Feasibility of Green Network Deployment for LTE Network Using Genetic Algorithm Technique

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***Abstract*—Green technology is a new term which is used to describe the energy efficient technologies. The main aim of the energy efficient technology is to reduce the total energy consumption while maintaining the functionality and quality of the respective technology. In the context of mobile communications technology, complying with the green technology strategy is a challenge. This is because of the tradeoff between the Quality of Service (QoS) provided and the total energy used in the transmission. Reducing the transmission energy may cause degradation in the QoS, more distinctively, in dense areas. This paper explores the possibility of achieving the green technology goal in planning and deployment of the Long Term Evolution (LTE) mobile network. A real scenario from operators in Kuala Lumpur, Malaysia is used for the purpose of the investigation. Pathloss estimation is based on ERICSSON 999 method and the region of interest is represented as Digital Terrain Map (DTM). The planned base station locations, transmission power and heights are provided by the operator. Genetic Algorithm is developed to estimate the base station parameters for more energy efficient LTE network deployment. Results show that a remarkable energy saving of about 26% of the operator transmission power could be achieved by selecting the appropriate base station parameters in planning stage while maintaining the QoS of the network.**

***Index Terms*—Green Network, Genetic Algorithm, LTE, Radio Network Planning.**

I. Introduction

SINCE the industrial revolution at the beginning of the nineteenth century, the demand of energy resources has been growing up relentlessly. This sudden and huge demand has had its impact on the environment leading to emerging issues of imbalance, and threatening our existence on earth due to global warming. As a result, the need of continuing the current life style has to consider sustainability, which could only be achieved if the environment is considered in the equation. The term green technology refers to all the measures and actions that are conducted in order to efficiently utilize the energy resources, nevertheless, producing the same desired product quality.

Mobile communication networks shares a significant part of the global energy consumption. Nowadays, the booming reliance on mobile services caused the requirements of mobile communication services to grow very rapidly. This increase adds tension on the power resources since it needs wider bandwidth and higher data rates to accommodate the market demands and the expanding number of users and services. Annually, it is estimated that 58 MW is the total power consumption of a network consisting of 20,000 3G base stations [1]. Base stations transmission power accounts for 60-80% of the total power consumed in the network [2]. These power consumption figures motivates the consideration of the green network planning as an essential step to reduce the impact of wireless technology on the environment, especially that there is a collective aim globally to decrease carbon footprint and total power consumption up to 20% by 2020 [3]. Green Network planning optimizes the network by spatially distribute the base stations and adjust their transmission power and configuration such that the total power of transmission is minimized. As the QoS is the main concern of all mobile communication companies, green network planning should consider Quality of Service (QoS) in the planning process to ensure the compliance of the green network with the requirements of mobile communication standards.

Long Term Evolution (LTE) is a global term describing what is commercially known as 4G mobile broadband network. The ability of the operators to preserve higher peak throughputs during higher spectrum bandwidth is the key advantage of LTE networks over HSPA+. In order for an LTE network to maintain high peak data rates in high spectrum bandwidth, it uses Orthogonal Frequency Division Multiple Access (OFDMA) for downlink. For uplink, however, it employs an approach known as Single Carrier FDMA (SC-FDMA) [4]. Similar to traditional networks, LTE base station power consumption compliance to the green network definition remains an open question.

Varieties of optimization methods are developed for base station location problem in [5]–[13].The main distinction between the different methods is the objectives used which are based on the network requirements and the constraints imposed in the optimization criteria. Tabu search algorithm and GA are compared in [9] for optimization of the number of base stations deployed for a specific area. The main objective of their work is to reduce the number of base station while maintaining maximum number of users served. Both methods showed a satisfactory convergence with better optimization achieved from the Tabu search while GA provided faster solution. The same conclusion was drawn from [5] where GA, Tabu search and simulated annealing algorithms has been compared. In [6], different scenarios of optimization have been compared for optimizing the configuration of base stations for Single Frequency Networks (SFN) using GA.

The scenarios focused on the carbon dioxide footprint (CO2), energy consumption, coverage optimization, number of active transmitters, and safety index as the objective functions. The authors compared the results by running each objective distinctively. Energy efficiency objective provided the minimum CO2 footprint and safety index. Genetic algorithm methods were developed for UMTS networks in [13]. Different objective functions have been evaluated to check the distribution of the resulted network. In [10], transmission power is considered part of the objective function to ensure signal strength received by the user to be bounded to provide required signal strength and satisfy the safety limits. More recently, network planning has been addressed for a uniformly distributed random base stations locations for operating network in Kuala Lumpur, Malaysia [7]. The total energy optimization was the main objective function. The GA estimates the best position of the base stations, transmission power, and height. The results demonstrated the possibility of deployment of energy efficient network.

In this paper a green network deployment strategy is investigated for Long Term Evolution (LTE) networks. The developed GA optimizes the base stations configurations for a real network operating in Kuala Lumpur, Malaysia. The objective function consists of two main parts. The first part is the minimizing functions such as the transmission power, number of base stations, safety index, and Transmission Power Root Mean Square deviation (TPRMS). While the latter contains the maximizing functions contains coverage probability and the average transmitter to transmitter distance.

The rest of this paper is organized as follows: Section II investigates data collection campaign. System model is presented in Section III followed by a description of GA and the objective functions in Section IV. Fifth Section discusses the results. Finally, the results of this work are concluded and future work is recommended.

II. Data Collection Campaign

Network planning involves distribution of base station antennas in the Region of Interest (ROI) to ensure a full coverage of the area. Base station antenna heights and transmission power should be selected carefully to provide the required QoS and to keep the field exposure and total power consumption within the acceptable range. Therefore, to configure the GA system to choose the suitable green network plan in a specific area, a digital representation of the area and the base station planned locations along with the base station heights and transmission power are required. Road test data will help to validate the GA proposed plan.

The ROI is represented by Digital Terrain Map (DTM) with a resolution of 1:5000 m provided by Jabatan Ukur Dan Pemetaan Malaysia (JUPEM). The DTM covers the metropolitan region of Kuala Lumpur city in Malaysia of an area of 54km^2. The projection used in the map is WGS84. The details of the latitude and longitude coordination are shown in Table I

Network base station distribution and configuration are provided by the Malaysian Communications and Multimedia

TABLE I
Map Attributes

Title	Value
Projection	WGS 84
Left Top Corner	3.19264568126254, 101.675051755914
Right Top Corner	3.19264568126254, 101.735764982316
Right Bottom Corner	3.11965924350193, 101.735764982316
Left Bottom Corner	3.11965924350193, 101.675051755914
Pixel Scale	0.0001306

Commission (MCMC) for Kuala Lumpur region. The planned base station antenna heights are calculated from the ground level and the transmission power is in dBW representing the EIRP power. All the base stations are Kathrin 742 215 model and polarized horizontally with continuously adjustable electrical tilt from 0-10. The locations of the base stations are in decimal latitude/longitude format projected on WGS84. The initial plan contains 160 base stations distributed in the region transmitting at 2112.4 GHz for downlink and 1922.4 GHz for uplink. The base stations antenna gain is provided as 18 dBi in the specified range of frequencies.

For the purpose of validating the GA proposed scenario coverage, MCMC provided a road test field measurements. Mobile antenna height used in the measurements is 1.5m. The road test has been conducted on irregular path covering the ROI as shown in Fig. 1 with a sampling rate of 0.5 sample per second. Spatial locations of the road test samples are provided in decimal latitude/longitude format.

Fig. 1. Road Test Map

III. System Model

Assuming a network consisting of k isotropic base station antennas distributed in a region of size $m \times n$ km where each base station location is represented by x_i latitude and y_i longitude forming a set of candidate locations:

$$\{(x_i, y_i)|1 \leq u \leq k\} \quad (1)$$

To allow the GA to select the active base station locations, the locations where the base stations are installed, each location will be associated with a digital flag defined as follows:

$$a_i = \begin{cases} 1 & \text{base station is installed} \\ 0 & \text{base station is not installed} \end{cases} \quad (2)$$

The height of each base station antenna is selected from a set of valid heights represented as:

$$\{h_1 | 1 \leq l \leq q\} \quad (3)$$

where q represents the length of the allowed base station antenna height list.

Similarly, the valid transmission power can be defined as incremental set of transmission powers where each base station antenna transmission power is a member in the set as follows:

$$\{Tp_j | 1 \leq j \leq z\} \quad (4)$$

where z is the length of the allowed base station antenna transmission power list.

This configuration increases the degree of freedom of the planning process where the GA is allowed to select the locations, heights and transmission powers independently for the base station antennas to satisfy the required criteria. The proposed solutions of the GA will be evaluated by calculating the required parameters on a set of regularly distributed test points represented by the set of test location pairs:

$$\{(Rx_i, Ry_i) | 1 \leq i \leq u\} \quad (5)$$

where u is the number of test points representing users.

The proposed network configuration must satisfy two constraints. The first constraint is that all the base station antenna heights in the network are within the range of the defined base station antenna heights. Similarly, the proposed base station antenna transmission power should be in the range specified in the transmission power list. For any proposal which does not satisfy the design constraints, a penalty will be applied according to the number of proposed base stations which violate the design constraint so that the proposed configuration is ignored from the next generation.

A. *Distance calculations*

The distance is calculated using the WGS84 reference ellipsoid with the parameters listed in Table II

TABLE II
WGS84 REFERENCE ELLIPSOID PARAMETERS

Title	Value
Semi major Axis	6378137
Semi minor Axis	6356752.31424518
Inverse Flattening	298.257223563
Eccentricity	0.0818191908426215

Two different distance matrices are used in this work. The first distance matrix represents the distance between every base station from each test point. This distance is used to calculate the system evaluation parameters such as coverage, received signal, and safety index.

To ensure a homogeneous distribution of the base stations over the ROI, the distance matrix between the base stations is calculated. This T_x to T_x distance matrix is useful when dealing with operator predefined base station locations.

B. *Shadow fadinge*

In dense areas shadow fading is represented as a summation of lognormal random variables. Each lognormal random variable represents the contribution of an obstacle blocking the line of site between the transmitter and receiver. Estimating the mean and standard deviation for the summation of the lognormal random variables is accomplished using the Wilkinsons method, described in [14] [15], assuming that the resulted summand is lognormal distributed random variable. The choice of Wilkinsons method in this work is due to its simplicity and validity in the range of standard deviation and mean used in this work. The number of lognormal variables used in the summation reflects the density of the area under consideration.

C. *Coverage probability*

The coverage probability is computed by considering the lognormal shadow fading with standard deviation of 10 dB representing metropolitan area in the ROI. The total shadow fading can be presented as a normal distribution function with zero mean and σ standard deviation as follows:

$$X = \frac{1}{\sqrt{2\pi\sigma}} e^{x^2/2\sigma^2} \quad (6)$$

The pathloss can be expressed in general as:

$$Pl = \overline{Pl} + X \quad (7)$$

where $\overline{Pl}$ is the local mean pathloss defined as:

$$Pl = A + Blog_{10}(r) \quad (8)$$

where A is the intercept point, $B = 10n$, n is the pathloss exponent, and r is the distance from the base station in meter.

By defining the Shadow Fading Margin (SFM), the probability of cell coverage can be defined by requiring the sum of the signal received and the SFM at distance r from the receiver to be greater than the mean pathloss, thus:

$$P_{cov} = Pr\left(Pl + SFM > \overline{Pl}\right) \quad (9)$$

Substituting eq. (7) in (9)) and calculating at distance r, yields:

$$P_{cov} = Pr\left(\overline{Pl}(r) + X + SFM > \overline{Pl}(R)\right) \quad (10)$$

$$P_{cov} = Pr\left(X > \overline{Pl}(R) - \overline{PL}(r) - SFM\right) \quad (11)$$

where r is the user distance from the base station and R is the radius of the base station.

Using eq. (8)

$$P_{cov} = Pr(X > A - Blog_{10}(R) - (A + Blog_{10}(r)) - SFM) \quad (12)$$

$$P_{cov} = Pr\left(X > Blog_{10}\left(\frac{R}{r}\right) - SFM\right) \quad (13)$$

From eq. (6), the coverage probability can be written as:

$$P_{cov} = \frac{1}{\sqrt{2\pi}\sigma}\int_{Blog_{10}(R/r)-SFM}^{\infty} \mathrm{e}^{\frac{x^2}{2\sigma^2}}\,\mathrm{d}x \quad (14)$$

Defining $t = x/\sigma$ and substituting in eq. (14)

$$P_{cov} = \frac{1}{\sqrt{2\pi}}\int_{\frac{Blog_{10}(R/r)-SFM}{\sigma}}^{\infty} \mathrm{e}^{\frac{t^2}{2}}\,\mathrm{d}t \quad (15)$$

$$P_{cov} = erf\left(\left(Blog_{10}\left(R/r\right) - SFM\right)/\sigma\right) \quad (16)$$

Equation (16) defines the coverage probability at a distance r from the base station. For cell coverage probability (Pcell), it is defined as the average of the coverage probability at all possible locations covered by the cell. Mathematically Pcell can be written as:

$$P_{cell} = \int_0^{2\pi}\int_0^R \mathrm{P_{cov}(r)}P(r,\varphi)\,\mathrm{d}r(d)\varphi \quad (17)$$

where $P(r,\varphi)$ is the distribution function of the mobile users.

For uniform users distribution, the probability of a user to be at distance r with angle φ from the base station can be defined as follows:

$$P(r,\varphi) = \frac{r}{\pi R^2}, 0 < r < R, and 0 < \varphi < 2\pi \quad (18)$$

From eq. (14), (17) and (18), the cell probability can be written as:

$$P_{cell} = \frac{2}{R^2}\int_0^R \mathrm{r}(erf((Blog_{10}(R/r) - SFM)/\sigma))\mathrm{d}r \quad (19)$$

Where the erf is defined as:

$$erf(t) = \int_{\frac{Blog_{10}(R/r)-SFM}{\sigma}}^{\infty} \mathrm{e}^{-t^2/2}\mathrm{d}t \quad (20)$$

Let define

$$x = \frac{(Blog_{10}(\frac{R}{r}) - SFM)}{\sigma} \quad (21)$$

Calculating for r, yields

$$\sigma x = (Blog_{10}\frac{R}{r} - SFM) \quad (22)$$

$$\frac{(\sigma x + SFM)}{B} = log_{10}\left(\frac{R}{r}\right) = \frac{ln\left(\frac{R}{r}\right)}{2.303} \quad (23)$$

where

$$ln(10) = 2.303 \quad (24)$$

$$\frac{(2.303(\sigma x + SFM))}{B} = ln(\frac{R}{r}) \quad (25)$$

$$\frac{R}{r} = e^{(}\frac{2.303\sigma x}{B}) \times e^{(}\frac{2.303SFM}{B}) \quad (26)$$

let

$$c = (\frac{2.303\sigma}{B}),\ \text{and}\ \ b = e^{(}\frac{2.303SFM}{B}) \quad (27)$$

Equation (27) will be:

$$(\frac{R}{r}) = be^{cx} \quad (28)$$

Changing the limits of the integration and substitute in eq. (19), yields:

$$r = (\frac{R}{b})e^{cx} \longrightarrow dr = (\frac{-cR}{b})e^{cx}dx = -crdx \quad (29)$$

$r \longrightarrow 0 \longrightarrow x \longrightarrow \infty$
$r \longrightarrow R = e^{cx} \longrightarrow (\frac{-ln(b)}{c}) = x$

$$P_{cell} = (\frac{2}{R^2})\int_{\infty}^{(\frac{-ln(b)}{c})} ((\frac{R}{b})e^{-cx}erf(x)(-c(\frac{R}{b})e^{-cx}))\mathrm{d}x \quad (30)$$

$$P_{cell} = (\frac{-2c}{b^2})\int_{\infty}^{(\frac{-ln(b)}{c})} (e^{-2cx}erf(x))\mathrm{d}x \quad (31)$$

$$P_{cell} = (\frac{2c}{b^2})\int_{(\frac{-lb(b)}{c})}^{\infty} (e^{-2cx}erf(x))\mathrm{d}x \quad (32)$$

By integration by parts eq. (32) yields:

$$P_{cell} = \frac{b^2 erf(\frac{-ln((b)}{c})}{2c} - \frac{e^{-c^2}}{2c\sqrt{2\pi}}erf(\frac{-ln(b)}{c\sqrt{2}} + \frac{c}{\sqrt{2}}) \quad (33)$$

Shadow Fading Margin can be calculated by noticing the minimum allowed SINR for LTE network. For downlink, LTE network minimum SINR for downlink is considered to be in the range of 16.5 dB to 11dB for the given transmission power range [16] [17]. The pathloss in eq. (8) can be represented as:

$$Pl(R) = P_t - G_t - L_b - SINR + G_r - L_r - N_r \quad (34)$$

Where:

P_t is the transmitting power of every base station.
G_t is the transmitter gain =18dBi.
L_b body losses =4dB.
G_r is the receiver antenna gain =0dBi.
L_r is the receiver losses =0.5dB.

N_r receiver noise =-132.28dB.

Using these values in eq. (34) and considering the range of transmission power yields the mean pathloss at the edge of the cell to be about 150dB. This value represents the maximum pathloass at the edge of the base station. The SFM is calculated as:

$$SFM = P_t - Pl(R) \quad (35)$$

The proposed system calculates the coverage probability for all the base stations available, and considers the minimum coverage as the objective function to be maximized.

D. Pathloss propagation model

The pathloss is computed using ERICSSON 9999 urban propagation pathloss model. The advantages of using this model are its adaptability for different scenarios and validity in the frequency range of LTE network. The pathloss model can be written as:

$$\begin{aligned} Pl = a_0 + a_1 log_{10}(d) + a_2 log_{10}(h_b) \\ + a_3 log_{10}(h_b) log_{10}(d) \\ - 3.2(log_{10}(11.75 h_r)^2) \\ + 44.49 log_{10}(f) + 4.75(log_{10}(f))^2 \end{aligned} \quad (36)$$

Where:
h_b : The BS height (m).
h_r: The MS antenna height (m).
d : The distance between the BS and MS (m).
f: The carrier frequency (MHz).

For urban areas the parameters a_0, a_1, a_2, and a_3 are 36.2, 30.2, 12, are 0.1 respectively as default [18].

E. Safety Index

Safety index is defined as the percentage of the amount of power received per unit area of the receiver to the allowable exposure limit. To avoid any health hazard from the propagating microwave, standards identified the limits of exposure allowed for human body [19]. In multi-antenna network, safety index is calculated as the total sum of the fractions of power densities received at the user site for every frequency (in case of multi frequency transmission). Power density at a specific distance r (m) from an base station antenna transmitting at power P (W) can be calculated as:

$$P_d = \frac{PG}{4\pi r^2}(w/m^2) \quad (37)$$

For n base stations, the total power density is:

$$P_d t = \sum_{i=1}^{n} \frac{P_i G_i}{4\pi {r_i}^2} \quad (38)$$

According to the IRPA Radiofrequency safety guidelines and Standards, the general public exposure limits to time varying electromagnetic field at 2000MHz is 10 w/m2 [20]. Thus the safety index can be defined as:

$$SI = \frac{P_{dt}}{10} \quad (39)$$

IV. GENETIC ALGORITHM

The main objects in the GA are the genes which form the chromosomes. Each genome represents the configuration of a base station and, hence, each chromosome describes the total proposed network configuration. In this work the chromosomes are constructed as binary string of $g * k$ digits where g is the number of digits for each genome and k is the total number of base stations in the topology. The number of digits on each genome g can be computed from eq. (2) (3) and (4) as follows:

$$g = 1 + \lceil log_2(q) \rceil + \lceil log_2(z) \rceil \quad (40)$$

The operator $\lceil . \rceil$ represents the ceiling function. Where the first digit is assigned for the flag, followed by the digits of the heights and then finally the digits of the transmission power, the construction of each genome and the corresponding chromosome are demonstrated in Fig. 2

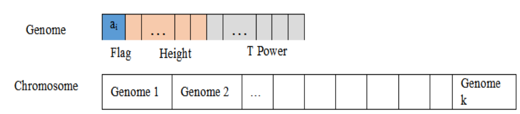

Fig. 2. Fig. GA Chrimosome construction

Initially the GA proposes a uniformly distributed set of chromosomes called the population. Based on a set of objective functions the GA will narrow down the search domain to the best population. The following subsections discuss the objective functions and the steps taken by the GA to converge to the solution.

A. Fitness functions

Each chromosome in the generated population will be evaluated based on a set of network model parameters and accordingly it will be assigned a fitness value indicating its suitability. The main aim of this work is to check the ability of the LTE network to comply with the green technology concept. This compliance suggests the reduction of total power consumed by the network while maintaining the QoS. Hence, the objective functions are designed in two groups. The first group consists of minimizing functions while the second group contains the maximizing functions. The following subsection will explain the minimizing group of functions followed by the maximizing functions

1) Minimizing objective Functions:

- *Number of active base stations*
  The first strategy to reduce the total power consumed is by reducing the number of base stations used in the network. Thus, number of active base stations proposed is impeded in the objective functions as follows:

$$activeT_x = \frac{\sum_{i=1}^{k} a_i}{k} \tag{41}$$

  where k is the total number of initial transmitters

- *Total power*
  As each base station transmission power is considered a decision parameter in the GA, the total power consumption should be mitigated as a minimizing objective function. The total power consumed by the proposed network is calculated as:

$$Power_{total} = \frac{\sum_{i=1}^{k} a_i T_{pi}}{T_{xpmax}} \tag{42}$$

  where $T_{xpmax} = k * T_{pmax}$, $T_{pmax} = 69$ watt, which is the max transmission power in LTE standard [21].

- *Safety Index*
  Minimizing the max SI received by the users from all the available base stations ensures the compliance of the proposed network configurations to the IRPA limits. The SI can be represented by:

$$SI_{max} = max(SI) \tag{43}$$

  where SI is the safety index calculated using eq. (39) for u users.

- *Transmission Power Root Mean Square deviation (TPRMS)*
  Assigning transmission power for every base station randomly may lead to imbalance in the network where some base stations transmit at significantly higher power compared to other nearby base stations. To homogenize the transmission power in the network, the TPRMS measures the fluctuation of transmission power between the proposed active base stations. Minimizing the TPRMS will help producing an even distribution of power in the network. Mathematically TPRMS is represented as:

$$TPRMS = \sqrt{\frac{\sum_{i=1}^{k} a_i (T_{pmean} - T_{pi})^2}{k}} / T_{xpmax} \tag{44}$$

  where

$$T_{pmean} = \frac{\sum_{i=1}^{k} a_i T_{pi}}{\sum_{i=1}^{k} a_i} \tag{45}$$

2) The maximize functions:

- *Coverage probability*
  Reducing the total transmission power of the network and the number of active base stations has a negative effect on the QoS. Quality of Service can be maintained by maximizing the coverage probability of the base stations. The cell coverage probability Pcell is calculated using equation (42). Maximizing the minimum coverage ensures the agreement of the proposed network configuration with the requirements of QoS. Thus, the coverage probability objective function is written as:

$$Pr_{covmin} = min(P_{cell}) \tag{46}$$

- *Base Station to Base Station distance*
  The distribution of the base stations in the ROI is a choice of the operator. Usually more base stations are allocated in higher population density areas. Though, the full coverage requirements suggest a more homogenous distribution of the base stations over the ROI. Thus maximizing the average distance between the base stations will help to improve the homogeneity of the proposed network topology. The average base station to base station distance is calculated as a percentage of the average distance to the reference distance as follows:

$$T_x 2T_{x_{distperc}} = \frac{T_x 2T_{x_{distavg}}}{T_{x_{distref}}} \tag{47}$$

  where $T_{x_{distref}}$ is selected to be the maximum distance in the ROI.

The Fitness function is defined as the summation of the weighted objective functions as follows:

$$\begin{aligned} Ft = (&acctiveTx \times w_1 + Power_{total} \times w_2 \\ &+ SI_{max} \times w_3 + TPRMS \times w_4 \\ &+ Pr_{covmin} \times w_5 + Tx2Tx_{distperc} \times w_6) \end{aligned} \tag{48}$$

The weights are used to give more significance to some objective functions over the others. This allows producing different configurations complying with different requirements of operators.

This fitness function will be evaluated for every chromosome to gauge its suitability. The chromosomes which produce the minimum fitness will be selected to undergo the crossover and mutation to generate the next offspring generation.

B. Penalty

Due to the random generation of population in the GA, the chromosomes might include base stations with heights or transmission powers which do not comply with the height and power limits. To reduce the possibility of the participation of those chromosomes in the next generation, a static penalty is applied on their fitness function as follows:

$$Ft_p = Ft + c_1 \times x_h + c_2 \times x_p \tag{49}$$

Where x_h represents the number of base stations which violates the height bounds, x_p is the number of base stations which violates the transmission power bounds for a given chromosome, Ft_p is the penalized fitness value, Ft is the fitness value, c_1 and c_2 are constants both are sat to 100.

C. Selection

After the chromosome evaluation, a certain percentage of the survived chromosomes will be selected to generate the offspring. The survived chromosomes are the ones with the best fitness value. These chromosomes hold the strongest genes which will improve the search domain in each iteration. The selection method used is the stochastic uniform selection

D. Crossover

The selected chromosomes undergo a crossover to generate the full population size. The crossover mixes different genes in the chromosomes in a random way to increase the possibility of generating better solutions. Since the problem in hand imposes a linear constraint on the decision variables, intermediate crossover algorithm is considered in this work with a percentage of 0.9

E. Mutation

To further increase the diversity of the generated offspring population, a mutation is performed on the offspring. Mutation alters a percentage of genes in a random set of chromosomes. Usually the mutation percentage is small, about 0.01%, which ensures a diverse population and yet maintains the strong characteristics of the generated chromosomes. Uniform mutation algorithm is used in this work.

F. Termination criteria

The proposed GA algorithm will terminate the execution if any of the following criteria is met: 1. The difference between the best fitness function in two consecutive iterations is less than a predefined tolerance, or 2. The maximum number of iterations is reached.

V. RESULTS AND DISCUSSION

The operator topology used in the results includes the network distribution and the base stations configuration in excel sheet format. The data provided includes the configuration of 112 base stations currently in operation along with 48 planned base stations sites forming a total of 160 base stations locations covering 54km^2 area. The topology proposed by GA is compared with the original plan in terms of coverage probability, the exposure safety index, total power of transmission, number of base stations used, and the balance of transmission power in the network. All the experiments are conducted on Dell station model Precision T3610, intel Xeon CPU 3GHz with 8GB RAM running on Windows 7, 64 bits OS. The proposed system is implemented on MATLAB. The GA algorithm parameters used in this work are listed in Table III and the network parameters are shown in Table IV

The following subsection starts by discussing the effect of coverage weight on the decision parameters followed by the second subsection which investigates the proposed topology QoS in contrast with the original plan. The last subsection elaborates on the validity of the proposed network in terms of pathloss and its compliance with the green network definition.

TABLE III
GENETIC ALGORITHM PARAMETERS

Parameter	value
Population size	200
Max. iterations	300
Number of test points	2000

TABLE IV
SYSTEM SIMULATION PARAMETERS

Parameter	value
Carrier frequency	2100 MHz
Bandwidth	10 MHz
Transmission power	20..70W
Antenna gain	18 dBi
Transmitter height	5..70 m

A. The effect of coverage probability weight

The main purpose of the weights is to provide different significance level to the objectives used in the fitness. This will help to direct the GA to produce network topologies comprising of different characteristics. Maintaining satisfactory coverage probability is vital for operators. To optimize the coverage weight to achieve the desired coverage, multiple simulation runs have been performed with incrementing the coverage weigh, w_5 in eq. (48), in the range from 0 to 10. The cumulative distribution function (CDF) of the obtained coverage in each run is shown in Fig. 3. It is observed that the average coverage probability is stable for weight value more than 6 as evident in Fig. 4. From the optimization viewpoint, maintaining high coverage probability is a compromise with the total transmission power in the network. Thus changing the coverage weight will affect the transmission power and the number of base stations activated. The effect of the coverage weight on both the total transmission power and the number of base stations used are depicted in Fig. 5 , 6, and 7 respectively. The results justify fixing the coverage weight to be 10 throughout the rest of this work while the remaining weights are held unchanged.

B. QoS of the proposed scheme

The scope of this discussion is to examine the behavior of the objective functions during the optimization and the validity of the final solution proposed by the GA in terms of total transmission power, number of base stations proposed, the distribution of the network, balance of the power on the base stations, the coverage probability, and the exposure safety index. Figures 8 - 13 shows the progress of the objective functions during the optimization. Since the coverage probability is assigned the highest weight, it shows a significant improvement and stability as shown in Fig. 8, reaching approximately 98% which is well above the standard of 95% required by the operator. This high coverage probability resulted from a network transmitting at only 41% of the total power assumed and only 54% of the total number of base stations initially planned by the operator as it is clear from Fig. 9 and 10 noting that the operator original network was transmitting at 67% of the total transmission power assumed with 70% of the total base stations are activated.

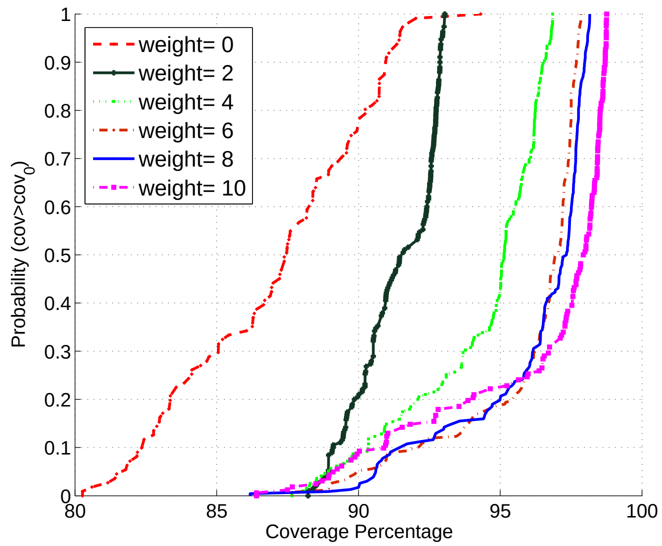

Fig. 3. Coverage probability CDF for different values of coverage weights

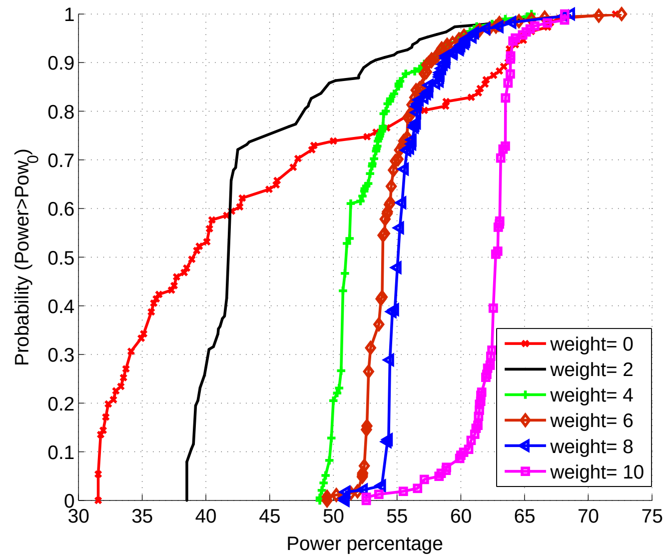

Fig. 5. Netowrk total transmission power CDF for different values of coverage Weight

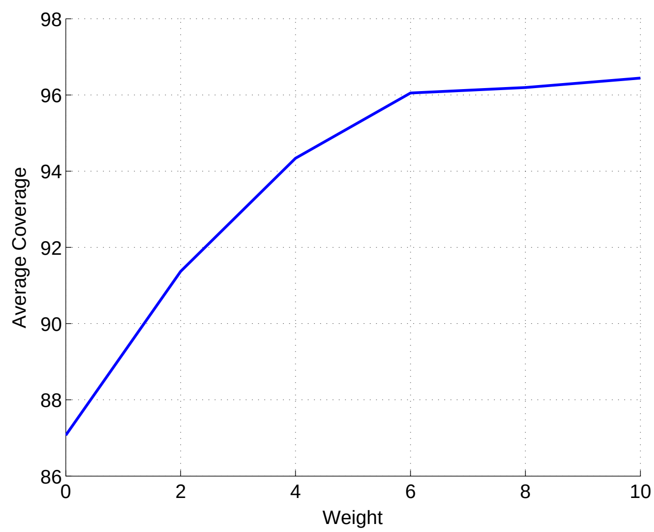

Fig. 4. Average coverage probability versus coverage weight

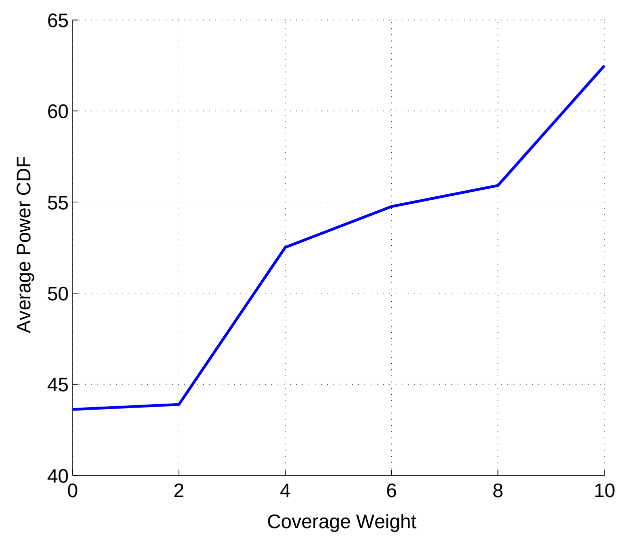

Fig. 6. Netowrk average transmission power versus coverage weight

This reduction in total power motivates the Green network planning strategy in LTE networks.

Moreover, operational economy of the network is more feasible from the operator viewpoint. Due to the uneven distribution of base stations provided by the operator as shown in Fig. 14, the TPRMS of the base station transmission power and the base station to base station distance are monitored in the objective functions. The TPRMS, Fig 11, in the proposed scheme shows an improvement throughout the optimization process. In the final result proposed by the GA, the transmission power of the base stations is narrowed in the range from 35W to 69W. The effect of the Base station to Base station average distance in Fig. 12 can be further illustrated by observing the proposed topology network map in Fig. 15. That Figure shows a satisfactory distribution of base stations in the ROI. This distribution helps improving the coverage probability utilizing less number of base stations and lower levels of total transmission power. Finally, the safety index progress in Fig. 13 shows stability with values in compliance to the standard.

C. The validity of the proposed scheme

To examine the validity of the GA proposed network, the pathloss map is calculated for the operator network plan and for the GA proposed network. The GA proposed network pathloss map shown in Fig. 17 demonstrates the validity of

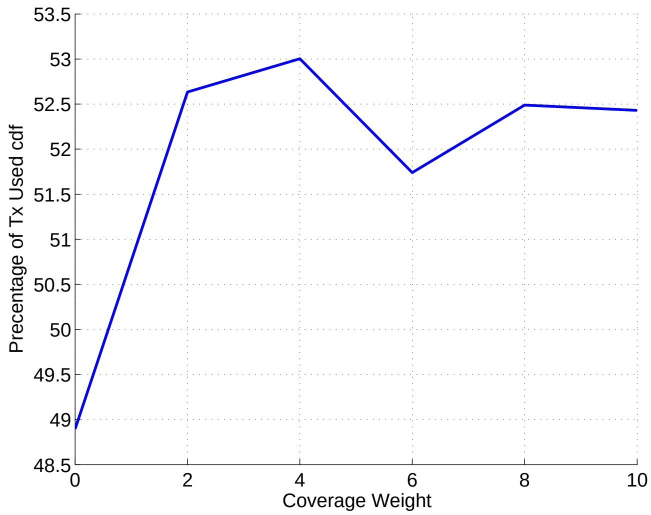

Fig. 7. Number of active base stations versus coverage weights

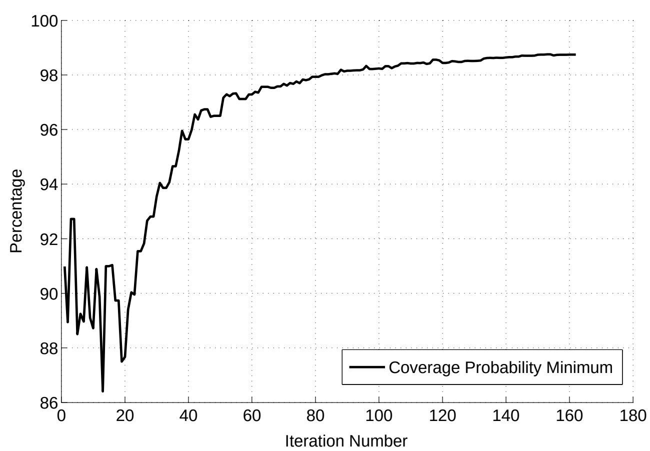

Fig. 8. Coverage Percentage

the proposed network. The pathloss provided by the proposed network ranges between 139.364 and 139.53 dBW as compared with the operator network in Fig. 16 which is in the range 140,883 and 140.052 dBW.

Furthermore, the proposed network parameters in terms of coverage probability, the received RSSI level, SINR, and SI distriputions are compared with the operator network in Fig. 18 , 19 , 20 and 21 respectively. The proposed network parameters show a good proximity to the operator network parameters. The road test measurements provided by the operator are compared with the calculated received power in the proposed network in Fig. 22 and Fig. 23 shows the cdf of road test measurements and the received power calulations of the proposed network.

The provided results illustrate the aplicability of the green network notion to the LTE networks without a significant loss of QoS. Moreover, the proposed system helps reducing

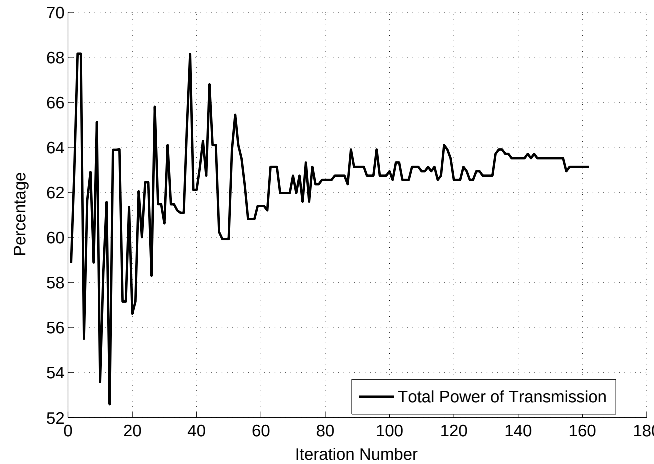

Fig. 9. Total Power of Transmission Percentage

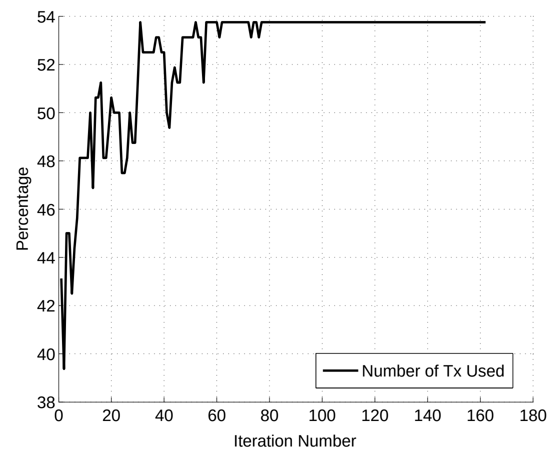

Fig. 10. Percentage of Number of Transmitters used

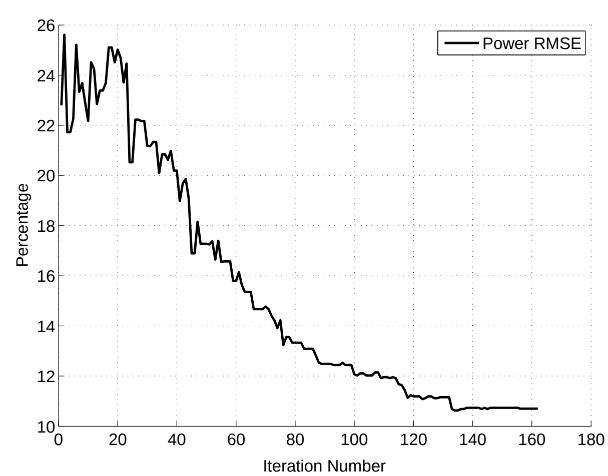

Fig. 11. RMSE Percentage

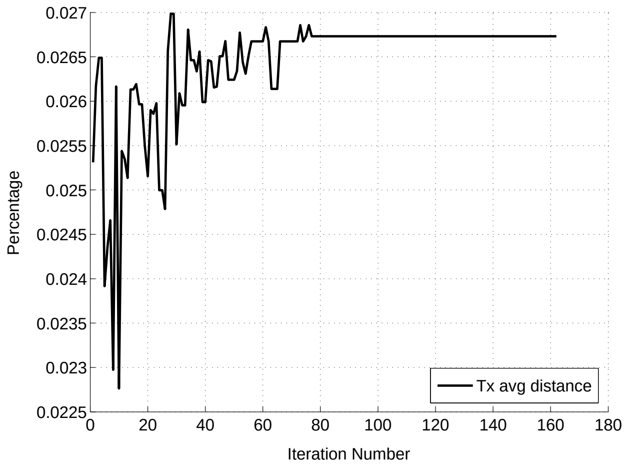

Fig. 12. Tx2Tx Average Distance Percentage

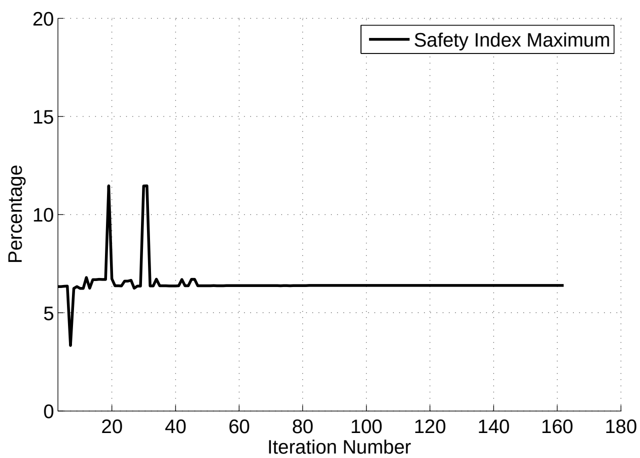

Fig. 13. Safety Index Percentage

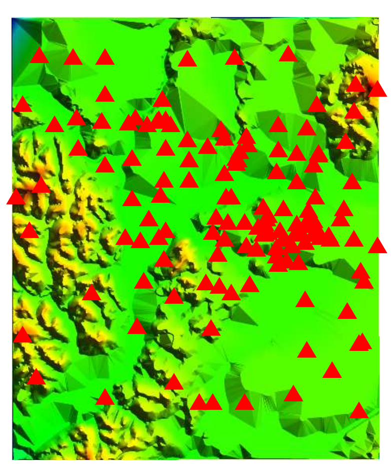

Fig. 14. Initial Network distribution provided by the operator

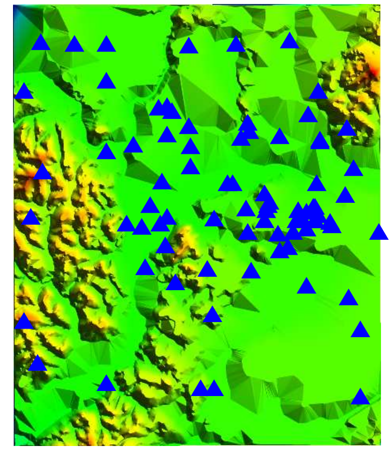

Fig. 15. GA proposed Network distribution

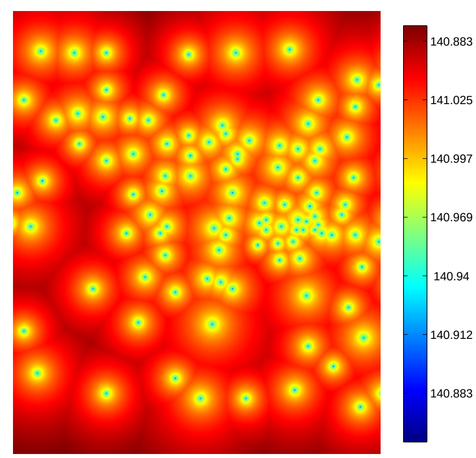

Fig. 16. Operator network pathloss map

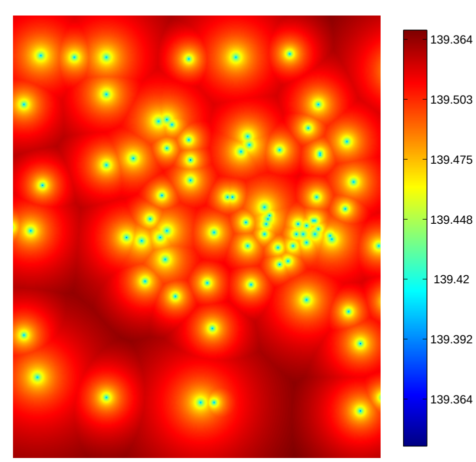

Fig. 17. GA proposed network pathloss map

the costs of installation and, more importantly, the cost of operation of the network by reducing the total power utilized in transmission and the total number of base stations required. It is worth to mention that the proposed GA optimized a network without imposing a major modifications on the network infrastructure. This motivates the adoption of the green network deployment strategy even for existing networks. Needless to mention the encouraging effects of such optimized network deployment strategies in reducing the degradation of the environment quality on the long run.

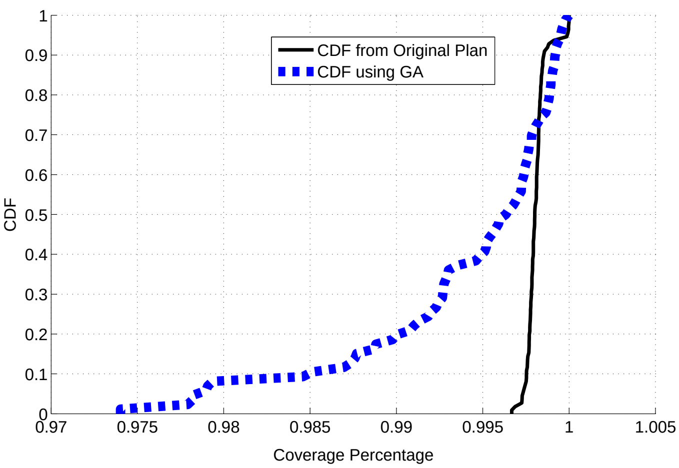

Fig. 18. CDF of Coverage

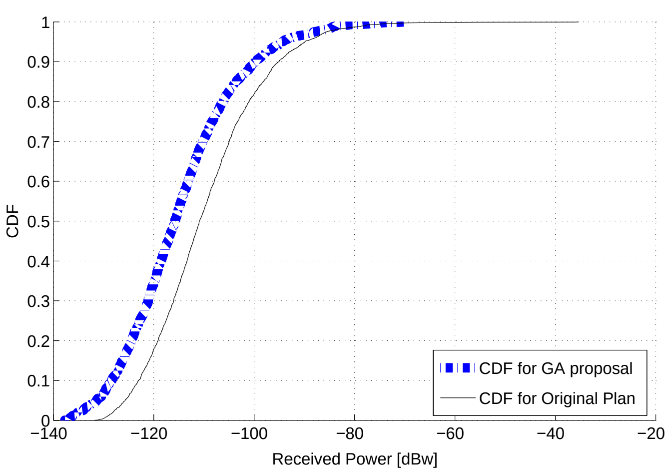

Fig. 19. CDF of RSSI

VI. Conclusion

In this paper Green network deployment is invistigated for LTE network. A Genetic Algorithm system is developed to propose the base stations configuration. The GA proposes the availability of the base stations and their locations from a list of candidate sites proposed by the operator along with the transmission power. The system selects the best network based on defined weighted objective functions. The

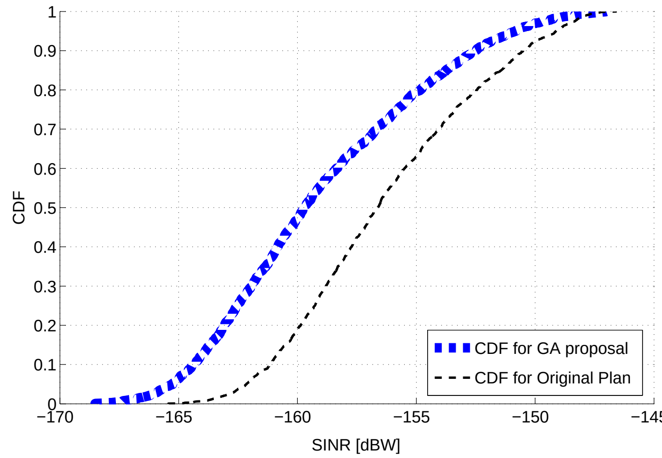

Fig. 20. CDF of SINR

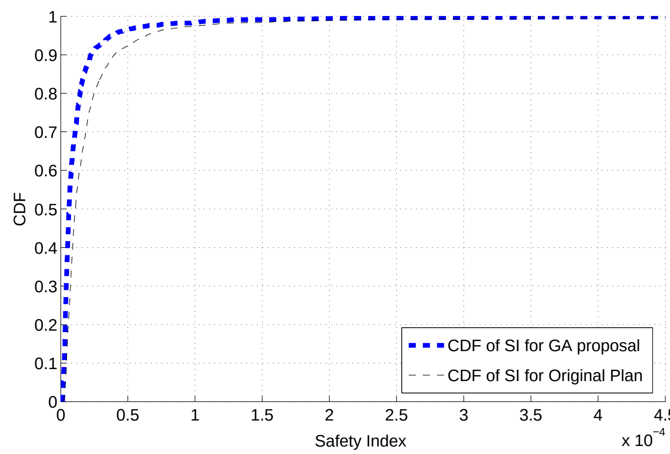

Fig. 21. CDF of SI

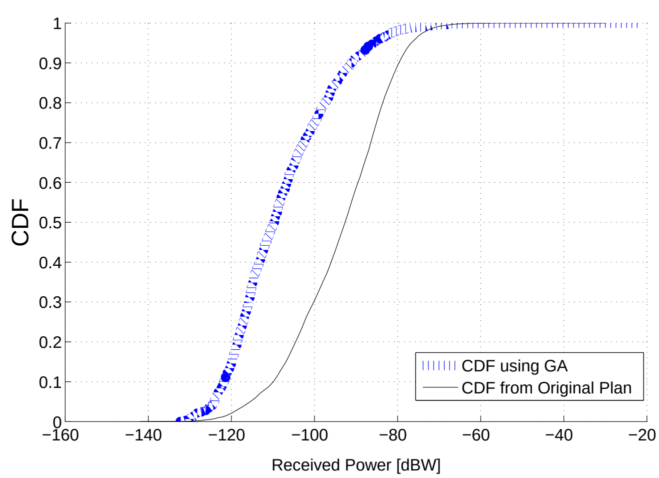

Fig. 22. CDF of Road Test

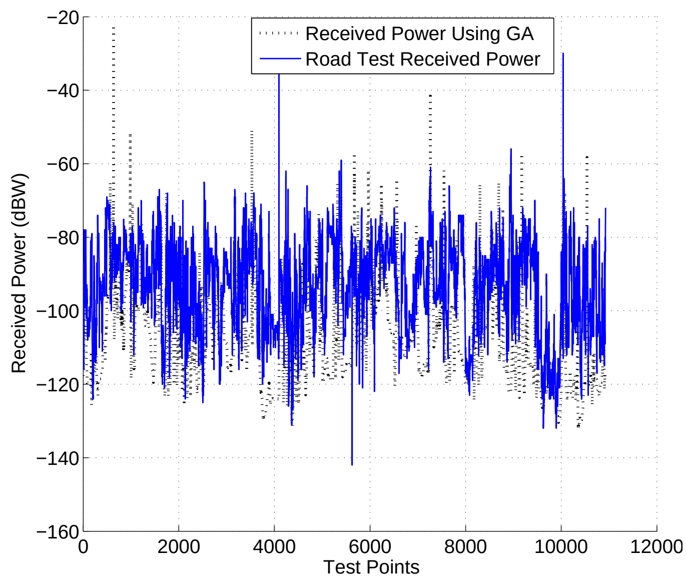

Fig. 23. Road Test

proposed network parameters are compared with the original network deployed by the operator. The results show that a reduction of up to 40% of transmission power utilised by the original operator network can be achieved in certain cases. This reduction resulted from the utilization of less than 60% of the total base stations to cover the same area and the power balance between the network base stations imposed in the system. The coverage probabilty and safety index of the proposed network are in close matching to the original network deployed. Furthermore, road test pathloss measurments for the ROI is compared with the proposed network estimated pathloss and it demonstrated the validity of the proposed network. In general, this work verified the feasibility of Green network deployment in mobile communication systems. Aside to the energy efficiency achieved, Green network concept could reduce the installation and operating costs of the network while providing a comparable QoS. Moreover, the results of this study show that compliance of operating network to the green network concept is attainable without significant modifications of the network infrastructure.

The objective functions used in this work are effective in guiding the GA to propose a balanced network with acceptable QoS measures. However, other objective functions could be utilized based on the requirements of the system.

To provide more emphasise on the users spacial distribution, frequency reuse and user density are recommended to be included in the objective function calculation in the future work.

Acknowledgment

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