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1 Introduction

According to the work item about UE positioning enhancements for TDD [1] some theoretical calculations have been presented at the WG1-meeting#15 in Berlin [2]. In order to proceed with the work item, some simulation results and a general concept for LCS for the 3.84 Mcps TDD mode are presented here.

2 Idle Periods for the 3.84 Mcps TDD mode

Location services that are based on air interface methods require to perform time of arrival measurements on signals from neighbouring base stations at the UE. In order to overcome the hearability problem all downlink transmissions in the serving cell must be switched off for a certain time period. In [2] some results have been presented concerning the coverage of LCS. It has been shown, that a coverage greater than 80% for a cell can not be achieved without idle periods. One major problem is the interference received from the transmissions in the serving cell.

2.1 Simulations with IPDLs

Figure 1 shows a hexagonal layout of seven cells for the LCS simulations. All measurements are performed on the midambles of length 512 chips.

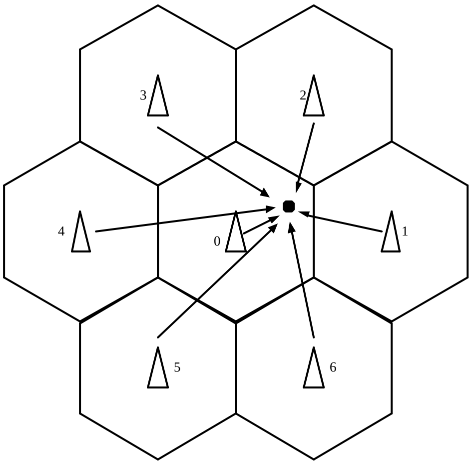

Figure 1: Cell configuration

The UE is located at random locations with uniform distribution over the centre cell. For each random placement, the path losses is computed from the UE to each of the seven NodeBs. The model for path loss computation is inverse fourth power law with an additional lognormal shadow fading component with 8 dB standard deviation. Because of the assumption of idle periods there are two phases for each measurement. In the first phase, all NodeBs transmit midambles but the UE only correlates against the midamble code for the serving cell. In the second phase all NodeBs except the serving NodeB transmit midambles and the UE correlates against the six relevant midamble codes.

For both phases for each position location, 5 measurements are repeated in time to provide a diversity element in the determination. It is assumed that the serving NodeB provides timing advance based on the earliest path so that position determination can be based on time of arrival measurements rather than time difference of arrival.

The path from each NodeB to the UE is treated as a 30.01 Urban multipath channel with independent fading for every measurement. The general simulation assumptions are as follows:

Parameter	Value
Range Law	$N = 4$
Propagation Standard Deviation	8 dB
Channel	30.01 – Urban
Time Diversity	5 Measurements
Receiver Sample Rate	2 samples/chip
Cell Radius	1000 m
NodeB Sync Error Standard Deviation	100 ns

Rather than specifying a transmitter power, the relative noise level has been computed to relate to an effective transmitter power providing a normal service. Because LCS will be based on existing signals, it is assumed that the service, provided through this signal, has a coverage of 98% with a Eb/No = 8 dB at the edge of the cell.

The coverage at the cell corner is based on an assumption of equal nominal path loss from the three nearest NodeBs with independent lognormal shadowing and selecting the best NodeB. For 8dB lognormal shadowing this corresponds to a shadow fading margin of about 5 dB.

The measurements are performed in two phase, as indicated earlier. During the first phase, the UE correlates only against the midamble of the serving NodeB. The correlation powers over a window of 50 chips are computed. This process is repeated over the diversity period, i.e. 5 results, and the powers are added together. Based on this result, the earliest strongest path is determined. In the second phase, the delays from surrounding base stations is performed in the same way as during the first phase, but now with idle periods in the serving cell. This leads to 6 correlation results, each representing the strongest earliest path received from each NodeB. From these paths the three strongest are selected and ranked into a descending order of the magnitude.

At this stage a total of four time of arrival measurements are available. It is assumed, that a timing advance measurement has been performed for the serving cell. Because the cells are synchronised this means, all measurements can be treated as time of arrival measurements.

Finally the position of the UE is computed using all four measurements based on a minimum mean square error computation. If the position of the UE can not be computed then the centre of the serving cell will be the estimate of the UE's position.

The results are presented in Figure 2. For 67% of all location attempts the radial error is less than 60 meters and for 95% the error is approximately 350 meters for LCS using IPDLs.

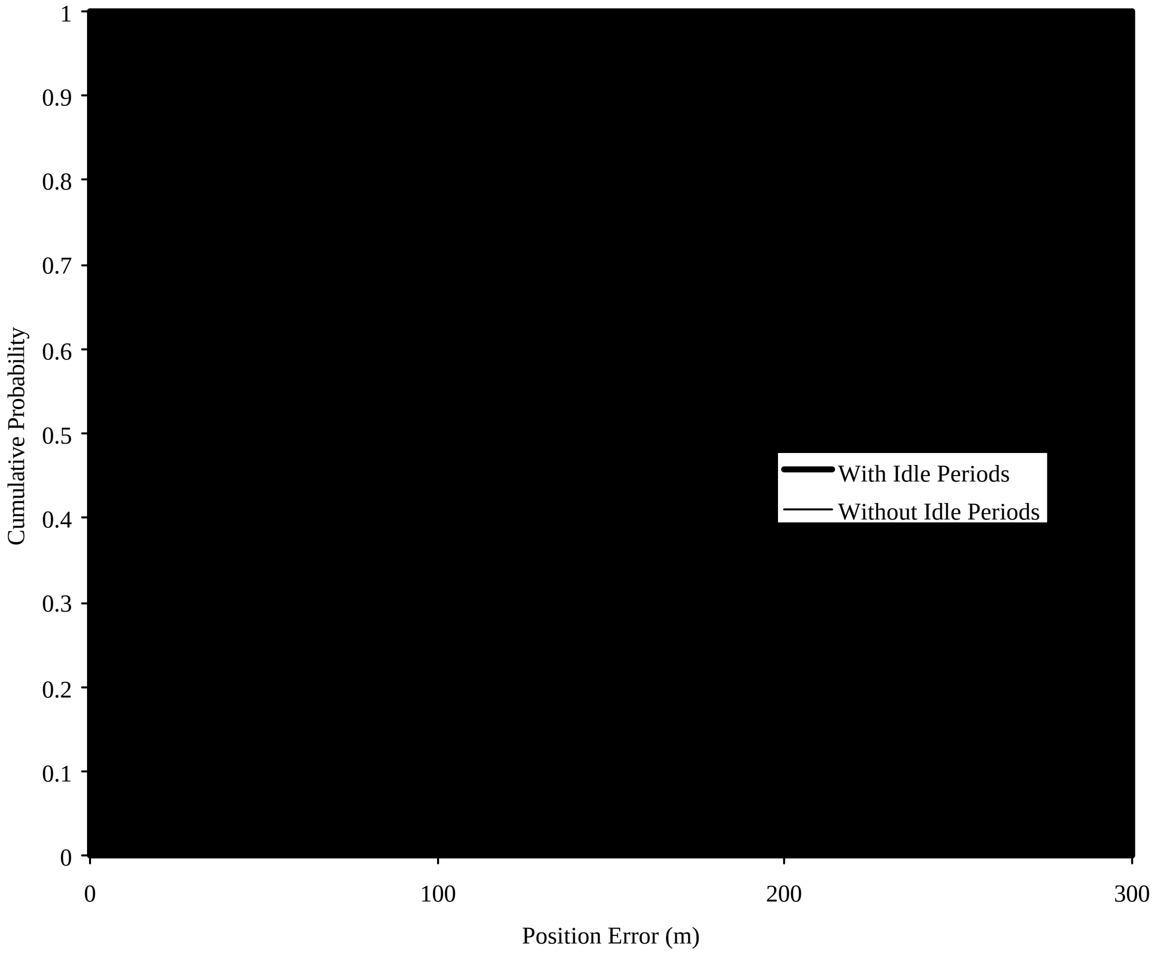

Figure 2: Cumulative Probability of Position Error

It has to be noted, that four measurements are needed for reliable positioning. It might be expected that this requirement would degrade the statistics of measurement since the probability of all three surrounding cells falling within the necessary power window would be reduced. However, this is not the case. Generally only three measurements actually contribute to the result. The reason for needing to handle four measurements is to increase the probability that the three used are those which form a triangle around the UE's position. Where the UE is outside the triangle the measurement errors can become very big - in fact so much so that the UE can appear to be inside the triangle even when it is not. Thus the reason for needing four measurements is to include a nearer NodeB even when shadowing makes a more distant NodeB provide a stronger signal. Thus we need all four measurements because we cannot determine a priori which subset of three will provide the better result.

2.2 Parameters for the IPDL in the 3.84 Mcps mode

To allow measurements on signals from other cells idle periods must be incorporated in the downlink transmission of the 3.84 Mcps TDD mode. The usage of IPDLs is well known in the FDD mode and already standardised [3]. The occurrence of IPDLs in FDD is based on several parameters and a pseudo random function [4]. The Common Pilot Channel (CPICH) is used for the OTDOA measurements. One main characteristic of the CPICH is that it is transmitted permanently, so the measurements can be performed at any time instant. Due to the time slot structure of the TDD mode signals are normally not transmitted in every timeslot. Furthermore the TDD mode offers great flexibility for the slot configuration, so the idle periods must occur in a predetermined way.

Time of arrival measurements will be performed on the midambles. This requires that the midambles in the serving cells have to be ceased. Channel equalisation won't work without midambles, so all data from the serving cell will be lost during that slot with idle periods. In contrast to the FDD mode it is more suitable to cease a whole slot in the TDD mode. The proposed scheme for the TDD-IPDLs is a bit different from the FDD-mode to allow idle periods in any slot [5]:

Similar to FDD, two modes for the idle periods exist: continuous mode and burst mode.

In continuous mode the idle periods are active all the time. In burst mode the idle periods are arranged in bursts where each burst contains enough idle periods to allow a UE to make sufficient measurements for its location to be calculated. The bursts are separated by a period where no idle periods occur.

The following parameters are signalled to the UE via higher layers:

IP_Status: This is a logic value that indicates if the idle periods are arranged in continuous or burst mode.

IP_Spacing: The number of 10 ms radio frames between the start of a radio frame that contains an idle period and the next radio frame that contains an idle period. Note that there is at most one idle period in a radio frame.

IP_Start: The number of the first frame with idle periods.

IP_Slot: The number of the slot that has to be idle [0..14].

Additionally in the case of burst mode operation the following parameters are also communicated to the UE.

Burst_Start: The SFN where the first burst of idle periods starts.

Burst_Length: The number of idle periods in a burst of idle periods.

Burst_Freq: The number of radio frames between the start of a burst and the start of the next burst.

In burst mode, the first burst starts in the radio frame with SFN = Burst_Start. The nth burst starts in the radio frame with SFN = Burst_Start + n?Burst_Freq. The sequence of bursts according to this formula continues up to and including the radio frame with SFN = 4095. At the start of the radio frame with SFN = 0, the burst sequence is terminated (no idle periods are generated) and at SFN = Burst_Start the burst sequence is restarted with the first burst followed by the second burst etc., as described above.

Continuous mode is equivalent to burst mode, with only one burst spanning the whole SFN cycle of 4096 radio frames, this burst starting in the radio frame with SFN = 0. In case of continuous mode the parameter IP_Start defines the SFN of the first frame with idle periods.

The time slot that has be idle is defined by two values: IP_Frame(x) and IP_Slot. IP_Frame(x) defines the xth frame within a burst in which the slot with the number IP_Slot has to be switched off.

The actual frame with idle periods within a burst is calculated as follows:

IP_Frame(x) = IP_Start + (x-1) ? IP_Spacing with x = 1, 2, 3, ...

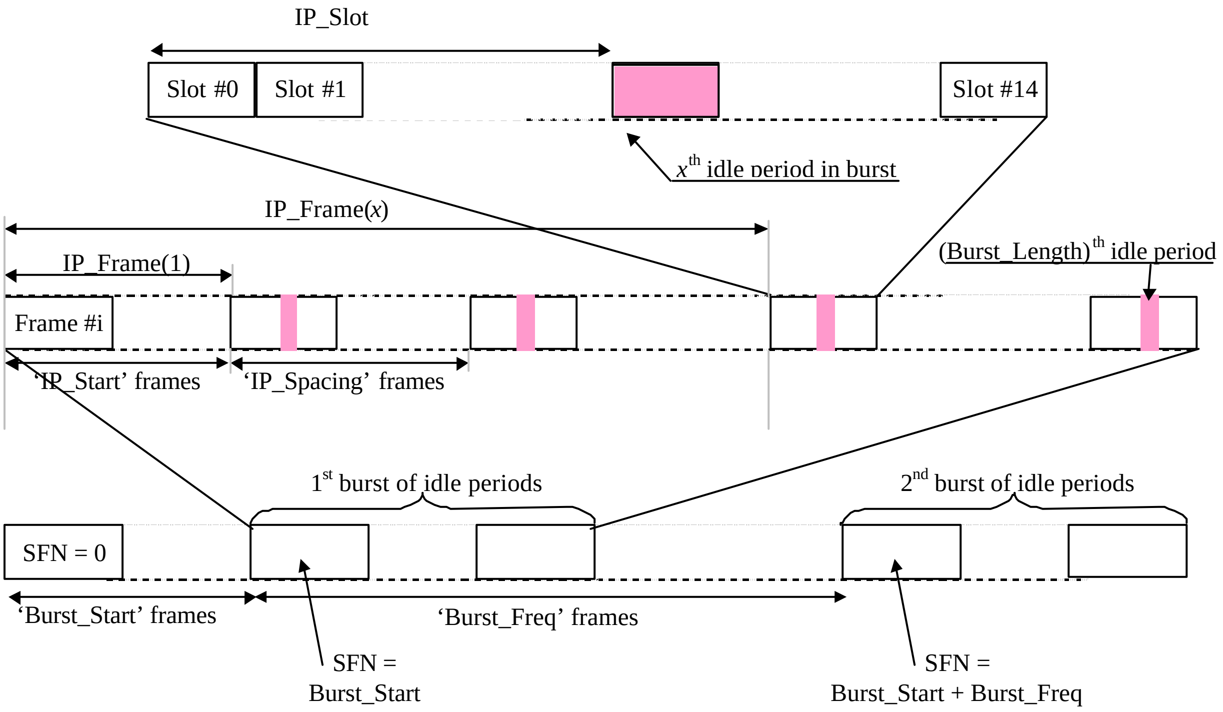

Figure 3: Timing of IPDLs in the 3.84 Mcps TDD mode

3 Measurements for LCS

Using the network's air interface for LCS requires that a suitable signal is present at each location estimation attempt. For FDD the Common Pilot Channel (CPICH) has the best properties: It is always present, transmitted with a constant high power and can be detected easily. Because of the slot structure used in the TDD mode, no channel is transmitted in all slots and no special pilot channel does exist.
To allow measurements in all TDD time slots, several possibilities to perform the time of arrival measurements should be allowed. Furthermore, the existing observed SFN-SFN type 2 measurement as defined in [6], which provides the required time of arrival measurements, is not restricted to any specific channel. The measurement for LCS itself is defined by the occurrence of the idle periods and the midambles that will be used for the correlation. Several possible channels are discussed in the following that could be used for LCS measurements

3.1 Beacon Channels

Beacon channels are transmitted with reference power and covers the whole cell. So they are very well suited for time of arrival measurements for LCS. Due to the near-far effect the beacon channels of surrounding cells can not be detected everywhere in the serving cell. Therefore IPDLs have to be used to improve the hearability.
For example, the BCH has beacon characteristics. The BCH is mapped onto the P-CCPCH. It is transmitted once per frame and it's position is determined by the SCH.
Uplink power control is based on a path loss estimation that will be done with the beacon channel. In the case, that an operator chooses to have the same timeslot for the beacon transmission in every cell, the ceasing of the beacon channel can cause a severe effect on the uplink power control. By signalling to the UE to use only the average value of the path loss during frames with idle periods the uplink transmission power can be set to a reliable value.

3.2 PICH

The Paging Indicator Channel (PICH) is also transmitted at a high power level, typically the same reference power level as the P-CCPCH and is therefore also usable for the time of arrival measurements. By means of higher signalling it is possible to have a certain reuse pattern for PICH transmissions in the TDD system to align with the IPDLs. For example a PICH is transmitted every 16th frame. Within a location area the content of the PICH is the same in every cell, so there can be benefits by correlating over the whole PICH burst.

3.3 Other downlink channels

The RNC is responsible for data transmission over the air. It can decide that the measurements will be done on physical channels transporting user specific data and signal the necessary parameters for the time of arrival measurements to the UEs and arrange the occurrence of the IPDLs in the cells.

4 Conclusion

It has been shown that LCS for the 3.84 Mcps TDD mode requires idle periods to reach a sufficient accuracy and coverage. Because of the slot structure used for TDD mode and the several possible channels that can be used for the time of arrival measurements it will be best not to restrict the measurement to any specific channel. This will give operators and manufactures the chance to implement a system that will work best for their specific conditions.

Because the measurement already exists and no special LCS signal is required, no changes to the Layer1 specification of the 3.84 TDD mode are needed.

5 References

[1] Tdoc RP#9(00)0509: new Work Item sheets related to UE Positioning

[2] Tdoc R1-00-1123: Air Interface Methods for TDD Location Services, source: Siemens

[3] TS 25.305: Stage 2 Functional Specification of Location Services in UTRAN, V3.3.0

[4] TS 25.331: RRC Protocol Specification, V3.4.1

[5] Tdoc R2-002418: IPDLs in TDD, source: Siemens

[6] TS 25.225: Physical layer – measurements (TDD), V3.4.0