches is associated with initial synchronization of a newly deployed NodeB or a NodeB that has, for some reason, lost its time reference and needs to reacquire it.

In the Passive Approach, a NodeB can listen passively until it achieves nominally correct time synchronization. No other Node B is in any way impacted. In the Active Approach, the special transmissions needed to support the concept need to be supported for hundreds of milliseconds, during which time, transmissions may interfere with operation.

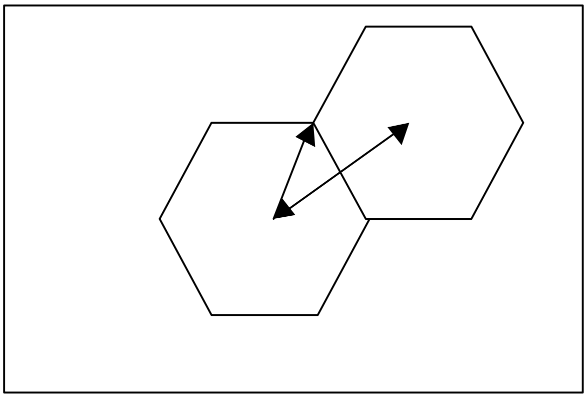
As a secondary issue, the Active Approach will require modification at Layer 1, while the Passive Approach needs no new burst type or transmission format; it is based on using existing features at Layer 1;.

4 Link Margin

Concerns have been raised that the Passive Approach may fail in certain situations due to insufficient received power; i.e. inadequate link margin. This section shows that there is sufficient path gain between adjacent cells to support this approach; at least for the Macro Cell case.

4.1 Macrocell Case

Assume cells layed out in the standard hexagonal pattern.



Two neighboring cells are separated by distance 2R.
A UE at the most distant range is a distance, 2R/sqrt(3)
The ratio of the two distances is sqrt(3)

The cells are layed out, and the power levels are selected so that the UE can receive sufficient Signal strength to perform cell search with several dB of fade margin.

Assume that the path loss obeys an R4 law for both UE and the cells. Then the path loss between cells is greater than the path loss beteen UE and cell by 20 log(3)=9.5 dB.

The noise figure of the receiving cell is 4 dB better than that of the UE; 9 dB versus 5 dB.

The UE receive antenna gain is no better than 0 dBi
The antenna of the receiving cell is at least 8 dBi (omni in azimuth); it could be as much as 17dBi.

At installation it can be verified that the two cells are not placed in a deep fade condition.

Therefore the net path gain between cells is bigger than the worst case path gain between cell and UE.

Path Gain between Cells>Path Gain between UE and Cell+4+8-9.5=2.5 dB

This is highly conservative because this analysis has not claimed the benefit of the following probable advantages.

- The UE needs several dB of fading margin
- The Cell to Cell path is probably closer to R3 than R4
- Sectored base stations will have up to an additional 8 dB of gain

4.2 Pico Cells

Further detailed analysis may be needed to predict performance for a pico cell case. For that case, there would be lower base station antenna gains, R3 rather than R4 path loss, and various attenuation issues; e.g. through a floor or wall. It has been proposed to permit Pico Cells to employ a higher noise figure receiver. There is more serious concern that a Pico Cell may not be able to detect the Synchronization Channel of its neighbor. Therefore more detailed propagation analysis will be needed to verify the reliability of the Passive Approach.

However, operationally there are several work-arounds. For example, measurements of relative Time of Arrival by UEs will provide useful information for Node B Sync. Because the maximum range of a Pico Cell is very small, uncertainty in propagation delay becomes insignificant. Therefore, observed Time Difference of Arrival measurements are virtually identical to observed Time Difference of Transmission, within the required uncertainty.

5 Conclusion

We have reviewed two proposed approaches for over-the-air node B synchronization; an Active Approach using a new wave form to be transmitted in the RACH time slots, and a Passive Approach, based on use of existing Layer 1 waveforms.

We have identified key issues
- Steady State Performance
- Link Margin
- Operational Issues.

We plan to provide more detailed analyses at RAN WG1#12 and encourage other companies to do the same.

6 References

[1] Synchronization of TDD Cells, TSGR3#6(99)905, Sophia Antipolis, France,August 23-27, 1999, InterDigital Comm. Corp.

[2] NBAP & RNSAP Procedure for TDD Synchronization (some additions/modifications to R3-99905)TSGR3#6(99) 882, Italtel / Siemens, August 23rd 1999,Sophia Antipolis, France

[3]Node B synchronisation for TDD, Siemens, TSGR1#10(00)0074, Beijing, China, January 18-21 2000

[4] Synchronisation of Node B's in TDD via Selected PRACH Time Slots, Siemens, TSG RAN WG1 (99)G42, New York, USA, October 12 - 15, 1999

[5] Node Sync Tracking Simulation:Impact of TOA measurement accuracy, InterDigital, TSG RANWG1(00)0469, Seoul, Korea, 10-13 April, 2000