# Novel Approach for Optimization of Cell Planning and Capacity

Ali Hakan IŞIK, İnan GÜLER

***Abstract***—- Configuration, Cost, base station output power are important resources in cellular mobile radio systems. The main idea of cell planning is the maximize capacity in another words number of subscribers and minimize cost at the same time. In a GSM system, where coverage areas are divided into cells in planning phase, the division method and its parameters have a great importance. This study explains GSM system and cell planning process, and gives information about the features of fuzzy logic algorithm. Fuzzy logic solves problems better than other control algorithms in which initial parameters are needed to be assigned by the designer, which have variables that aren't defined well and change with time and where system expert's knowledge and experience have great importance in design process. Cell planning has same important problems that it's variables aren't defined well, change with time. These important problems of cell planning are the cell radius, base station number and power, TRU (transceiver unit) number, N (number of cells per cluster), cost, CIR (channel interference ratio), D (distance between two cells which use same frequency at the same time) are found for urban, suburban and rural areas by using omni or three sector antennas. GSM cell planning is simulated by using fuzzy logic algorithm, a computer program is written to determine what kind of configuration changes have to be made so as to minimize the number of base station, and hence the total system cost, and also to maintain the requirements of the maximum traffic demand. In addition, input and output data can be defined through the interface which is created in C++ Builder programming language.

***Keywords*****—** Fuzzy Logic, GSM, Cell Planning, Capacity.

## I. Introduction

In this study, it is intended to optimize cost, output power, configuration of a cellular system that consists of base stations which cover three different areas (urban, suburban and rural areas) and use two types of antennas (omni or three sector antennas). In cellular systems, GSM subscribers' conversation time, their movement and environmental condition depend on parameters that aren't defined well and change with time. In order to solve this problem, fuzzy logic algorithms which control parameters that aren't defined well and change with time is chosen. Output power of base station is found for three different areas (urban, suburban and rural areas) by using Hata-Okumura propagation model. This study explains mobile telecommunication technologies and their features. Fundamental structure of GSM system and its units, operating principles, cell planning steps are examined. Cell planning is performed for the data which is obtained from a private GSM Company. Initial solution is obtained from draft cell planning process, later, in real time cell planning process, system parameters which is obtained from previous solution is tried to be optimized by using the developed software which uses fuzzy logic algorithms limits.

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## II. Mobile Communication

At the present day, important mobile telecommunication technologies are Bluetooth, Wavelength Division Multiplexing (WCDMA), Universal Mobile Telecommunications System (UMTS), General Packet Radio Service (GPRS) and GSM. Bluetooth which operates in 2.45 GHz frequency band provides high speed synchronous data communication in closed areas. WCDMA is the third generation mobile communication technology that provides voice, video and data communication up to 2 Mbit/s speed. Universal Mobile Telecommunications System is used for whole third generation technologies. These technologies provide voice, video and data communication. General packet radio service (GPRS) is packet switching technology that provides data communication from 28,8 kbit/s to 115 kbit/s over existing GSM network. GSM is second generation technology that provides voice and data by using frequency division multiplexing and time division multiplexing [1, 2, 17].

## III. GSM

First GSM 900 system which was developed in 1991 is a cellular mobile telecommunication system which is digital, performing free movement, providing voice and data communication. GSM architecture is composed of mobile station (MS), base station subsystem and Network Switching Subsystem. Mobile station consists of mobile phone and SIM card that define GSM subscriber to network. Base station subsystem consists of base station and base station controller. Radio transmitter and receiver existing in base station connects mobile station to cellular network. Base station that provides coverage area with radio frequency is located between base station and mobile station and performs channel encoding and decoding. Base station controller is located between base station and mobile switching subsystem and performs hand-over between base stations and controls base station propagation power. Main functions of mobile switching center that is located in network subsystem are management of subscriber and call, switching, routing and pricing [2, 3].

## IV. Cell Planning

Cell, the main unit of cellular system, is the area coverage with radio frequency in the form of hexagon. Division method and its parameters have a great importance so as to define this area. This process is performed with cell planning. Four matters of cell planning are cellular system, interference, cell planning process and traffic. In order to cover service area omni or three sector antennas are used in cellular system. Omni directional antenna is preferred for low subscriber capacity and wide rural area, three sector antennas is preferred for high subscriber capacity and urban area. Cell set is a number of cell in every set. Existing frequency is re-used depending on cell number in this set. D (distance between two cells which use same frequency at the same time) must be high enough so as to prevent interference and reduce hand-over, small enough so as to increase capacity and reduce cost[15]. The major aim of cell planning is to find four values compatible with each other as a part of system requirement. Environmental effects and signal having the same frequency with the carrier have fading effect and disturbance on the carrier frequency. This situation is called as "interference". There are three different kinds of interferences. These are co-channel interference, adjacent channel interference, multidirectional fading. In this study, input variables are defined in graphical interface, after that these variables are handled in draft cell planning process, so draft configuration, cost, CIR (Channel interference Ratio) are found. Using configuration, cost, CIR which is found in draft cell planning, new traffic value is optimized and base station power is found in real time cell planning. The other important issue in cell planning is traffic. Most important traffic concepts are channel, grade of service (GoS), and erlang. Channel is a circuit that performs communication. There are eight channels in a radio frequency. Quality of Service comprises requirements on all the aspects of a connection, such as service response time, loss, signal-to-noise ratio, cross-talk, echo, interrupts, frequency response, loudness levels, and so on. A subset of telephony QoS is Grade of Service (GOS) requirements, which comprises aspects of a connection relating to capacity and coverage of a network, for example guaranteed maximum blocking probability and outage probability [7]. Erlang is a basic traffic density unit. In other words, Erlang is usage of circuit per hour. After the channel and GoS is handled in Erlang B table the system traffic capacity is found [4, 5, 6].

## V. Capacity

In our study, we used GSM 900 private region values which is obtained from Telsim which new name is Vodafone Turkey. 124 frequency channels are shared between two companies in Turkey GSM 900 network. In order to solve this problem, GSM operators develop frequency reuse models in the world. These models define simultaneously using of existing frequency in different cell cluster. There are three different mostly used cell cluster model in three sector antennas. In order to cover urban areas which has high subscriber, 3/9 cell cluster model is used as shown in below.

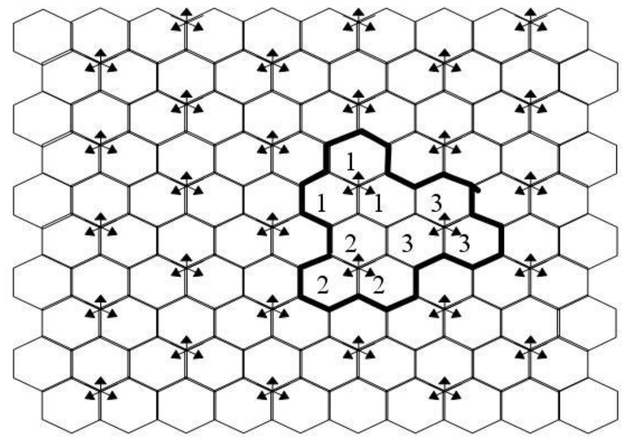



Fig. 1. 3/9 Frequency Reuse Model

For instance, if we move from 7/21 cell cluster model to 3/9 model, cost decrease, capacity and interference.

When we use same frequency at the same time, we have to pay attention to D value.

$$D = R\sqrt{3N} \quad (1)$$

D is distance between two cells which use same frequency at the same time, R is cell radius, N is cell cluster value.

Frequency Reuse Distance must be big enough in order to prevent interference, big enough in order to decrease hand-over, small enough in order to increase capacity, small enough in order to decrease cost. These are limitations of system design[18].

If D value is increased, the possibility of common channel interference will reduce. It is desired to have high N value so as to decrease interference and low N value so as to meet increasing traffic requirement. Calculation of D value is shown in below.

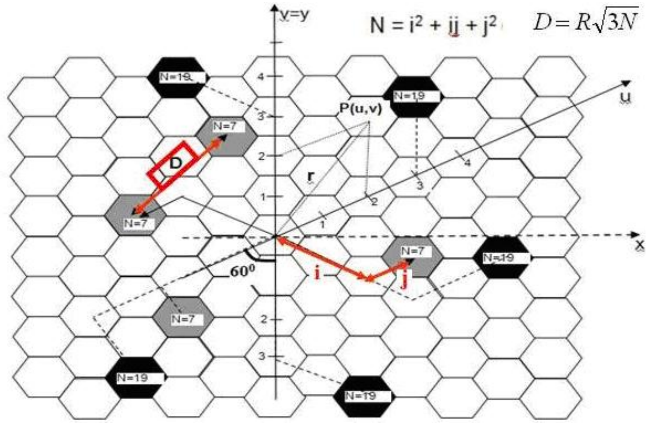


Fig. 2. Calculation of D value

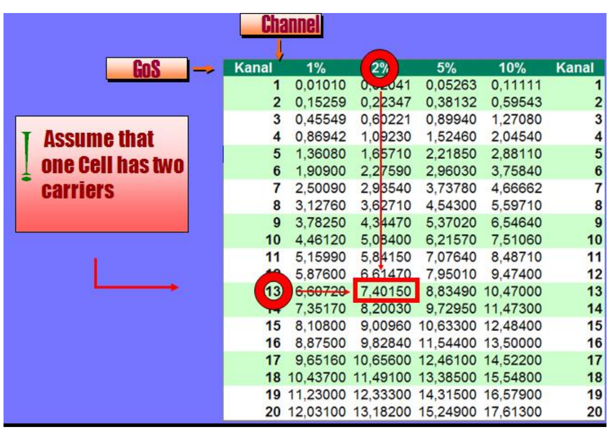
For covering related areas, we have also pay attention to CIR(Channel interference Ratio) value. It is obtained for omni and three sector antennas with two different formulas. For omni directional antennas (2) formula is used.

$$\frac{C}{I} = \frac{1}{2(q-1)^{-4} + 2(q)^{-4} + 2(q+1)^{-4}} \qquad (2)$$

For instance if N=7 $q = \sqrt{3N} = \sqrt{3x7} = \sqrt{21} = 4{,}6$ is obtained.

For this value CIR is found as 17 db. This value is lower then 18 db and there is not any communication problem with this value. In developed software N is defined in GUI, calculated for two types of antennas with different formulas and controlled with while loop.

Capacity is found with Erlang B table as shown below.




| Kanal | 1% | 2% | 5% | 10% | Kanal |
|---|---|---|---|---|---|
| 1 | 0,01010 | 0,[illegible]041 | 0,05263 | 0,11111 | 1 |
| 2 | 0,15259 | 0,22347 | 0,38132 | 0,59543 | 2 |
| 3 | 0,45549 | 0,60221 | 0,89940 | 1,27080 | 3 |
| 4 | 0,86942 | 1,09230 | 1,52460 | 2,04540 | 4 |
| 5 | 1,36080 | 1,65710 | 2,21850 | 2,88110 | 5 |
| 6 | 1,90900 | 2,27590 | 2,96030 | 3,75840 | 6 |
| 7 | 2,50090 | 2,93540 | 3,73780 | 4,66662 | 7 |
| 8 | 3,12760 | 3,62710 | 4,54300 | 5,59710 | 8 |
| 9 | 3,78250 | 4,34470 | 5,37020 | 6,54640 | 9 |
| 10 | 4,46120 | 5,08400 | 6,21570 | 7,51060 | 10 |
| 11 | 5,15990 | 5,84150 | 7,07640 | 8,48710 | 11 |
| [illegible] | 5,87600 | 6,61470 | 7,95010 | 9,47400 | 12 |
| 13 | 6,60720 | 7,40150 | 8,83490 | 10,47000 | 13 |
| [illegible] | 7,35170 | 8,20030 | 9,72950 | 11,47300 | 14 |
| 15 | 8,10800 | 9,00960 | 10,63300 | 12,48400 | 15 |
| 16 | 8,87500 | 9,82840 | 11,54400 | 13,50000 | 16 |
| 17 | 9,65160 | 10,65600 | 12,46100 | 14,52200 | 17 |
| 18 | 10,43700 | 11,49100 | 13,38500 | 15,54800 | 18 |
| 19 | 11,23000 | 12,33300 | 14,31500 | 16,57900 | 19 |
| 20 | 12,03100 | 13,18200 | 15,24900 | 17,61300 | 20 |

Fig. 3. Erlang B Table

In figure 3., we assume that we have two carrier frequencies in another word thirteen channel, 0.002 GoS value. Three channels is used for synchronization and control, 0.002 GoS value is acceptable for healthy communication. These parameters are evaluated in Erlang B table and 7.40150 Erlang is found.

Likewise, by using Erlang B table cell planning process is performed. Firstly approximate subscribers and its' traffic values are estimated then required number of channel in found. Under a lot of limitations such as CIR, GoS etc., available frequency are reused and capacity requirement is tried to meet.

Capacity is directly proportional to TRU and grade of service (GoS), inversely proportional to number of cell in each cluster. As previously stated, CIR is related with D value. If the number of subscriber is continuously increasing, we need to increase the capacity of our system. In order to achieve this problem, we have a lot of options. Some of these are;

- To increase the number of TRU
- To increase the value of GoS
- To enlarge Frequency band(changing from GSM 900 to GSM 1800)
- To narrow the field of frequencies re-use distance(By using frequency hopping, changing frequency re use model for instance from 4/12 to 3/9 )

Limitations of capacity are;

- Maximum number of TRU in a base station
- CIR value
- GoS must be lower than 0.002

## VI. Fuzzy Logic Algorithm

Fuzzy logic is firmly fixed on mathematical representation of human thinking system so as to deal with uncertainty. Particularly, fuzzy logic is used for non-linear, multivariate, uncertain systems that could not be easily modeled [4]. Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. Just as in fuzzy set theory the set membership values can range (inclusively) between 0 and 1. In fuzzy logic the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values {true, false} as in classic predicate logic [8]. While variables in mathematics usually take numerical values, in fuzzy logic applications, the non-numeric linguistic variables are often used to facilitate the expression of rules and facts.[9]

In this study, input variables of fuzzy logic are traffic error and traffic error variation per user. Output variable is cell radius. Triangle membership functions are defined for input error, input error variation and output. Membership degree, in other words output variable degree is changed depending on this triangle's width and numbers. Seven membership functions, in other words fuzzy sets are defined for output. Membership degree is found with the evaluation of input variables in membership functions. Membership degree is found with the formula given below:

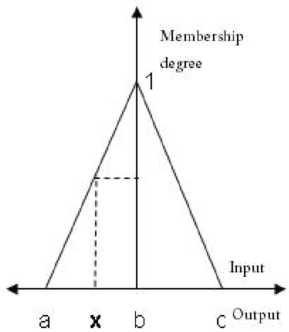



Fig. 4. Membership degree

$$\text{Membership degree} = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right) \quad (3)$$

Firstly fuzzy inference method (fuzzification) is defined in second stage of fuzzy logic. There are four different important fuzzy inference methods. These are max-dot, min-max, tsukomato and takagi sugena. In this study, min-max fuzzy inference method is used. As shown below, 6 Rule Tables has been defined for 3 Different Areas and 2 Different Antennas.

| $x_1 \backslash x_2$ | P | S | N |
|---|---|---|---|
| P | PK | S | PB |
| S | PK | PB | PB |
| N | N | PK | S |

Fig. 5. Rule table used for fuzzy inference

In min-max method, an example fuzzy inference is performed as follows: IF (x1 = P) and (x2 = S) THEREFORE (u = S) *min(1, 0.482) = 0.482 *(S). Digital value is obtained from defuzzification. There are four different defuzzification methods. These are maximum membership method, average weight method, center of gravity method and mean-max method. In this study, average weight method is used. In this method, membership values are multiplied with central value of fuzzy sets which is obtained from rule table, after that results are summed and at the end results are divided into the summation of membership degrees.

$$z^x = \frac{\sum \mu_c(z).z}{\sum \mu_c(z)} \quad (4)$$

Here, z is called as the center value of triangle, $\mu_c$ is called as the membership degree [7, 8, 9].

## VII. Base Station Power

Transmitter power is an important resource in cellular mobile radio systems. Effective power control can increase system capacity and quality of service. A commonly used measure of the quality of service is the carrier to Interference Ratio (CIR) at the receiver. The main idea on power control schemes is to maximize the minimum CIR in each channel of system.

The power control is being used in the most existing cellular systems. In addition to increment the life of terminal batteries, the power control prevents the base station's receiver to be blocked when it receives an over amount of power. In general, there are two algorithms to control the power. First, the algorithms are based on this rule that increasing the path gain will cause the power to be decreased. In the simplest and most used kind of these algorithms, the intensity of the receiving signal is remained constant, and to reach the goal path gain should be compensated completely. In another kind of this structure, only some changes of path gain will be remunerated. Both structures will cause a slight increase in the capacity. The second kind of algorithms that we used will be designed on the quality of connection which the main factor of it is the Carrier to Interference Ratio (CIR) [14, 16].

In this study, output power of base station is found for three different areas (urban, suburban and rural areas) by using Hata-Okumura propagation model. Input values of Hata-Okumura propagation model are operating frequency, base station height, mobile station height, cell radius [10, 11, 12, 13]. Output value is base station propagation power for different areas. Different formulas which are used for output power of base station are shown below.

For urban areas:

$$P_{tu} = P_{r\min} + L_o + L_u - G_t - G_r \quad (5)$$

For suburban areas:

$$P_{tsu} = P_{r\min} + L_o + L_{su} - G_t - G_r \quad (6)$$

For rural areas:

$$P_r = P_{r\min} + L_o + L_r - G_t - G_r \quad (7)$$

Parameters of these formulas;

$P_{r\min}$ =Minimum receiver sensitivity

$G_t$, $G_r$ =Transmitter and receiver antenna gain

$L_u$, $L_{su}$, $L_r$ =Loss for urban, suburban, rural areas respectively

$L_o$ = Additional Loss

$f_c$ = Operating Frequency (900 Mhz)

$$L_u = 69{,}55 + 26{,}16 \log f_c - 13{,}82 \log h_b - a(h_m) + (44{,}9 - 6{,}55 \log h_b) \log R \quad (8)$$

$$a(h_m) = 3{,}2(\log 11{,}75\, h_m)^2 - 4{,}97 \quad (9)$$

$$L_{su} = L_u - 2\left[\log \frac{f_c}{28}\right]^2 - 5{,}4 \quad (10)$$

$$L_r = L_u - 4{,}78(\log f_c)^2 + 18{,}33 \log f_c - 40{,}94 \quad (11)$$

## VIII. Developed Software

Firstly, initial values are defined with GUI(Graphical user interface) in developed software. After that, in order to provide healthy communication CIR is controlled with while loop. If CIR is greater then 18 db cell cluster number is redefined. Then draft cell planning is performed and configuration (Number of BTS and TRU), Cost, CIR are found. With new traffic value real time cell planning is started. In this process, fuzzy logic algorithm is used for optimization of base station radius. Configuration, cost and base station output power depend on this value. Up to four times, base station radius is recalculated if real time cost is higher then draft cost.

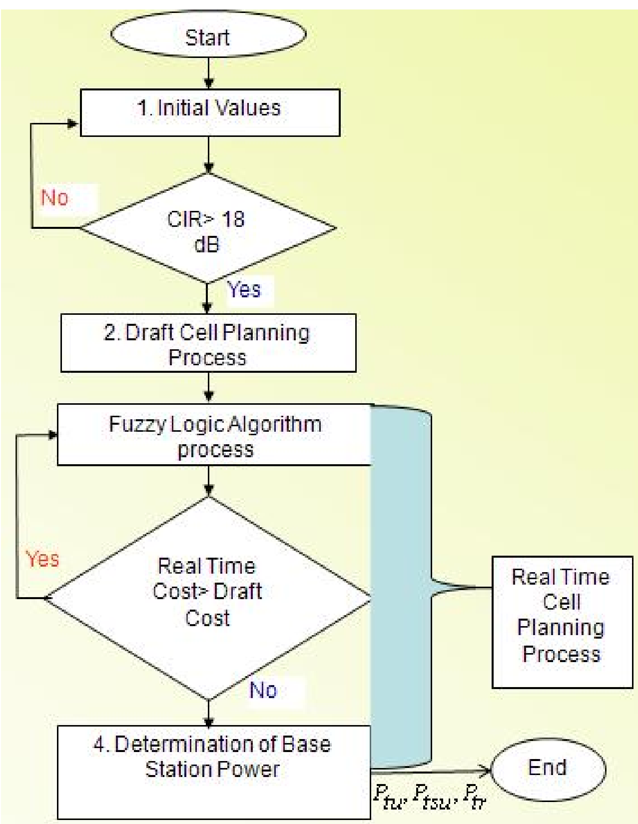



Fig 6. Flowchart of Developed Software

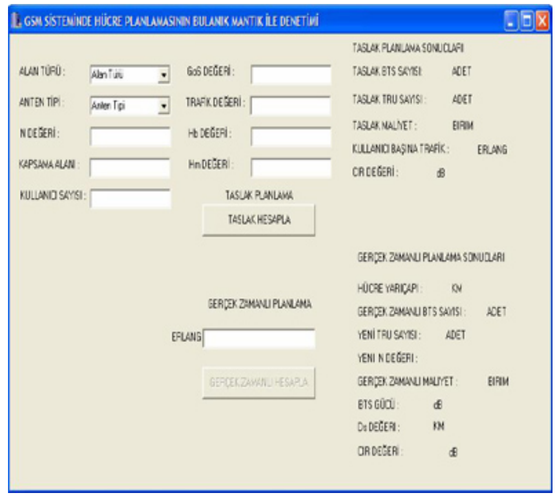



Fig. 7. Developed software GUI

## IX. Discussion

There isn't any way except trial and error method to find fuzzy logic parameters, so it takes too much time to find solution for this issue. This feature extends the time for solution. If desired, scaling factor, number and type of membership functions, rule table will be changed so as to obtain more effective results. This provides flexible and effective results with respect to other control algorithms.

## X. Results

The In this study, controlling of cell planning with fuzzy logic in a GSM system is searched. Our problem is the optimization of base station number in other words cost, system configuration that meets system traffic requirement, base station propagation power. Fuzzy logic algorithms control system better than the other algorithms in which initial parameters are needed to be assigned by the designer, which have variables that aren't defined well and change with time. Likewise in cell planning, total traffic isn't defined well and changes with time and so on. Similar features between two systems provide easiness in solution. In fuzzy logic algorithms, initial values are needed to be assigned by the designer and system expert's knowledge and experience in design process have great importance. The provided degree of control depends on initial values. Similarly in cell planning, initial traffic value, N (number of cells per cluster), subscriber number etc. are defined by system experts. Depending on these values, desired solution is tried to be obtained. In this study, it is observed that similar features of fuzzy logic algorithm and cell planning provide effective results. Practical traffic values, base station number that depend on other variables, cost are tried to be optimized, increasing traffic requirement is tried to be met, base station propagation power is tried to be obtained. Results indicate that system traffic requirement together with minimum cost is approximately achieved.

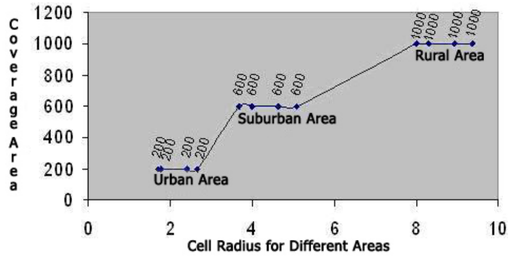



Fig. 8: Cell Radius for different areas

As shown in Fig. 8, cell radius and coverage area are small in urban areas that have high capacity requirement and frequent reusing of existing frequency; in rural areas these values are higher.

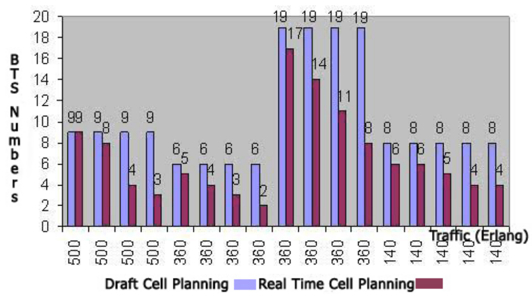



Fig. 9. Changing of base station number

As shown in Fig. 9, compared to draft cell planning, base station number is decreased in real time cell planning.

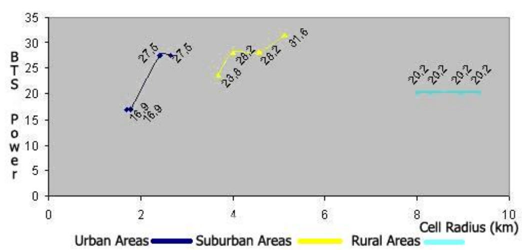



Fig. 10. Changing of base station propagation power

As shown in Fig. 10, cell radius is low and base station propagation power is high in urban areas; however cell radius is high and base station propagation power is low in rural areas.

As shown in Fig. 11, total system cost is reduced in real time planning using fuzzy logic algorithm contents

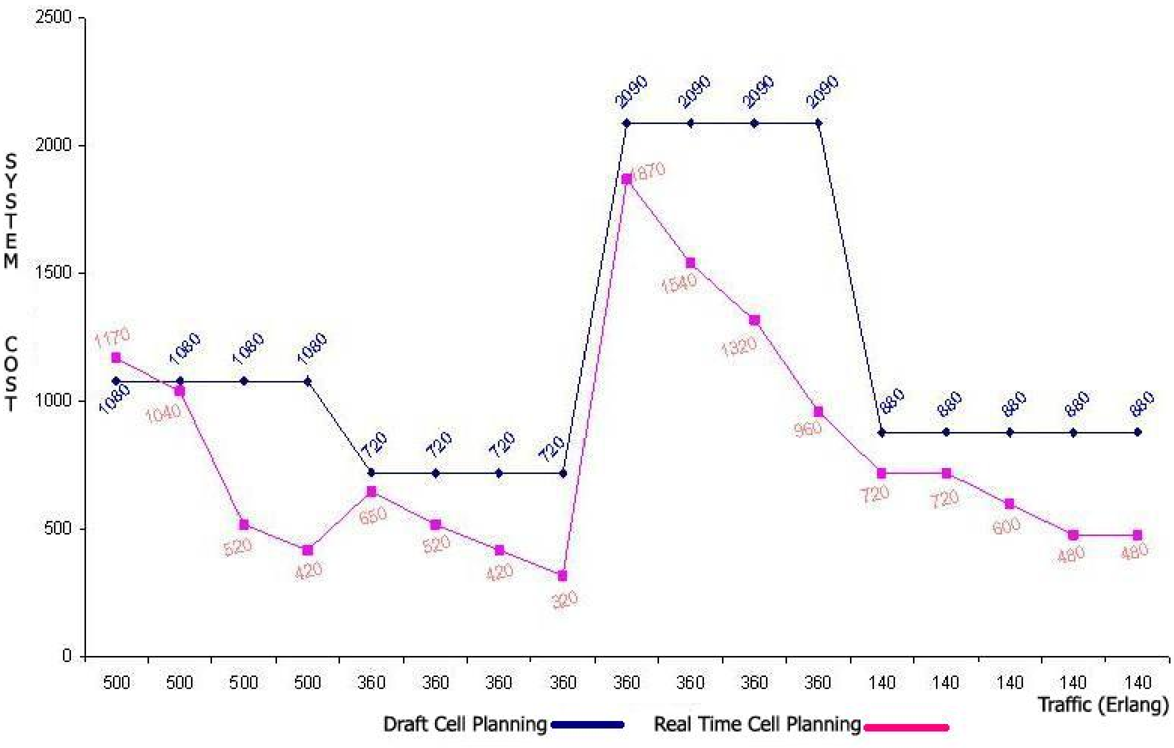



Fig. 11. System Cost

## I. Conclusion

GSM and fuzzy logic algorithm same features are starting reasons for this study. These are undefined and changing variables, initial parameters assignment and system expert's knowledge. By using these similarity, configuration, cost, and base station output are tried to optimize.

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