eNodeB Position Forecasting of LTE Based On BTS Existing Using *Fuzzy C-Means* and *Harmony Search* Methods

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***Abstract*— Fourth generation technology that is 4G LTE (Long Term Evolution) on mobile network has been developed in Indonesia. These developments force telecommunication service providers to upgrade existing infrastructure to the latest technology. The service upgrade process to the latest generation in this 4G LTE service utilizes existing base stations as BTS with the latest technology called eNodeB. In fact, not all existing BTS will be upgraded to eNodeB in the time span until 2020 with consideration of the traffic conditions of 4G LTE users and the resulting coverage. Therefore, a plan is required with a method that can provide solutions in optimizing the utilization of existing base stations as new eNodeB 4G LTE in the city of Denpasar. This research has proposed Fuzzy C-Means method to get eNodeB cluster center point for clustering process followed by optimization process using Harmony Search method. This study uses several variables for the optimization process, including: Denpasar city traffic, number of eNodeB needs in 2020, and coverage of each existing BTS. The result of the planning simulation shows that the optimal existing base station is used as the 123 BTS eNodeB site of 211 BTS, and there are 41 new potential eNodeB points considered optimal with total path loss value of 136085,8338 dB.**

***Keywords*— Fuzzy C-Means; Harmony Search; Path Loss, Optimasi, LTE Introduction**

I. INTRODUCTION

The number of internet users in Indonesia is growing very rapidly. This is shown by the survey results from MarkPlus Insight Netizen Survey which shows that the number of internet users in Indonesia has reached 61 million people in 2012. That number makes the percentage of internet users compared to the population is 23.5%. Of these, 40% of them access the internet more than 3 hours a day. Research from Boston Consulting Group assesses the number of internet users in Indonesia will continue to increase to three-fold by 2015 compared to 2010 [1].

Based on this, one of the cities in Bali, Indonesia is developing the fourth generation technology that is 4G LTE. Denpasar is the administrative center of Bali, Indonesia with the highest population density compared to other districts [2]. With these conditions, Denpasar became the center of infrastructure development, especially telecommunications. The development of this infrastructure is expected to provide good communication services in Denpasar.

LTE is a communications technology standard developed by 3GPP (3rd Generation Partnership Project), which serves to solve the increasing demand for communication services with the speed of data and the broader spectrum. LTE is a mobile technology that capable of supporting data, voice and video applications. LTE have 100 Mbps of Transfer data rate on downlink and 50 Mbps on uplink. Coverage of LTE provides greater capacity to reduce operational costs and use multiple antennas [3].

Several methods have been done to optimize the placement of telecommunication towers or Base Tranceiver Station (BTS), such as by using analytical coverage method and Quality Of Service (QOS)[4]-[7]. In addition to these methods there is an optimization method by using data mining to determine the optimal point of the BTS[8]-[11]. Data mining methods can provide solutions based on forecasting results in accordance with the reality conditions.

This research is focused on the application of Fuzzy C-Means and Harmony Search method to determine the optimal position of eNodeB point. Fuzzy C-Means (FCM) is chosen as a clustering method because this method can provide smooth and effective results to increase the homogeneity of each cluster[12]. Harmony Search algorithm is chosen as an optimization method because this algorithm has advantages that is pitch adjustment that can make process improvement on solution which is local optimally and structure of HS algorithm is relatively easy[13]. The objective of this research will be to produce an optimal mapping of eNodeB in Denpasar. The simulation results using fuzzy c-means clusterization followed by the optimization process of harmony search able to produce an optimal planning based on minimum total pathloss value.

This paper is organized as follows: The Cell Planning Scheme is shown in chapter II, The explanation of the optimization method shown in chapter III, Optimization Results is shown in IV and the last conclusion is shown in chapter V.

II. CELL PLANNING SCHEME

In cell planning of eNodeB, this research using link budget calculation model and cell capacity calculation. The propagation model used to determine the link budget is the Walfisch-Ikegami Propagation Model. The Walfisch-Ikegami model is an empirical model of propagation for urban areas that can be used for both macrocell and microcell [14]. Figure 1 shows the BTS exciting coverage in Denpasar.

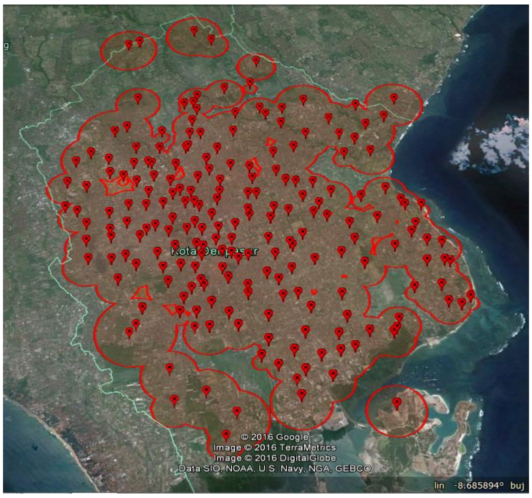

Fig 1. BTS Eksisting Coverage

To calculate cell capacity, several steps were performed: cellular user analysis, traffic analysis of each customer, and eNodeB requirement analysis until 2020. Table 1 shows eNodeB needs of each sub-district in Denpasar.

TABLE 1. ENODEB NEEDS OF EACH SUB-DISTRICT IN DENPASAR

Territory	Needs eNodeB	BTS Existing	Added eNodeB
South Denpasar	110	85	25
East Denpasar	57	55	2
West Denpasar	99	34	65
North Denpasar	74	37	37

III. OPTIMIZATION METHOD

The Optimization process is used to find the optimal solution of the LTE 4G eNodeB planning that has been calculated in the previous chapter. This research uses 2 methods for optimization process that is Fuzzy C-Means and Harmony Search.

A. Fuzzy C-Means (FCM)

Fuzzy C-Means is a data clustering technique in which the presence of each data point in a cluster is determined by the degree of membership.

The basic concept of FCM, first is to determine the cluster center, which will mark the average location for each cluster. In the initial conditions, the cluster center is still not accurate. Each data point has a membership level for each cluster. By repairing the cluster center and the degree of membership of each data point repeatedly, it will be seen that the center of the cluster will move towards the right location. This loop is based on the minimization of objective function that describes the distance from the data points assigned to the center of the cluster which is weighted by the degree of membership of the data point.

The algorithm of fuzzy c-means is as follows [15]:

1. Input data to be grouped, ie X is a matrix of size $n \, x \, m$ (n = number of data samples, m = attribute of each data). X_{ij} sample data to-i (i=1,2,….,n), the attributes to - j (j=1,2,…, m).
2. Determine the number of clusters (c), ranks for the partition matrix (w), maximum iteration ($MaxIter$), least expected error (ξ), initial objective function ($P_o = 0$), and initial iteration ($t = 1$).
3. Generate random numbers μ_{ik}, i=1,2,…,n; k=1,2,…,c as elements of the initial partition matrix U.
4. Calculate the center of the $k - cluster$: V_{kj}, with k=1,2,…,c; and j=1,2,…,m, using equation 1 :

$$V_{kj} = \frac{\sum_{i=1}^{n} ((\mu_{ik})^w . X_{ij}}{\sum_{i=1}^{n} (\mu_{ik})^w} \qquad (1)$$

with :

V_{kj} = center of k-cluster for j-attribute

μ_{ik} = degree of membership for the i sample data in the k-cluster

X_{ij} = i data, j attribute

5. Compute the objective function on the t iteration using the equation (2):

$$P_t = \sum_{i=1}^{n} \sum_{k=1}^{c} \left(\left[\sum_{j=1}^{m} \left(X_{ij} - V_{kj} \right)^2 \right] \left(\mu_{ik} \right)^w \right) \qquad (2)$$

with:

V_{kj} = center of k-cluster for j-attribute

μ_{ik} = degree of membership for the i sample data in the k-cluster

X_{ij} = i data, j attribute

P_t = objective function on the t iteration

Calculate the partition matrix change using the equation (3):

$$\mu_{ik} = \frac{\left[\sum_{j=1}^{m}\left(X_{ij} - V_{kj}\right)^2\right]^{\frac{1}{w-1}}}{\sum_{k=1}^{c}\left[\sum_{j=1}^{m}\left(X_{ij} - V_{kj}\right)^2\right]^{\frac{1}{w-1}}} \quad (3)$$

with i=1,2,…,n; and k=1,2,…,c

where :

V_{kj} = center of k-cluster for j-attribute

X_{ij} = i data, j attribute

μ_{ik} = degree of membership for the i sample data in the k-cluster

6. Check stop condition::

If : $\left(\left|P_t - P_{t-1}\right| < \xi\right)$ or $\left(t > MaxIter\right)$ then stop. Jika not :$t = t + 1$, repeat step 4.

B. Harmony Search

In the adjustment there are three choices, namely the famous musical harmony based on their memories, playing harmony of music similar to the famous musical harmony but there is little adjustment, or create a new musical harmony. Geem formulates these three options in a quantitative optimization process. The three components are formulated into the use of harmony memory, tone adjustment, and random generation process .[13].

The use of harmony memory is important because the harmony memory can guarantee that good harmony will be considered as elements of the new solution vector. In order for harmony memory to be used effectively, the HS algorithm adopts a parameter called Harmony Memory Considering Rate (HMCR). If the rate is too low, only a few elite harmonies are selected and can cause the convergence process to be too slow also. If the rate is too large, it will cause many harmony memory tones to be used and not have time to explore other tones, which in the end will be difficult to achieve a good solution. Therefore, it is usually used HMCR = 0.7 ~ 0.95.

The second component is tone adjustment which has several parameters such as bandwidth (bw) and Pitch Adjusting Rate (PAR). The music tone adjustment means changing the tone frequency, it means generating slightly different values on the HS algorithm. Equation (4) is a tone adjustment formulation:

$$X_{new} = X_{old} + bw \times \varepsilon \quad (4)$$

Where X_{new} = new tone after tone adjustment

X_{old} = tone stored in harmony memory

bw = *bandwidth*

ε = random number with interval [-1,1]

A low-value PAR with narrow bandwidth can cause slow convergence due to limited exploration in large search spaces. On the other hand, high PAR with wide bandwidth can lead to over-spread solutions of potential optimal solutions. Therefore, it is usually used PAR = 0.1 ~ 0.5. The following are the steps of the HS algorithm:

1. Initialize problem and parameter algorithm.
2. Initialize harmony memory.
3. Generating new vector solutions.
4. Update harmony memory.
5. Check the criteria for dismissal.

The first step of the HS algorithm is the initialization of the problem and the parameters of the algorithm. Here is an example of an optimization problem:

$$\min f(x_i)$$
$$subject\ to\ x_i \in X_i$$
$$i = 1, 2, ..., N; L_i \le X_i \le U_i$$

Where, $f(x_i)$ = the purpose function

x_i = the decision variable i

X_i = interval of decision variable i

N = the number of decision

L_i = the lower limit of the decision variable i

U_i = the upper limit of the decision variable i

Then the HS algorithm parameters consist of Harmony Memory Size (HMS), HMCR, PAR, bandwidth, and termination criteria.

The second step of the HS algorithm is the initialization of harmony memory. At this stage a random harmony memory matrix is generated which contains the vector solutions as much as HMS. Here is an example matrix of harmony memory:

$$\begin{bmatrix} X_1^1 & X_2^1 & \dots & X_{N-1}^1 & X_N^1 \\ X_1^2 & X_2^2 & \dots & X_{N-1}^2 & X_N^2 \\ \dots & \dots & \dots & \dots & \dots \\ X_1^{HMS-1} & X_2^{HMS-1} & \dots & X_{N-1}^{HMS-1} & X_N^{HMS-1} \\ X_1^{HMS} & X_2^{HMS} & \dots & X_{N-1}^{HMS} & X_N^{HMS} \end{bmatrix}$$

The third step of the HS algorithm is to generate the new solution vector (x_i'). The generation of new vector solutions is based on three rules such as the use of harmony memory, tone adjustment, and random generation process. In the first rule, the new solution vector is taken from the harmony memory when the value of the random number generated for the first time under HMCR and the random number generated for the second time above PAR. The value of the first decision variable in the new solution vector (x_i') is taken from the harmony memory by selecting one value at the interval ($x_1^1 \sim x_1^{HMS}$). The values of other decision variables ($x_2', x_3', \dots, x_N'$) are determined in the same way. In the second rule, the generation of new solution vectors is done through a tone adjustment process. If the value of the random number generated for the first time under HMCR and the random number generated for the second time under PAR, a tone adjustment process will be made. Equation (5) is the tone adjust formula:

$$x_i^{'} = x_i + bw \times \varepsilon \quad (5)$$

where $x_i{'}$ = new tone after adjusting the tone
x_i= the tones that stored in harmony memory
bw = *bandwidth*
ε = random numbers with interval [-1,1]

In the third rule, the new solution vector is generated randomly with possible interval values ($x_i^{'} \epsilon X_i$). It happens when the value of the random number generated for the first time over HMCR. In the third rule there is no generation of random numbers for the second time because the value of random numbers generated for the first time over HMCR.
The fourth step of the HS algorithm is to update harmony memory.

If the value of the new solution vector is better than the vector value of the ugliest solution in the harmony memory seen from the point of view of the value of the objective function, the new solution vector will be inserted into the harmony memory and the badest solution vector in harmony memory will be issued. If the value of the new solution vector is worse than the worst solution vector value in harmony memory, there will be no change in harmony memory.

The fifth step of the HS algorithm is to check the termination criteria. If the termination criterion has been reached then iteration is stopped, if not reached then back to step three. There are several types of dismissal criteria such as maximum number of iterations, no change of solution after several iterations, and others.

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IV. Optimization Result

Fig 3 shows eNodeB identification process from start to optimization process. Where before performing the optimization process calculation of the number of eNodeB needs and calculate the existing BTS coverage.

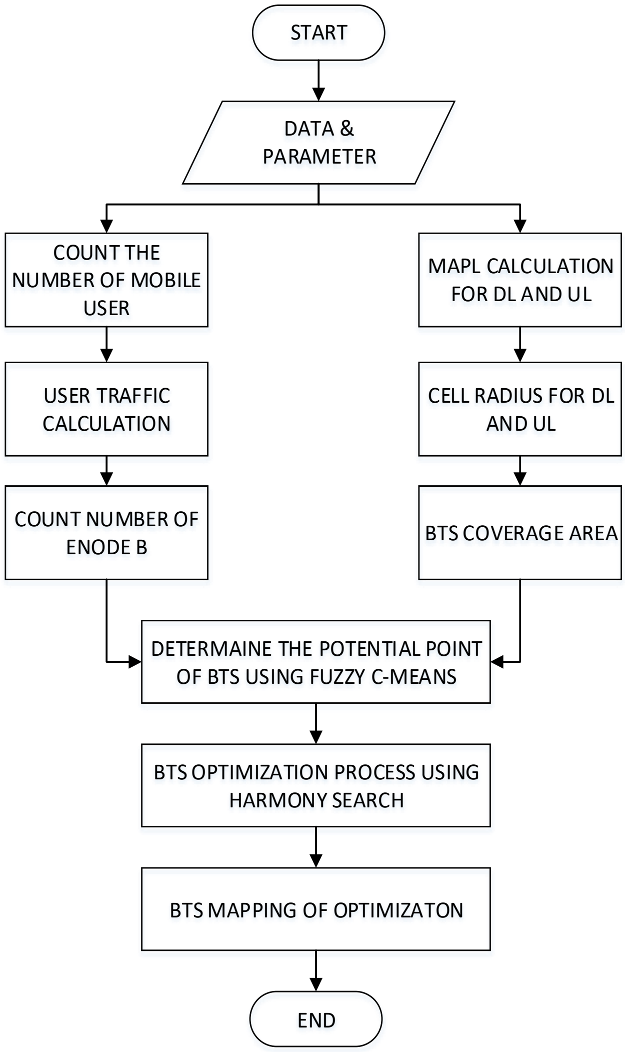

Fig 2. The flow of the eNodeB planning proccess

A. *New eNodeB Potential Point Analysis Using Fuzzy C-Means*

This study uses Fuzzy Substractive Clustering to determine how many clusters are. Determination of the number of clusters is determined based on 3 variables that is the population of each sub-district, the area of each sub-district, and the number of needs eNodeB for 5 (five) years ahead.

TABLE 2. Variable of fuzzy Substractive Clustering

Territory	**Population Predictions (person)**	**Large of area (km^2)**	**Addition of BTS**
Denpasar Selatan	200.390	49,99	21
Denpasar Timur	107.450	22,31	2
Denpasar Barat	182.160	24,06	65
Denpasar Utara	137.000	31,22	37

The parameters used in the Fuzzy Substractive Clustering process are:

- *Influence range* (r) = 0.3;
- *Accept ratio* = 0.5;
- *Reject ratio* = 0.15;
- *Squash factor* (q) = 1.25;

Enter the value of the normalized variable with the .dat file format into matlab. Figure 3 shows the results of Fuzzy Substractive Clustering.

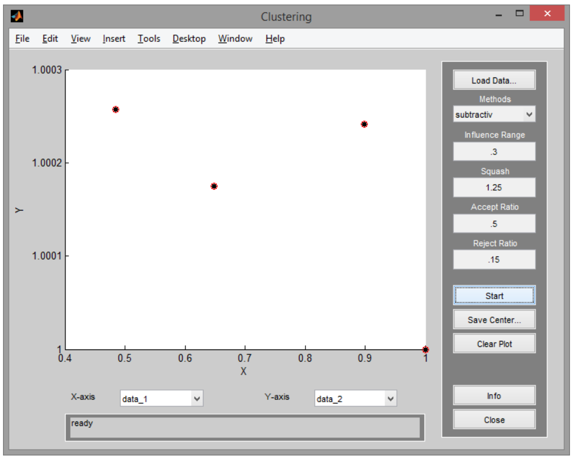

Fig 3. The Results Fuzzy Substractive Clustering

Figure 3 shows the number of clusters totaling 4. So for the next process is to enter the value of the cluster into Fuzzy C-Means parameters. The following parameters are used in the Fuzzy C-Means process:

```
k        = 4;
w        = 2;
iterasi  = 100;
t        = 0.000001;
info     = 2;
```

The input data used in the Fuzzy C-Means process is the coordinate point of the Existing BTS of each sub-district. Figure 4 shows Fuzzy C-Means process for South Denpasar subdistrict.

The black point image is the existing base of South Denpasar BTS of 85 BTS and 4 red dots representing the cluster's center point which is considered the eNodeB potential point. The coordinates of the cluster's central point for the subdistrict of South Denpasar are as follows:

1632565,2027	9022354,3801
1629216,2372	9022297,1457
1629160,8201	9025124,6109
1633807,8499	9024857,2622

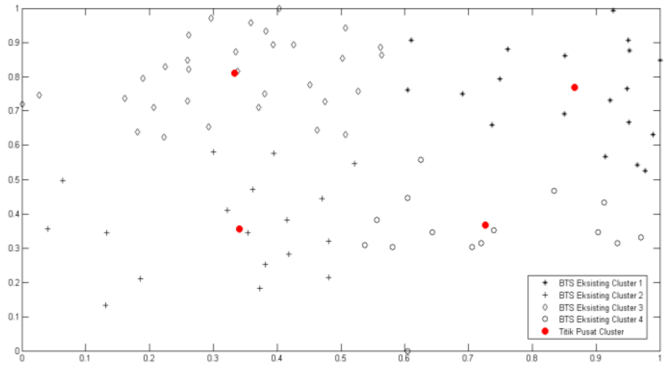

Fig 4. Clustering Result of South Denpasar

Based on the results of Fuzzy C-Means, we get 16 eNodeB potential points. Figure 5 shows the mapping of the eNodeB potential point with the existing tower in the city of Denpasar.

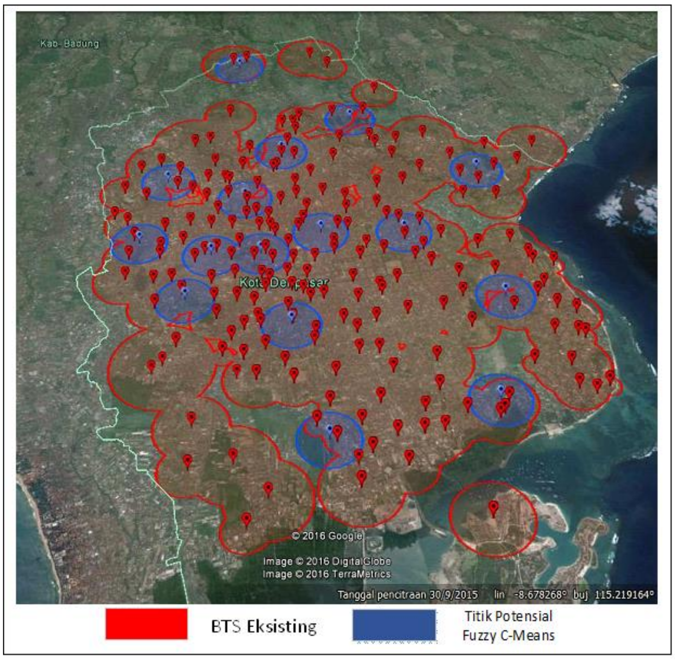

Fig 5. Mapping of Potential Points with Existing Tower

Figure 5 shows there are still areas that have not been covered by BTS coverage. This is because the variables used in the Fuzzy C Means process are only 3 variables, such as population number 2020, total area, and number of eNodeB additions for the next 5 years that have been normalized.

To be able to cover all areas that have not covered the existing BTS, then in this research determination of potential eNodeB points is done randomly with high specification and coverage is taken based on the height and average coverage of existing base stations.

Figure 6 shows the results of the existing BTS mapping and eNodeB potential points based on Fuzzy C-Means process results and random point determination. Red is the 211 point Existing BTS points, the blue color represents the new eNodeB points obtained from the Fuzzy C-Means process, which is 16 points, and the yellow is the new eNodeB point obtained from the random point determination.

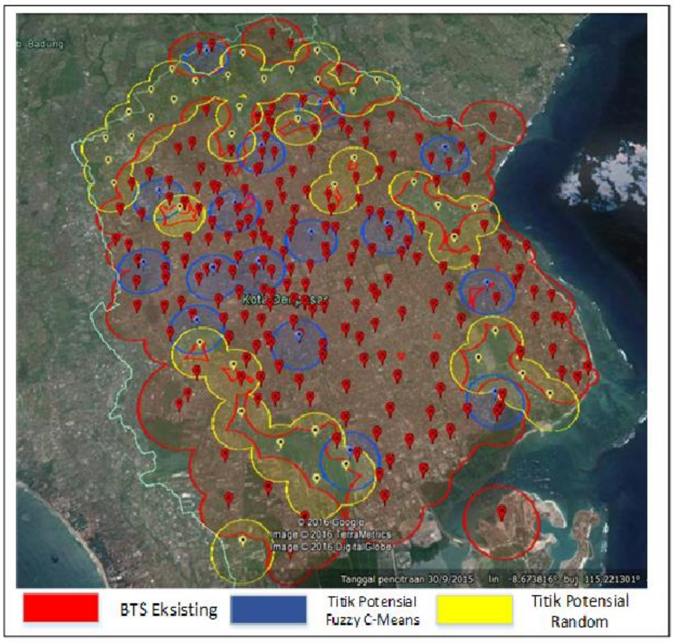

Fig 6. Potential Point Mapping, Existing Tower, and Random Potntial Points

B. *BTS Optimization Process using Harmony Search*

After knowing the potential point for the addition of new eNodeB, then next is to do the optimization process by using Harmony Search method. The first iteration process is to generate the value of Harmony Memory at random. HM contains temporary solutions that we generate. In this case, HM measures 211, then calculate the value of its objective function. The optimal solution is obtained from minim path loss function. To determine the point value of path loss function at potential point *h* (height of tower) and *r* (radius) is determined randomly. The values of h and r are generated by: $tL + rand\,(tU - tL)$ and $rL + rand\,(rU - rL)$.

In this study in determining the smallest path loss value of harmony search process is done with 2 stages. The stages are as follows:

- First is to search for the smallest path loss value value from 200 times iteration which is tested 5 times.
- Second is the iteration process where for the stoping criteria value based on the smallest path loss path value from the first stage. Thus, the optimal point of BTS is obtained based on the least path loss value.

This experiment was conducted a number of 5 experiments, so that will be selected the least path loss value. Table 4 shows the result of iteration with the smallest path loss value.

Based on table 4, the result of optimization resulted in total path loss value of 136085,8338 dB. The Harmony Search process produces 123 existing BTS from 211 BTS selected as eNodeB 4G LTE and there are 41 new potential eNodeB points that are considered to contribute optimally in Denpasar City with total path loss value of 136085,8338 dB. Harmony Search also alters the height and potential point radius initially based on the height and average radius of the existing base station.

TABLE 4. ITERATED HARMONY SEARCH RESULTS

No Id	Coordinate		High of BTS (m)	BTS radius (m)	Total Path Loss (dB)
	Long (m)	Lat (m)			
51	1633138	9028958	24	2751	136085,8
228	1628774	9033775	37	2336	
153	1626377	9028311	15	1193	
260	1627079	9025746	30	2785	
196	1633579	9026268	15	1193	

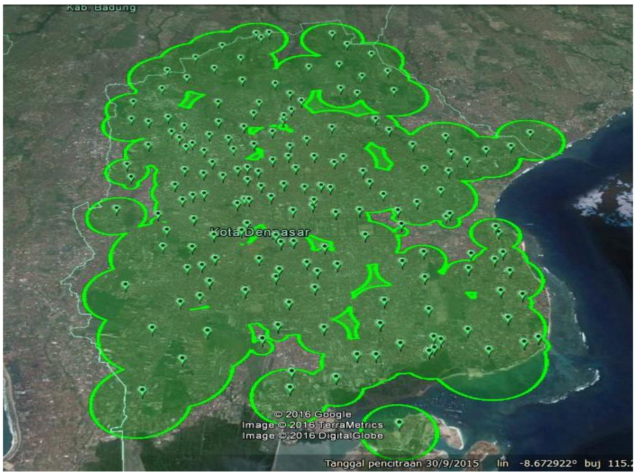

Fig 7. Mapping of Harmony Search Optimization Result

Figure 7 shows the optimum results of eNodeB optimization process in 2020 after going through the optimization process using Harmony Search. In the picture seen some areas that have not been covered and there are some eNodeB whose position is still coincide with other eNodeB. This is because Harmony Search only looks for a minimal path loss value of some combination of all eNodeB sums. Harmony Search does not take into account the distance between eNodeB and coverage.

V. CONCLUSION

This research has done the calculation of eNodeB 4G LTE requirement in 2020 in Denpasar City which subsequently determine new potential eNodeB using Fuzzy C-Means clustering technique, and lastly do eNodeB point optimization using Harmony Search method.

Fuzzy C-Means and Harmony Search method is able to optimize eNodeB placement optimization process, which resulted in 123 BTS of existence selected to be eNodeB 4G LTE and there are 41 new eNodeB points considered to give optimal contribution in Denpasar with total path value loss of 136085,8338 dB.

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