

# OPTIMIZATION OF CHANNEL ASSIGNMENT FOR MOBILE COMMUNICATION USING TABU SEARCH

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**ABSTRACT:** Mobile communication is a process of exchanging information by connecting two parties through a wireless network. Practically, mobile communication system involves a large coverage area. However, there has only limited channels to accommodate all the users. Hence, with the increasing number of mobile users recently, it leads to channel assignment problem (CAP). To optimize the channel assignment problem, an initiative is taken to reuse the existing channels in an efficient way with the minimum interference occur in the channels assignment. This helps to optimize the usage of the channel assignment in mobile communication. Tabu Search (TS) technique is implemented to solve the CAP by searching for the global optimum solution with the minimum interference cost value. The reallocated channels are being analyzed on the value of the penalty cost based on the penalty cost function. The optimization of the channels assignment is a process of reducing total channels required as the solution is improved. An analytical analysis is carried out to investigate the effect of demand calls and the number of available channels on the cost value.

**KEYWORDS:** *Channel Assignment; Tabu Search; Optimization; Reuse Channel*

## 1.0 INTRODUCTION

In globalization era nowadays, communication is one of the interesting parts for exchanging information among people. Mobile device is widely used for a communication network system. Communication process is propagating through a radio frequency medium. Radio Frequency (RF) is a form of electromagnetic wave frequencies which is in a range extending from around 3 kHz to 300 GHz; including the frequencies that are normally used for communications or radar signals.

On November 2015, United States (U.S.) population statistics shown that 87 percent of people those ages 18 years old and above owned mobile phone [1]. Since the number of mobile users is increasing, therefore the need of the channel is increased. Mobile communication needs unused voice channel pair. Basically in communication system, there will be source and destination for the information to be transferred. The information is being transferred from source by using channel to the destination. Channel is a flow path for the information to be transferred. The channel has different range of frequency. Each frequency range has its own purpose of usage. Therefore, as the amount of consumer increasing recently, the need for the limited existing channel is also increased.

There are three models in channel assignment problem which are Static Channel Assignment (SCA), Dynamic Channel Assignment (DCA) and Hybrid Channel Assignment (HCA) [2]. SCA is known as channel assignment that is consists of a fixed number of unused voice channels assigned in each of cell for communication process. Then for DCA is channel assignment that is temporarily being assigned in a cell along the duration of a call is being made. The channel of the call used will be changed based on the nearest location of the BS. The probability of a call is being rejected by using DCA model is reduced. For this project, SCA is used to assign the channels in cells based on the demand.

Until today, various heuristic techniques are being used to solve variety of channel assignment crisis occurred. Heuristic techniques solve problems by giving a close-optimal solution at a relevant computational cost. It is non-algorithmic methods that are applied to algorithmically complex Channel Assignment Problems (CAP) to generate efficient solutions [3]. It is being used for the SCA or DCA models by implement it in Genetic Algorithms (GA) [4-5], Neural Networks (NNs), Simulated Annealing (SA) [6-7], Tabu Search (TS)

[8-9], Artificial Intelligence (AI) [10] and Local Search [11]. The main objective of the CAP is to assign the existing channels to call so that the usage of channels is being maximized, since the channels are limited. Then, interference between the frequencies (channels) is needed to be optimized to minimum value. At the same time, the number of frequencies on each of base station must be large enough to satisfy the demand in the cell.

Besides, a research is being carried out on cellular radio of channel assignment to solve CAP by using simulated annealing technique since the previous project is based on the graph coloring algorithms. The research shows the design neighborhood structure of channel allocation of cellular radio gives positive impact on quality and efficiency of the channel assignment [4]. Some researches were done by transforming the connected graphs that represent channel assignment into single-row networks in real time basis [12-13].

Tabu Search technique is suitable to be used to make the channel assignment used efficiently by allowing of any interference occurred, but for searching better solution interference free is preferable [13]. Basically, Tabu Search was first explored in 1977s [14]. It is consisted of classical Tabu Search and reactive Tabu Search. Normally, classical Tabu Search is used to solve channel assignment problem. It is based on list of neighborhood data with a set of critical and corresponding components referred to the channels requirement [15].

The implementation of Tabu Search in mobile communication involves the channel assignment part. The main objective in this research is to optimize channel assignment in mobile communication by minimizing the interference cost value using Tabu Search, followed by investigation on the effect of demand calls and number of available channels towards the cost value. The relation between the parameters is important since it provides the crucial information to the designing of better algorithm.

## **2.0 PROBLEM STATEMENT**

Based on the experience, the demand in cell  $j$  where  $j=1,2,\dots,N$  is recorded and represented by one-dimensional matrix channel demand,  $D_j$ . Total channels used is represented by  $M$ . The constraint of the channel assigned between cell  $i$  and  $j$  is the minimum separation of the frequency,  $C_{i,j}$  called non-interference constraint. It is

given in a four-dimensional matrix  $C$  of row,  $i$  and column,  $j$ . The set of binary,  $X_{j,k}$  shows that channel  $k$  is assigned to cell  $j$  if  $X_{j,k}$  equals to value of one. Otherwise, it will be zero value.

To achieve interference-free assignment, the constraint of  $C_{i,j}$  must be satisfied. However, slight interference is acceptable to increase the availability of channels. If the minimum separation constraint is violated, interference will occur and a penalty value will be imposed by cost tensor,  $P_{j,i,m}$  where  $m$  is distance between channels assigned to cells  $i$  and  $j$ . The value of the cost tensor shows the degree of the interference occurred.

The penalty cost function shows the severity level of the interference occurred among the assigned channel. In this paper, the penalty cost function value is known as cost value. The problem formulation for the static channel assignment model is stated as followed [16].

The penalty cost function is shown in Equation (1) as follows:

$$F(X) = \sum_{j=1}^N \sum_{k=1}^M X_{j,k} \sum_{i=j}^N \sum_{q=k+1}^M P_{j,i, (|k-q|+1)} X_{i,q} \quad (1)$$

where  $m=|k-q|$ . This function computes the value of total penalty imposed to a given channel allocation. Penalty is imposed when the assigned channels violate the minimal frequency separation constraint. Binary variables,  $X_{j,k}$  where  $j = 1, 2, 3, \dots, N$  and  $k = 1, 2, 3, \dots, M$  represents the allocation of channel  $k$  assigned in cell  $j$  if the value is one, otherwise zero.

The relationship between set of binary variables,  $X_{j,k}$  and the demand requirement of the channels in each cells,  $D$  is shown in Equation (2) as follows:

$$\sum_{k=1}^M X_{j,k} = D_j, \quad j = 1, 2, 3, \dots, N; \quad k = 1, 2, 3, \dots, M \quad (2)$$

The cost tensor,  $P$  is given in Equation (3) where it checks the violation of minimal frequency separation constraint.

$$P_{j,i,m} = \max\{C_{j,i} - m, 0\} \quad (3)$$

where  $C_{ji}$  is a matrix  $C$  with row  $j$  and column  $i$ . The function  $C_{ji} - m$  is used to check if the assigned channels violate the minimum separation constraint. If  $C_{ji} - m > 0$ , it shows the violation happen and the value will be recorded as  $P_{j,i,m}$ . In other words, if the  $m$  value is larger than the minimum separation value where it gives negative value, it means no violation happen and cost tensor will be zero value. This computation is done by  $\max\{C_{ji} - m, 0\}$  where zero value will be taken when  $C_{ji} - m < 0$ .

A penalty cost or cost value,  $F(X)$  is being charged due the interference of the channel occurred. The higher the amount of the penalty cost shows the stronger the interference occurred between the channels. The penalty cost is low when the channel  $k$  and  $q$  are far enough from each other. The objective of this research is to find the allocation of channels that minimize the total cost value that represents the interference and to analyze the effect of demand calls and number of available channels on the cost value.

### **3.0 METHODOLOGY**

To solve the channel assignment problem, Tabu Search algorithm is coded using MATLAB's software to assign the channels. The general process implementation of Tabu Search in channels assignment is illustrated in a flowchart as shown in Figure 1. First, an initial solution is created based on the parameters required as shown in problem statement. Next, several neighbourhood solutions will be generated from the initial solution and evaluated in terms of cost value. The solution with the lowest cost value is recorded as current solution and it will be stored in tabu list to avoid the same solution from being generated in the next few iterations. The purpose of this forbidden use of solution in tabu list is to increase the variability of neighbourhood solutions that may lead to the reach of optimal solution. In each of the iterations, when the current solution appears to be the best, it will be stored as the best solution. If the stopping criteria is not being met, the process will proceed to the next iteration to generate several neighbourhood solutions based on the current solution. The optimal solution is found when then stopping criteria is met.

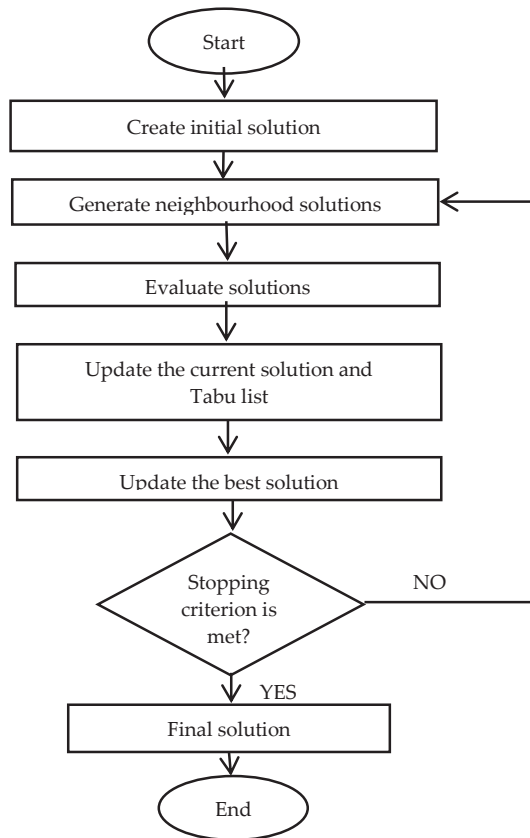


Figure 1: A flow chart of Tabu Search method

An example is illustrated to show the method used in this project. The data of  $N = 4$  cells and  $M = 13$  channels are being used. Demand of the channels or number of calls in each of the cells is  $D_j = [1, 1, 1, 3]$ . The

compatibility matrix,  $C_{ij} = \begin{bmatrix} 6 & 5 & 0 & 0 \\ 5 & 6 & 0 & 1 \\ 0 & 0 & 6 & 2 \\ 0 & 1 & 2 & 6 \end{bmatrix}$  shows the minimum

separation of frequency between cell  $i$  and cell  $j$ .

An initial solution is randomly generated as in Figure 2. The initial channel assignment is channel 1 in cell 1, channel 2 in cell 2, channel 3 in cell 3 and channel 1, 4, and 13 in cell 4. From the coding of algorithm in the MATLAB, the data is analyzed for 50 iterations which means the coding algorithm is looping for 50 times. In each of the loop, the channels are randomly swapped to produce twelve solutions in a neighborhood.

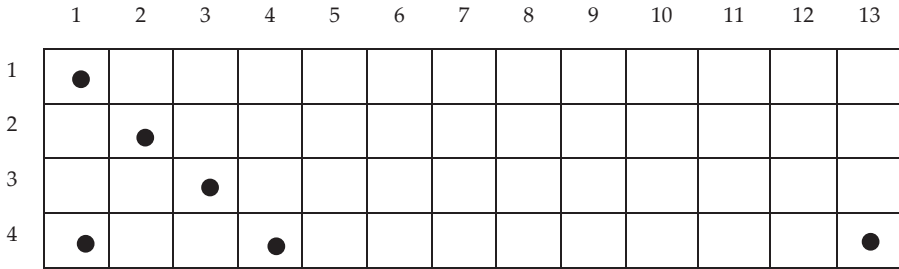


Figure 2: The initial allocation of assigned channel for the channel assignment problem

As the iteration runs, the cost value is computed and recorded to be observed. The coding of cost value is written in a function of 'costvalue' function where the process of calling back function is needed to evaluate the cost value. The coding of the channel assignment problem in MATLAB's is evaluated the cost value as shown in Figure 3.

```
function costvalue = COSTVALUE(X,N,M,D) %function to calculate
cost value
    C=[6 5 0 0; 5 6 0 1; 0 0 6 2; 0 1 2 6]; %non-interference
constraint
    sum2=0; %initialize sum2
    sum3=0; %initialize sum3

    %looping process to calculate the total of interference cost
value
    for j=1:N
        for k=1:M
            sum1=0;
            for i=1:N
                for l=1:M
                    m=abs(k-l); %distance between channel k and l
                    P= max((C(j,i)-m),0); %cost tensor
                    %sum1 current+previous interference
                    sum1 = sum1 + (P*X(i,l));
                end;
            end
            %sum2 current+previous interference
            sum2 = sum2 + (X(j,k)*sum1);
        end
    end
    %total interference without interference with itself
    sum3=sum2-D*C(1,1);
    %cost value of interference from the assigned channel
    costvalue = sum3/2;
end
```

Figure 3: Coding of computation for cost value

The important initialized parameters are the current and best binary set and their respective cost value, iteration for number of neighborhood for each of the cells and the forbidden iteration for forbidden strategy, to make sure the optimization process is run properly. Then, by running the algorithm coding on MATLAB's software, a pool of candidate solutions stemmed from the initial solution. The process of creating the first solution from the initial solution is by reallocate any of one assigned channel. It is a process of assigning channels arbitrarily based on the demands needed in each cell. Then process of reallocation of channel is randomly done by replacing a channel used from the current channel with an unused channel in the same cell at a time. For example, the initial channel assigned in the Figure 2 has interference value of eight. In other words, the current cost value of initial assigned channel is eight. Then, a neighborhood is formed by swapping the assigned channel to another unused channel. One neighborhood contains 12 feasible solutions with different binary set. Among the 12 feasible solutions, the binary set with the lowest cost value is set as the current solution. If the cost value of current solution is lower than the best stored value, the current solution will be updated as the best solution. For example, the allocated channel in cell 1 is reallocated from channel 1 to channel 11 as shown in Figure 4 and the current cost value evaluated decreases to four. So, the current cost value holds a value of four for the first generated solution.

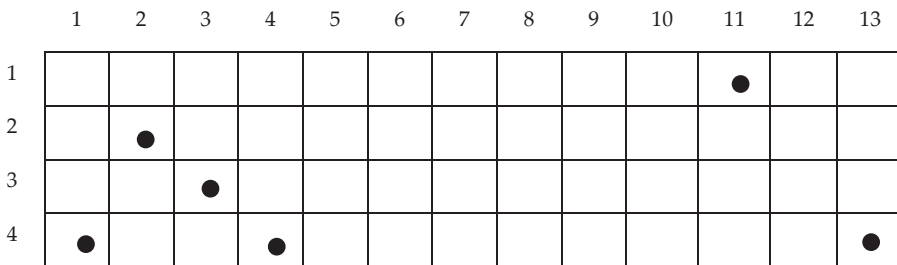


Figure 4: The first assigned channel for channel assignment

The other assigned channels remain the same. In this research, only one channel is swapped at a time so that the effects on the interference occurred can be seen clearly. As the neighborhood is created, an assigned channel is randomly choosing and being free, and an unused channel will be assigned as a replacement. Meanwhile, the freed channel is prohibited to be assigned in the next few iteration and is recorded in Tabu list. In Tabu Search technique, each movement of the channel is being recorded by using Tabu characteristic which is called as Tabu list. The channel used in Tabu list is forbidden to be reused in



a prefixed number of iterations. This aims to avoid creating the same binary sets in the neighborhood. In other words, all binary sets vary from each other in the neighborhood.

Whenever current solution is updated, the previously visited solution is being recorded in memory called Tabu list. The moves in Tabu list are forbidden moves. This is needed to prevent the production of same solution in neighborhood. The moves are freeing based on the freeing strategy. However, according to the aspiration criterion, if the Tabu moves has a sufficiently attractive evaluation where it may result in the lowest cost value than any of the visited solution, that particular Tabu moves will be free from Tabu list. The process of channel assignment continues to reallocate the channel and the cost value is found lower than the best solution at the thirteenth neighborhood/loops as shown in Figure 5 with the cost value of two. Then, this new current solution is stored as the new best solution for the channel assignment problem.

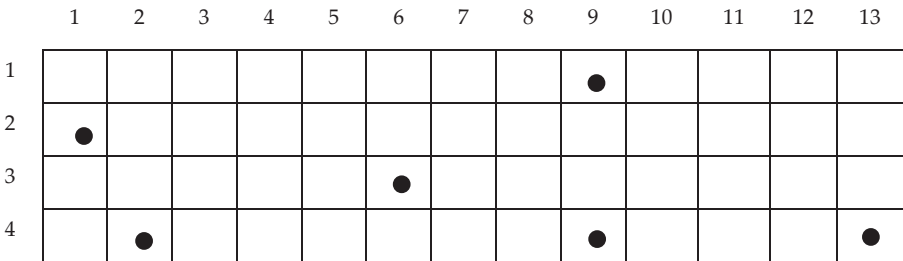


Figure 5: The thirteenth assigned channel for channel assignment

The process continues and the binary set with a cost value lower than two is found at the twenty-sixth neighborhood as shown in Figure 6 which the cost value of one. The best solution is then updated and its corresponding best cost value is changed from two to one.

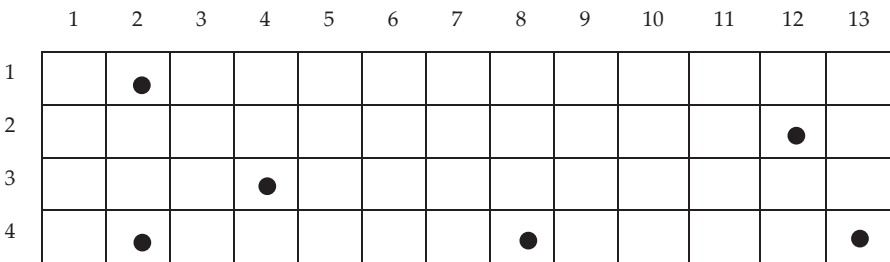


Figure 6: The twenty-sixth assigned channel for channel assignment

Since the interference contributes to the cost penalty value, the coding algorithm is created for the problem formulation used. In this case,

termination criteria used is based on the number of iterations reaches the setting of maximum number of iteration. The process of searching for the best solution will stop when the termination criterion is satisfied and hence the final solution is found.

#### **4.0 RESULT AND DISCUSSION**

To investigate the relation between the cost values of interference with the number of available channels, the data is varied based on the available channels,  $M$  and the demand requirement,  $D$  in each of the calls. Data set is used where the demand is varied in 5, 10, 15, 20 and 25 for the channel assignment problem. The parameters of channel assignment problem for data set, is set as follows [17]:

Number of cells,  $N = 4$ ;

Number of available channels,  $M = 5, 10, 15, 20, 25$ ;

Demand of calls,  $D = 5, 10, 15, 20, 25$ .

The minimum frequency separation constraint between the cells  $i$  and  $j$  for zero interference, is represented by matrix  $C_{ij}$ . In this case, the  $C_{ij}$  used is a square matrix with size  $N$  by  $N$ . In other words, if  $C_{ij}$  is zero, it means the same channel could be assigned in cells  $i$  and  $j$  without any interference. When  $C_{ij}$  is non-zero, the value, let say 5, presents that two frequencies assigned in cell  $i$  and  $j$  must be differed by at least 5 units in order to achieve zero interference. Otherwise, a penalty would be imposed and revealed in cost value.

Since heuristic method does not give a unique solution, the result is obtained from the best result among 3 trials for each of the cases. The result for  $D = 5$  and 10 for  $N = 4$  is shown in Figure 7. For the first case which is five demands in the channel assignment, the number of available channel is tested with step size of 5, from 5 to 25 available channels. It is found that the cost value evaluated is from one, then being minimized to zero cost value when the number of available channels increases. It means that, the channel assigned reaches the level of free-interference as the available channel increases. In other words, the constraint of the compatibility matrix is fully satisfied and the distance of the frequencies between the assigned channels is far enough to each other.

Then, the demand is increased to ten in case 2 in the channel assignment. The cost value is found optimized from 70 to 4 as the availability of channels increases. As the termination criterion reaches

the maximum limit, the best cost value found along the neighborhood process is four with 25 channels used. As shown in Figure 7, as the number of demand increased from five to ten, the cost value of each of the categories,  $M$ , increases too. With the fixed number of channels, the higher demand of calls will lead to higher cost value since interference is higher.

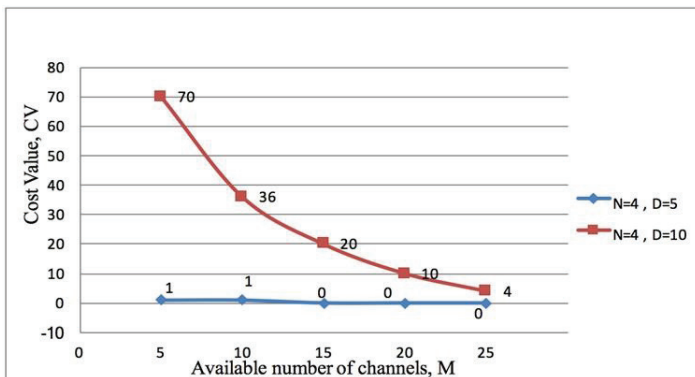


Figure 7: Cost value versus number of available channels for low demand values

The experiment is further run with the demands of 15, 20 and 25, and the result is shown in Figure 8. It is found that the cost values decrease about 65% from 102, 207, and 328 to 29, 70 and 123, respectively, as the number of channels increases from 10 to 25 with a step size of 5. None of the channel assigned reaches the stage of interference free as the demands of the channel increases. In other words, the constraint of the compatibility matrix is not satisfied and there is interference occurred between the assigned channels.

Next, by using a fixed number of channels, for example  $M=15$  in Figure 8, cost values for the case of demands 15, 20 and 25 are 65, 135 and 229, respectively. This is due to the higher number of demands requiring more channels to serve the calls. By using the same number of available channels, the channels assigned will be closer to each other in the case of higher demands, and hence, the cost value increases as more penalty is imposed on the violation of minimal separation of channels.

In overall, the results show the cost value depends on the demand sizes and the number of available channels in the network. The larger is the demand, the more channels are needed to keep the cost value low. The higher is the cost value, the more number of calls may be blocked and the quality of mobile communication decreased. Hence,

in channel assignment problem, channels need to be assigned optimally with lower cost value to provide higher quality services in mobile communication.

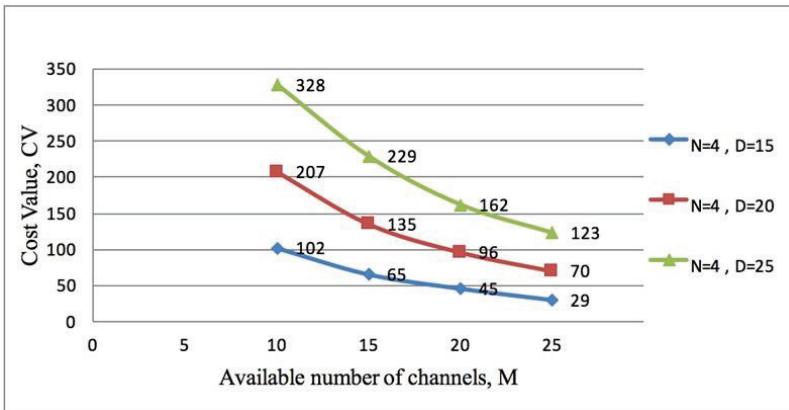


Figure 8: Cost value versus number of available channels for high demand values

#### 4.0 CONCLUSION

As a conclusion, this paper presents the implementation of Tabu Search in solving channel assignment problem in mobile communication. Interference is allowed at the minimum level. Cost penalty value is computed based on the problem formulation for each of the obtained candidate solutions. The lower cost penalty represents the lower interference occurs. The optimization of channel assignment is achieved as the optimal solution is found based on the best solution which is the lowest cost value as termination criterion is met. The optimal solution is obtained by carrying out exhaustive search using the developed coding algorithm where new neighborhood is generated from current solution in each of the iterations. Based on the result, it is found that, the larger of the iteration is allowed, the lower of the cost value may be produced. Practically, the demand of the channel assignment is varied to see the effect of the demands on the cost value. It is found that, for a fixed available channel, as the number of the demands increases, the cost value increases too. To keep the cost value low, more channels are needed to satisfy the demand calls. The calls with lower cost value will contribute to the higher quality of calls eventually.

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