Trial Results from Adaptive Hand-Over Boundary Modification in GERAN

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Modification of hand-over boundaries allows resizing of the effective cell service area. This method has been used in GSM/EDGE Radio Access Network (GERAN) to deal with tele-traffic congestion that is caused by operator tariffs. Results from the application of this method in an actual network show that significant performance benefits can be obtained.

Introduction: The tariff policy of a cellular network operator has a paramount impact on the tele-traffic load in the network. Offering free off-peak (i.e. evening) calls will inevitably lead to an increase in the level of evening traffic as free mobile phone calls replace chargeable fixed-line calls. Due to free evening airtime, the traffic tends to be generated in residential areas where day-time (i.e. peak) traffic is comparatively low. As a consequence, network capacity would have to be added in these areas to cater for calls that provide no extra call revenue. To maximize revenue, operators aim to handle this additional off-peak traffic demand with the existing network infrastructure. This goal can be achieved if spare capacity, which may be available in some cells, can be utilized to carry traffic from the congested cells, so additional resources do not have to be deployed to cope with new capacity demands. It is important to bear in mind that, under normal conditions, traffic balancing between cells is not possible, since calls are handled by the cell that offers the strongest/best signal level (i.e. minimum pathloss). This principle is generally applied, since interference can be minimized when mobiles are connected to the best-serving cell, where power-control can be used effectively to reduce the transmit power of both the base station and the mobile terminal.

Traffic Sharing Methods: Two methods for carrying traffic on a sub-optimal serving cell in GERAN are described in the literature: Directed-retry and Modification of Hand-Over (HO) boundaries. Directed-retry [1] is applied during the call set-up phase, directing calls from a

congested best-serving cell to a surrounding cell that also provides coverage in the area where the call attempt is being made. However, very shortly after call establishment a HO from the non-optimal cell to the best-serving cell will be attempted. Therefore, this feature, while reducing blocking of call attempts, only provides little permanent capacity increase. Modification of the HO boundaries [2,3] allows resizing of the effective service area to match the spatial traffic distribution in the network. It is thus possible to reduce the “size” of a congested cell whilst enlarging the “size” of an adjacent cell with spare capacity. Hence, the traffic handling capability of the network is tailored to the traffic demand, i.e. the effective network capacity is increased compared to the use of normal HO boundaries. It is worth noting that this method does not reduce coverage levels in the network as HO parameters are modified instead of cell output powers.

Adaptive HO Boundary Method in GERAN: Cell resizing is achieved by modifying the so-called Power Budget (PBGT) handover margin. This parameter determines how much stronger the signal level from a neighboring cell has to be before attempting a best-server (i.e. PBGT) HO. In common propagation environments, this PBGT margin is set to a fixed value that counteracts ping-pong handover due to shadow fading. The adaptation principle is shown in Fig. 1, where the handover of a mobile station moving from cell A to cell B is analyzed. Cell signal level distributions (dotted line), together with the signal level experienced by the user (dashed and solid bold line), have been depicted over distance. To enlarge cell A with respect to cell B, the HO margin A→B is raised from 6 dB to 12 dB, i.e. signal level from cell B has to be 12 dB stronger than that of cell A for a call to be handed over. From the figure, it can clearly be observed that the service area of cell A has been enlarged in the direction of cell B. It is worth noting that Fig. 1 shows the HO boundary principle only for a pair of cells, although this principle can be simultaneously applied to all neighboring cells that mobiles can be handed to.

The adaptation of the HO boundaries aims at balancing traffic between neighboring cells. Congestion time is used as an estimator for call blocking probability in a cell. Changes to the PBGT margin are proportional to the difference in congestion time experienced by each pair

of cells, resulting in permanent modification of cell service area. Likewise, the PBGT margins from A→B may be different than those from A→C.

Trial Set-Up: The above-described methodology has been applied to a live network twice daily to deal with the peak-time and off-peak-time traffic behavior resulting from tariff policy. The trial area consisted of 95 cells providing seamless coverage. The PBGT margins on the adjacencies of all these cells were amended in both time periods based on the respective congestion time observed on the previous day. The analysis of this data proved suitable, since the call volume in a cell remained virtually unchanged from Monday to Friday within peak and off-peak period.

Trial Results: The results displayed here cover a time interval of two consecutive weeks. The method was enabled (i.e. ON) during the first week, whereas it was disabled (i.e. OFF) in the following week. To determine the impact of the method on the network, comparison of the traffic carried in the network during these two weeks must be drawn first. Fig. 2 depicts the sum of Busy Hour (BH) traffic carried by the trial cells for four consecutive days with and without the use of the method. It is observed that the traffic level during both weeks was quite similar. The overall daily BH traffic averaged over the corresponding four days was 1012.1 Erl when the method was ON, while the respective traffic during the OFF period was 979.9 Erl. This means that when the method was active the traffic level was on average 3.3% higher than during the inactive period.

Fig. 3 displays the daily call blocking rate averaged over the trial area for both periods. It can be noticed that the average blocked call rate was 1.7% when the method was ON, whilst this rate raised to 3.7% (i.e. 54% increase) when the method was OFF. This blocking rate increase during OFF period was noticed despite the fact that the carried traffic reduced by 3%. These results show conclusively that the method enables the network to carry more traffic and reduce call blocking, thus increase the effective network capacity.

It is worth noting that the dropped call rate also benefited from the method, caused possibly by a higher handover success rate due to congestion relief in the network. When the method was in use, the dropped call rate averaged about 1.6%, while the dropped call ratio increased to 2.3% (i.e. 31% increase) when it was OFF. This improvement was achieved at the expense of a slight call quality impairment, expected due to the fact that some calls were not carried by the best-serving cell but the next best cell offering spare capacity instead.

Conclusions: The principle of HO boundary modification has been applied in a real network in order to deal with congestion problems caused by operator tariff policy. Modifying the HO margins twice a day on an adjacency-by-adjacency basis, it was shown that more traffic could be carried in the network while also reducing the blocking of call set-up attempts. The call quality deteriorated slightly, since some calls were not carried by the best-server cell but the second best instead. However, this deterioration is out-weighted by the fact that more traffic can be handled by the network without the need for any hardware upgrades, thus providing a cost effective method to increase network capacity.

References

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Figure captions:

Fig. 1 HO boundary displacement between Cell A and B by means of margin adaptation.

- ▪▪▪▪▪▪ Signal level distribution with distance from BTS
- ——— Connection signal level for HO PBGT margin = 6dB
- — — Connection signal level for HO PBGT margin = 12dB

Fig. 2 Total daily BH traffic in the trial area.

Fig. 3 Daily BH call blocking rate averaged over all cells in the trial area.

Figure 1

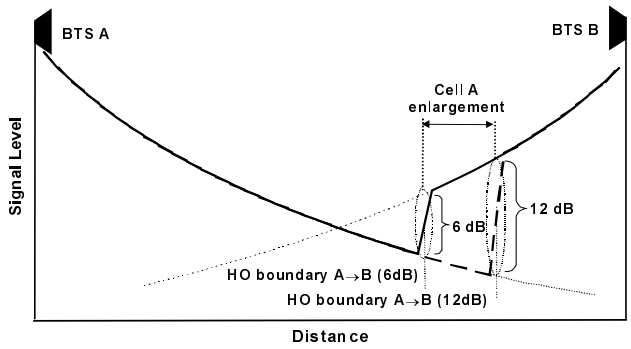

BTS A
BTS B
Cell A
enlargement
Signal Level
6 dB
12 dB
HO boundary A→B (6dB)
HO boundary A→B (12dB)
Distance

Figure 2

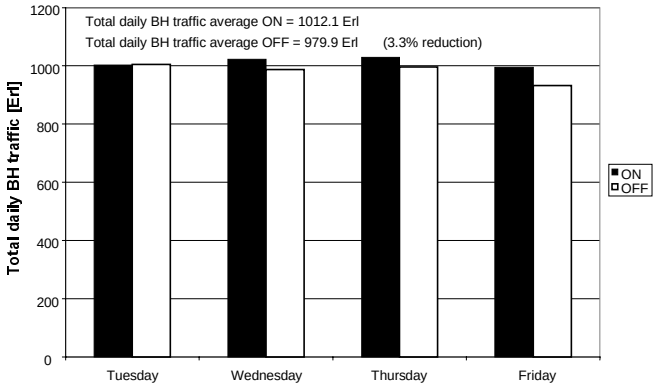
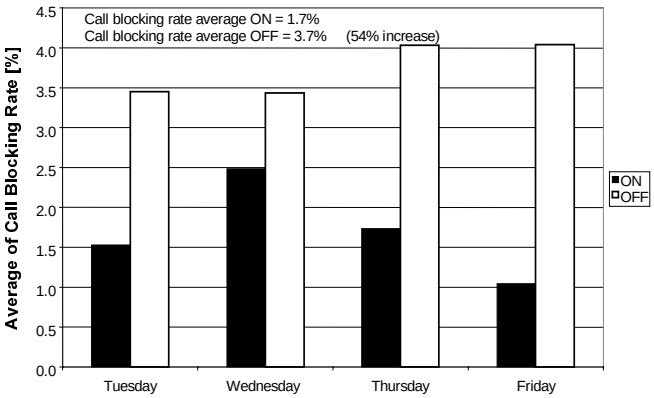

Total daily BH traffic average ON = 1012.1 Erl
Total daily BH traffic average OFF = 979.9 Erl (3.3% reduction)
Total daily BH traffic [Erl]
1200
1000
800
600
400
200
0
Tuesday
Wednesday
Thursday
Friday
ON
OFF

Figure 3


Call blocking rate average ON = 1.7%
Call blocking rate average OFF = 3.7% (54% increase)
Average of Call Blocking Rate [%]
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Tuesday
Wednesday
Thursday
Friday
ON
OFF