The Use of Cell Zooming for Outage Compensation in Cellular Radio Networks

S. N. Manegene, P. L. Kibet and S. Musyoki

Abstract—The emerging treads in cellular communication are shifting from the manual operation and maintenance to more automated one as in the Self-Organizing Networks (SON) defined by the Third Generation Partnership Project (3GPP) release 8. The idea is to have an autonomous system that requires minimum human intervention. One of the areas of focus in the self-organizing networks (SON) is in outage compensation for self-healing. Cell outage is the total loss of radio services in the coverage area of a cell.

Cell zooming has been adversely used in the area of optimization and power saving but its applicability in outage compensation in the 2G and 3G setting has not been given the weight it deserves. Its behavior can however be exploited for cell outage compensation.

This paper explores the technicality and practicability of the use of cell zooming in outage compensation. It considers the environment under which cell zooming can be applied and the various other considerations that should be taken into account in order to succeed in outage compensation using this method.

***Keywords*—**Cell Zooming, Outage compensation, Self-Healing, Self-Organizing Networks (SON)

I. INTRODUCTION

THEgoal of every service provider is to maximize on profit. This is possible by ensuring customers are attracted to their services by providing them with a good experience and by minimizing expenses. This is where SON comes in handy because SONs help reduce expenses through automation as well as maximize opportunities by actively preventing and correcting failures which are the biggest nuisance to customers. There is a significant increase in the profits by the operators and or lowering the cost of telecommunication services by use of SON since studies have shown that 17% of Capital Expenditure (CAPEX) is used in installation and configuration while 24% of revenue is used up in maintenance [1-2].

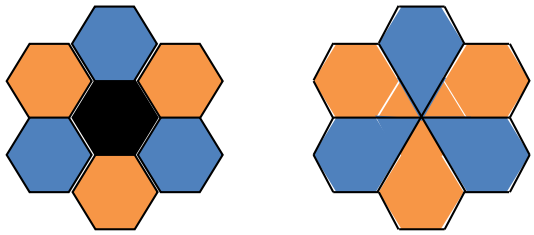
While addressing the benefits of Self Organizing Networks (SONs), we cannot overlook the cost implication of replacing old technology. Thus a gradual introduction of new technology is preferred. Part of this research is to identify key factors that are critical to adapt the existing mobile network infrastructure so that it exhibits significant level of intelligence that will lower overall downtime in mobile network and thus reap the benefits of SON.

The scope of the study is limited to the mobile radio network and more specifically will address a self initiated healing in the event of a total outage.

II. CELL OUTAGE COMPENSATION

Cell outage is the total loss of service from a serving radio as a result of a 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 [3]. Fig 1below gives a summary of what happens in a cell compensation scenario. It consists of a 7 cell cluster which when the central cell goes out of coverage, the other cells extend to cover the area once covered by the cell that is in outage.

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 neighboring cells [4-5].



7 Cluster cells with black cell as target

Same cluster after compensation

Fig 1: Outage Compensation Scenario

During compensation using neighboring 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 [6-8].

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The preferred method in this research for compensation is by use of cell zooming.

A. *Cell Zooming*

In order to compensate for cell outage, one of the methods that can be used automatically is cell zooming. Cell zooming in this case implies 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[9], [10]. Each of the approaches to cell zooming has its advantages and disadvantages but the best approach would involve an optimal combination of the three.

1. Electrical Zooming

This the adjustment of the cell size by varying electrical power dissipated by the antenna. The power received by the mobile station (MS) antennas is critical. This is because there is a minimum power of -105 dBm required by the MS in order to sustain a communication between the radio and the MS and a minimum power of -114 dBm is required to be received at the BTS antenna to sustain communication with a MS [11]. In Kenya, the received levels are specified as In-car = -100 dBm, Indoor = -95 dBm and Outdoor = -105 dBm [12]. To arrive at this, link budgeting is done.

The link budget calculations are used to determine the maximum allowable path loss (MAPL) in the system. The MAPL for the downlink is given by:

$$\mathrm{MAPL_{DL}} = \mathrm{MS_{RX_{sensitivity}}} - \mathrm{BS_{TX_{pwr_{max}}}} - \mathrm{Loss_{DL}} - \mathrm{Margins_{DL}} + \mathrm{Gains_{DL}} \quad (1)$$

where

- $\mathrm{BS_{TX_{pwr\_max}}}$ is peak RF power at Carrier Unit
- $\mathrm{MS_{RX_{sensitivity}}}$ is the Mobile Station sensitivity
- $\mathrm{Loss_{DL}}$ is the losses of the system
- $\mathrm{Margins_{DL}}$ is the margins coming from the propagation phenomena
- $\mathrm{Gains_{DL}}$ is the system gains

The maximum cell radius is calculated from the COST-Hata propagation model because a comparative study[13]showed this is the most consistent model for urban areas. The Cost-Hata propagation model is given as:

$$PL = 46.3 + 33.9\log f - 13.82\log h_b - R_a(h_m) + (44.9 - 6.55 log h_b) log R_a + C \quad (2)$$

where

- PL is the maximum path loss in dB
- f is the frequency in Hz
- h_b is the base station height in meters
- R_a is the cell radius in km
- h_m is the mobile receiver height in meters
- C is 0dB for medium cities and sub-urban areas or 3dB for metropolitan cities

After getting the value of the maximum path loss (PL) in dB from the link budget, the radius (R_a) in Km can be calculated as follows

$$R_a(h_m) = \{1.1\log(f) - 0.7\}h_m - \{1.56log(f) - 0.8\} \text{for urban areas} \quad (3)$$

2. Electrical tilt

This is obtained by changing the characteristics of signal phases on each element of the antenna, as seen in Fig 2. A BTS antenna is constructed using several antenna elements usually 2 to 8 and each element is fed with the same signal but at different phases in order to achieve the tilt. The electrical tilt may have a single fixed value or may be variable. If the variation is done electrically, this is referred to as Remote Electrical Tilt (RET). An electrical down tilt, tilts both the front and the back lobe downwards. Fig 2 [10] shows an illustration of 4 element antenna fed with signal at different phases in order to achieve the tilt.

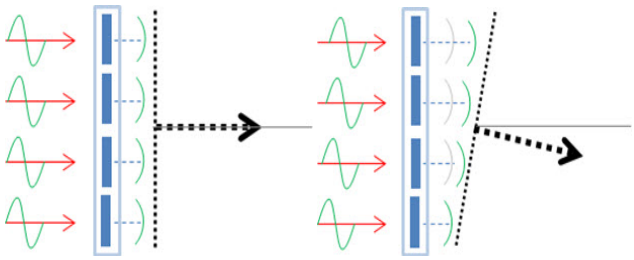

Fig 2: Illustration of Electrical Tilt

3. Mechanical Tilt

A mechanical tilt involves tilting the antenna usually through specific accessories on its bracket consequently altering the direction of propagation of the signal. This tilt can be done manually or electronically. A mechanical down tilt will tilt the front lobe downward but the back lobe will tilt upward[10]. An illustration is given in Fig 3.

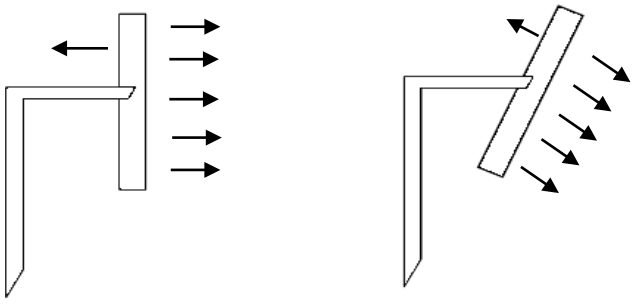

Fig 3: Illustration of Mechanical tilt

B. *Subscriber calling pattern*

Proper understanding of cellular radio capacity planning and subscriber behavior is important. All over the world the desire to communicate is highest between 5pm and 9pm with a busy hour (period of peak traffic) being used for the planning purposes. Statistics in Kenya shows a subscribers calling pattern with traffic highest at 1900hrs.

The statistics used for this investigation are for the months of October and November and seem to suggest a constant calling habit by mobile users. The graphs Fig 4 and Fig 5 show the traffic pattern of one week for various weekdays and the traffic pattern is similar except on Sundays where the traffic growth is delayed but eventually catches up at 1400hrs.

To show that the same pattern is replicated over the other weeks, the pattern for two weekdays, Tuesdays and Thursdays, are plotted for the six weeks and shown in Fig 6 and Fig 7 respectively.

From these graphs it can be observed that it is only 2 hours in a day that have traffic above 85% of the peak traffic. That is, 1900 hrs and 2000 hrs with 1900 hrs being the consistent busy hour. From 2100 hrs to the next day 1800 hrs the traffic is below 85% of the peak traffic.

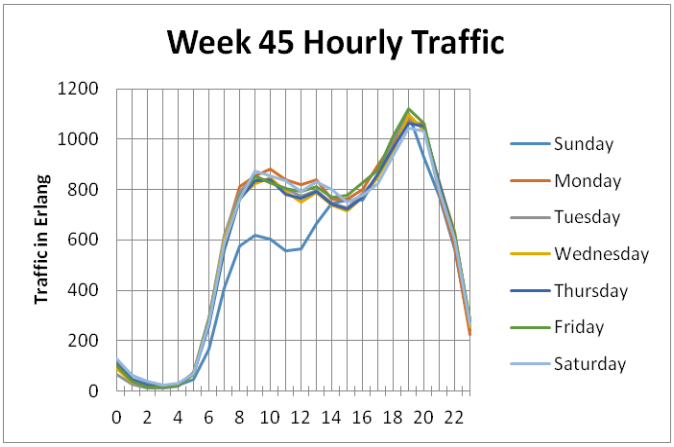

Fig 4: Plot of Week 45 Traffic Pattern

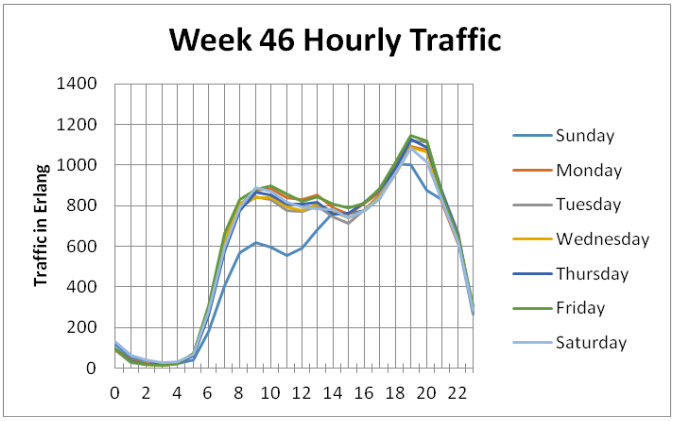

Fig 5: Plot of Week 46 Traffic Pattern

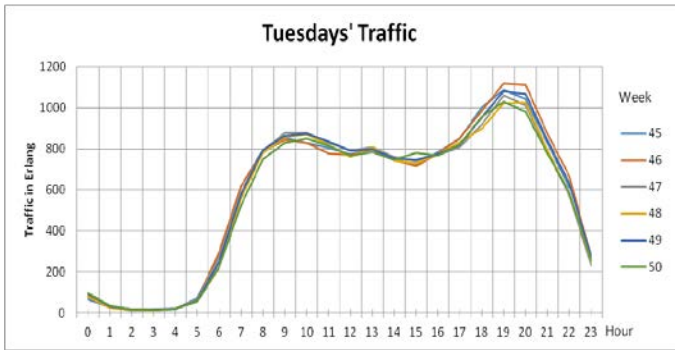

Fig6: Subscriber Calling Behavior for Tuesdays

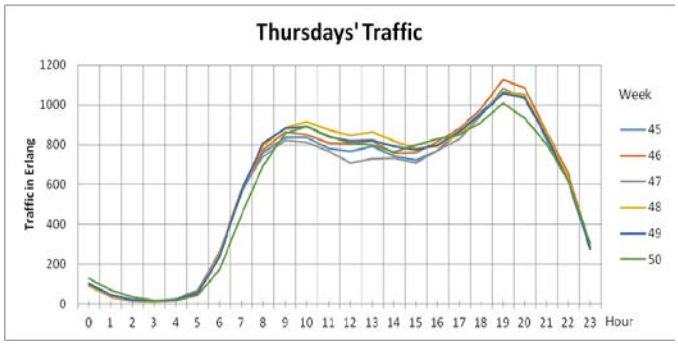

Fig7: Subscriber Calling Behavior for Thursdays

In a theoretical 7-cells-cluster homogeneous network, it will be possible to share the traffic of the failed cell with the neighboring cells for 22 hours of a day without requiring extra capacity. In this homogenous network, Fig 1, all the cells have the same capacity and equal traffic. When the 85% of peak traffic for the failed cell is shared among the 6 healthy cells, each cell gets 14% extra from the failed cell traffic so that the compensating cells will be loaded to 99% of peak load. During the two hours peak period in a day, the traffic in the compensating cells in the cluster would overwhelm the cells if they are sized just to capacity.

C. Signal strength

According to CCK's latest report [14], all communication service providers have maintained good received signal levels well beyond the target even though most only got 50% overall score on Quality of Service (QoS). The outdoor showed a minimum of -86dBm against -105dBm set target. This implies that signal strength allows for easy zooming without necessitating major adjustment in the input power.

However, it is important to monitor the interference between cells as this impact on the overall quality of service due to the effects it has on handovers and consequently handover and interference related call drops.

Equation (1), (2), and (3) are used to plan for the desired signal strength.

D. 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).

Telephone traffic is dependent on two factors:

- Arrival rate of calls
- Average duration of calls (Mean Holding Time)

Traffic is given by,

$$\alpha = ch \qquad (4)$$

where

α = Traffic in Erlangs
h = Mean Holding time per call
c = Average number of call per unit time

Traffic table is computed using Erlang B formula. In this formula, the blocking probability is given by:-

$$B(n,a) = \frac{a^n/_{n!}}{\sum_{k=0}^{n} \frac{a^k}{k!}} \quad (5)$$

where

- B(n,a) is the blocking probability
- n is the number of trunks
- a is the traffic in Erlangs

III. Conclusion

This paper is part of an ongoing research on outage compensation and therefore presents only preliminary findings. Outage compensation using cell zooming has not been explored much in the past but there are indicators that its practical application will not be difficult especially in the Kenya environment. This is because, both the received signal levels and subscribers calling pattern, suggests a predictable trend and hence an encouragement to pursue the research further.

Significant progress has been achieved in analyzing the subscriber calling behavior with a positive indication that the application of cell zooming in outage compensation is possible. However, in order to make conclusive deductions, it is important to further analyze actual traffic data to find out if the available capacity can sustain outage compensation beyond the 22 hours per day window. Further, a recommendation on the reserve capacity required will be given. Again the coverage studied assumed a homogeneous cluster but this may be far from the reality. Thus real data will be used to get a better picture.

When outage compensation is achieved by this using cell zooming method, it is expected to result in improved subscriber experience and lower on the service cost. This is because of how seamlessly and effortlessly faults can be cleared.

Further research will seek to break through the resources limitations and recommend an acceptable self healing design that can be adopted by operators as a step towards Self Organizing Networks

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