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Title: Pilot signal coverage for Location Services (LCS)

Document for: Discussion & Action

1 Summary

This contribution reports on coverage availability of pilot signals for location services (LCS). The simulation results indicate that for 94% of the coverage area, at least one other pilot is available at the UE location. This permits a location estimate to be made by observing the time-difference-of-arrival (OTDOA) method supplemented by a round-trip-time (RTT) measure. It is proposed that the OTDOA-RTT method be included as the basic standard method for LCS in UTRAN release 99. A further contribution (99c37) details the text for document 25.231 to support this basic method.

2 Discussion

Introduction

The basic standard OTDOA-RTT location method involves measurements of the UTRA radio transmissions made by the UE and the Node-B (or LMU). These measures are then sent to a Position Calculation Function (PCF) in the Serving RNC where the location of the UE is calculated (see document 25.923).

The primary standard measurements are of the observed time difference of arrival (OTDOA) of downlink signals received at the UE. These measurements, together with other information concerning the surveyed geographic location of the transmitters and the relative time difference (RTD) of the actual transmissions of the downlink signals may be used by the PCF to calculate an estimate of the position of the UE. Each OTDOA measurement for a pair of downlink transmissions describes a line of constant difference (hyperbola) along which the UE may be located. The UE's position is determined by the intersection of these lines for at least two pairs of base stations.

If a sufficient number of downlink signals are not available, a secondary measure is made at the Node-B. The secondary measure is of the Round-Trip-Time (RTT) for transmissions between the serving transmitter and the UE. This measurement defines a line (arc) of constant distance (radius) from the transmission site in the sector served. This measure may be used to supplement the TDOA measurements made by the UE. The location of the UE being the intersection of the arc from the serving transmitter and the line of constant difference (hyperbola) between the serving and second transmitter sites.

In the event that sufficient primary measures are available, the secondary measure is not needed. However, with the use of the secondary measure, the location may be estimated even if the UE can only receive transmissions from two transmitters. Monte Carlo studies of the pilot-to-carrier interference ratio, reported below, for a number of environments have shown a 94% availability for at least one other pilot. The use of the OTDOA-RTT technique thus permits availability of the LCS in the majority of the coverage area. In the remainder of the cases, the UE is typically very close to the serving Node-B transmitter and its receiver is blocked by the strong local signals. In these cases the UE may be so close to the transmitter that no other location information is needed beyond the RTT distance and sector estimate.

Pilot Observability

In order to do the location estimation using pilots, the first issue is how many pilots the mobile can receive with a certain Ec/Io . In this section, we provide quantitative simulation results for this coverage.

Without loss of generality, assuming each base station total transmit power is 1, the calculation of pilot carrier to interference ratio may be given by:

$$Pilot\left(\frac{E_c}{I_o}\right)_i = \frac{PilotFraction \times PathLoss_i}{\sum_{k=1}^{NumberOfSectors} Loading \times PathLoss_k}$$

where (forward link) loading is assumed 100%. PilotFraction is 0.17. PathLoss is the total path loss between the base station and the mobile which includes propagation loss (COST-231 Hata model), log-normal shadowing with 8dB standard deviation, and antenna loss due to horizontal and vertical pattern. In this example the pilot fraction represents the combined effect of the continuous and the traffic channel pilots.

A network cluster of 19 tri-sectorized cells, 57 sectors, is considered in the simulations. The shadowing correlation from between sectors of the same base station is 100% and from different base stations is assumed to be 50%. Monte-Carlo simulation results for the pilot carrier to interference ratio for different environments are presented in Table 1 through Table 5. The tables show the probability that the Pilot Ec/Io is above a specified value. Note that the serving base station is the one from which the mobile receives the strongest Ec/Io, and the 1st, 2nd and 3rd are the next three strongest Ec/Io in decreasing strength.

Table 1. The pilot carrier to interference ratio in a dense urban environment.

Pilot Ec/Io	**>-10dB**	**>-15dB**	**>-20dB**	**>-25dB**	**>-30dB**
serving		1.00		1.00	
1st		0.36		0.90	
2nd		0.06		0.79	
3rd		0.00		0.63	

Table 2. The pilot carrier to interference ratio in an urban environment.

Pilot Ec/Io	**>-10dB**	**>-15dB**	**>-20dB**	**>-25dB**	**>-30dB**
	0.59	1.00		1.00	1.00
	0.00	0.35		0.88	0.97
	0.00	0.05		0.77	0.94
	0.00	0.00		0.61	0.86

Table 3. The pilot carrier to interference ratio in a suburban environment.

Pilot Ec/Io	**>-10dB**	**>-15dB**	**>-20dB**	**>-25dB**	**>-30dB**
serving	0.61	1.00	1.00	1.00	1.00
1st	0.00	0.33	0.69	0.85	0.94
2nd	0.00	0.04	0.43	0.73	0.90
3rd	0.00	0.00	0.21	0.58	0.82

Table 4. The pilot carrier to interference ratio in a quasi rural environment.

Pilot Ec/Io	**>-10dB**	**>-15dB**	**>-20dB**	**>-25dB**	**>-30dB**
serving	0.61	1.00	1.00	1.00	1.00
1st	0.00	0.33	0.69	0.85	0.94
2nd	0.00	0.03	0.43	0.73	0.90
3rd	0.00	0.00	0.21	0.59	0.82

Table 5. The pilot carrier to interference ratio in a rural environment.

Pilot Ec/Io	**>-10dB**	**>-15dB**	**>-20dB**	**>-25dB**	**>-30dB**
serving	0.61	1.00	1.00	1.00	1.00
1st	0.00	0.34	0.69	0.85	0.94
2nd	0.00	0.03	0.43	0.73	0.90
3rd	0.00	0.00	0.21	0.59	0.83

These results show that the pilot Ec/Io from the serving base station is always above –20 dB. For a pilot observability threshold of –30dB, then for more than 90% of the coverage area, the mobile can see at least three pilots simultaneously at full traffic load. The pilot coverage area will be better than this with less than full traffic load. This multiple coverage is highest (over 94% at full traffic load) in urban and dense urban environments and lower (90%) in the rural environments. Thus in a high percentage of cases, the OTDOA measures will be sufficient to calculate a location estimate.

These results also show that for 94% of the coverage area (97% in dense urban/urban), at full traffic load, at least one other pilot is observable. Measurement of OTDOA for this one other pilot, together with a RTT measurement made by the Node-B, can be used to calculate a location estimate for the UE. Thus in a higher percentage of cases, the OTDOA measure together with an RTT measure, will be sufficient to calculate a location estimate.

The OTDOA-RTT technique can be used for LCS for nearly all practical cases. For the small percentage of UE that are located so close to the Node-B that they are blocked from receiving other pilots, the RTT measure of the radial distance and the sector information may be sufficient to locate the unit. Other techniques, such as measurement of signals on other carriers may also assist in these cases.

Pilot signal measures

The preceding section has shown the coverage of the pilot at an SNR of –30 dB. This section considers if this SNR is adequate for location estimation. The chip level simulation results show that with suitable integration times, a 125 metre uncertainty can be achieved.

A sampling rate operating at 2.56 the chip rate is considered in our simulation because of the TOA accuracy required. One half chip time is approximately equal to 40 meters.

The following are the results from Monte-Carlo simulations with 50 runs for each case. In each table the parameter, X_Yms combining indicates X ms total integration time with coherent pilot signal integration over Y ms and incoherent combining over X/Y coherent results. Ideally, to obtain statistically more significant results, it is desirable to increase the number of simulation runs. One sample error in tables below is equal to 1 / 2.56 chip duration.   However, in order to gather simulation results on a large number of parameters we reduced the simulation run to 50.

Table 6. The error probability in TOA est., 400_5ms combining, SNR=-30dB.

MS speed	0-sample error	1-sample error	2-sample error	3-sample error	4-sample error	>4-sample error
1km/h	0.92	0.06	0	0	0	0.02
50km/h	1	0	0	0	0	0
100km/h	0.9	0.1	0	0	0	0

Table 7. The error probability in TOA est., 400_10ms combining, SNR=-30dB.

MS speed	0-sample error	1-sample error	2-sample error	3-sample error	4-sample error	>4-sample error
1km/h	0.96	0.02	0	0	0	0.02
50km/h	0.94	0.06	0	0	0	0
100km/h	0.78	0.22	0	0	0	0

Table 8. The error probability in TOA est., 400_20ms combining, SNR=-30dB.

MS speed	0-sample error	1-sample error	2-sample error	3-sample error	4-sample error	>4-sample error
1km/h	0.98	0.02	0	0	0	0
50km/h	0.90	0.10	0	0	0	0
100km/h	0.70	0.30	0	0	0	0

Table 9. The error probability in TOA est., 200_5ms combining, SNR=-30dB.

MS speed	0-sample error	1-sample error	2-sample error	3-sample error	4-sample error	>4-sample error
1km/h	0.82	0.14	0	0	0.02	0.02
50km/h	0.94	0.06	0	0	0	0
100km/h	0.86	0.14	0	0	0	0

Table 10. The error probability in TOA est., 200_10ms combining, SNR=-30dB.

MS speed	0-sample error	1-sample error	2-sample error	3-sample error	4-sample error	>4-sample error
1km/h	0.90	0.10	0	0	0	0
50km/h	0.90	0.10	0	0	0	0
100km/h	0.74	0.26	0	0	0	0

Table 11. The error probability in TOA est., 200_20ms combining, SNR=-30dB.

MS speed	0-sample error	1-sample error	2-sample error	3-sample error	4-sample error	>4-sample error
1km/h	0.88	0.10	0	0	0.02	0
50km/h	0.68	0.28	0.02	0	0	0.02
100km/h	0.36	0.50	0	0.02	0	0.12

The results show that the TOA estimate improves as the integration time increases.

Table 10, shows satisfactory TOA estimates with -30dB SNR. In this case the 200ms of pilot data is chopped into 20, 10ms pieces which are coherently combined and then incoherently combined 20 times to get the power delay profile. Improved results can also be obtained with longer integration time for incoherent combining.

Performance

The results for the accuracy of TOA estimation shown in the previous section are for a pilot with the SNR greater than or equal to -30dB at the mobile. The probability for a mobile to have at least three pilots is around 90%. A one sample error for the TOA measure is assumed. Therefore, a bound on the probability of successful position location using TOA estimation can be obtained by multiplying the probability of successful TOA estimation under the condition of -30dB by the probability that the mobile has at least three pilots with the SNR above -30dB.

In the case of table 10, the overall error probability is given as follows,

Table 12. Probability of location est., 200_10ms combining, 1km/h MS speed.

environment	success	fail
dense urban	0.95	0.05
urban	0.94	0.06
suburban	0.90	0.10
rural	0.90	0.10

Table 13. Probability of location est., 200_10ms combining, 50km/h MS speed.

environment	success	fail
dense urban	0.95	0.05
urban	0.94	0.06
suburban	0.90	0.10
rural	0.90	0.10

Table 14. Probability of location est., 200_10ms combining, 100km/h MS speed.

environment	success	fail
dense urban	0.95	0.05
urban	0.94	0.06
suburban	0.90	0.10
rural	0.90	0.10

3 Conclusion

These results have shown that pilot signals can be used to provide or assist in position location. Three or more pilots are visible to a mobile with high probability. At least one other pilot is observable with 94%

probability. TOA can be estimated with a suitable integration interval.   It is recommended that pilot signal timing measurements be used as the basis for LCS methods in UTRAN.