An approach for selecting optimum number of base stations using harmony search

Abstract:
In order to improve the quality of broadband communications services, cellular providers have upgraded from 3.5G cellular technology to 4G Long Term Evolution (LTE). The consequence is the provider must build a communications infrastructure that is 4G LTE eNodeB network but efficiently in terms of financing. The solution that can be taken is to utilize a Base Transceiver Station (BTS) of the existing GSM network as 4G LTE eNodeB. Due to the characteristics of different networks, not all of the existing BTS can be used. Therefore, this paper has conducted a study of determining optimal number of base stations for the eNodeB in Denpasar using Harmony Search (HS) method. In the implementation, the HS will optimize points of the base stations based on the analysis of total path loss that was calculated using Walfisch-Ikegami propagation models. The simulation results showed 169 of the 211 existing BTSs chosen as optimal 4G LTE eNodeBs having a total pathloss value of 117,087.18 dB. In other words, there are 22 existing BTSs are not considered optimal and the total pathloss value is reduced by 3168.43 dB.

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I. Introduction
The development of a technology, especially in telecommunication field is currently growing very fast. It is marked by increased number of cellular subscribers in Indonesia [1]. The increased number of users is not only increased in urban areas, but also in the countryside. In addition, an increased number of internet users in Indonesia is also growing rapidly. Research from the Boston Consulting Group assessed that number of internet users in Indonesia will continue to increase until tripled in 2015 compared to 2010 [2]. This makes companies of telecommunication providers vying to improve the current infrastructure so that it could give good services. There is currently development process of cellular technology in Denpasar, Bali, from 3.5G (HSDPA) technology to 4G (LTE). It is due to the increased number of internet users in Denpasar. One of 4G LTE infrastructures that is being built is eNodeB. eNodeB is interface connecting subscribers to the LTE network. eNodeB is analogous to the BTS in GSM network.

Keywords
IEEE Keywords
Optimization, Base stations, Long Term Evolution, Poles and towers, Urban areas, Mathematical model, Music

Related Articles
Fast motion planning for multiple moving robots
Inverse kinematics of redundant robots using genetic algorithms
broadband networks, cellular radio, Long Term Evolution, radio transceivers, search problems

base stations, harmony search, broadband communications services, cellular providers, 3.5G cellular technology, 4G LTE eNodeB network, GSM network, BTS, harmony search methods, Denpasar, Weifisch-Ikegami propagation models

Harmony Search, Pathloss, Weifisch-Ikegami, Optimasi, LTE

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An Approach for Selecting Optimum Number of Base Stations using Harmony Search

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Abstract— In order to improve the quality of broadband communications services, cellular providers have upgraded from 3.5G cellular technology to 4G Long Term Evolution (LTE). The consequence is the provider must build a communications infrastructure that is 4G LTE eNodeB network but efficiently in terms of financing. The solution that can be taken is to utilize a Base Transceiver Station (BTS) of the existing GSM network as 4G LTE eNodeB. Due to the characteristics of different networks, not all of the existing BTS can be used. Therefore, this paper has conducted a study of determining optimal number of base stations for the eNodeB in Denpasar using Harmony Search (HS) methods. In the implementation, the HS will optimize points of the base stations based on the analysis of total path loss that was calculated using Welfisch-Ikegami propagation models. The simulation results showed 189 of the 211 existing BTSs chosen as optimal 4G LTE eNodeBs having a total pathloss value of 117,087.18 dB. In other words, there are 22 existing BTSs are not considered optimal and the total pathloss value is reduced by 3169.43 dB.

Keywords—Harmony Search, Pathloss, Walfisch-Ikegami, Optimasi, LTE

I. INTRODUCTION

The development of a technology, especially in telecommunication field is currently growing very fast. It is marked by increased number of cellular subscribers in Indonesia [1]. The increased number of users is not only increased in urban areas, but also in the countryside. In addition, an increased number of internet users in Indonesia is also growing rapidly. Research from the Boston Consulting Group assessed that number of Internet users in Indonesia will continue to increase until tripled in 2015 compared to 2010 [2]. This makes companies of telecommunication providers vying to improve the current infrastructure so that it could give good services.

There is currently development process of cellular technology in Denpasar, Bali, from 3.5G (HSDPA) technology to 4G (LTE). It is due to the increased number of internet users in Denpasar. One of 4G LTE infrastructures that is being built is eNodeB. eNodeB is interface connecting subscribers to the LTE network. eNodeB is analogous to the BTS in GSM network.

The eNodeBs have grown rapidly, causing environmental problems in communities located around the eNodeBs. The increased number of eNodeBs in urban areas, especially in Denpasar, do not only impact to the surrounding community but also it can damage the spatial structure of the city. Therefore, it is needed a proper method to determine an optimal amount of eNodeBs in a particular area in Denpasar.

There are several methods can be used to optimize the placement of telecommunication towers, including analysis of coverage and Quality of Service (QoS) [3] [4] [5]. The process of optimization is calculating the value of QoS and coverage that are used as parameters to determine optimal number of point towers. In fact, there were few studies that used data mining method to determine the optimum point [6] [7] [8]. This method is able to provide optimal solutions based forecasting in accordance with the condition and reality.

This paper focuses on calculating total pathloss of the existing base stations which would then be optimized using the HS algorithm to determine optimal positions of the eNodeB points. Calculation of the total pathloss of the existing base stations was carried out using link budget Ikegami Welfisch method. The optimization process in this paper used HS algorithm since it has an advantage of its pitch adjustment that can perform improvement process on local solutions that are optimal and relatively easy structure HS algorithm [9]. The objective of this paper is to produce an optimal mapping of eNodeBs in Denpasar.

Simulation results showed that the HS algorithm can produce an optimal mapping of eNodeB positions based on the total value of minimum pathloss.

This paper is organized as follows: Chapter I shows the background of the problem, Chapter II shows the propagation models that are used to get the total pathloss, Chapter III shows the application of HS in optimization, Chapter IV shows the results and discussion, Chapter V demonstrate conclusions.
II. PROPAGATION MODEL WELFISCH IKEGAMI

The optimization process of eNodeB points is carried out after calculating total pathloss of the existing BTS. Propagation Model is a calculation model that is used to predict coverage and total pathloss of the existing BTS. In this paper, Walfisch-Ikegami propagation model is used. Walfisch-Ikegami model is an empirical propagation model for urban areas which can be used either for macrocell or microcell.

Walfish-Ikegami propagation model is typically used under the following conditions [10]:

\[
\begin{align*}
\theta_x & \equiv \frac{\theta}{\theta_x} - \frac{\theta}{\theta_x}, \\
\theta_y & \equiv \frac{\theta}{\theta_y} - \frac{\theta}{\theta_y}
\end{align*}
\]

\[
\begin{align*}
\alpha_x & \equiv \frac{\alpha}{\alpha_x} - \frac{\alpha}{\alpha_x}, \\
\alpha_y & \equiv \frac{\alpha}{\alpha_y} - \frac{\alpha}{\alpha_y}
\end{align*}
\]

Calculation of pathloss value using Walfisch-Ikegami models is divided into two conditions, namely Line of Side (LoS) and Non Line of Side (NLoS). Fig. 1 shows an example model of Walfisch - Ikegami. In a LoS condition, pathloss value is calculated using Equation (1) below:

\[
L_{\text{LoS}}(\text{dB}) = 42.6 + 26 \log_{10} d + 20 \log_{10} f
\]  

Path loss value in NLOS condition is calculated using equations as follows:

\[
\begin{align*}
L & = L_{\text{fast}} + L_{\text{rtss}} + L_{\text{msd}} \\
L_{\text{fast}} & = 32.45 + 20 \log_{10}(d) + 20 \log_{10}(f) \\
L_{\text{rtss}} & = -16.9 + 10 \log_{10}(w) + 20 \log_{10}(h_{\text{roof}} - h_m) + L_{\text{ari}}
\end{align*}
\]

Where,

\[
L_{\text{msd}} = L_{\text{bsh}} + k_a + k_d \log_{10}(d) + k_f \log_{10}(f) - 9 \log_{10}(b)
\]  

\[
L_{\text{bsh}} = -18 \times \log_{10}(1 + (h_b - h_r)); h_b > h_r
\]

Where,

\[
k_f = \begin{cases} 
-4 + 0.7 \left( \frac{f_c}{925} - 1 \right) & : \text{for medium cities} \\
-4 + 1.5 \left( \frac{f_c}{925} - 1 \right) & : \text{for metropolitan areas}
\end{cases}
\]

\[
k_a = 54 : h_b > h_r \\
k_d = 18 : h_b > h_r
\]

III. HARMONY SEARCH

The optimization process is used to obtain an optimal solution of points of the existing base stations based on the coverage and height of the existing base stations. This paper uses the method of HS to determine optimal number of eNodeBs.

HS algorithm is an algorithm that emulates music improvement process by a group of musician. This algorithm was found by Zong Woo Geem in 2001. In this algorithm the improvement process will occur on harmony of music being played. There are three possible choices occur when the improvement process. Those are playing a musical harmony which is similar to the famous music based up on memory, harmony of music is similar but there is a slight compliance, and create a new harmony of music. These three options are formulated in a quantitative optimization process: 1) harmony memory usage, 2) tone adjustments, and 3) random generation process [9].

HS method solves an optimization problem (minimizing function) using following steps:

- Step 1. Parameter Initialization

Some parameter model have to be rated Harmony Memory Consideration Rate, HCMR (eg 0.7 - 0.95),
sample size HMS (eg \( N = 0.20 \)), and pitch adjusting rate (PAR = 0.3). Determine the pitch bandwidth \( b \) randomly, \( x_L \) (lower limit) and \( X_u \) (upper limit) for the value of the variable.

- Step 2. Harmony Memory (HM) Initialization
  HM consists of \( N \) initial solution. These solutions can consist of one variable to \( p \) variables. These solutions are generated randomly. All candidates are evaluated to find a worst solution.

- Step 3. Make improvement on the existing solution. For each variable, values randomly taken from HM. Using certain procedure, these values will be adjusted such that if they meet certain rules (using generation of random numbers and compared with HMCR and PAR) new values will be obtained.

- Step 4. Update HS
  The new solution will be compared with the worst pollution in the \( N \) initial population. If the new solution is better then it will replace the previous worst solution vector.

- Step 5. Check the stopping criteria
  If the termination criteria have not been met, go back to the step 3 to pick one of solution vectors randomly from the first variable. Termination criteria can be used in the form of the number of iterations or the absolute value of the difference between two successive objective function values.

IV. APPLICATION OF OPTIMIZATION IN HARMONY SEARCH eNODEB

Based up on the steps of HS method explained in Chapter III, the application method on optimization HS eNodeB can be explained as follows:

![Fig. 2. Research overview](image)

- Analysing the existing base stations and calculating the total pathloss generated by the existing base stations using the Link Budget calculation. Propagation model used in the link budget calculation is Walfisch-Ikegami.

- Optimising number of eNodeBs using HS. The result of the calculation based on link budget will then be optimized to obtain optimal amount of eNodeB points having total pathloss value which is minimum.

- Mapping the eNodeBs obtained from optimization process using HS. The result of this mapping is the result of eNodeBs optimization eNodeB having total pathloss value which is minimum.

Fig. 2 shows a flowchart application of optimization HSC method on eNodeB.

V. RESULT AND DISCUSSION

In this paper, a location case study taken for eNodeB optimization process is Denpasar. It is assumed all the existing BTS in Denpasar will be upgraded to an eNodeB. Hence, there are 211 eNodeBs that are used as inputs in the optimization process.

<table>
<thead>
<tr>
<th>Region</th>
<th>Existing BTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Denpasar</td>
<td>78</td>
</tr>
<tr>
<td>East Denpasar</td>
<td>55</td>
</tr>
<tr>
<td>West Denpasar</td>
<td>34</td>
</tr>
<tr>
<td>North Denpasar</td>
<td>37</td>
</tr>
</tbody>
</table>

A. Analysis of Existing Total Pathloss BTS

In this section we will perform total pathloss analysis of the existing BTS. This paper uses welfisch Ikegami propagation model to calculate pathloss values of each the existing BTS. These pathloss values will be used as parameter for optimization process using HS. Fig. 2. shows the steps to calculate Coverage of the Existing BTS.

Fig. 3 shows the mapping of the existing BTS in Denpasar. It can be seen in Figure 3 that the existing base stations almost cover the entire territory of Denpasar. The total value of pathloss generated by the existing BTS amounted to 120,256.61 dB.

B. Optimization Process Using BTS HS

After performing the calculations of the total pathloss and coverage, the next step is optimization process using HS. The parameters used in the process are shown in table 2.

The first iteration process is HM randomly generate value containing temporary solutions. In this regard, HM has size of 211 pieces, which then the objective function is calculated. The optimal solution is obtained from minimization function pathloss value. To determine value of the pathloss function point at potential points then value of \( h \) (high tower) and \( r \) (radius) are determined randomly. \( h \) and \( r \) value generated by means:

\[
\begin{align*}
\text{Calculating the value of EIRP} & \\
\text{Calculating the value of MAPL} & \\
\text{Calculating the Path loss of Existing BTS} & \\
\text{Calculating the Total Pathloss of Existing BTS} & \\
\end{align*}
\]

In this paper, determining value of the smallest pathloss HS process is done in 2 stages. The stages are as follows:

- First is finding average value of the smallest path loss of the 200 iteration which is tested 5 times.
- The second is to perform the iterative process where the criteria for stoping value based on the average value of the smallest path loss from the first stage. So we get the optimal point base stations based on the value of the smallest path loss.
TABLE 2. HS METHOD PARAMETERS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of the existing population (HMEksis)</td>
<td>211</td>
</tr>
<tr>
<td>HM of the sample population size (HMS)</td>
<td>211</td>
</tr>
<tr>
<td>Value of the HMCR (HMCR)</td>
<td>0.7</td>
</tr>
<tr>
<td>Value of the PAR (PAR)</td>
<td>0.3</td>
</tr>
<tr>
<td>Lower limit of the sequence number (nL)</td>
<td>1</td>
</tr>
<tr>
<td>Upper limit of the tower height (tU)</td>
<td>42</td>
</tr>
<tr>
<td>Lower limit of the tower height (TL)</td>
<td>15</td>
</tr>
<tr>
<td>Upper limit of the cell radius (Ru)</td>
<td>2.857</td>
</tr>
<tr>
<td>Lower limit of the cell radius (rL)</td>
<td>8.392</td>
</tr>
<tr>
<td>Height of MS (hm)</td>
<td>1.5</td>
</tr>
<tr>
<td>Cutoff frequency (fc)</td>
<td>1800</td>
</tr>
<tr>
<td>Range of sequence numbers (bn)</td>
<td>(nU-nL)/10</td>
</tr>
<tr>
<td>Range of the tower height (bt)</td>
<td>(tU-tL)/100</td>
</tr>
<tr>
<td>Range value of the cell radius (br)</td>
<td>(rU-rL)/100</td>
</tr>
<tr>
<td>Number of variables (N)</td>
<td>5</td>
</tr>
</tbody>
</table>

TABLE 3. THE RESULT OF HS ITERATION

<table>
<thead>
<tr>
<th>No</th>
<th>Id</th>
<th>Coordinate</th>
<th>The height of the BTS (m)</th>
<th>The radius of the BTS (m)</th>
<th>Total Path Loss (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>1627877,9</td>
<td>9021389,4</td>
<td>30</td>
<td>2857</td>
<td>117087.18</td>
</tr>
<tr>
<td>183</td>
<td>1630630,5</td>
<td>9031035,1</td>
<td>15</td>
<td>1193</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>1629086,4</td>
<td>9027965,6</td>
<td>27</td>
<td>2834</td>
<td></td>
</tr>
<tr>
<td>188</td>
<td>1631095,5</td>
<td>9028023,9</td>
<td>15</td>
<td>1193</td>
<td></td>
</tr>
<tr>
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Figure 4 shows the result of optimal optimization process of eNodeB after through optimization process using HS. As seen in Figure 4, there is no significant changes between after and before optimization. This is because the number of eNodeBs removed is not much (22 eNodeBs). In Figure 4 also shows the coverage in Denpasar does not decrease so the optimization does not reduce the total coverage of the existing eNodeB. HS only minimizes pathloss value on the existing eNodeB.
VI. CONCLUSION

This research has computed the total pathloss of the existing BTS in Denpasar using welfisch-Ikegami propagation model which further optimized using the HS.

The optimization result is 189 of the 211 existing BTSs elected as optimal 4G LTE eNodeBs having a total pathloss value of 117,087.18 dB. In other words, there are 22 existing BTSs are not considered optimal and the total value is reduced by 3169.43 pathloss dB.

REFERENCES


