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Application of Cell Zooming in Outage Compensation

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Abstract: *The introduction of mobile communication has changed how people behave and their demand for connectivity is anywhere and anytime. This demand is driven by the fact that essential services have moved from mere telecommunication to very crucial services like money transfer services, e-learning and medical services. However, terrorism threats, vandalism, environmental disasters and general failures are also on the increase and these threaten the availability of mobile services anytime and everywhere. It is thus critical that measures are taken to ensure availability of service amid these threats. Cell zooming promises to provide a self-healing solution that would ensure the demand for service is anytime and anywhere is sustained. This paper investigates the application of cell zooming in outage compensation. Cell zooming is achieved by adjusting the input power to the transmitter or the height of the transmitter. The study developed an algorithm based on Okumura-Hata propagation model to estimate the required height or power input to the transmitting antenna needed for the compensation. The results are fed to Atoll Planning Software by Forsk to simulate the Received signal levels pattern. The results have revealed that it is possible to achieve outage compensation using cell zooming. This is in line with the proposal by Third Generation Partnership Project (3GPP) to have self-organising networks (SONs) that require minimum human intervention for their operation.*

Keywords: *Cell Zooming, Outage compensation, Self-Healing, Self-Organizing Networks (SON), Radio Network Planning, Mobile Traffic Analysis, Erlang B*

I. Introduction

Cell outage is the total loss of service from a serving radio station as a result of a radio link failure. These failures can be caused by a disruptive event such as power failure, equipment failure, and communication breakdown with other elements in the network or a traffic surge that shuts down the cell through overload protection mechanism. The main aim of a self-healing network is to promptly reduce the impact of the failure as much as possible [1]. The network should be able to respond quickly so that as soon as fault is detected and its impact quantified, compensation is introduced. The speed at which this should be implemented means that the compensation cannot be done manually and hence the need for automation. The first step involves the effort to mitigate the problem by means within the radio equipment itself but when there is a complete cell outage, this is not possible and the compensation has to be done by the neighbouring cells [2], [3].

During compensation using neighbouring cells, a tradeoff between capacity and coverage is made in order to alleviate the impact as much as possible. Optimization must also be done in order to maintain the affected cells within the planning parameter range **[**4**], [**5**], [**6**].**

Link Budget, Path Loss and Propagation Models

The performance of a communication link depends on the quality of the transmit power, transmitting antenna gain, and receiving antenna gain. In between the transmitting and receiving antenna, the signal gets attenuated and this attenuation is the path loss. Thus path loss is the attenuation of the power density of an electromagnetic wave as it travels through space. Link budgeting is used to account for all the losses and gains in the link to ensure that acceptable signal level is received for effective communication.

To determine path loss, transmitter output is first evaluated. Transmitter output is boosted by system antenna gain and reduced by transmission line and connector losses. Link budget can be summarized in equation (1) below

$$P_T - T_L + G_T - P_L + G_R + R_L = R_S \tag{2}$$

Where
P_T = transmitter power
T_L= Transmitter cable and connector losses
G_T = Gain of transmitter
P_L = Path loss
G_R =Gain of receiver
R_L = Receiver cable and connector losses
R_S =Receiver power

Effective Isotropic Radiated Power (EIRP) is given by:

$$\mathrm{EIRP} = \mathrm{P_T} - \mathrm{T_L} + \mathrm{G_T} \quad (3)$$

wherethe above definitions apply.

When the power transmitted by the antenna minus all the losses is greater than the minimum allowed signal levelof the receiving antenna, then communication is possible between the two radios. However, it is prudent to add margin to the minimum allowed received levels for a more reliable link.

$$\mathrm{P_T} - \mathrm{T_L} + \mathrm{G_T} - \mathrm{P_L} + \mathrm{G_R} + \mathrm{R_L} = \mathrm{R_S} + \mathrm{Margin} \quad (4)$$

Rewriting this equation yields

$$\mathrm{P_T} - \mathrm{T_L} + \mathrm{G_T} - \mathrm{P_L} = \mathrm{R_S} - \mathrm{G_R} + \mathrm{R_L} + \mathrm{Margin} \quad (5)$$

but

$$\mathrm{RSSI} = \mathrm{R_S} - \mathrm{G_R} + \mathrm{R_L} \quad (6)$$

Where RSSI is the received signal strength indicator.

It is thus noted

$$\mathrm{EIRP} = \mathrm{MAPL} + \mathrm{RSSI} + \mathrm{Margin} \quad (7)$$

Where MAPL is the maximum allowable path loss.

A number of empirical propagation models have been proposed that help in predicting path loss and propagation pattern but for the purpose of this investigation, only Okumura-Hata Model was considered.

Okumura-Hata Model

In this model, Path Loss is given by [**7**],

$$\mathrm{PL} = \mathrm{A} + \mathrm{B}\log(\mathrm{d}) + \mathrm{C} \quad (8)$$

where A, B, and C are factors that depend on frequency and antenna height.

$$A = 69.55 + 26.16\, log(f_c) - 13.82\, log(h_b) - a(h_m) \quad (9)$$

$$B = 44.9 - 6.55\, log(h_b) \quad (10)$$

Where

f_c = frequency in MHz

d = distance in km

h_b= height of base station in meters

The function $a(h_m)$and the factor C depend on the environment:

For small and medium-size cities:

$$a(h_m) = (1.1\, log(f_c) - 0.7)h_m - (1.56\, log(f_c) - 0.8) \quad (11)$$

C = 0

For metropolitan areas:

$$a(hm) = 3.2(log(11.75h_m)^2 - 4.97 \quad (12)$$

C = 0

For suburban environments:

$$C = -2\left[log\left(\frac{f_c}{28}\right)\right]^2 - 5.4 \quad (13)$$

For rural areas

$$C = -4.78\,[log(f_c)]^2 + 18.33 log f_c - 40.98 \quad (14)$$

The function $a(h_m)$ in suburban and rural areas is the same as given in equation (10)

1. Outage Compensation Using Cell Zooming

One of the methods that can be used automatically for outage compensation is cell zooming. Cell zooming is the adjustment of the cell size by varying electrical power dissipated by the antenna or by varying the tilt angle of the antenna either by mechanical or electrical means [**8**], [**9**] or by varying the height of the antenna.

Electrical Zooming

For a specific region, path loss is dependent on frequency and distance. Thus at fixed frequency, path loss will be dependent only on distance. Consequently, increasing the radiated power means there is a net margin to allow for a longer distance. Similarly, reducing the power would lower the overall distance that the acceptable signal can cover. This is the electrical zooming. It is achieved by varying the power fed to the transmitting antenna to vary the coverage radius.

Height adjustment

Figure 1 summarizes the effects of varying the height of the transmitter on the coverage distance. The higher the antenna, the longer the possible coverage distance

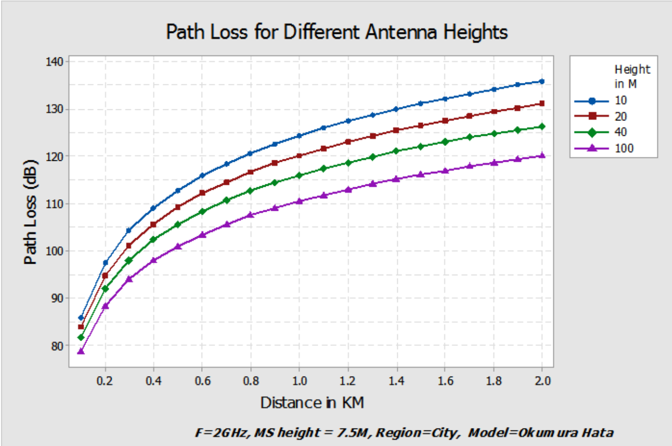

Figure 1: Path Loss for Different Transmitter Heights

2. Factors Affecting Compensation Using Cell Zooming

Received Signal Levels

A coverage area is a region within which the received signal level is within acceptable limit of -105dB. This is the minimum power required by the Mobile Station (MS) to sustain a communication between the radio and the MS and a minimum power of -114dBm is required to be received at the Base Transceiver Station (BTS) antenna to sustain communication with a MS [**10**]. The received levels are recommended as In-car=-100dBm, Indoor=-95dBm and Outdoor=-105dBm [**11**].

Capacity

This is the size of available resources for carrying traffic. Usually, the limiting capacity is that of traffic channels (TCH). The other channels on a radio hardly get congested except in a case of extreme traffic or as a result of equipment fault.

The size of traffic channels is calculated using Erlang B calculator or read from traffic tables. These tables give the number of traffic channels (trunks) required to sustain a given traffic at a given probability of blocking. Blocking probability is referred to as Grade of Service (GoS). Capacity issues can be addressed by using the following methods:

Multi Radio Access Technology (Multi-Rat)

This is where one site is served by multiple radios of different radio technologies with each of the radio technology being independent of the other. These technologies include GSM at 900 MHz, GSM at 1800MHz and UMTS (3G) at 2100MHz. Introduction of 3G on 900MHz is in initial stages. It is common to have these technologies on the same site together. This is termed as a technology collocation [**5**]. These two technologies work simultaneously but in the event one fails the other takes over all the traffic. However, while a 3G phone can operate on 2G environment, the converse is not true. At the same time, the quality of data service is greatly affected when a 3G subscriber downgrades to use 2G technology. Again, when it's the 2G feed that fails, then the 2G users who do not have 3G capable handsets are put out of service. More so, the amount of traffic that can be carried by one technology is limited during planning since planning is done with the consideration that the two technologies work on complementary basis and not as a substitute of each other [**4**].

Adaptive Multi Rate-Half Rate (Amr-Hr)

A standard voice encoding is at 16Kbps at the radio level. Any encoding method reducing the bit-rate to 8kbps or less is the half rate. This doubles the available capacity but compromises on the speech (voice) quality. To set a balance between capacity and quality, the half rate is normally introduced when a particular capacity threshold is reached and is only allowed in areas whose speech quality will not be greatly compromised. For example, areas where low signal strength is already compromising sound quality should not be candidate for half rate. The AMR codec provides operators with a means to optimize the balance between voice quality and spectral efficiency by continuously selecting the optimal speech codec rate for the current radio and traffic conditions.

The AMR codec provides radio link adaptation in difficult Radio Frequency (RF) environments by an optimal combination of speech and error-correcting channel coding. AMR-HR uses lowest codec rates in good RF conditions to maximize on coverage and spectrum utilization and dynamically changes to higher codec rates when the RF conditions are poor at the compromise of capacity and spectral efficiency [**12**].

Dynamic channel allocation

Traffic channels are either configured as voice or data channels in GSM. Some of the channels can be configured as dual channels and these are capable of both voice and data. Dynamic adjustment can be made either to increase the allocation for voice or data, depending on which traffic type is high. Usually, voice is given priority over data with the potential of dropping a data call in order to service a voice call in the event there are no channels to service it [**13**].

Cow

Cell on Wheel is a cellular radio that is normally mounted on a movable container, which is transported on road or by air to a location, which has no coverage or has gone out of coverage and restoration of service would take long to be effected. This method is especially useful in a disaster scenario and in areas where high traffic is anticipated because of a certain event such as public rallies.

Subscriber Calling Pattern

The goal of every cellular network planning team is to strike a balance between coverage and capacity. There are two aspects of coverage. One looks at the number of subscribers covered while the second is the geographical region. The end product is the volume of traffic generated in an area. In areas where the call density is high, the available capacity has to be adjusted to meet this demand. This leads to two types of planning: one in which major consideration is coverage especially in rural (sparsely populated) areas and the second one, which concentrates on providing capacity in dense traffic urban region.

The density of calls is what determines the volume of traffic rather than the number of subscribers. We could have a region with few subscribers that call very frequently and for long. This determines the density of radios that are installed in a region. This is because there is a limitation on the number of calls a radio can accommodate in an instant.

II. Compensation Process

The key requirement in compensation was to establish the compensation parameters by solving the Okumura-Hata path loss equations. This solves for the maximum allowable path loss and hence the coverage distance.

Solving For Coverage Distance

$$\mathbf{PL - A - C = B\log(d)} \qquad \textbf{(15)}$$

$$\mathrm{d = antilog}\,\frac{\mathrm{PL - A - C}}{\mathrm{B}} \qquad (16)$$

From and using equation (17) **maximum allowable distance was calculated as follows**
Equation (18)was used to calculate the coverage radius for specific path loss.
Substituting the values of A, B and C as given on 61 gives

$$\mathrm{d = antilog}\left(\frac{\mathrm{P_L - 69.55 + (26.16 * \log(f_c)) - (13.82 * \log(h_b) - a(h_m))}}{\mathrm{44.9 - 6.55\,\log(h_b)}}\right)$$

(19)

Solving for Base Station height

From the equation $\mathrm{PL = A + B\log(d) + C}$ **(8(20)**
Let $\mathrm{B\log(d) = G}$
Therefore $\mathrm{PL = A + G + C}$
Solving equation **(21)** for $h_b$gives

$$(\mathbf{h_b}) = \mathbf{antilog}\left(\frac{\mathbf{69.55 + 26.16\,\log(f_c) - a(h_m) + 44.9\log(d) - PL}}{\mathbf{(13.82 + 6.55\,\log(d))}}\right)$$

(22)

Therefore, for known values of Maximum Allowable Path Loss and coverage distance, the required height of the base station can be evaluated using this formula.

Solving for transmit power

We know$\mathrm{EIRP = MAPL + RSSI}$
Target RSSI is set and for a specific distance. MAPL can be calculated as already shown.

III. Simulations and Results

Three simulations were carried out for different complexity. Two of them were completely experimental while the third used data from an existing installation.

Experimental Network Cluster

This considers two clusters: One cluster which has even distribution of cells in the cluster, all antennas are at the same height, the traffic is evenly distributed, the cells are of equal capacity and the terrain is ideal – homogenous cluster. The second cluster has even distribution of cells but the radiated power and antenna height are varied –non homogenous cluster.

During compensation of a 3 sectored cell the compensation distance is 1.5 times the healthy distance. The data on Table 1, Table2 and

Table **3**were used for compensation and the signal level patterns generated are on Figure 2 to Figure 4 below.

Table 1: Simulation parameters

PARAMETER	VALUE
Target RSSI	-90dBm
MAPL	150dB
Mobile station antenna height (h_m)	1 m
Frequency (f_{MHz})	900
Propagation Model	Okumura-Hata (Medium & small city)

Table2: Compensation values for Homogenous Configuration

	Before compensation	Compensation by height	Compensation by EIRP
Antenna height	35m	63.9m	35m
EIRP	60dBm	60dBm	65.1dBm
Distance	4.66km	6.99km	6.99km

Table 3: Compensation values for Non-Homogenous Configuration

	Before compensation		Compensation by height		Compensation by EIRP	
	EIRP	h_b	EIRP	h_b	EIRP	h_b
A	60	35	60	35	60	35
B	61.7	25	61.7	52.3	68	25
C	57.9	40	57.9	81.8	64	40
D	60	35	60	35	60	35
E	60	35	60	35	60	35
F	60	35	60	35	60	35
G	55.4	55	55.4	109.8	61.3	55
Distance	4.66km		6.99km		6.99km	

The compensation parameters on Table2 and

Table **3** were calculated using equation (5) and (17) and the distance using equation (16)

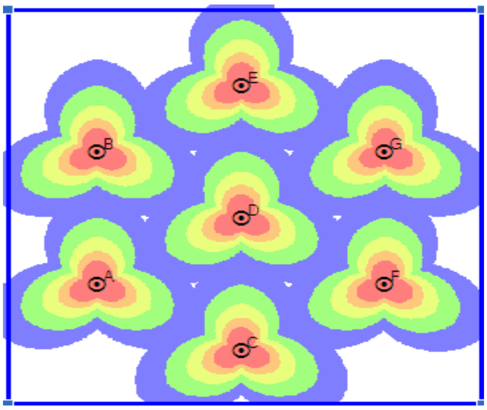

Figure 2: Coverage by Signal Level for a healthy 3 sectored cluster

When the network is simulated with the 7 cells such that the coverage distance is exact separation distance between the cells, it was observed that small pockets with unacceptable signal levels are generated around the central cell. These are however acceptable compromise.

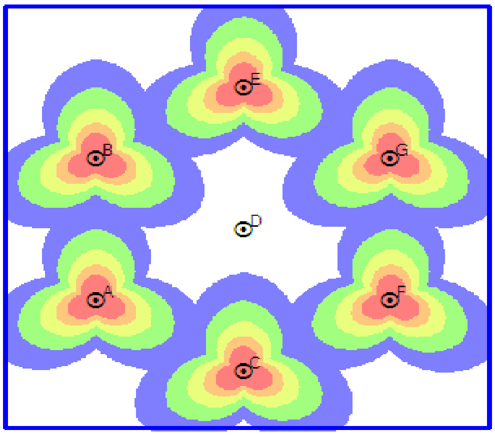

Figure 3: Coverage by Signal Level for a homogenous single sectored cluster after Cell D is switched off

After Cell D is switched of as shown in Figure 3 the area that was covered by cell D is left with signal level below acceptable RSSI. The compensation yields the pattern in Figure 4 again with some small pockets of signal below the acceptable signal level.

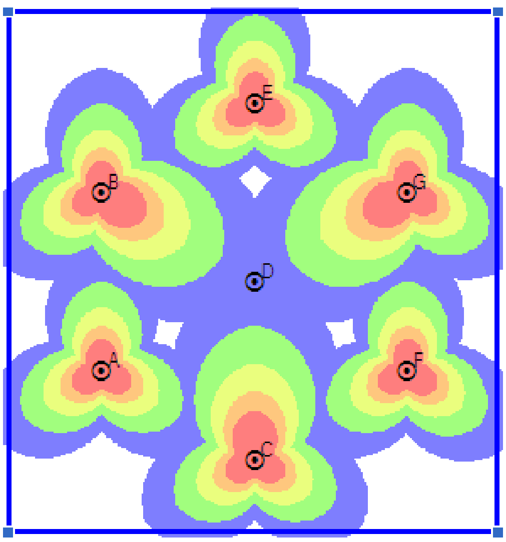

Figure 4: Coverage by Signal Level for a homogenous 3 sectored cluster after Cell D is switched off but with compensation using cells B, C & G

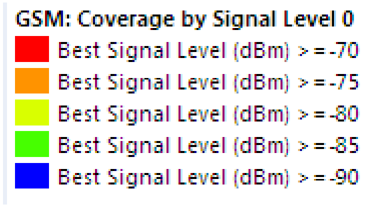

Figure 5: Signal levels definition

The signal level distribution pattern in Figure 2 to Figure 4 applies to both the homogenous and non homogenous simulation. This was the case because the coverage area was equal for both clusters.

Simulation Using Data Obtained From A Live Network

Data for 17 cells from an existing network (safaricom) was used to generate the coverage on

Figure 6 with the RSSI restricted to -90dBm. Two areas were identified as region A and B. The signal level available in region A is still acceptable even after a target cell failed as shown in Figure 7 and Figure 8.

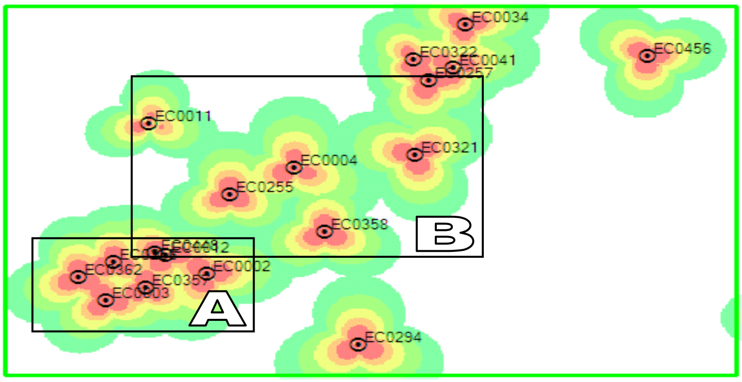

Figure 6: Signal Level of Cells of an existing network -90dBm RSSI

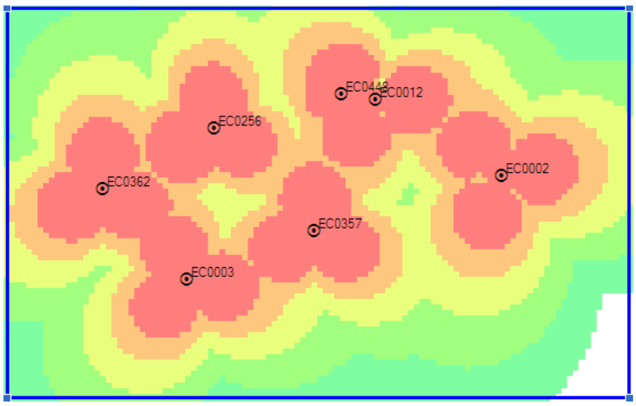

Figure 7: Close up for region A when healthy

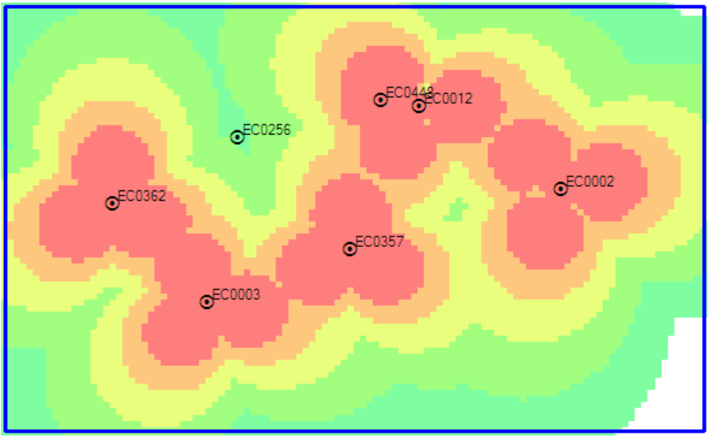

Figure 8: Region A with Cell EC0256 failed

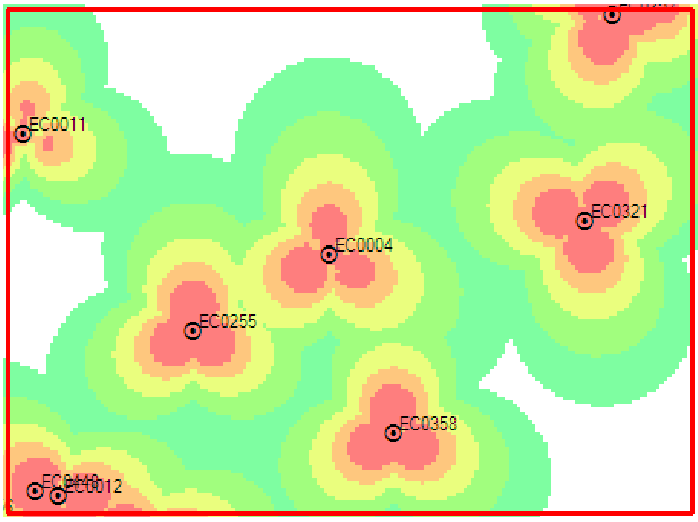

Figure 9: close-up for healthy region B

Figure 9is an example of an area with a relatively low density of radios. When cell EC0004 fails, as shown in Figure 10,a significant area, which was under the cell coverage is left with signal below the target RSSI necessitating compensation. Two cells were selected for compensation. Cell EC0321 sector 3, which is at an azimuth of 290 and cell EC0255 sector 1 at 0 azimuth.

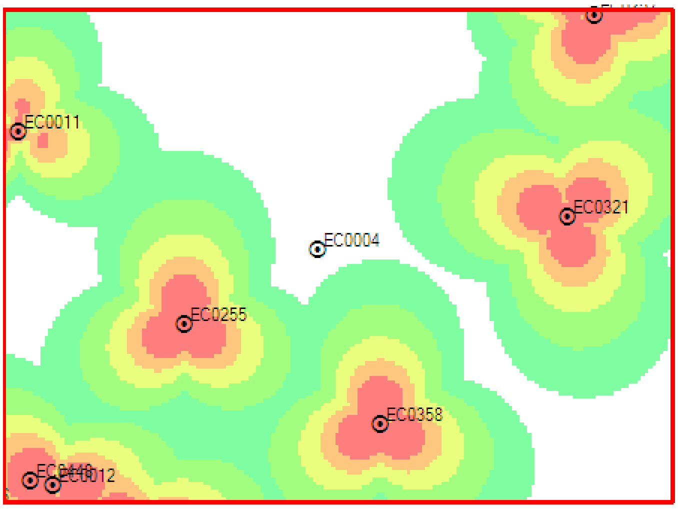

Figure 10: Close-up for region B with cell EC0004 Failed

The power was increased for the two sectors from 57.3dBm to 62dBm EIRP and the azimuths changed from 290 to 270 and 0 to 30 respectively. This gave an acceptable compensation for the received signal level. However, use of only two sectors to compensate gives a huge load to the compensating cells. A huge reserve capacity will be required in the compensating cells in order to accommodate for the load. Nevertheless, it is not uncommon to have some cells that are of small capacity and their compensation can be adequately taken over by just one big cell. Figure 11 demonstrates this compensation.

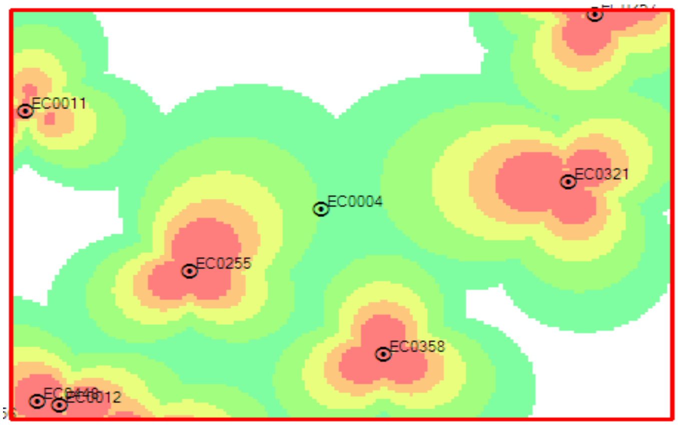

Figure 11: Region B after compensation for cell EC0004

IV. Conclusions

In this work a self-healing radio network was simulated with different complexity levels which shows that it is possible to implement this kind of network in real network. Simulation using data from actual network was included and this also agreed with theory.

The study shows how self healing can be implemented by introducing compensation through cell zooming. Two methods of self healing including height adjustment and power adjustment were considered and these gave good results. Since the simulator that was used from Atoll is very popular in the telecommunication industries, then the results obtained are representative of real network situation.

However, in order to handle the extra traffic that results from the failed cells during the busy period, the study suggests provision of some extra (reserve) capacity that should be calculated on an individual cell basis proportional to the traffic in the cluster. Other suitable methods of ensuring capacity is adequate include use of dynamic channel allocation. Though this does not exactly increase the trunk size, it would help in relieving the traffic level by prioritizing on requirement. Though AMR-HR is very good, it may at times introduce quality degradation. This may however be accepted considering any network optimization goal is to balance all factors for best results.

The study also revealed that a real network can be categorized into two regions according to the density of antennas. The much cluttered regions have high received signal levels and compensation should focus on additional capacity on the trunks. In a scattered area, the compensation can be achieved through neigbouring cells. However, consideration of power and height adjustment alone did not provide an optimal relief. It is important to consider the element of azimuth as it proved a major player both to the success of the compensation as well as for maintaining the health of the unaffected cells.

It is worth noting that, however, for cell zooming compensation method to maintain optimal characteristics, its various factors in Height, Electrical and Mechanical tilts and Power Levels must be well matched.

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