OPTIMIZATION OF CHANNEL ASSIGNMENT IN MOBILE COMMUNICATION USING TABU SEARCH

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DECLARATION

I declare that this report entitled "Optimization of Channel Assignment in Mobile Communication using Tabu Search" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

Signature : ………………………………………………

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Date : ………………………………………………

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Degree of Electrical Engineering.

Signature : …………………………………………..

Supervisor Name : DR. LOH SER LEE

Date : …………………………………………..

DEDICATION

This project is dedicated to my beloved family especially my father, Ramli bin Hamid, my mother, Mashetoh binti Idris, and my siblings. Thank you for all your support and encouragement to me.

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In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have been contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my main project supervisor, Dr. Loh Ser Lee, for encouragement, guidance critics and friendship. Without her continued support and interest, this project would not have been same as presented here.

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ABSTRACT

Communication is one of the integral parts of science that has been a focus point for exchanging information among parties at locations physically apart. Mobile communication is a wireless form of communication in which voice and data information is emitted, transmitted and received via microwaves. It allows individuals to converse with one another and transmit and receive data while moving from place to place. With the increase in mobile user rates in the present, existing channels are quite limited and can lead to channel assignment problem (CAP). Therefore, to reduce the channel assignment problem an attempt or action must be taken by reusing existing channels to minimize interference in channel assignments. Reduced interference leads to an increase in capacity and throughout of the system. Tabu Search is one of the techniques that can be used to resolve channel assignment problem. Tabu Search is a meta-heuristic that guides a local heuristics search procedure to explore the solution space beyond local optimality. Optimization process is implemented by first to determine the initial solution then the initial solution is used to generate the solution of the neighborhood. The channel allocated being analyzed the value of the penalty cost based on the penalty cost function. The process will be repeated until obtain the lowest penalty cost function and chosen as the final solution. An analytical analysis is carried out to investigate the effect of number of iterations and number of available channels on cost value. The results will compare by varying the demand required in the channel assignment with different number of channels used and some improvement will be implemented in. As the result shows that the number of channel would have an effect in reducing cost values and with the new improved coding number of iterations can be reduced in getting the cost values.

ABSTRAK

Komunikasi merupakan salah satu bahagian yang penting daripada Sains yang telah menjadi satu titik tumpuan untuk bertukar-tukar maklumat antara pihak-pihak di lokasi fizikal selain. Komunikasi mudah alih adalah bentuk komunikasi di mana suara dan data maklumat dikeluarkan, dihantar dan diterima melalui ketuhar gelombang mikro tanpa wayar. Ia membolehkan individu untuk berbual antara satu sama lain dan menghantar dan menerima data semasa bergerak dari satu tempat ke tempat. Dengan peningkatan kadar pengguna telefon mudah alih pada masa sekarang, saluran sedia ada agak terhad dan boleh membawa kepada masalah tugasan saluran (CAP). Oleh itu, untuk mengurangkan saluran masalah tugasan sesuatu usaha atau tindakan mesti diambil dengan menggunakan semula saluran sedia ada untuk mengurangkan gangguan dalam saluran tugasan. Mengurangkan gangguan yang membawa kepada peningkatan dalam keupayaan dan sepanjang sistem. Cari tabu merupakan salah satu teknik yang boleh digunakan untuk menyelesaikan masalah tugasan saluran. Carian tabu adalah sebuah meta-heuristik yang membimbing prosedur carian tempatan heuristik untuk meneroka Ruang penyelesaian luar optimality tempatan. Pengoptimuman proses dilaksanakan oleh pertama untuk menentukan penyelesaian awal maka penyelesaian awal digunakan untuk menghasilkan penyelesaian kejiranan. Saluran yang diperuntukkan sedang dianalisis nilai kos hukuman berdasarkan fungsi kos penalti. Proses ini akan diulang sehingga mendapat penalti paling rendah kos fungsi dan dipilih sebagai penyelesaian muktamad. Analisis analisis dijalankan untuk menyiasat kesan jumlah lelaran dan bilangan saluran yang tersedia pada nilai kos. Keputusan akan membandingkan dengan permintaan yang diperlukan di dalam saluran tugasan dengan nombor yang berbeza daripada saluran yang digunakan dan beberapa penambahbaikan akan dilaksanakan pada tahun. Kerana hasilnya menunjukkan bahawa bilangan saluran akan mempunyai kesan dalam mengurangkan nilai-nilai kos dan dengan baru meningkat pengekodan jumlah lelaran boleh dikurangkan untuk mendapatkan nilai kos.

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MIN	-	Mobile Identification Number
MSC	-	Mobile Switching Centre
BS	-	Base Station
CAP	-	Channel Assignment Problem
FCA	-	Fixed Channel Assignment
DCA	-	Dynamic Channel Assignment
HCA	-	Hybrid Channel Assignment
AM	-	Amplitude Modulation
PSTN	-	Public Switched Telephone Network
GA	-	Genetic Algorithm
SA	-	Simulated Annealing
LS	-	Local Search
TS	-	Tabu Search

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Tracing the flows of globalization, communication is a way to connect with others somewhere in different places. Telephone is one of the tools used in communication process goes through radio frequency media. Frequency of radio is one of the electromagnetic wave frequency located in an environment ranging from 3 kHz to 300 GHz, including frequencies used in radio or radar communications.

Each phone has its own Mobile Identification Number (MIN). in the process of making one call, two important components will be involved namely Mobile Switching Centre (MSC) and Base Station (BS). In general, wireless communication will take place and be organized in one form of cell. Each cell has a channel controlled by BS and at the same time it is also controlled by the MSC. The communication process between the connector and the receiver occurs when the user makes a call through the MSC.

Therefore, the MIN receiver will be sent to the MSC and will be processed by sending it to BS to find where it is from. After that, BS will resend the signal to the MSC for notification that the phone is in its cell area. Furthermore, the MSC will request BS to access the unused voice channel pair of caller receivers to communicate.

With the rapid increase of mobile phone users, channel channeling methods should also be enhanced. In general, in the communication system will be a source and destination for the information transferred by channel. Each channel has a different frequency range and its own use. Then, as the number of user increase, the needs for existing channel also increases.

In using the channel reuse technique, it will lead to interruptions throughout the communication process. The disturbances are divided into three types; co-channel, adjacent channel and co-site channel. Co-channel interference occurs due to the allocation of the same channel to nearby cells. For example, when the communication process occurs the same channel will be used in several cells from different BS. Second, the adjacent channel occurs because of the adjacent channels allocation for a pair of adjacent cells together. Adjacent channel disorders occur when adjacent channels are used in nearby cells. Next, co-site interference is due to the adjacent channel allocation that cannot be separated by the minimum spacing within the same cell. Co-site interference occurs due to the recipient filter is not perfect that allow near frequencies to fit into the pass band. The interference can be mitigated by proper channel submission.

Channel assignment problem (CAP) is dividing into three models which are Fixed Channel Assignment (FCA), Dynamic Channel Assignment (DCA) and Hybrid Channel Assignment (HCA). The FCA involves a set of permanent nominal channels allocated to each cell. The number of channels in the system is divided into one set and assigned to the cell to cover the entire coverage area. DCA is the practice in which all channels are stored in a central pool and dynamically assigned to radio cells when a new call arrives in the system. After the call is completed, the channel is restored to the central pool. For HCA, the total number of channels available for service is divided into fixed and dynamic sets. A call blocking probability defined as the probability that a call arrives to a cell and finds both the fixed and dynamic channels busy.

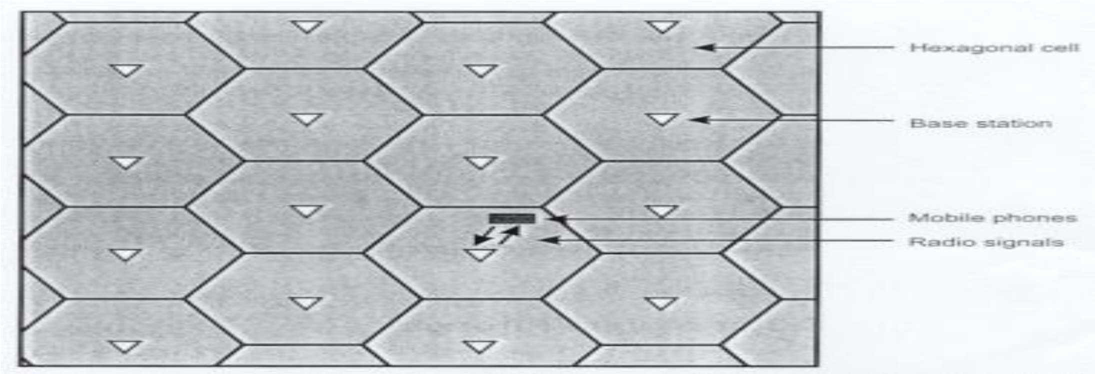

Figure 1.1: Base station in each of the cells

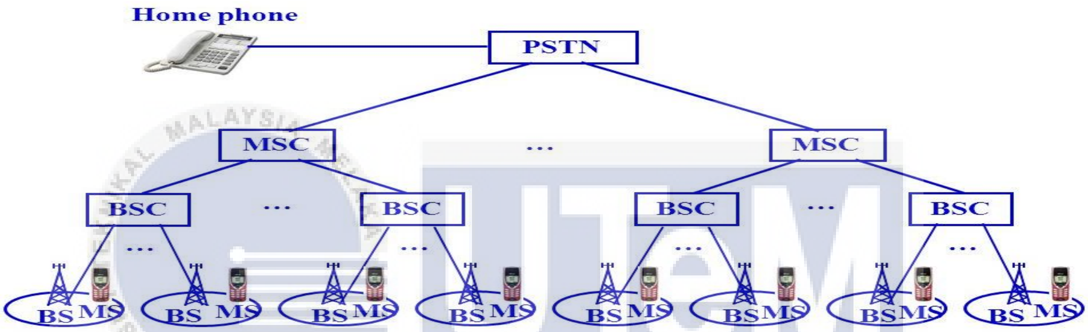

Figure 1.2: Structure of basic mobile communication

1.2 Motivation

Cell phones have become an important technology in everyday use. Mobile phone users have increased by 40 % each year. However, due to availability of existing channels. It can cause a noise or call problem to be denied. An interruption between channels in calls occurs when frequency constraints are not met in the channel assignment. Therefore, optimization of channel assignment problem is very important to get the best call quality. With existing technology, various ways have been used to solve this problem. Tabu Search is one of the methods in optimizing channel assignments to produce optimal solutions with minimal distractions to reduce declined call due to limited channels.

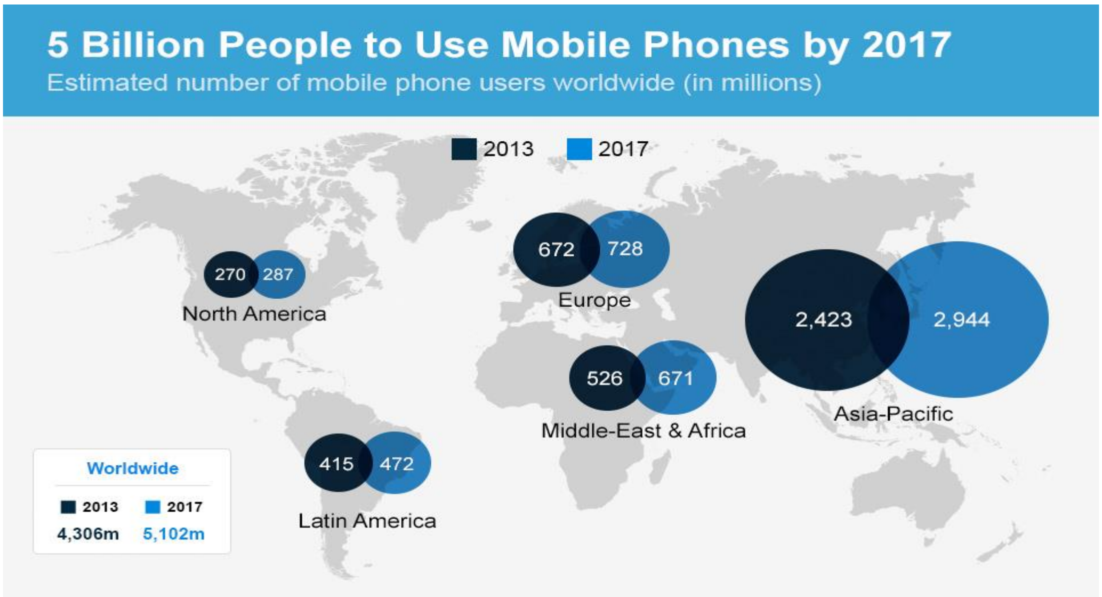

Figure 1.3: Mobile phone users’ worldwide statistics

1.3 Problem Statement

Channel assignment problem is the main focus in this project. There would be an optimization that could be done. Interference in channel assignment or communication system would act as the disruption when making a call in other word, noise. So, the interference or cost values will be calculated by using the problem formulation that would be stated later in next paragraph and will be optimize to get the lower cost values.

The whole network is divided into N cells and total number of channels available is M. The channel request or demand is given in one-dimensional matrix D. The non-interference constraint is stored in a symmetrical $N \times N$ compatibility matrix C. C_{ij} provides the minimum frequency separation between the channels assigned to cells i and j, for a hassle-free task.

Suppose that $X_{j,k}$=$X_{j,l}$=1, calls in cells j and i have been assigned channels k and l, respectively. One way to measure the level of the interference caused by the assignments is to weigh every pair of tasks with a cost tensor $P_{i,j,m}$, where $m = k + 1$ is the distance between channels k and l.

To achieve interference-free assignment, the constraint of $C_{i,j}$ must be met. However, little disruption will be allowed to increase the availability of channels. If the minimum separation limit is violated, interruptions will occur and a penalty value will be imposed by cost tensor, $P_{i,j,m}$.

The penalty cost function indicates severe of the interference occurred between the given channels. In the value function cost of the project this is called the cost value. The problem formulation for the static channel assignment models is described below.

Penalty cost function:

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

where $m = k + 1$

$$X_{j,k} = \begin{cases} 1, & if\ cell\ k\ is\ assign\ to\ channel\ j \\ 0, & otherwise \end{cases}$$

where $j = 1, 2, 3 \ldots N;\ k = 1, 2, 3 \ldots, M.$

$$\sum_{k=1}^{M} X_{j,k} = D_j$$

where $j = 1, 2, 3 \ldots N;\ k = 1, 2, 3 \ldots, M.$

The cost tensor:

$$P_{i,j,m} = \max\{C_{i,j} - m, 0\}$$

where $C_{i,j}$ is a matrix C with column i and row j.

Cost value, $F(X)$ is being charged due to channel disruption. It can be calculated based on the penalty cost function. The higher is the total cost value, the stronger is the interference that occurs between the channels among the cells. Costs are reduced when channels k and l are far from each other. The formula aims to reduce the total cost of penalty occurred.

1.4 Objectives

There are two main objectives associated with this project:

- To optimize channel assignment in cellular network using Tabu Search.
- To improve Tabu criterion and randomizing procedure of Tabu Search method.

1.5 Scope

Channel assignment problem is the primary target in this project in minimizing the disruption. The model used is a Fixed Channel Assignment (FCA) where each cell is assigned to a number of fixed voice channels. Tabu Search technique is being used in this project and Tabu Search coding will be generated using MATLAB software and data is analyzed for 100 maximum iterations which means the recurring coding algorithm is for a maximum of 100 times.

1.6 Significant of Study

The main target in this project is to optimize the limited channel allocation in mobile communications. Low distractions can generate high quality communication. The optimum solution where the channel disruption value is minimized and at the same time the use of existing channels will be maximized and will leading to an efficient communication between users.

1.7 Project Outcomes

At the end of this project the expected result is minimizing interference by improved Tabu Search algorithm for channel assignment problem. To optimize channel assignments, the process of creating an immediate settlement of the best solution in the hope of finding a better solution until the pre-reach trial limit is reached. Analysis will be conducted to confirm the effectiveness of the proposed Tabu Search increase.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Literature research on channel assignment problem, channel allocation schemes and heuristic techniques will be described in this chapter. Heuristic technique is popular when it optimizes the channel assignment problem and has been used by researchers using various types of techniques.

2.2 Communication History and Setting

Communication is one of the important parts that are always focused on exchanging information between users in different locations. The first wire line telephone system was introduced in the year 1877 and mobile communication system as early as 1934 was based on Amplitude Modulations (AM) [1]. With increased demand for newer and better mobile communications and the development of mobile communication systems have started with any new changes. Initially, mobile communication was limited to certain users and the concept cellular was never designed to be commercially made.

However, with the development of newer and better techniques starting from the 1970s and with the mobile users now connected to the Public Switched Telephone Network (PSTN), there has been an astronomical growth in the cellular communication systems[1]. In addition, various movements are defined by the transmitter power, the type of antenna usage and the frequency of operation. With the increasing number of telephone users, the frequency spectrum becomes more limited in its use and has made it a major problem.

2.3 Channel Assignment

The problem of channel assignment in cellular networks has been modelled as an optimization problem with binary solutions. The problem is broken down into several cells and multiple channels. Channel assignment problem can be divided into different categories depending on the comparison basis. It can be divided into three models, Fixed Channel Assignment (FCA), Dynamic Channel Assignment (DCA) and Hybrid Channel Assignment (HCA).

The FCA involves a set of permanent nominal channels allocated to each cell. The number of channels in the system is divided into one set and assigned to the cell to cover the entire coverage area. DCA is the practice in which all channels are stored in a central pool and dynamically assigned to radio cells when a new call arrives in the system. After the call is completed, the channel is restored to the central pool. For HCA, the total number of channels available for service is divided into fixed and dynamic sets. A call blocking probability defined as the probability that a call arrives to a cell and finds both the fixed and dynamic channels busy. HCA scheme is defined as the probability that a call arrives to a cell and finds both the fixed and dynamic channels is busy [2].

2.4 FCA Vs. DCA

There are several comparisons between FCA and DCA. The FCA model is more in line with the high uniform traffic load, while DCA performs better lower traffic density if the traffic loads are not uniform. On the other hand, the FCA model has low freedom in the channel and maximum in the success of the channel but DCA is very flexible to allocate the channels and not necessarily the maximum channel acceptance. Other comparisons between these two schemes are shown in the Table 2.1.

Table 2.1: Comparison between FCA and DCA [2]

Fixed Channel Assignment	**Dynamic Channel Assignment**
Success of maximal channel reuse	Not always success of maximal channel reuse
Sensitive to time and space changes	Insensitive to time and time space changes
Grade is unstable on the service of each cell in an interference cell group	Grade is stable on the service of each cell in an interference cell group
High forced of call rejection probability	Low to moderate forced of call rejection probability
Suitable for large cell environment	Suitable in micro-cellular environment

2.5 Heuristic Techniques in Channel Assignment Problem

Heuristic techniques are the best approach to problem solving that use practical methods but are not optimally guaranteed but sufficient to achieve the goals. There have few main types of heuristic techniques, Genetic Algorithms (GA), Simulated Annealing (SA), Local Search (LS) and Tabu Search (TS).

2.5.1 Genetic Algorithm

Genetic Algorithms and custom heuristic search algorithm based on the idea of natural and genetic selection of evolution. Genetic Algorithms (GA) has been proposed as new computing tool to solve optimization problems. GA techniques are robust and they can deal successfully with a wide range of problem areas [3].

The idea of GA is a combination of good features from a variety of different views and produces highly relevant features and the suitability of the new environment is greater than the existing ones. GA is a recurring procedure that maintains a set of settlement candidates called residents for each iteration. The result observed in the research show that GA can be used to get the optimal solutions for channel assignment in mobile communications [3].

2.5.2 Simulated Annealing

Simulated Annealing (SA) is a random technique which exploits an analogy between the way in which a meta cools and freezes into a minimum energy crystalline structure and the search for a minimum in a more general system [4]. SA has been developed to address a very nonlinear problem. An important feature of SA's algorithm is that it does not require expert knowledge on how to solve specific problems.

Based on previous research, optimization processing is done in a stochastic way where it focuses on optimal solutions globally and is guaranteed if the cooling schedule is low. In the result, SA is very effective in solving combative optimization problems, such as channel assignment problems in radio network planning. This approach has both noisy nature and chaotic searching characteristics, so it can search in a smaller space and continue to search after the disappearance of chaos [5].

2.5.3 Local Search

Local search (LS) is a heuristic method to solve computational optimization problems that are more difficult. LS can be used for problems that can be used for problems that can be formulated as finding solutions in maximizing the criteria among some of the candidate solutions. LS algorithm shifts from solution to another solution in candidate solution space by applying local changes, so that solutions are considered optimal. LS algorithm takes on a neighboring relationship and works according to the following high-level schemes. Throughout the implementation of the algorithm, it remembers the minimum cost settlement so far. Therefore, think about the relationship of one another as defining the graph on the set of all possible solutions with the edges joining the neighboring solution.

Based on previous research, Local Search was developed to a new centralized method that is stochastic local search algorithm for channel assignment problem [6]. The objective is to minimize the network interference while satisfying the interface constraint. The algorithm assigns channels to communication links rather than radio interfaces and not only does preserve the network topology, but is also independent of the network routing layer [6].

2.5.4 Tabu Search

Tabu Search (TS) is a meta-heuristic that guides a local heuristic search procedure to explore the solution space beyond local optimality. One of the main components of TS is the use of custom memory, which creates more flexible search behavior. The adaptive memory feature of TS allows the implementation of procedures that are capable of searching the solution space economically and effectively [7].

Based on the previous research, the basic form of TS is founded on ideas proposed by Fred Glover. Memory-based commencement is a key feature of TS that approaches alternative forms or memory that suit the effective strategies for exploiting them. This method is based on procedures designed to transcend local qualifying or optimum borders, rather than treating them as a barrier. TS are based on the premise that problem solving, in order to qualify as intelligent, must incorporate adaptive memory and responsive exploration [7]. TS can be viewed as a start in the same way as local search or regular neighborhood repeating iteratively from one solution to another until selecting selected criteria meets the conditions. For the examples, there are two types of TS training methods that have been used in optimizing the channel assignment problem which are The Extended Tabu Search method (ETS) and The Tabu Search method with Path Relinking (TSP) [8].

2.6 Conclusion

As a conclusion, communication is one of the process that happen around us in daily life for example when we making a call. There would be an interference that can be occur because we still have very limited channels that can cover all calls. There are many ways that come to solve this problem like reusing the channels also based on all of the heuristic techniques, we overcome the problem of noise and limit the interference. Based on all the heuristic techniques, local search would be a great method in optimizing channel assignment problem because it can be used for problems that can be used for problems that can be formulated as finding solutions in maximizing the criteria among some of the candidate solutions.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Represents the flow of the research about this project. Methodology of this research includes the method that will be carried out to complete the research. Coding algorithms developed based on the Tabu Search method.

3.2 Implementation of Tabu Search in Channel Assignment Problem

To solve the problem of a channel assignment, a group of candidate solutions derived from the current best solution, known as neighborhood will be generated from an initial settlement based on channel requirements. From the list of solutions, the best solution will be selected and the new neighborhood is once again generated based on the current best solution. This process is repeated iteratively and compared to the best solution.

Due to interference contributing to the penalty cost value, coding algorithms will be developed based on problem formulation. Tabu Search algorithm based on the chosen parameter value is needed to solve the channel assignment problem. To generate a solution, the channel is assigned randomly according to the number of channels required in the cells. The general flow of Tabu Search is presented in Figure 3.1.

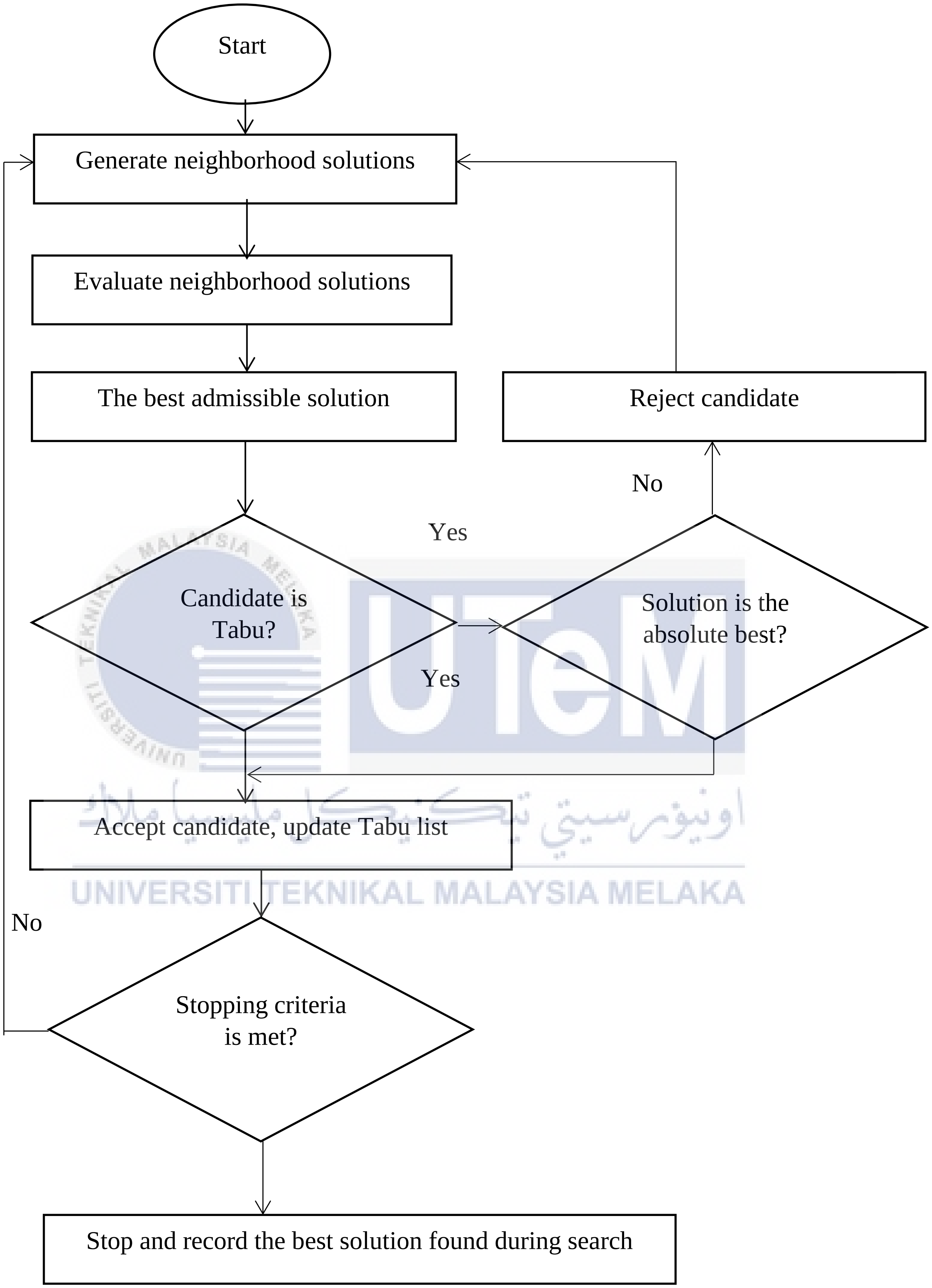

Figure 3.1: Flowchart of Tabu Search method

From Figure 3.1 neighborhood size is selected based on request size. Requests represent the number of channels required in each cell. The initial solution will be evaluated and recorded as the best solution. Based on initial settlement, the neighborhood will be created by changing the allocation of certain channels from the initial solution and the best solution from the neighborhood will be selected.

Then, a new neighborhood is created based on the current best solution and the process repeats for some iterations. After that, all the solutions will be compared and the best solution is accepted. There are several types of termination criteria used in Tabu Search, such as an expiration time interval, the neighborhood set is null, or the iteration number reaches the maximum iteration number setting. The process for best neighborhood solution will stop when the termination criteria is satisfied and therefore final solution is produced.

3.3 Strategies, Parameters and Stopping criteria of Tabu Search

There are several factors influencing the objective function when using TS method; strategies, parameters and stopping criteria. There are three main strategies in TS method; forbidding strategy, freeing strategy and short-term strategy. Forbidding strategy is controlling anything that enters into the tabu list. Freeing strategy is controlling all what and when exits the tabu list. Short-term strategy manages the interactions between prohibited strategies and releasing strategies to selecting trial solutions.

Choosing parameters of Tabu Search is an important aspect because it might give different results. A good configuration can cause the algorithm to converge to best results in a short time while a worse setting can cause algorithm to run for a long time before finding a good solution or even sometimes might result into very good optimization results. Tabu Search comes with some different parameters like neighborhood size, tabu list size, tabu content type and long-term strategies.

There are some immediate stopping conditions or criteria that could be followed, which are there is no feasible solution in the neighborhood solution and K is larger than the maximum number of iterations allowed. The number of iterations will stop since the last improvement is larger than a specified number.

In addition, condition aspiration, form of tabu moves and maximum size of tabu list that will concern most in this project. TS is a major way to exploit memory to classify a subset of movements in a neighborhood as prohibited. Classification relies on search history, and especially on the visibility or frequency of moving components or specific solutions called attributes, have participated in producing past solutions. For the TS stopping condition, stopping criteria can, for example, uses a fixed iteration number, a fixed amount of CPU time, or a successive iteration number without the best objective value enhancement.

3.4 Algorithms of Tabu Search

The demand requirement of the channel assignment, d is shown in a set of data that in total D is 120 channels. The compatibility matrix of the minimum separation of frequency between cell i and cell j is set. The diagonal terms, $C_{i,j}$ = 2 indicate any two channels assigned in the same cell must be at least two frequencies apart. In this project, procedure of randomization is improved from swapping one channel to two channels in the iterations. The notation num_swap represents number of channels swapped in an iteration; 1 for swap one channel and 2 for swap two channels. The data set of channel assignment problem is shown as follows:

Number of cells, $N = 21$

Number of available channels, $M = \{50,60,70,80,90,100\}$

Demand of the number of calls in each of the cells,

$D_j = [2,6,2,2,2,4,4,13,19,7,4,4,7,4,9,14,7,2,2,4,2]$

The minimum of frequency separation constraint between the cells i and j,

$C_{i,j} =$ (shown in Figure 3.3)

```
%Optimization of channel assignment problem using Tabu Search technique
N=21; M=100;  d=[2;6;2;2;2;4;4;13;19;7;4;4;7;4;9;14;7;2;2;4;2];
X=zeros(N,M);
D=0;
num_swap=2; % Choose either 1(swap 1 channel) or 2(swap 2 channels)
```

Figure 3.2: Data set in MATLAB's code

As the iteration runs, the cost value is computed and recorded. The cost value is written in a function handle of 'COSTVALUE' where the process of calling back function is needed in order to evaluate the cost value. The coding of the channel assignment problem in MATLAB's is evaluated the cost value as shown in Figure 3.3.

```
unction costvalue = COSTVALUE(X,N,M,D) %function to calculate cost value
   C=[2 1 1 0 0 1 1 1 1 0 0 0 0 1 1 1 0 0 0 0 0;
   1 2 1 1 0 0 1 1 1 1 0 0 0 0 1 1 1 0 0 0 0;
   1 1 2 1 1 0 0 1 1 1 1 0 0 0 0 1 1 1 0 0 0;
   0 1 1 2 1 0 0 0 1 1 1 1 0 0 0 0 1 1 0 0 0;
   0 0 1 1 2 0 0 0 0 1 1 1 0 0 0 0 0 1 0 0 0;
   1 0 0 0 0 2 1 1 0 0 0 0 1 1 1 0 0 0 0 0 0;
   1 1 0 0 0 1 2 1 1 0 0 0 1 1 1 1 0 0 1 0 0;
   1 1 1 0 0 1 1 2 1 1 0 0 0 1 1 1 1 0 1 1 0;
   1 1 1 1 0 0 1 1 2 1 1 0 0 0 1 1 1 1 1 1 1;
   0 1 1 1 1 0 0 1 1 2 1 1 0 0 0 1 1 1 0 1 1;
   0 0 1 1 1 0 0 0 1 1 2 1 0 0 0 0 1 1 0 0 1;
   0 0 0 1 1 0 0 0 0 1 1 2 0 0 1 0 0 1 0 0 0;
   0 0 0 0 0 1 1 0 0 0 0 0 2 1 1 0 0 0 0 0 0;
   1 0 0 0 0 1 1 1 0 0 0 0 1 2 1 1 0 0 1 0 0;
   1 1 0 0 0 1 1 1 1 0 0 0 1 1 2 1 1 0 1 1 0;
   1 1 1 0 0 0 1 1 1 1 0 0 0 1 1 2 1 1 1 1 1;
   0 1 1 1 0 0 0 1 1 1 1 0 0 0 1 1 2 1 1 1 1;
   0 0 1 1 1 0 0 0 1 1 1 1 0 0 0 1 1 2 0 1 1;
   0 0 0 0 0 0 1 1 1 0 0 0 0 1 1 1 1 0 2 1 1;
   0 0 0 0 0 0 0 1 1 1 0 0 0 0 1 1 1 1 1 2 1;
   0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 1 1 1 1 1 2];

   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 = sum1 + (P*X(i,l)); %sum1 current+previous interference
                end;
            end
            sum2 = sum2 + (X(j,k)*sum1); %sum2 current+previous interference
        end
    end
    sum3=sum2-D*C(1,1); %total interference without interference with itself
    costvalue = sum3/2; %actual cost value of interference
end
```

Figure 3.3: Coding of 'COSTVALUE'

Then, the cost value of coding that will be used to analyze by using the TS techniques. It is an important parameter that control sets of currents and best binary. This is because to ensure process of optimization can be handled properly.

```
%%start to analyze objective function to get the costvalue
Current_CV = 99999;   %start the current cost value high value
Best_CV = 99999;      %start the best cost value high value
iteration = 3;       %this set data will be inner looping for 3 times
K = 100;              %stopping criteria
p=1;  q1=1; q2=1;
Current_X=X         %let binary setX as initialize for currentX
Current_CV = COSTVALUE(X,N,M,D)%calling COSTVALUE function from other file
temp_X=X; %set the assigning channel for initial solution
forbidden_iter=10;
Tabu_list=zeros(N,M);
index=0;
non_improv=0;
```

Figure 3.4: Parameter for Tabu Search algorithm

After that, continue coding algorithm by running the MATLAB's software, the process of giving channel is based on requests that are needed in each cell. Then the process of reallocation of random channels are done by replacing the used channel to an unused channel in the same cell at one time. The stopping criteria is set where the iteration will stop when the solution is not improved for a fixed number of iterations.

```
%starting to create neighbourhood
for r=1:K  %process assigned channel is repeatedly up to K times
    for s=1:iteration  %swap between two channel allocate
        for i=1:N
            %Randomly change the first chosen channel
            k=randi(M);
            for j=k:M
                if (X(i,j)==1)
                    rand_1=j;
                    break
                else
                    for j=1:k
                        if (X(i,j)==1)
                            rand_1=j;
                            index=1;
                            break
                        end
                    end
                    if(index==1)
                        index=0;
                        break
                    end
                end
            end
            for j=1:999
                k=randi(M);
                %avoid assign channel at the used channels
             if (Tabu_list(i,k)<=0 && X(i,k)==0)
                rand_2=k;
                break
             end
         end
         if (d(i)>1 && num_swap==2)% Randomly change the second chosen channel
             k=randi(M);
             for j=k:M
                 if (X(i,j)==1 && j~=rand_1)
                     rand_3=j;
                     break
                 else
                     for j=1:k
                         if (X(i,j)==1 && j~=rand_1)
                             rand_3=j;
                             index=1;
                             break
                         end
                     end
                     if(index==1)
                         index=0;
                         break
                     end
                 end
             end
             for j=1:999
                 k=randi(M);
```

The improvement

```
                %avoid assign channel at the used channels
                if (k~=rand_2 && Tabu_list(i,k)<=0 && X(i,k)==0)
                    rand_4=k;
                    break
                end
            end
        end
        %Update the new assigned channels
        temp_X(i,rand_1)=0;     %the current channel is being move(swap)
        temp_X(i,rand_2)=1;     %the unused channels is being assigned(swap)
        if (d(i)>1 && num_swap==2)
            temp_X(i,rand_3)=0;
            temp_X(i,rand_4)=1;
        end
        CV=COSTVALUE(temp_X,N,M,D);
        if (CV < Current_CV)      %the best solution is chosen
            Current_CV = CV;  %record the current cost value of random channel assigned
            Current_X = temp_X;  %record the assigned channel in each of the cell
            p = i;
            q1 = rand_1;
            if (d(i)>1 && num_swap==2)
                q2 = rand_3;
            end
        end
        temp_X=X;   %the setX is being reset to original setX
    end


    end
    Current_CV
    Current_X

    X=Current_X; %update the current solution
    temp_X=X;
    %tabu list strategy
    Tabu_list(p,q1)=forbidden_iter; %%forbidden strategy (avoid repeating assign the same location)
    if (d(i)>1 && num_swap==2)
        Tabu_list(p,q2)=forbidden_iter;
    end
    Tabu_list=Tabu_list-1        %freeing strategy (iteration decrease)

    if (Current_CV<Best_CV)   %%verify the best solution
        Best_CV=Current_CV
        Best_X=Current_X
    else
        non_improv=non_improv+1;
    end
    %Stopping criteria
    if (non_improv==10)
        break;
    end
end
Best_CV %show the last best solution of cost value
Best_X  %show the last best solution of assigned channels
```

Stopping criteria

Figure 3.5: Improved coding algorithm of TS method

Once the neighborhood is created, the allocated channel is randomly selected and the unused channels are assigned as replacements. In the same time, channels that are being freed are prohibited to allocated back to the next iterations and the iterations will be recorded in the tabu list. Channels used in tabu list was forbidden to be reused in a number of prefixed iterations. This is to avoid creating a set of binaries in the same neighborhood. In other words, all set in a binary different from each other in the neighborhood.

In the process of creating neighborhood solution, it will produce a pool of solutions in which one call is reassigned with a new channel from the current solution. The process keeps repeating as long as the stopping criteria is not reached. Neighborhood solution is created by reallocated assigned channels in a cell in a random method. As a solution is generated, its corresponding cost value is computed using the penalty cost function. The cost value represents the severeness of interference occurred among the assigned channels.

As a conclusion, randomization procedure is improved by swapping two channels in each of the iterations. The interference that occurred during the process can be optimize and with using the randomizing procedure method lowest cost value can get from the lowest number of iterations.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter will elaborate more on the findings gathered of this project. This chapter will perform all the mechanism involved with the result refers to the channel assignment problem. Based on the result, I would discuss about how the Tabu Search technique in optimizing the channel assignment.

4.2 Results and Discussion

The channel assignment problem is resolved by earning initial solution randomly. Furthermore, the required parameters are the number of cells in the region, the number of channels available, the demand requirements or the number call request for each cell and the minimum demand for the call between the calls specified in the compatibility matrix.

Dimension of compatibility matrix presents the minimum frequency constraints between the two calls to get the minimum disruption between the channel assignment. It shows that the minimum requirements of the channels needed to be separated by two frequencies from one another. The channel assignment data is used to run simulations and the results are being analyzed. The given channel is random. The 'num-swap' in coding controls two different functions in reducing the number of iterations in obtaining cost value.

All the results that have been collected are shown in graphical form to be analyzed. There two categories of graphs have been made. Figure 4.1 to Figure 4.5 show the 'Cost Value and Number of Iterations versus Number of Channels'. Figure 4.6 to Figure 4.11 show 'Cost Value and Number of Iterations versus Non – improvement (parameter)'. All the graphs show the effect different randomizing procedure in getting the cost value.

In Figure 4.1 to Figure 4.5, the parameter has been set with the non – improvement in the range from 2 to 10 and the number of channels is from 50 to 100. All the graphs are shown in the following figures.

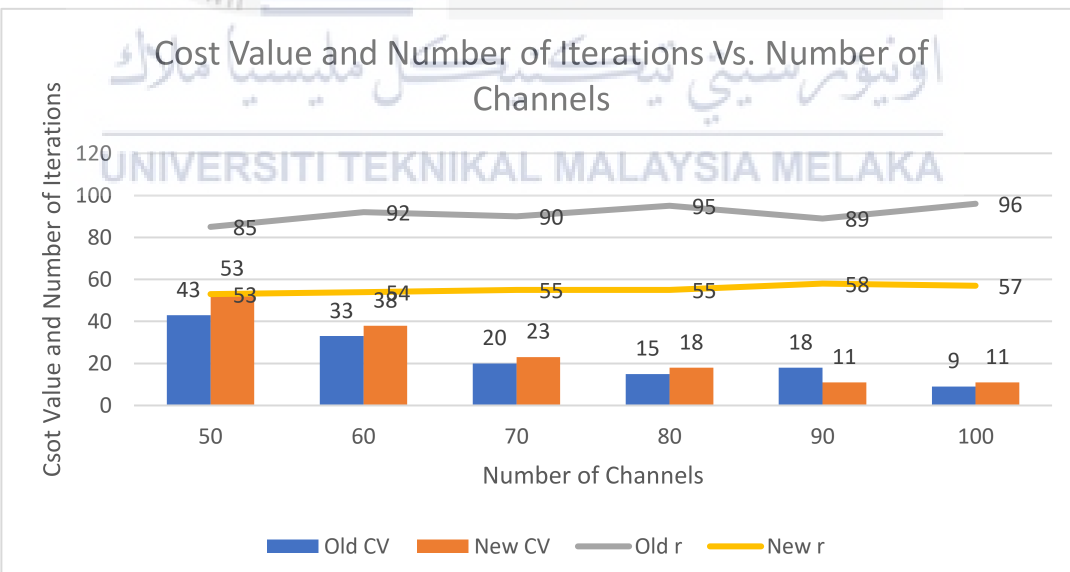

Figure 4.1: Cost Value and Number of Iterations vs. Number of Channels with non – improvement of 2

From Figure 4.1, it shows that the number of iterations, *r*, is reduced by *'NEW' function coding (num_swap = 2)* compared to the *'OLD'* function coding *(num_swap = 1)*. The total average reduction on number of iterations for this graph is 39.09%. All the reductions for each channel are shown in percentage in the Table 4.1.

Table 4.1: Percentage of reduction for Figure 4.1

Number of Channels	r_{old}	r_{new}	Percentage of Reduction (%)
50	85	53	37.65
60	92	54	40.43
70	90	55	38.89
80	95	55	42.11
90	89	58	34.83
100	96	57	40.63

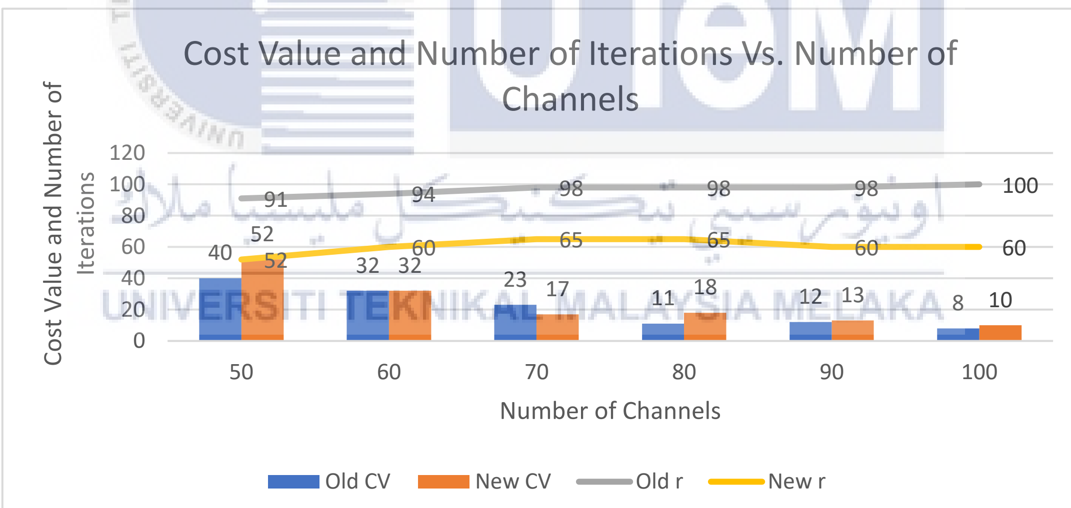

Figure 4.2: Cost Value and Number of Iterations vs. Number of Channels with non – improvement of 4

From Figure 4.2, it shows that the number of iterations, *r*, is reduced by *'NEW' function coding (num_swap = 2)* compared to the *'OLD'* function coding *(num_swap = 1)*. The total average reduction on number of iterations for this graph is 37.53%. All the reductions for each channel are shown in percentage in the Table 4.2.

Table 4.2: Percentage of reduction for Figure 4.2

Number of Channels	r_{old}	r_{new}	Percentage of Reduction (%)
50	91	52	42.86
60	94	60	36.17
70	98	65	33.67
80	98	65	33.67
90	98	60	38.78
100	100	60	40

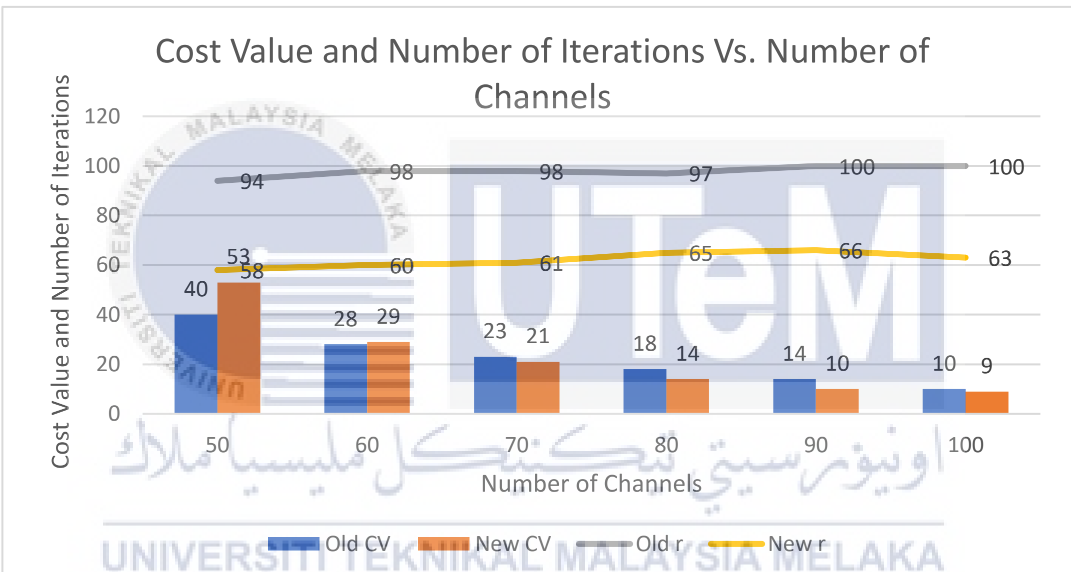

Figure 4.3: Cost Value and Number of Iterations vs. Number of Channels with non – improvement of 6

From Figure 4.3, it shows that the number of iterations, *r*, is reduced by *'NEW' function coding (num_swap = 2)* compared to the *'OLD'* function coding *(num_swap = 1)*. The total average reduction on number of iterations for this graph is 36.48%. All the reductions for each channel are shown in percentage in the Table 4.3.

Table 4.3: Percentage of reduction for Figure 4.3

Number of Channels	r_{old}	r_{new}	Percentage of Reduction (%)
50	94	58	38.3
60	98	60	38.78
70	98	61	37.78
80	97	65	33
90	100	66	34
100	100	63	37

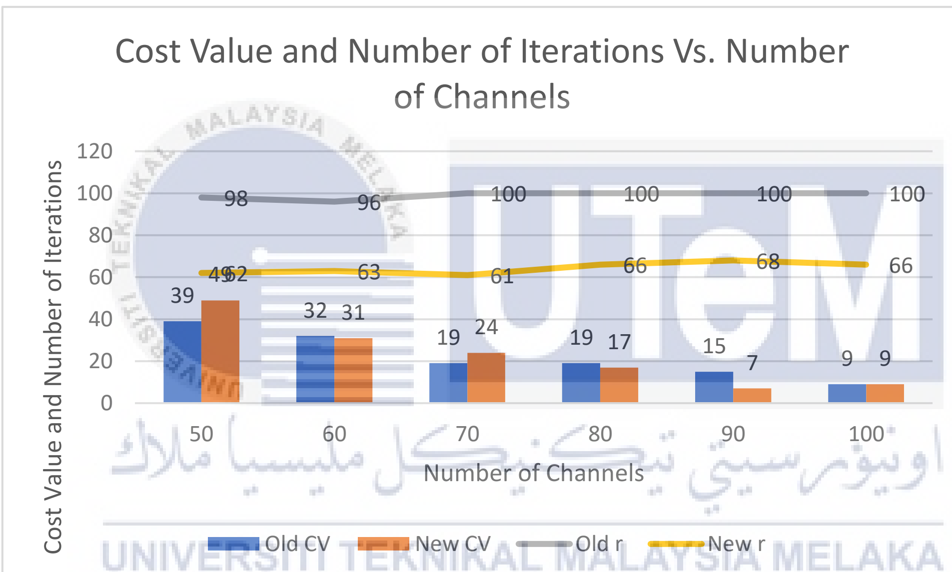

Figure 4.4: Cost Value and Number of Iterations vs. Number of Channels with non – improvement of 8

From Figure 4.4, it shows that the number of iterations, *r*, is reduced by *'NEW' function coding (num_swap = 2)* compared to the *'OLD'* function coding *(num_swap = 1)*. The total average reduction on number of iterations for this graph is 35.02%. All the reductions for each channel are shown in percentage in the Table 4.4.

Table 4.4: Percentage of reduction for Figure 4.4

Number of Channels	r_{old}	r_{new}	Percentage of Reduction (%)
50	98	62	36.73
60	96	63	34.38
70	100	61	39
80	100	66	34
90	100	68	32
100	100	66	34

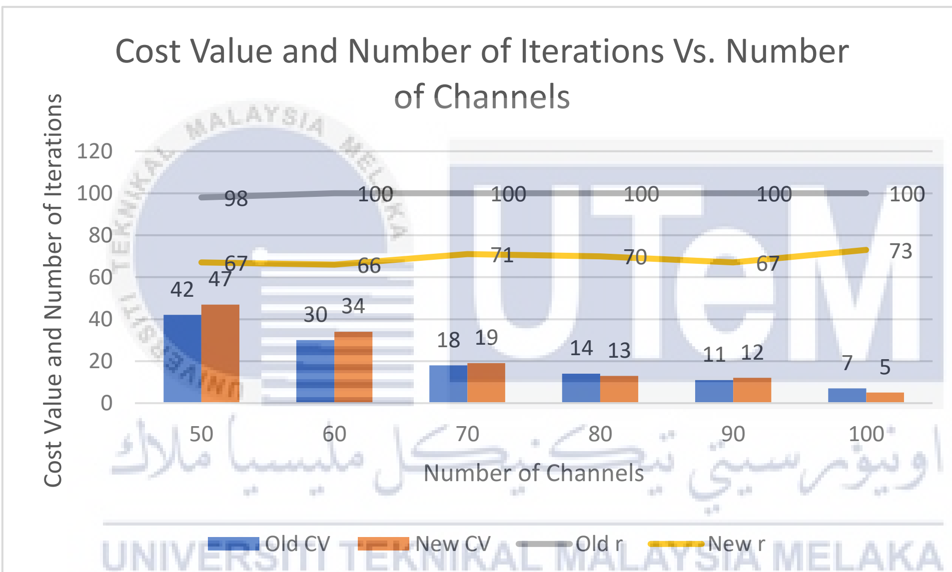

Figure 4.5: Cost Value and Number of Iterations vs. Number of Channels with non – improvement of 10

From Figure 4.5, it shows that the number of iterations, *r*, is reduced by *'NEW' function coding (num_swap = 2)* compared to the *'OLD'* function coding *(num_swap = 1)*. The total average reduction on number of iterations for this graph is 30.77%. All the reductions for each channel are shown in percentage in the Table 4.5.

Table 4.5: Percentage of reduction for Figure 4.5

Number of Channels	r_{old}	r_{new}	Percentage of Reduction (%)
50	98	67	31.63
60	100	66	34
70	100	71	29
80	100	70	30
90	100	67	33
100	100	73	27

As the non – improvement parameter increases, the reduction percentage from each graph the average on cost value reduces. Then, grand total average of reduction percentage on cost value based on the graphs is 35.78%. This shows that after doing the improvement, the efficiency of Tabu Search algorithm is increased as the number of iterations can be reduced to get the reasonable low-cost value.

Subsequently, the analysis is continued with new cost value to identify the lowest cost value. Analysis is done by summing up all new cost values for each graph. As a result, the graph with non – improvement parameter of 10 has the lowest cost value with a total of 130. It shows that non – improvement of 10 is the most optimum.

Table 4.6: New cost value with non – improvement of 10

Number of Channels	New CV
50	47
60	34
70	19
80	13
90	12
100	5
Total	130

Meanwhile, Figure 4.6 to 4.11 present the ‘Cost Value and Number of Iterations Versus Non – improvement (parameter)’ and all the six graphs do not show significant to the cost value. In other words, not influence to cost value or number of iterations. All six graphs are shown below.

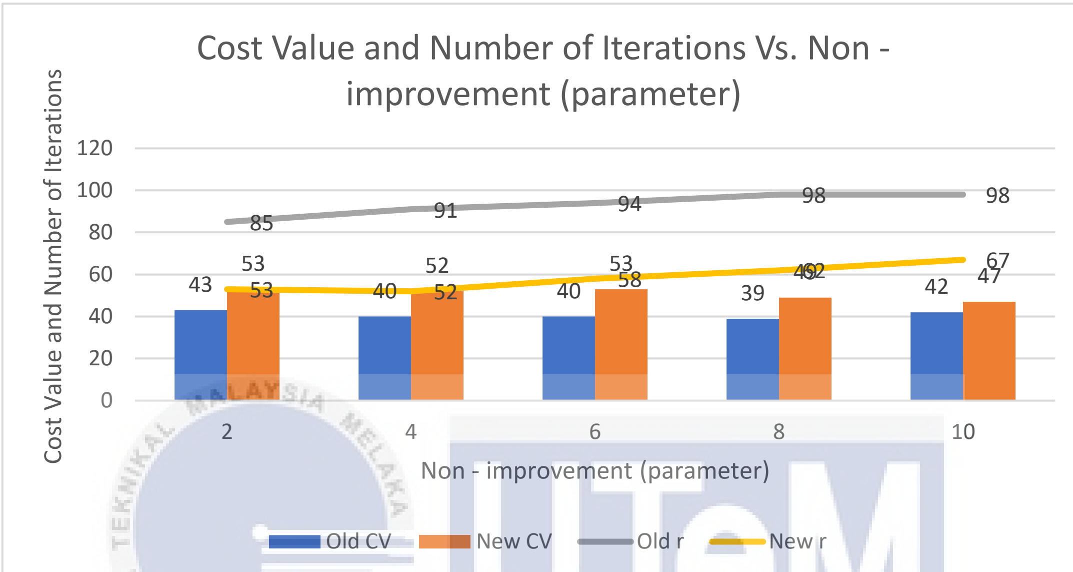

Figure 4.6: Cost Value and Number of Iterations vs. Non – improvement (parameter) with Number of Channel of 50

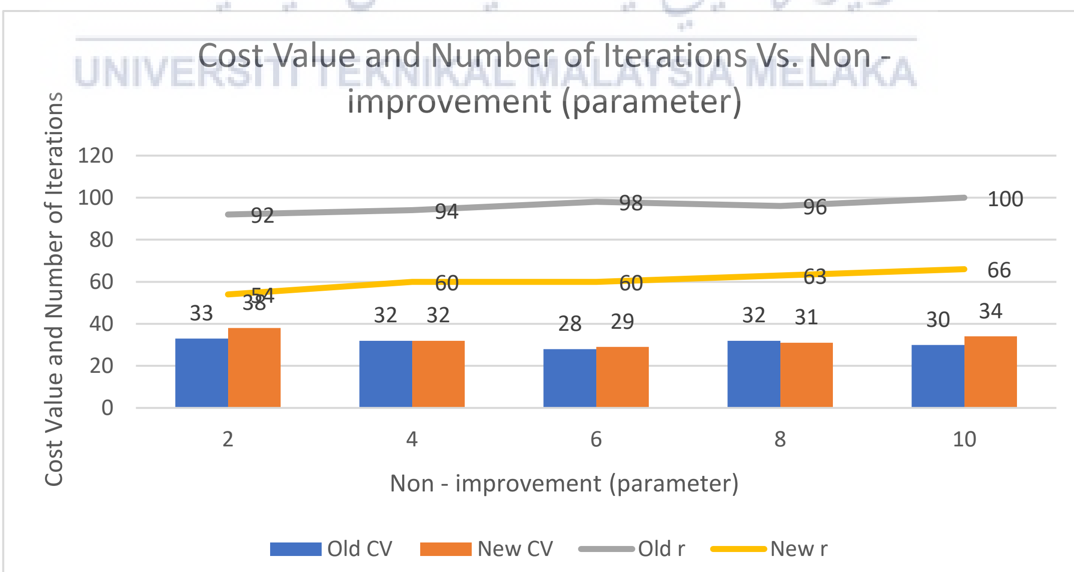

Figure 4.7: Cost Value and Number of Iterations vs. Non – improvement (parameter) with Number of Channel of 60

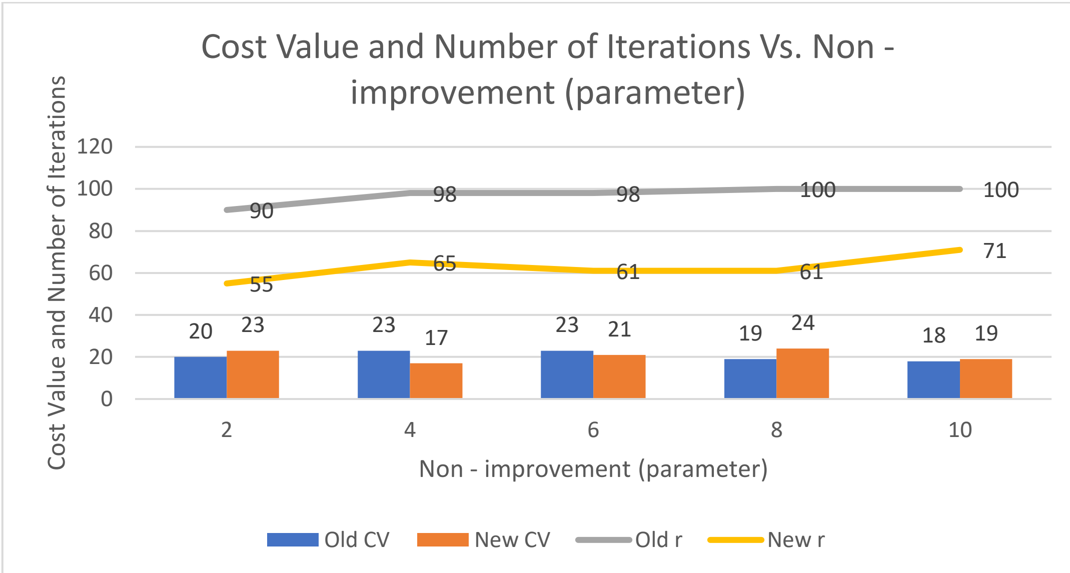

Figure 4.8: Cost Value and Number of Iterations vs. Non – improvement (parameter) with Number of Channel of 70

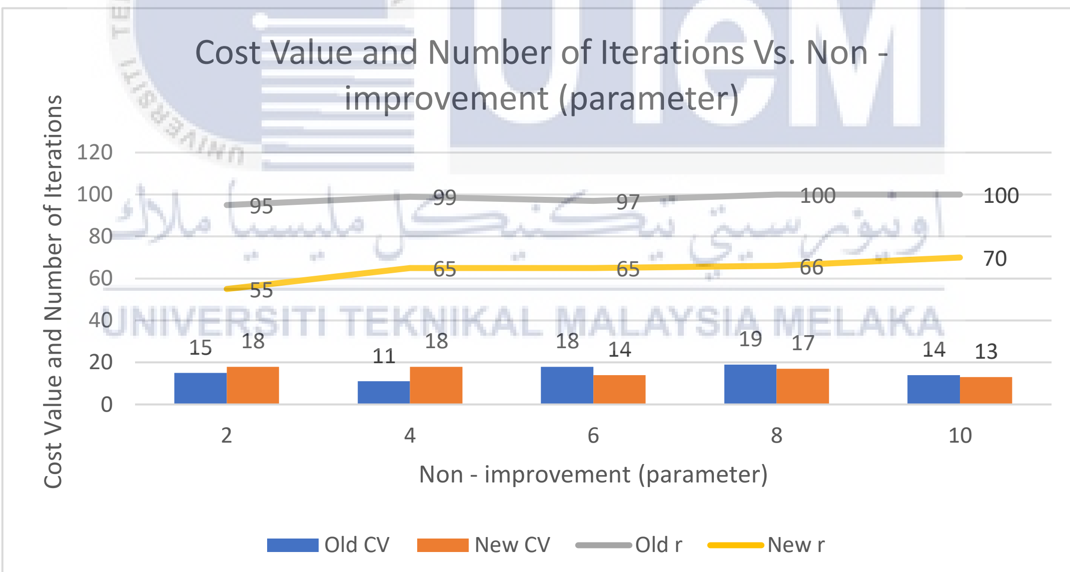

Figure 4.9: Cost Value and Number of Iterations vs. Non – improvement (parameter) with Number of Channel of 80

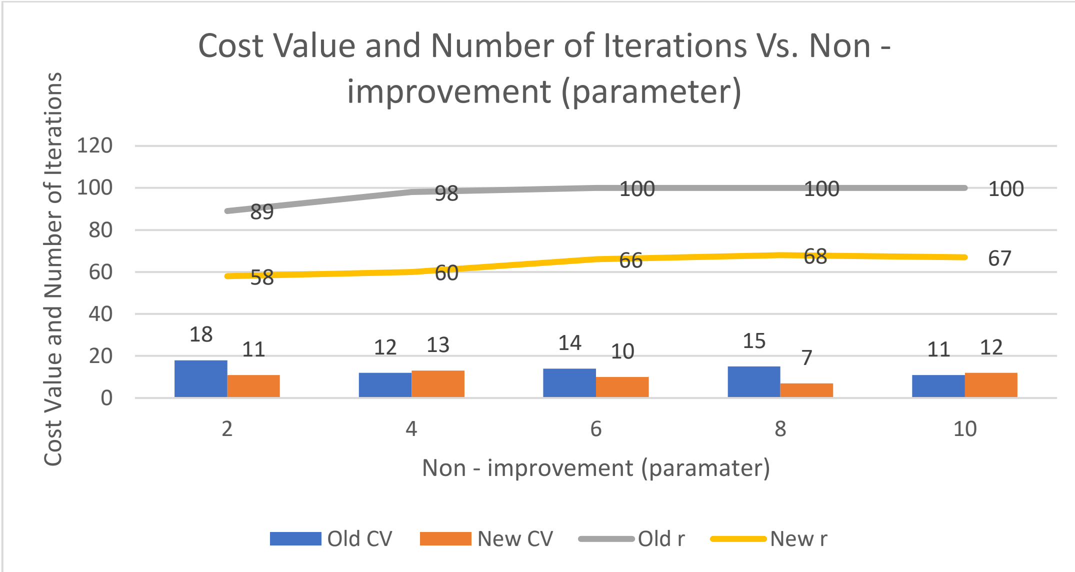

Figure 4.10: Cost Value and Number of Iterations vs. Non – improvement (parameter) with Number of Channel of 90

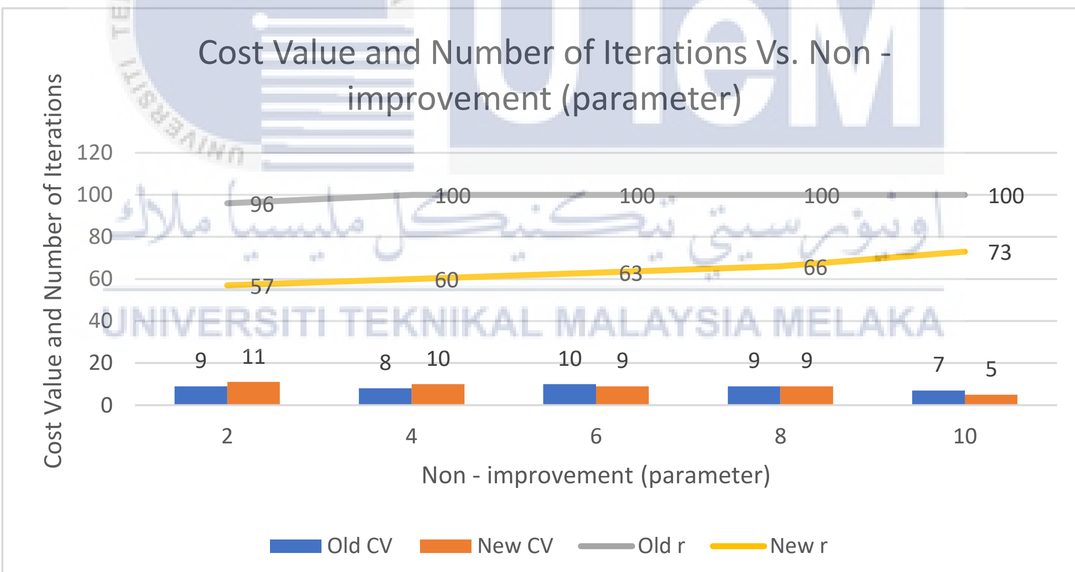

Figure 4.11: Cost Value and Number of Iterations vs. Non – improvement (parameter) with Number of Channel of 100

From all the results, it shows that non – improvement has given an effect on the percentage of reduction on number of iterations. It is because higher non – improvement parameter allows iteration to proceed to reach better result. In this project, non – improvement of 10 gives the best optimum solution.

Then, number of channels also have an effect on the cost value the higher the number of channels, the lower is the cost values. Conclusion can be made that higher the number of channels lead the lower cost value. This is because when the number of a valuable channels is high, interference can be reduced.

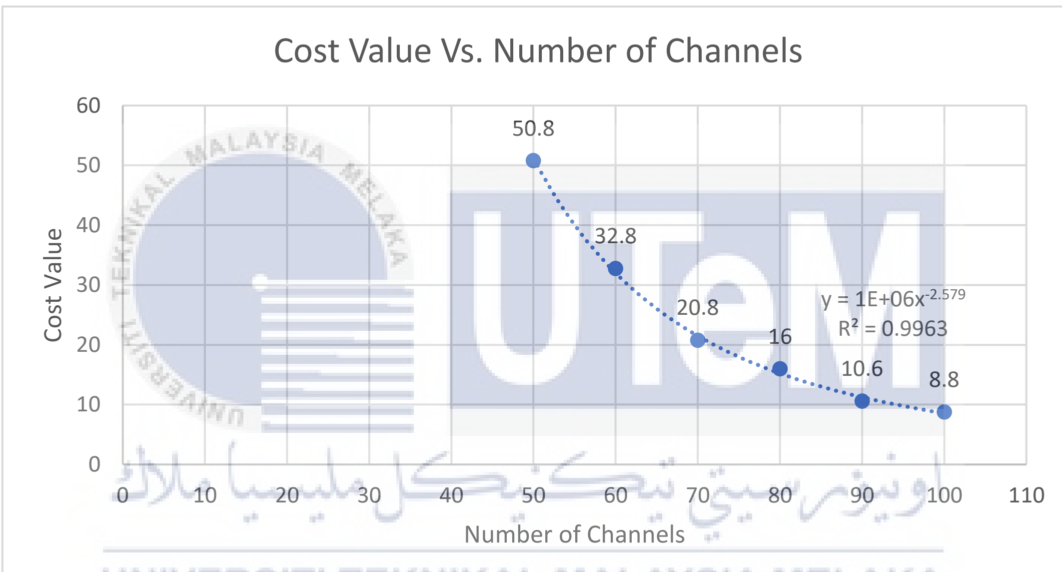

Figure 4.12: Cost Value vs. Number of Channels

Figure 4.12 shows that the effect of number of channels on cost value. From the graphs, number of channels are between 50 to 100, meanwhile, the cost value are the data that collected before that in form of average of cost value. It shows that the higher the number of channels the lower is the cost value.

As a conclusion, from all the results that been collected it shows that number of channels can make a different to cost value that the bigger the number of channels the smaller cost value. Other than that, after doing some improvement, the number of iteration can be reduced to get the cost value.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, this project presents the implementation of Tabu Search in solving the problem of channel assignment in mobile communications but still interference should be allowed at a minimum level. The cost value is calculated based on the problem formulation for each settlement of the candidate solutions. The lower the cost value represents the lower the disturbances.

The coding algorithm is developed based on Tabu Search technique using MATLAB software to complete the search for channel assignment problems. Optimization of channel assignment is achieved when optimum solutions are found based on the best solution which is the lowest cost value when termination criteria is met. The optimal solution is obtained by carrying out the parameter of Tabu Search using the developed coding algorithm.

A conclusion has been made as the higher the number of available channels the lower is the cost value. In other words, the bigger the number of channel the smaller the interferences that can occurs. After doing some improvement and some randomizing procedure, the number of iterations to calculate the cost value also can be reduced.

5.2 Recommendation

In a real life, the available number of channels are very limited so the interference still exists in communication system. Then, the interference can still be optimized by using the hybrid channel assignment of channels borrowing strategy due to our limited available number of channels.

REFERENCES

[1] C. Engineering, "Lecture Notes on Mobile Communication," no. November, 2009.

[2] Cheeneebash, Jayrani, Rughooputh, and Harry, *A Comprehensive Review of Methods for the Channel Allocation Problem*. 2014.

[3] N. M. Nasrabadi, "Genetic Algorithms Approach to the Channel Assignment Problem," *Asia-Pacific Conf. Commun.*, vol. 2, pp. 564–567, 1995.

[4] N. B. Prajapati, R. R. Agravat, and M. I. Hasan, "S Imulated a Nnealing for L Ocation a Rea," pp. 1–7, 2010.

[5] S. Li and L. Wang, "Channel assignment for mobile communications using stochastic chaotic simulated annealing," *Connect. Model. Neurons, Learn. Process. Artif. Intell.*, pp. 757–764, 2001.

[6] M. A. H. Newton, D. N. Pham, W. L. Tan, M. Portmann, and A. Sattar, "Stochastic Local Search Based Channel Assignment in Wireless Mesh Networks," pp. 832–847, 2013.

[7] F. Glover, M. Laguna, and R. Marti, "Principles of tabu search," *Approx. Algorithms Metaheuristics*, vol. 23, pp. 1–12, 2007.

[8] F. Glover and R. Martí, "Tabu Search," *Tabu Search*, pp. 1–16, 1986.

APPENDIX

Appendix A: Project Gantt Chart