Title: Impact of Antenna Downtilting on Network Performance in GERAN Systems

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Abstract: Antenna downtilting is often mentioned in the literature as a powerful method for improving network performance in cellular systems. The antenna elevation angle on a number of GSM EDGE Radio Access Network (GERAN) cells has been modified to quantify the impact of this method in a real network. In addition, a novel approach to prioritize the cells to be tilted based on network statistics has been tested. Trial results indicate that downtilting can improve certain performance aspects, especially those related to signal quality, but not all of them on every cell.

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Impact of Antenna Downtilting on Network Performance in GERAN Systems

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Abstract

Antenna downtilting is often mentioned in the literature as a powerful method for improving network performance in cellular systems. The antenna elevation angle on a number of GSM EDGE Radio Access Network (GERAN) cells has been modified to quantify the impact of this method in a real network. In addition, a novel approach to prioritize the cells to be tilted based on network statistics has been tested. Trial results indicate that downtilting can improve certain performance aspects, especially those related to signal quality, but not all of them on every cell.

Introduction

Utilizing the correct elevation angle on each cell in a cellular network is important to ensure that the signal level is maximized within the dominance area of a cell and minimized everywhere else. Consequently, by deploying the most appropriate tilt angle, the Carrier to Interference (C/I) ratio within the dominance area of a cell is maximized, leading to optimum system performance. However, constant network evolution due to variation of subscriber density and addition of new cells requires on-going modification of the tilt angle to ensure that cell performance is constantly maximized.

The benefits of tilt angle optimization on system performance have been analyzed in a number of papers [1-4], but these studies are commonly based on simulations. While these studies generally show clear performance benefits, the applicability of their results to real networks might be limited by some of the modeling assumptions. Thus, it is of great interest to determine which performance gain can be obtained from antenna tilting in actual GERAN networks.

Antenna tilt optimization involves determining which cells require tilt modification, establishing the amount of tilt-angle change and implementing this change. As remotely-tiltable antennas are relatively rare, most tilt changes require site visits and climbing the antenna mast, thus making antenna tilting an expensive activity. Hence, there is the need to strictly prioritize the cells to be tilted. Once cells requiring tilt changes are determined, the selection of their new tilt-angle is based on manual analysis of measured and predicted data for the selected cell and their neighboring (=adjacent) cells, which is not addressed here for the sake of brevity.

Within this framework, a trial has been conducted to determine the performance benefits that increasing the tilting angle can provide for selected cells. Likewise, a novel approach for establishing which cells require a tilt change based on network statistics has also been tested. In the following section, the novel approach to the problem of prioritizing cells to be downtilted is outlined. The subsequent sections describe the trial set-up and provide a discussion of the observed results.

Novel Cell-selection Methodology

A key design criterion is to utilize information measured by mobiles as opposed to data obtained from propagation prediction tools, which are traditionally used for this task. The improved accuracy of measured over predicted information can hopefully be converted into larger performance gains than would otherwise be achievable.

The essence of the proposed method is to rank all cells by the amount of traffic that is carried beyond the planned (i.e. expected) service area of each cell. The method consists of three steps, which are applied to each of the candidate cells.

Firstly, the distance from the cell to all its defined adjacent cells is determined. This distance, labeled “nominal distance”, is defined as the spatial separation to the furthest configured adjacency and thus characterizes the site/cell density of the area in which the cell is located.

Subsequently, the actual serving distance of the cell, labeled “measured distance”, is characterized based on measurements from the network. As opposed to the “nominal distance”, the “measured distance” provides information about the actual distance at which the cell provides service and it can be considered as a random variable. Its probability density function is derived from Timing Advance (TA) information. TA is specified in the GERAN standards [5] and is provided about twice per second from all mobiles while in a call. TA information contains a measurement of the distance between the current location of the mobile and the serving cell. Collecting these TA samples over long time periods, such as several days, normally produces sufficient distance samples to provide a statistically reliable distribution for describing the "measured distance".

Finally, once the "nominal distance" and "measured distance" distribution are known, it is possible to estimate the percentage of TA samples that originate beyond the "nominal distance". This principle is shown in Figure 1, where the cumulative distribution of the "measured distance" for a single cell is presented. In this example, 10% of the TA samples fall beyond the "nominal distance". By comparing the ratio of the TA samples that originate beyond the "nominal distance" it is possible to prioritize the candidate cells. The larger the percentage of the TA samples that originate beyond the "nominal distance", the higher the need to downtilt a cell.

The proposed prioritization limits the number of cells that have to be investigated in subsequent stages of the analysis and thus focuses work-effort on the most suitable cells. It is envisaged that in addition to this indicator other cell performance indicators, such as the number of dropped calls, the traffic load and the interference level in this cell, can also be utilized in fine-tuning the cell prioritization. However, it is worth noting that such additional information was not considered in the trials presented in the following sections.

Limitations in the proposed Method

One limitation in the outlined method is the fact that the resolution of TA information is of 550 m intervals and limited to 35 km. Furthermore, statistics about the distance between mobile and base stations, used for the "nominal distance" definition, are normally not saved in 550 m, but in larger distance intervals. The choice of larger intervals is governed by memory storage limitations. In the trial network, instead of having 64 bins of 550 m for the distance up to 35 km, only 10 bins were available. Nevertheless, it is envisaged that the provided information is still more accurate than predicted information.

Description of Trial Set-up

A total of 8395 cells were included in this downtilt analysis. On these cells, the average tilt angle before the trial was 2.4 degrees. Because of man-power limitations, only 35 cells could be selected for downtilting based on the results of the above-described methodology. These were macrocells isolated from each other and located in either rural or suburban environments. A downtilt increase of 1 degree was applied to 21 cells, 10 cells experienced tilt increases of 2 degrees, whereas 4 cells were downtilted by 3 degrees. The selection of the downtilt angle was based on manual analysis of additional network information as well as propagation predictions.

Performance Analysis

Table 1 summarizes the performance impact of the tilt changes on the tilted cells. The indicators in Table 1 display the performance of the call set-up (i.e. SDCCH, Slow Dedicated Control CHannel) and call completion (i.e. TCH, Traffic CHannel). Likewise, ratios of poor call signal quality both in the uplink (UL) and in the downlink (DL) are presented, together with the average Busy-Hour traffic. Each of the pre- and post-tilting values shown is the average of the measurements collected during one week for all tilted cells.

It can be seen in Table 1 that the average traffic carried by the cells reduced by 13.6%. This was expected as downtilting reduces the coverage area of the tilted cell. A remarkable decrease of bad quality samples was obtained, especially in the UL, where the maximum transmit power of handsets limits the maximum connection distance. The ratio of poor DL samples also reduced, but not as much as in the UL direction. The call set-up phase also benefited from the reduced cell size as the signaling channel (SDCCH) seizure rate increased while the corresponding failure rate decreased, again in line with expectations. Similarly, the Traffic Channel (TCH) seizure rate also improved due to the optimized cell size. However, against expectations, the Traffic Channel (TCH) failure rate increased from 3.79 to 3.87%. This slight increase was due to an increase of this indicator on one cell. Unfortunately, it was not possible to determine if this increase was solely due to the change in tilt angle or if other occurrences within the cell (e.g. a hardware fault) could have caused this effect.

Likewise, analysis of performance impact on cells surrounding the tilted cells (not shown here) indicates no significant performance degradation. All these results indicate that the method to determine suitable cells for downtilting as well as the manual selection of the tilt angle was successful. Detailed studies of individual cells (not shown here) indicate that each cell displays a unique reaction to the tilt angle change, which might in some cases be quite unexpected. This unique response of cells to tilt changes makes it difficult to predict how a specific indicator on an individual cell would change. However, when a large number of cells are considered, the expected performance trends are normally observed.

Conclusions

A tilting campaign has been carried out to determine the gains that antenna downtilting can provide in GERAN networks. A new methodology to determine which cells to downtilt based on Timing Advance network statistics has been applied. Comparison of the pre- and post-tilt performance on the tilted and surrounding cells have shown that certain performance indicators improved. However, the magnitude of the performance benefits varies strongly from cell to cell, making it difficult to predict the exact impact of the implemented change on an individual cell. Further work would be required to refine the selection of the cells to downtilt based on additional measured network statistics, as well as to determine by which angle the existing tilt should be changed.

References

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Figure captions

Figure 1: Comparison of cumulative distribution of "measured distance" and "nominal distance" for a single cell.

Table captions

Table 1: Results of pre-tilting and post-tilting performance analysis on downtilted cells.

Figure 1

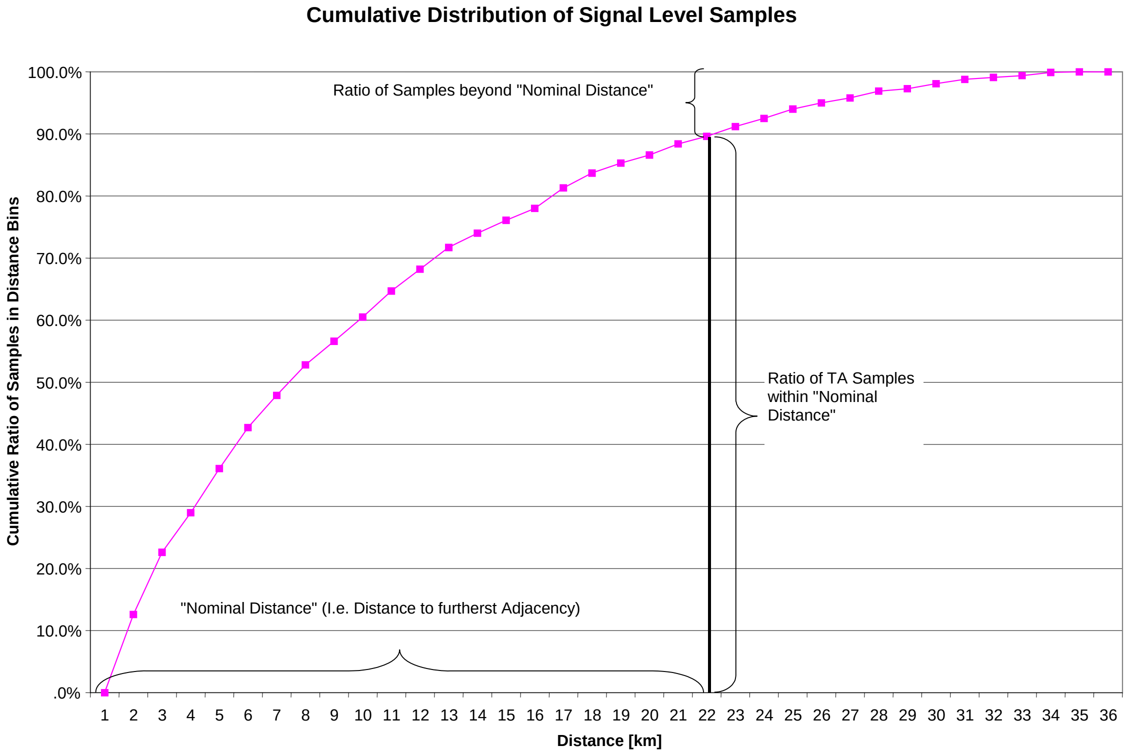
Cumulative Distribution of Signal Level Samples
Ratio of Samples beyond "Nominal Distance"
Ratio of TA Samples within "Nominal Distance"
"Nominal Distance" (I.e. Distance to furtherst Adjacency)
Cumulative Ratio of Samples in Distance Bins
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
.0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Distance [km]

Table 1

Downtilted cells	Pre-Tilt	Post-Tilt	Difference	Difference [%]
Signaling Channel (SDCCH) Seizure Rate	99.64	99.81	0.17	0.17
Signaling Channel (SDCCH) Failure Rate	7.15	6.39	-0.76	-10.63
Traffic Channel (TCH) Seizure Rate	99.98	100	0.02	0.02
Traffic Channel (TCH) Failure Rate	3.79	3.87	0.08	2.11
Ratio of poor UL Quality Samples [%]	5.24	4.64	-0.60	-11.45
Ratio of poor DL Quality Samples [%]	5.82	5.35	-0.47	-8.08
Average Busy-Hour Carried Traffic [Erl]	2.71	2.34	-0.37	-13.65