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Agenda Item: Adhoc 29 (Positioning)

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Title: Initial Simulation Results for the OTDOA-PE positioning method

Document for: **Discussion**

Introduction

This paper presents in more detail the Positioning Elements (OTDOA-PE) based positioning procedure and gives the first simulation results which are based on PEs being detected within idle periods.

The OTDOA-PE method is based on transmission of symbols in the downlink at known times with regard to the timing of the serving cell Node B. These symbols are transmitted by PEs (positioning elements) which are placed in locations other than those of the Node B equipment (one of the interesting options is to consider the potential for PE functionality to be integrated in repeaters).

This procedure has an advantage over the existing methods in certain environments or locations where other reference sources (Node Bs, satellites) may not be visible to the UEs such as may be the case at the edge of cellular coverage and indoors. The PE method is proposed as optional to be used either in conjunction with other positioning methods or in isolation. The measurements are very similar to the ones required for OTDOA-IPDL and If supported by terminals an operator will have the choice of ignoring this capability, installing a few PEs in order to achieve positioning where it is not possible with other methods, or installing a significant number of PEs in order to achieve higher accuracy throughout the system.

The positioning procedure

The PEs monitor the downlink and synchronize to the transmissions of a Node B. Each PE is associated with one or with combination of 256 chip code/symbol generated with the same procedure as the 16 S-SCH codes used in for the second step in synchronization. If combination is applied the symbols used for the PE transmitted signals should belong to the same group of S-SCH codes. Each PE transmits its identifying symbols at predetermined instances within a downlink multiframe (as received at PE position). The PE coordinates are known to the network, so the multiframe timing at the PE position is known and consequently the transmission instances with regard to Node B's timing is known. Measurement of the time of arrival of the PE symbols at a UE can be used as an additional OTDOA measurement or as a TOA measurement when the RTT measurement is available.

Transmissions from PEs can be pre-configured or configured by the network which communicates with PEs as if they were UEs. Configuration involves transmission repetition patterns within a multiframe and transmission power. PE transmissions can be periodical – in every multiframe - to accommodate periodical positioning of mobiles, or on demand. In the latter case all PEs in a cell will belong to the same paging group and will transmit in response to the paging indicator being set for their group.

System issues

Given that PEs synchronize to base stations, are at known positions and transmit at precise offsets with regard to a base stations frame boundaries as seen at the PE, there is no need for measurements by the LMU. This would anyway have been very difficult due to the very short duration of PEs transmissions.

Capacity loss in the downlink should be lower than with IPDL when PEs are used in a system that does not employ idle periods. Their transmitted power will probably have to be higher compared to when they only transmit within idle periods, but whilst idle periods guarantee data loss for all UEs in the cell this is far from true for PE transmissions.

The PE based method may also be the only method to achieve positioning when there are no other BTS to be heard even if the serving BTS pauses transmission, as may be the case at the edge of coverage, indoors, or in rural areas. In some of these cases such as indoors or in the presence of high rise building GPS may also be unable to offer a solution.

Positioning elements are of <u>small volume</u> (handset like) and are configured via the air interface. Their transmitted power will be in the order of handset transmissions, and they can be powered by small solar panels. No modifications are needed to Node B behavior. The very small size, independence from backhaul transmission, and low power requirements should help keep the overall cost of deploying them reasonable.

Simulation conditions

The main aim of the first phase of the simulations is to evaluate the potential for an increase in positioning accuracy with the use of PEs.

The procedure was the following:

White noise at –99dBm was added to the signals from all but the serving base stations at the UE position and the result of timing detection procedure was recorded. Up to this point the procedure is identical to OTDOA-IPDL positioning.

Subsequently, the PE signal is added to the overall signal received at the UE in each idle period and the detection procedure for each BTS is followed again and in addition correlations with the PE code are performed in order to detect the PE timing as well.

In this way any degradation in base station detection that the addition of the PE signal may incur is taken into account and the results present a fair comparison of overall accuracy with each individual measurement having used the exact same channel impulse responses, slow fading and noise conditions for both OTDOA-IPDL and OTDOA-IPDL-PE.

The fixing algorithm is a Weighted Least Squares algorithm based on Taylor series expansion. The weights were based on correlator output related C/(I+N) estimates. When this fixing algorithm fails to converge or positions the UE outside the sector, the UE position is chosen amongst a large number of regularly spaced positions within the sector to be the one for which the OTDOA measurements come closer to the measurements made by the UE.

The simulation assumptions are given in the following table:

Idle Period Length	5 * 256 chips (5 symbols)
Average Frequency of Idle Periods	10 Hz
Number of Idle Periods	10
Channel Model	T1P1.5 Models : Urban A, Bad Urban
Cell Radius	1 km
Pathloss Model	beta + alpha * 10*log(range in meters)
Urban :	alpha = 3.52; beta = 29.03
Signal Used for BTS detection	Common Pilot
Signal Used for PE detection	3 different 256chip S-SCH like codes
Chip Rate	3.84 Mchips/s
Vehicle Speed	50 km/hr
BS Total (ERP)	43 dBm
Common Pilot Transmit Power	33 dBm
PE transmitted power	27dBm
Lognormal Fading Sigma	8 dB
Number of Sectors	3 per site

The following assumptions have also been made:

- The reference for the OTDOA measurements is the signal from the serving site which is measured outside the idle periods and has no associated error. This should be inconsequential in view of the fact that we are interested in relative performance.
- When the algorithm fails to converge (estimated mobile position out of sector boundaries, large errors in first path detection, not enough measurements) a method that is based in griding the cell in several points with calculation of the minimum theoretical error for each estimated point, is used. If no base station signal neither PE signal is detected, UE is placed in the center of the cell.
- No UEs are in handover
- The primary and secondary synchronization codes are included in the base station signals and each carry 5% of the base station power. Correlation in the idle periods is done using the base station scrambling codes with only the primary synchronization codes at the beginning of each slot.

Simulation Results

Simulations were ran for the UrbanA and BadUrban environments as there is little scope for improving the already good accuracy obtained with IPDL in other environments. For these results a single PE is used in the center of the sector transmitting 0.5Watts.

The CDF of the radial error is presented separately for the simulations for which there were at least 2 OTDOA measurements made and for all the simulations which comprise a large number of cases when the UE is placed in the middle of the sector in the absence of enough OTDOA measurements. Paradoxically, the results for all the simulations are better than for those where a calculation has been performed for the UE position. This is contrary to what happens in the rural environment and can be attributed to the small cell size associated with the UrbanA and BadUrban environment and the considerable delay of the first path in relation to the line of sight arrival time.

The CDF results which can be found in appendix A are in broad but not very good agreement with the results presented by Motorola in [4]. The main factor has to be the fact that we have not performed measurement of the serving BTS relative to which all OTDOA measurements are made. This results in an increased error for our simulations as we reference all measurements to the LOS component which will not be present most of the time. Another possible factor is differences in the multipath rejection techniques. In any event, the important aspect in our simulation is the comparative rather than absolute accuracies.

As the results show there is improvement in accuracy even though this is not spectacular. When PEs are detected they tend to have lower average measurement error than that associated with BTS measurements. This suggests that biasing the fixing algorithm to make better use of the accurate PE measurements may increase accuracy. Accuracy will also benefit from more PEs, optimized positioning of PEs in a sector (based on Geometric Dilution of Precision studies) and also of further refinement of the power transmitted by the PE. It is important to increase the percentage of instances in which at least 2 OTDOA measurements are made so that the distorting effect of placing the UE in the center of the sector can be reduced or eliminated.

An analysis of the effect that the PE transmissions have on detection of other base stations is given in figure 3 in appendix B. It shows that the PE signal provides a second OTDOA measurements which enables UE position evaluation in almost 50% of the cases in which in the absence of PE transmissions the UE would have made only one or no OTDOA measurements. Also, the additional interference introduced by the PE signal 'masked' signals from other NodeBs and reduced what would have been a sufficient number of OTDOA measurements to less than 2, in only a very small percentage of the simulations.

Conclusions

The results have demonstrated the potential of the PE based positioning procedure for enhancing accuracy. Such an improvement was shown for the BadUrban and UrbanA environments with a single PE in a sector, transmitting within IPDL idle periods and with low power. It was shown that the PE can be received accurately and without significantly reducing detection probability of BTSs by the UE. More simulations results will be presented for different configurations aimed at justified the adoption of a PE related measurement in RAN specifications.

<u>Further Study</u>

Further work will involve:

- Simulations with the two BTS nearest to the sector's edge being switched off to emulate edge of coverage conditions
- simulations with more than one PE per sector
- simulations with a different propagation environment for the PE as would be the case if it was installed below rooftop in order to have LOS with certain areas within a sector
- simulations with OTDOA measurements of PEs and BSs without idle periods
- simulations that make use of RTT which can transform the PE measurement from OTDOA into a TOA measurement

References

[1] T1P1.5/98-110 Evaluation of Positioning Measurement Systems

[2] R1-99346 Recapitulation of the IPDL positioning method, 3GPP RAN WG1

[3] Wade H. Foy, “Position-Location Solutions by Taylor Series Expansion”, IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-12, No.2, March 1976, pp 187-193.

[4] Brendan Ludden, Luis Lopes, “Cellular based location technologies for UMTS: A comparison between IPDL and TA-IPDL”, 2000 IEEE 51st Vehicular Technology Conference, May 15-18, Tokyo.

APPENDIX A

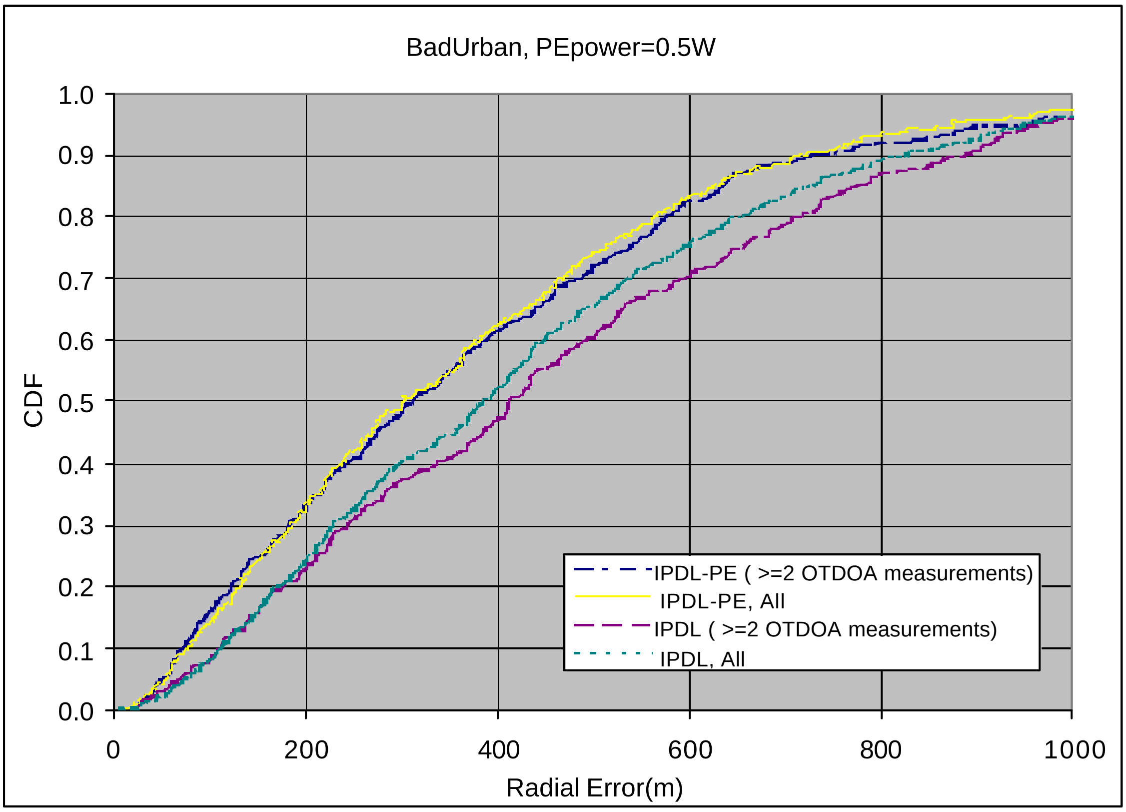

Figure 1

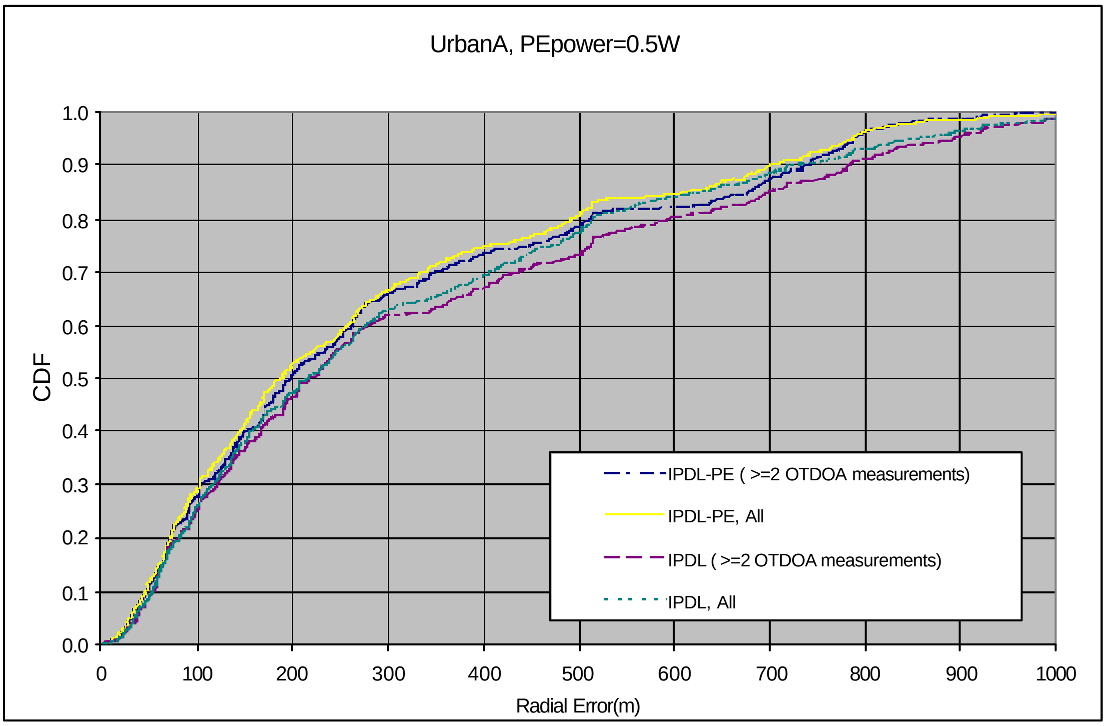

Figure 2

Table 1: Results for BadUrban

	Percentage of simulations in which the UE made at least 2 OTDOA measurements	67% error: at least 2 OTDOA measurements	67% error: all results	90% error: at least 2 OTDOA measurements	90% error: all results
IPDL-PE	63%	457m	448m	771m	724m
IPDL	51%	555m	513m	893m	828m

Table 2: Results UrbanA

	Percentage of simulations in which the UE made at least 2 OTDOA measurements	67% error: at least 2 OTDOA measurements	67% error: all results	90% error: at least 2 OTDOA measurements	90% error: all results
IPDL – PE	74%	318m	305m	724m	703m
IPDL	66%	400m	369m	784m	717m

APPENDIX B

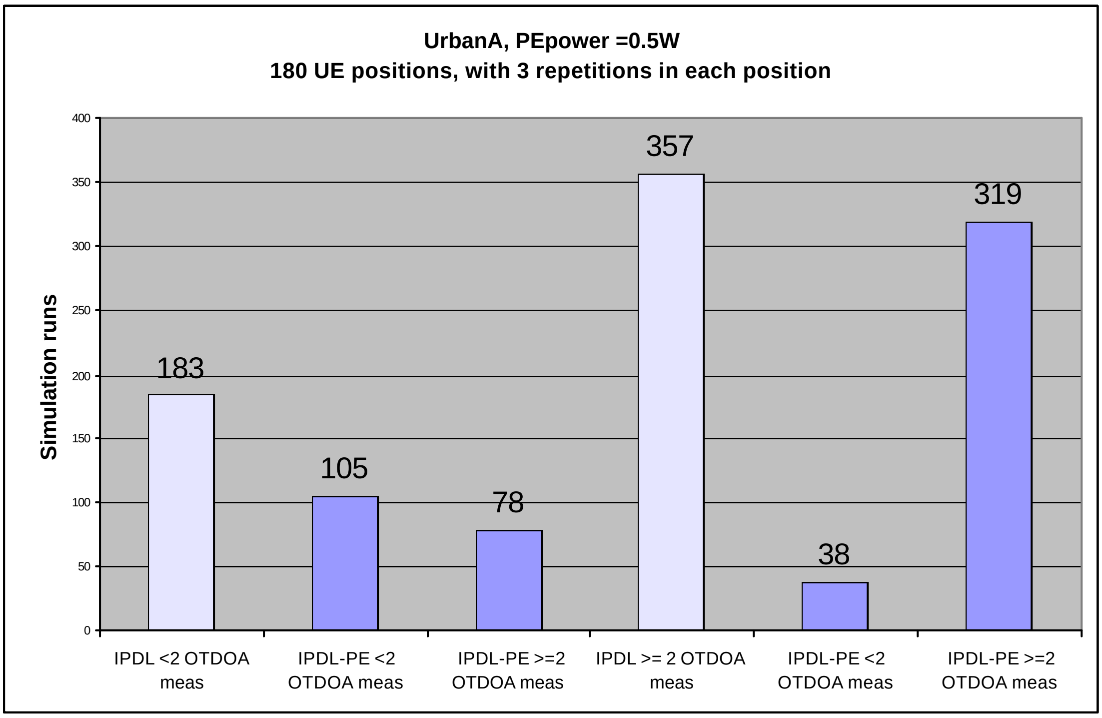

Figure 3

The first bar in the graph above gives the number of simulations that resulted in less than 2 OTDOA measurements being made by the UE before the PE signal was added. In those cases no calculation could be performed for the UE position and the position was then assumed to be at the center of the cell. The two bars that follow show in how many of these simulations the number of measurements remained less than 2 after the addition of the PE, and in how many cases a calculation of the UE position became possible when detection of the PE signal provided the second OTDOA measurement. The third bar shows that in just under half of these cases a calculation became possible with the PE signal.

The fourth bar shows in how many simulations there were already 2 OTDOA measurements before the addition of the PE. The last two bars show that in only just over 10 percent of these 357 simulations the addition of the PE signal resulted in a reduction of the OTDOA measurements being made to less than 2.