# DIVERSE CELL INTERACTION IN DYNAMIC CELL SIZING AND VC-PGA CELL PRIORITY SELECTION METHOD

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**Abstract** - Dynamic cell sizing is a flexible load-balancing scheme which allows potential capacity gains by modifying its coverage area at any given time for optimum performance. In this paper, the diverse interaction among cells will be discussed. The preliminary description of forward link capacity gain on a single cell serves as groundwork for discussions on bi-directional impact of cell-pairs and the multifarious interactions of cells in a CDMA network. The diverse interaction of cells is then made analogous to that of community members in a virtual community in genetic algorithm. The cell to be given highest priority cell over shrinking in the virtual community is selected by the Virtual Community Parallel Genetic Algorithm (VC-PGA). By this method, the number of cell attenuations may be controlled, the emergence of coverage holes reduced and thus, the quality of service increased.

**Keywords** - dynamic cell sizing, bi-directional impact, diverse cell interaction, coverage holes, VC-PGA

## I. INTRODUCTION

Dynamic cell sizing is a mechanism that attempts to keep the forward and reverse link handoff boundaries balanced by changing the forward link coverage according to the changes in the reverse link interference level [1][2].

Reverse link handoff boundary is defined as the contour of mobile locations between neighboring cells where the received signal to noise ratio at the two base stations is the same. Referring to Fig. 1, the reverse link handoff boundary between cell sites A and B is the locations such that

$$\frac{E_{bA}}{N_{tA}} = \frac{E_{bB}}{N_{tB}} \qquad (1)$$

where $E_{bi}/N_{ti}$ is the signal to noise ratio received at base station $i$ for the mobile under consideration, $E_{bi}$ is the received bit energy and $N_{ti}$ is the spectral density of total interference at base station $i$.

Forward link handoff boundary is defined as the contour of the mobile locations where

$$\frac{E_{cA}}{I_o} = \frac{E_{cB}}{I_o} \qquad (2)$$

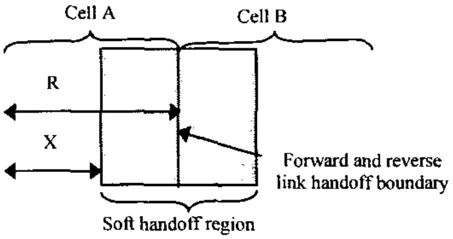

Figure 1. A balanced forward and reverse link handoff boundary case for two cells A and B

where $E_{ci}$ is the received pilot chip energy of $i$-th pilot and $I_o$ is the spectral density of the total power seen by the mobile.

It can be seen from (1) and (2) that, if the interference levels are the same at both base stations and the same amount of power is transmitted on the pilot channel from each base station, then the forward and reverse handoff boundaries will coincide; the boundary will be half way between the two cell sites for a uniform propagation model.

As the reverse link traffic load is increased, the thermal noise at the base station increases. It is clear from (1) that the reverse link handoff boundary will move closer to the base station whose rise over thermal noise is greater. Then, to balance the reverse and forward link handoff boundaries, the pilot signal of the cell with greater base station interference must be reduced. The mechanism used to reduce pilot power on a cell based on the increase in the reverse link interference level is referred to as dynamic cell sizing [1][2].

The purpose of this paper is to model the diverse interaction of cells in dynamic cell sizing. Section II gives an overview of the soft handoff process. Section III discusses the uni-directional impact of pilot signal on a single. This serves as groundwork to Section IV which examines the bi-directional impact of cell-pairs. Section V aims to model the diverse interaction of cells by the *virtual community* model used in genetic algorithm. The VC-PGA algorithm will be used to select the cell to be allocated the highest priority over cell size reduction across the virtual community

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## II. OVERVIEW OF SOFT HANDOFF PROCESS

In CDMA systems, overlapping regions called soft handoff regions are necessary for mobiles near the cell boundary to perform handoff and to counteract fluctuations of receiving power [2] (Fig. 1). The mobile measures the pilot $E_c/I_o$ from neighboring cell sites. If a pilot is found whose $E_c/I_o$ is above a threshold called T_ADD, the mobile reports that pilot to the base station. The pilot is to be included in the set of pilots in soft handoff referred to as the active set. On the other hand, if the $E_c/I_o$ of a pilot in the active set is below a threshold called T_DROP for more than a certain time, the mobile will report that pilot to the base station. The pilot may then be removed from the active set. Therefore, the pilot $E_c/I_o$ values as measured by the mobile primarily determine the handoff region. Fig. 1 shows the handoff boundary of two adjacent cell sites marked as A and B. Since $I_o = I_{oA} + I_{oB} + N_o$ where $I_{oi}$ is the power spectral density of the total signal received from cell site $i$ at the mobile and $N_o$ is the thermal noise power spectral density, then we get $I_o \approx I_{oA}$ near the edge of the soft handoff region closer to cell site A. In other words, the edge of the soft handoff region near one cell site is primarily determined by the total signal power from that cell site [1].

Since the left side of the soft handoff region in Fig. 1 is determined by $E_{cB}/I_o$, i.e. the signal to interference ratio seen on pilot B, then the left side of the handoff region does not move when the pilot power of cell A is reduced. The right edge of the soft handoff region (Fig. 1) however is determined by $E_{cA}/I_o$, therefore, as the pilot power of cell A is reduced, the right edge of the soft handoff region moves closer to cell site A as shown in Fig. 2. Therefore, if dynamic cell sizing is active, then as cell loading is increased in cell A and surrounding cell sites remain lightly loaded, the soft handoff region inside the neighboring lightly loaded cell sites will reduce.

## III. UNI-DIRECTIONAL OF PILOT SIGNAL ON SINGLE CELL

On the forward link, once a given cell becomes heavily loaded, the cell sizing algorithm will reduce the cell's coverage by shedding some of the traffic to the surrounding cells, thereby relieving the overloaded cell.

Consider the case where cell A in Fig. 2 is heavily loaded and cell B lightly loaded. Then, in order to move the handoff boundary by an equal amount that the interference has risen in a cell, the dynamic cell sizing algorithm will introduce an attenuation equal to α on the forward link of cell A in response to a rise over thermal noise in cell A's reverse link. The pilot by $E_{cA}/I_o$ seen from pilot of cell A will be changed to

$$\frac{\alpha E_{cA}}{I_{oA} + I_{oB} + I_{oC}} \tag{3}$$

which is smaller than it used to be prior to cell sizing. The α factor is due to cell sizing on cell A. Now the edge of the soft handoff region closer to cell B will move away from cell B. Assuming that 35% of the cell area is in soft handoff and approximating the cell area by a circle, we have X=0.8R in Fig. 1. We note that for large path loss exponents of 4, inside cell B the denominator of (3) will be dominated by $I_{oB}$. Therefore, the handoff boundary moves to the left in Fig. 2 approximately 1 dB for each dB of attenuation introduced by cell sizing on cell A.

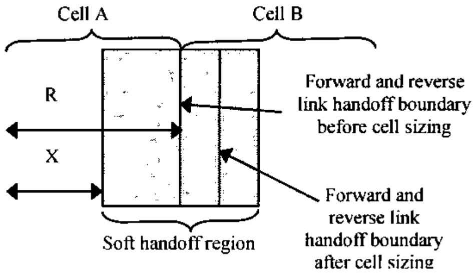

Figure 2. Handoff boundary has moved closer to cell B due to loading on cell B

As the handoff boundary is moved closer to cell A, the one benefit that may be obtained is that users that are inside cell B and are in soft handoff with cell A may fall out of soft handoff with cell A, relieving some capacity from cell A to be used for users that are inside cell A.

Another effect of dynamic cell sizing is that the traffic channel forward gains will increase by the same amount as the cell sizing attenuation, until the total traffic channel power going out of the cell becomes close to what it was prior to breathing attenuation. The output power after cell sizing will be less due to lower power on overhead channels (assuming overhead channels are not power controlled). The reduction of total transmit power due to reduced power on the overhead channels will eventually be used by new users and therefore the total transmit power will remain unchanged before and after cell sizing under heavy loading conditions [1][4]. Of course, for mobiles whose forward gains were near their upper limit, their allocated power will decrease due to hitting the upper limit of the forward gain.

Based on the above discussion, the forward link capacity of a heavily loaded cell, which is surrounded, by lightly loaded cells may be increased through cell sizing. Cell sizing increases the capacity of the heavily loaded cell using two mechanisms. First, cell sizing reduces power on the overhead channels equal to the amount of cell sizing attenuation. For instance, if 25% of the power had been allocated to the overhead channels and 1dB attenuation was applied to cell, then the amount of power on overhead channels would reduce to 20% of total available power before cell sizing. This results in approximately 6%

increase in forward link capacity due to reduced overhead. The second mechanism that increases forward link capacity is by shedding mobiles to other lightly loaded cells. As discussed above, one dB attenuation will result in reduction of soft handoff region of the surrounding cells from 35% to 25%. Therefore, under uniformly distributed traffic conditions there may be up to 10% increase in capacity. Therefore, one dB of breathing may provide at most 15% capacity increase in a heavily loaded cell that is surrounded by lightly loaded cells [1].

## IV. BI-DIRECTIONAL IMPACT OF CELL-PAIRS

In Section III, we controlled the size of a particular cell by varying the adjacent cell's pilot power. Realistically, the cell whose size is being controlled may also vary its pilot power to dynamically change the size of the other cell. Thus, for each pair of cells, the impact is bi-directional.

The dual directional interaction of cell-pairs leads to interesting occurrences. Assume the instance when a center cell and all its first tier neighbors are heavily loaded. At the outset, the center cell's dynamic sizing mechanism moves the boundary between the center cell and an adjacent cell inwards towards the direction of the center cell so as to allow the mentioned neighbor to accommodate the additional traffic in the center cell. However, due to a lack of channels in the other cell too, its mechanism may instead move the boundary further away from the center cell. Thus, the courses of action taken by the mechanism of the two adjacent cells contradict one another. If both were to shrink simultaneously to take care of the increasing traffic load in its own cell, then coverage holes would develop (shown in Figures 3a and 3b). Consequently, calls are dropped and grade of service may not be maintained. The dual directional influence is similar for all cell-pairs. Thus, coverage holes may develop between any two heavily loaded cells.

A center cell will receive dual directional impacts from all cells within its first tier. Similarly, all first tier cells will also receive dual directional impacts from its surrounding first tier cells. The same influence is observed in cells of subsequent tiers. Thus, a multifarious interaction of a vast number of cells is observed.

## V. MODELLING THE DIVERSE CELL INTERACTION

The bi-directional impact of cell-pairs and interaction of cell-pairs with other cells leads to difficulty in determining the priority to be given to cells over reduction of cell size in an attempt to decrease traffic load.

To aid in deciding the cell priority for cell size reduction, the diverse interaction of cells may be thought to be analogous to that of community members in a Virtual Community Parallel Genetic Algorithm (VC-PGA) Model [5].

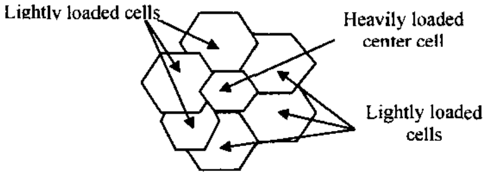

Figure 3a. No coverage holes develop when a heavily loaded cell is surrounded by lightly loaded cells

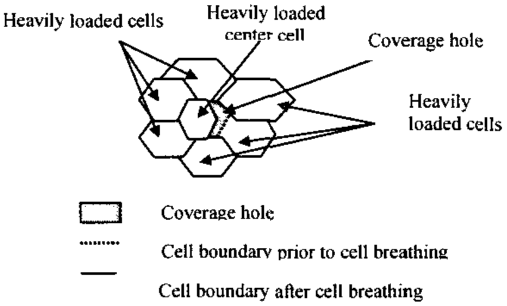

Figure 3b. Coverage holes develop when a heavily loaded cell is surrounded by heavily loaded cells

Two major parallel genetic algorithms (PGA) are reported in literature, namely the *island model* and the *cellular model*. *Island model* (or network model) runs an independent genetic algorithm (GA) with a sub-population on each processor, and the best individuals in a sub-population are communicated either to all other sub-populations or to neighboring population [6][7]. *Cellular model* (or neighborhood model) runs an individual on each processor, and cross with the best individual among its neighbors [8]. Cellular model can be seen as a massive extension of island model where population is reduced to a single individual on each processor.

A cluster of five to six cells is made to resemble the *local community* (LC) formed among neighboring processors, whereby each local community has an elected server processor to facilitate exchanges of best individuals within community and with other communities as shown in Fig. 4. A group of cell clusters or *local community* then forms a *virtual community* (VC) to facilitate exchange of best local individuals across the community [5]. The VC too has a server. However, the VC server is not predetermined but is periodically updated. The connection of cells by the VC-PGA model is shown in Fig. 4.

The VC-PGA procedure for selection of cell to be given highest priority over size reduction is described as follows:

**Step 1**: Set up local communities of cells and virtual communities in a group of cell clusters. A local community (LC) is formed with adjacent cells, and one of the cells is elected as its local community server. Grouping local community servers forms a virtual community (VC). Higher-level virtual communities may be formed if necessary. The local community server with the highest pilot signal is elected as the virtual community server. On first run of the algorithm, arbitrarily elect any of the local community servers as the virtual community server.

**Step 2**: On each local community server, compare the pilot powers from all cells in the local community. Make an ordered list of pilot powers of cells within the local community. Designate cell with lowest pilot power as cell with highest priority in size reduction within the local community. For other cells in the local community, the priority for size reduction will be in accordance with the ordered list of pilot power. The compliance with the local ordered list of pilot power applies only to cells whose soft handoff regions are shared with cells of the cells of same local community. Otherwise, a higher order ordered list takes precedence.

Send all chosen highest priority cell, that is, the cell with the lowest pilot power of each local community, to the virtual community server.

**Step 3:** In the meantime, the elected virtual community server will the compare the pilot signal strength of received local lowest pilot signals from all local communities. The cell with the lowest pilot signal strength will have highest priority over size reduction. Hierarchy of priority for other cells will be in accordance with virtual community's ordered list of received local lowest pilot signal. As mentioned in Step 2, for cells whose soft handoff regions are shared with cells of a different local community, the order of precedence for cell reduction will adhere to the *virtual community's* ordered list of pilot power.

**Step 4:** Send the selected cell having the lowest pilot power to all members of the virtual community. The selected cell is designated as the cell with the highest priority in cell size reduction. For cells whose soft handoff region is shared with members of the same local community, the priority for size reduction will be in accordance with the ordered list of pilot power. Otherwise, when shared with cells out of its own local community, the virtual community's ordered list of pilot power is adhered to.

Meanwhile, the highest of all received lowest local pilot signals will be elected as the virtual community server for the next run as its load is the least loaded.

Virtual community model gives three advantages over island model: (i) Local sub-population can get globally fittest individuals, (ii) The communication overhead is much less expensive, and (iii) The evolution surface of solution space is independent from topology of network of workstations [5].

By the same token, the method of determining the lowest pilot signal in a group of cell clusters by the virtual community model possesses three virtues. (i) In the *island model*, though the selection of lowest pilot signal is done, the process is more random and not as organized as it is in the *cellular model*, whereby the lowest pilot signal is obtained from a group of cell clusters. The selected lowest pilot signal then in effect has highest priority over cell size reduction. On the other hand, the priority of shrinking for other cells is given by either the local community's ordered list of pilot power or the virtual community's. (ii) Very little communication overhead is imposed as the base stations need not communicate among themselves to exchange pilot signal levels. Information exchange and comparisons are done at the local community servers and virtual community servers only. (iii) The evolution surface of cell selection space is independent of the topology of the cellular network. Thus, no special arrangement of cells is needed for implementation of the VC-PGA algorithm for selection of lowest pilot signal.

## VI. CONCLUSION

Cell sizing was shown to be capable of increasing the forward link capacity by two mechanisms, by reducing power on overhead channels and by shedding traffic of heavily loaded cells to lightly loaded cells [1][4]. However, the bi-directional influence of cell-pairs and its more diverse interaction within the network was seen to bring about the emergence of coverage holes.

To facilitate designation of cell priority in size reduction, the Virtual Community Parallel Genetic Algorithm is employed. The selected cell will have the highest priority in shrinking. Other cells will have priorities following the ordered list of

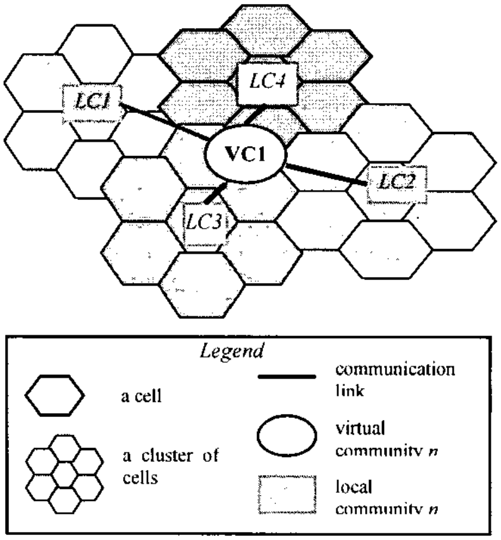

Figure 4. Diverse cell interaction - VC-PGA Model Analogy

either the local community's ordered list of pilot power or the virtual community's. Thus, the number of cell attenuations allowed within a network may be controlled efficiently and effectively. The emergence of coverage holes is reduced and thereby, the quality of service provided is increased.

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