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Title: Air Interface Methods for TDD Location Services
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1 Introduction

Location services (LCS) in UMTS provide mechanisms to determine the actual geographical location of a user equipment (UE) [2]. For UTRA-TDD only the Cell-ID based method, the assisted GPS method or OTDOA methods shall be supported in R99 for LCS.
The work item “Support of UE positioning in UTRA-TDD” [1] defines air interface methods as a work item for R00. Here we present an analysis of the existing methods and possible candidates for other air interface based methods.

2 Analysis of the existing methods

Both the cell-ID based method and the assisted GPS method are not affected by the properties of the UTRA-TDD air interface. These methods are not subject of this analysis because their accuracy and availability is network independent.

2.1 The statistics of cell relative powers for LCS

The provision of location services (LCS) requires that time difference of arrival signals be available from a minimum of three NodeB/cells at a user equipment (UE). If these signals are transmitted at the same time on the same frequency then they can be distinguished only on the basis of their different code structures. In order to measure all such signals, their relative power differences must be small compared with the processing gain of the codes (taking into account the cross correlation properties of the code set in use). Where this cannot be achieved, the LCS sub-system will be subject to the Near-Far effect in which strong wanted signals mask weaker wanted signals.
For this reason the distribution of the relative powers of signals from NodeB/cells at a UE is of considerable interest. Consider the scenario of Figure 1.

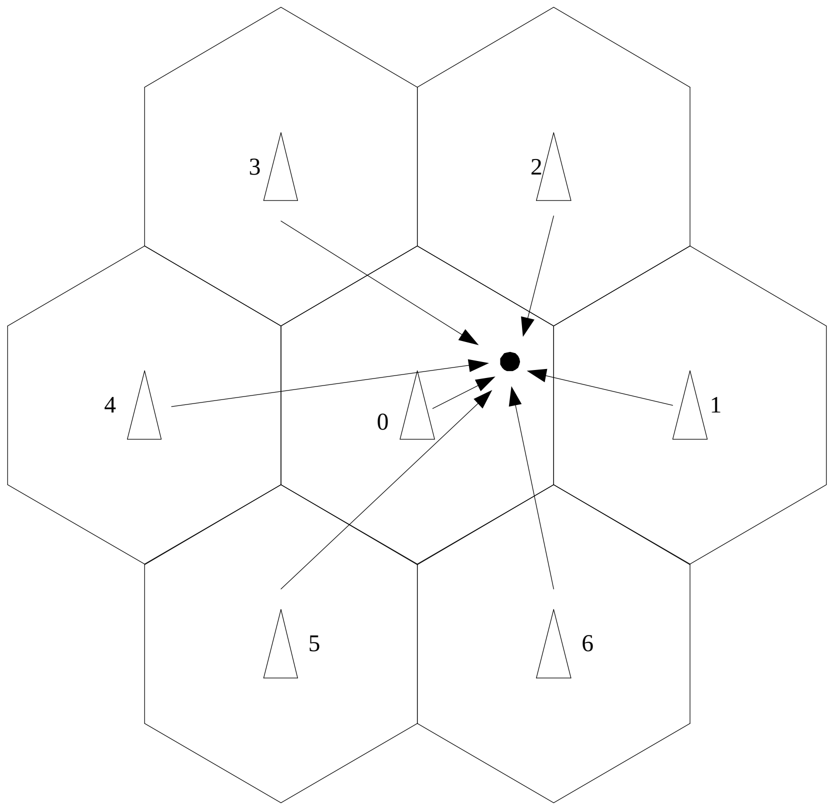

Figure 1: Scenario for Reception of LCS Signals

Here a UE, physically located in cell 0, is receiving signals from a total of 7 NodeBs (we ignore contributions from more distant NodeBs). In order to perform successfully a location measurement, the received powers of the three strongest signals arriving at the UE must all fall within a power ratio limit - i.e. the strongest of the three must be no more than R dB stronger than the weakest of the three where R is a number dependent on the properties of the codes in use. In the position shown one would expect the three strongest signals to be coming from NodeBs 0, 1 and 2. However, in a realistic scenario with shadowing this will not necessarily be the case. Indeed even the centre cell, 0, need not necessarily always fall amongst the strongest three.

Here we present the results of a simple Monte Carlo evaluation of the probabilities of the ratio exceeding R, for a range of values for R. This can, in turn, be used to determine the required properties for the codes for a specified coverage for provision of location services.

A UE is placed at random within the centre cell and the distances to all 7 base stations are computed. The paths losses are computed according to a range law of order 4. An additional lognormal shadowing component with standard deviation of 8 dB is independently generated and added to each of the paths. The three strongest paths are then identified and the ratio of the strongest to the weakest determined (in decibels). The values of the ratio are accumulated into a cumulative distribution which is shown in Figure 2, below.

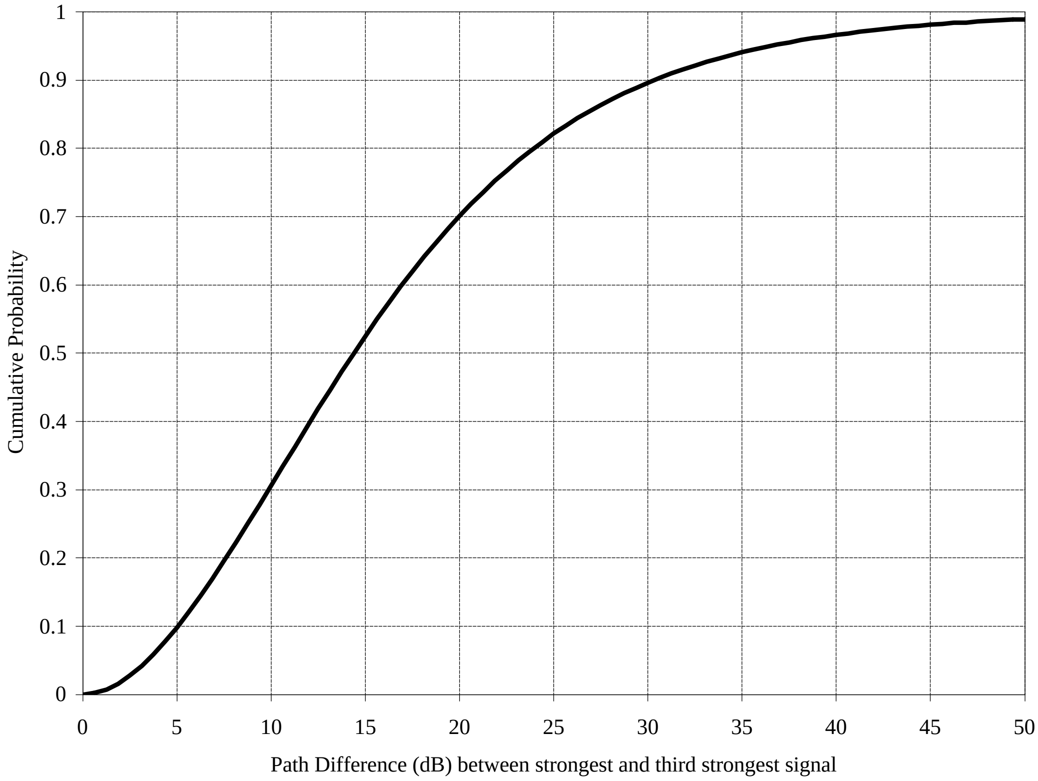

Figure 2: Cumulative Probability of Path Differences

It is clear from this curve that the coverage for this case is very small for any reasonable protection ratios. For example, if signals with a power difference of only 6 dB can be resolved then only about 13.5% of the cell is covered. Even for a resolution ratio of 20 dB the coverage is only 70%.

2.2 OTDOA method

Only the OTDOA method utilises measurements that are performed on signals sent by the NodeBs. That is the SFN-SFN observed time difference [3]. The main purpose of this measurement is for handover.

Obviously this OTDOA measurement is performed on the midambles of the P-CCPCHs from neighbouring cells relative to the received P-CCPCH of the serving cell. Two different SFN-SFN measurements are required for an unambiguous calculation of the UE's position by the position calculation function (PCF). Thus a total of two SFN measurements are required in addition to the serving cell's SFN

For one SFN-SFN measurement the UE must reliably detect two midambles, one of course from the serving cell. Assuming there is only the transmission of the P-CCPCH in one time slot and the UE receives interference from an equidistant interferer with the same power as the neighbour midamble so we find an S/I of 0 dB. The midamble length of 512 chips results in a processing gain of 27 dB, therefore the S/I would increase to 27 dB for midamble codes with crosscorrelation properties behaving as random noise; further investigation of the actual cross correlation properties is required. But with path fragmentation (the first path in the 30.03 urban model [5] is about 3 dB down on the total) this comes to a realistic mean value of about 24 dB.

Reliable detection of this midamble (high probability of detection, low false detection rate) would require non-coherent averaging over several frames. This would also provide an element of diversity gain over fading. Now consider an attempt to receive the midamble from a neighbouring

cell whose signals are subject to greater attenuation than the strongest (usually the serving cell) midamble. A pathloss difference of 24 dB will bring the mean S/I on the earliest path down to 0 dB. At this level it might just be possible to detect the path with non-coherent combining over a reasonable time period. Further increases in path difference would make detection impracticable.
Assuming that the UE can detect two signals from neighbouring cells with the same path difference of 24 dB the coverage according to figure 2 will be only 80%. We have to keep in mind, that this 80% holds only if the UE can detect two midambles from other cells with an S/I of at least 24 dB. The OTDOA method locates the terminal by the intersection of two hyperbolae, the positions of the transmitting antennas and the timing differences of the cells.
But nevertheless 80% is an unacceptable low figure, so the SFN-SFN based OTDOA method does not provide enough availability of the LCS in the cell. Therefore we should investigate improvements of the existing OTDOA method and other methods using the air interface as well.

3 Other air interface methods

3.1 SCH listening

The current definition of the SCH consists of the sum of one primary synchronisation code sequence (PSC) and three secondary synchronisation code sequences (SSC). Because of cell sync it will be possible to differentiate the primary PSCs on the basis of offset. This is large enough to be unambiguous with respect to range/location. Depending on the offsets, two or more SCHs transmissions heard by one UE may be partially overlapped in time. Thus the auto correlation properties of the PSC are of concern. It may be possible to do cell planning so that surrounding cells have non overlapping SCHs but there are probably not enough degrees of freedom in the available number of time offsets.
In any event, the main source of interference for LCS reception will not be the PSC (or the SSC) but the traffic since this can be at significantly higher power and is always overlapped. Suppose the total SCH power is equivalent to one (SF = 16) code and that eight codes (with SF=16) are transmitted at full power. Because the PSC has one half of the power of the SCH this means that the interference power will frequently be 16 x (or 12 dB) higher than the PSC. Thus, given a code length of 256 for the PSC leading to a processing gain of 24 dB, the overall S/I for a UE receiving a PSCH in the presence of a full traffic load will be 24 - 12 = 12 dB.
If the UE is receiving equal interference from another cell then this falls to 9 dB. With path fragmentation the average S/I comes down to 6 dB. Figure 2 indicates a coverage of about 13.5% which is totally unacceptable.
For a single cell all of the interference comes from the traffic transmissions from that cell. The interference is subject to a multipath diversity gain (e.g. the receiver sees interference from all paths) whereas the wanted signal is only the earliest path. Thus, the S/I will generally be partially fading even though the interference and wanted signal both come from the same cell. Even with a non fading S/I, 9dB would not be adequate for reliable detection of a single sample.
It should also be remembered that the above discussion applies only to the interference limited case. Whilst interference limitation may be a reasonable assumption for UEs operating out to the edge of their cells, it is unlikely to be realistic for UEs operating at double range, e.g. close to one cell but attempting to receive a signal from another cell.

3.2 Usage of blanking

One possible approach to limit the interference and therefore to increase the S/I would be to switch off transmissions in the serving cell during a special time period to increase the hearability because the main source of interference is the traffic in the serving cell.
But blanking will cause a loss of data in the downlink direction, so the idle periods have to occur infrequently, for example in every 5th frame. The measurements will also be performed less

frequent and therefore no averaging over several frames is possible. Now a higher S/I is required to detect the signals because no diversity gain over fading can be achieved.
Since adjacent cells use different midambles it may be possible to detect multiple midambles simultaneously. However, verifying this will require evaluation of the cross correlation properties of the midamble code set.

4 Conclusion and alternatives

The existing OTDOA method and the presented SCH listening method do not provide sufficient cell coverage. Therefore we propose the following procedure to continue with the work item in Release 2000.
It has to be investigated if blanking can significantly increase the coverage for LCS. Because of the very poor coverage for normal SCH listening there will definitely be no great improvement with blanking for SCH listening. Blanking together with BCH midamble detection may be the most promising approach, but the impact due to blanking has to be considered (coverage and data loss) and the cross correlation properties of the midambles must be verified.
Because it is still not clear, if any of the mentioned methods will provide sufficient cell coverage, some alternatives could be considered and investigated for R00 as well.
The first possible method is called “pseudo active”. This method uses information about the distance between a UE and its NodeB (known from the applied timing advance TA and the received timing deviation RTD) and only one SFN-SFN measurement. If the UE is in idle mode, it starts to build up an RRC connection. As soon as the distance is known, the connection will be released. So only one neighbouring cell must be detected and this could increase the coverage.
In order to achieve cell synchronisation a synchronisation burst is proposed [4]. This burst is designed (high transmission power, 2400 chip sequence for detection, all other transmissions are switched off) to be reliably detected in neighbouring cells and could also be used for LCS as a second alternative.

5 References

[1] Tdoc RP#7(00)0053: “Work Item Description: Support of Location Services in UTRA TDD”

[2] TS 25.305: “Stage 2 Functional Specification of Location Services in UTRAN”, V3.2.0

[3] 3TS 25.225: “Physical layer – measurements (TDD)”, V3.2.0

[4] Tdoc R1#8(99)g42: “Synchronisation of NodeBs in TDD via selected PRACH time slots”, source: Siemens

[5] TR 101 112 V3.2.0: “Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03)