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A HYBRID ALGORITHM FOR SOLVING FREQUENCY ASSIGNMENT PROBLEM IN CELLULAR NETWORK

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Abstract

Frequency allocation problem is considered an NP problem which requires a large search space to find the optimal solution. This paper presents a hybrid algorithm between the Hopfield neural network and the tabu search techniques algorithm to allocate frequencies in the cells of cellular network. The cellular telephone system is composed of small regions called cells, it's depends on the principles of frequencies reuse due to the limited number of frequencies. As a result to this reuse the problem of frequency allocation is a raised. Simply it can be defined as the allocation of different frequencies to each cell and it's neighbouring. In this hybridization the principles of short term memory and candidate list in tabu search are embedded in Hopfield neural network to control the operation of neuron selection.

Keywords: Hopfield neural network, Tabu search, Frequency allocation, Frequency reuse, Hybrid techniques.

1. Introduction

The cellular telephone system is composed of small regions called cells. Each cell is provided with an antenna for frequency propagation, this antenna is controlled by AC powered network called base station [1]. Cell size and cell proliferation are relate to each other in regulated processes such that the increase in population will increase cell size [2]. Frequency reuse is one of the fundamental concepts in wireless systems that involve the partitioning of an RF radiating area into cells [3]. However, the re-use principles raises the problem of frequency assignments [4], which require a careful planning to avoid co-channel interference (i.e., different user in neighbouring cell must not use the same frequency for communication) [5]. Many methods have been proposed to solve this problem like graph colouring techniques [6], lower bounds [7], and allocation method [1]. For research purpose the cellular area is considered as undirected graph G= (V, E), where vertex represents

Nomenclatures

E	Set of edges
E obj	objective function,
Eg	Energy
F	Set of frequency
f(v)	Frequency at cell v
f(w)	Frequency at cell w
Fit c,f	fitness of neuron at location (c, f),
G	Undirected graph
H	Available frequency
M	Set of neighbourhood
N	Set of Neighbourhood
n	Set of used frequency
netk	Activation of Neuron k
Sk(t)	Current state
Sk(t+1)	New State
Tc,f	Threshold for neuron at location c,f
Uk	Threshold of State k
v	Cell in cellular area
V	Set of vertex
V c,f	Output of neuron at location (c,f).
w	Cell in cellular area
X	Set of solution
x	Current solution
y	Best solution
Wjk	Weight between Neuron j and k
Yj	Output of Neuron j

Greek Symbols

Θ_k	Bias

Abbreviations

FAP	Frequency Allocation Problem
HNN	Hopfield Neural Network
TS	Tabu Search

cell and edge represents connectivity. F is a finite set of frequency, if (v, w) € E then f (v) ≠ f(w) (i.e., if cell (v) and cell (w) is a neighbour then a frequency f can be assigned to cell (v) only if this frequency is not assigned to cell (w) [8].

2. Tabu Search

Tabu Search (TS) is an iterative procedure designed for the solution of optimization problems. TS starts with a random solution and evaluates the fitness function for the given solution. Then all possible neighbours of the given solution are generated and evaluated [9]. TS exploit data structures of the search history as condition of the next move. Following is how simple TS works

i. Let X= current solution

ii. Generate neighbouring solution x∈ N.

iii. Find best neighbouring solution y.

iv. Check if y is accessible, if yes, replace current solution X=Y otherwise select best neighbour and continue check.

3. Hopfield Neural Network

A Hopfield net is a recurrent neural network that has a synaptic connection pattern such that there is an underlying Lyapunov function for the activity dynamics. Started in any initial state, the state of the system evolves to a final state; that is a (local) minimum of the Lyapunov function [10]. The Hopfield network consists of a set of ***N*** interconnected neurons which update their activation values asynchronously and independently of other neurons. All neurons are both input and output ones. The activation values are binary. Originally, Hopfield chose activation values of **1** and **0** for binary network or values **+1** and **-1** for continuous network [11]. Figure 1 shows simple Hopfield networks with 3 neurons. The necessary equations for modelling the network are:

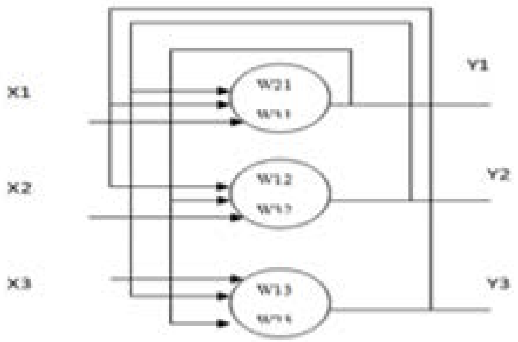

Fig. 1. Hopfield NN with 3 neurons.

4. Proposed Work

The cellular area in HNN model is represented as an $F \times C$ matrix of neuron, where *f* is the row number and represents the possible allowed frequency. *C* is the column number and represents the cell number in the cellular area. Each neuron in the matrix is identified by double indices *(f,c)*. The neuron at location *(f,c)* shows the frequency allocated to a specified cell denoted by *c*. In order to characterize the neuron activity at location *(f,c)*. The neuron state $V_{f,c}$ is defined as :

$$V\, f,c = \begin{cases} 1 & \text{if frequency f is allocated to cell c} \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

In this matrix there is more than one neuron active at the same row but only one neuron allowed to be active at the same column to discourage allocating more than one frequency to the same cell.

The objective function is defined as:

$$E_{obj} = -\frac{1}{2}\sum_{f=1}^{F}\sum_{c=1}^{C} fit_{f,c} \ V_{f,c} \tag{2}$$

Fitness of neuron is computed related to the cell based on the number of neighbourhood cell that have the same frequency. In the best case ***fit = 0***, which mean no interference among neighbouring cell.

Two Types of connection weights are used, **connection weights** between neuron at the same row or different row and column, these weight are assigned to a positive value and connection weight between neuron at the same column, this weight is assigned a negative value = -1, to discourage activate them. This is computed based on the fitness value as follows:

$$bias = \frac{1}{(fit+1)} \tag{3}$$

In the best case when ***f*** **= 0**, the ***bias*** **=1**.

Neuron selection process is controlled by the short term memory or the recency based memory where the selected neuron is either blocked in reset or unchanged state for specified number of iteration determined by using tabu-Active tenure. The tabu-active tenure is computed based on the difference between the maximum number of allowed frequency and the number of neighbourhood interferences frequency and can formulated as follows:

$$\textit{Tabu-Active} = \begin{cases} F-n & if\ F-n>0 \\ F & if\ F-n=0 \end{cases} \tag{4}$$

In fact tabu-active tenure can take arrange of value from 1 to F. the worst case for tabu- active tenure = 0, this mean there is an interference with all frequency set , in this case the tabu-active is set to F.

Neurons that are candidate for activation is stored in candidate. Each time a specified neuron is deactivated and added to block list in the form (c,f,tabu-active), a new candidate list item is added in the form ***(C,H)***,where C is the old interference cell and H is the hamming distance between the maximum number of frequency allowed and the number of neighborhood frequency of all frequency for example, if all allowed frequency is (1,2,3) and interference set is (2,3) then, H = 1, threshold value control the neuron state and its effected by the tabu-active value and computed as follow:

$$Tc,f = \begin{cases} net\ c,f & if\ Tabu-Active=0 \\ F\times net\ c,f & if\ \ Tabu-Active>0 \end{cases} \tag{5}$$

The necessary steps for the proposed work are explained in Fig. 2.

5. Simulation and Discussion

The proposed hybrid algorithm is implemented on a cellular area consisting of 19 cells as shown in Fig. 3. Only four frequencies available in frequency set which is (1, 2, 3, 4) respectively. For implementation purpose the cellular area is represented using adjuncy matrix to reflect the neighbourhood relationship among cells, where 1 indicates there is a neighbour and 0 indicates there is no neighbourhood relationship. External and internal modelling for the problem using HNN is shown in Figs. 4 and 5 respectively. The simulation process start with a solution constructed with in heuristic way s= 12243242314123342432 and explained in Fig. 6.

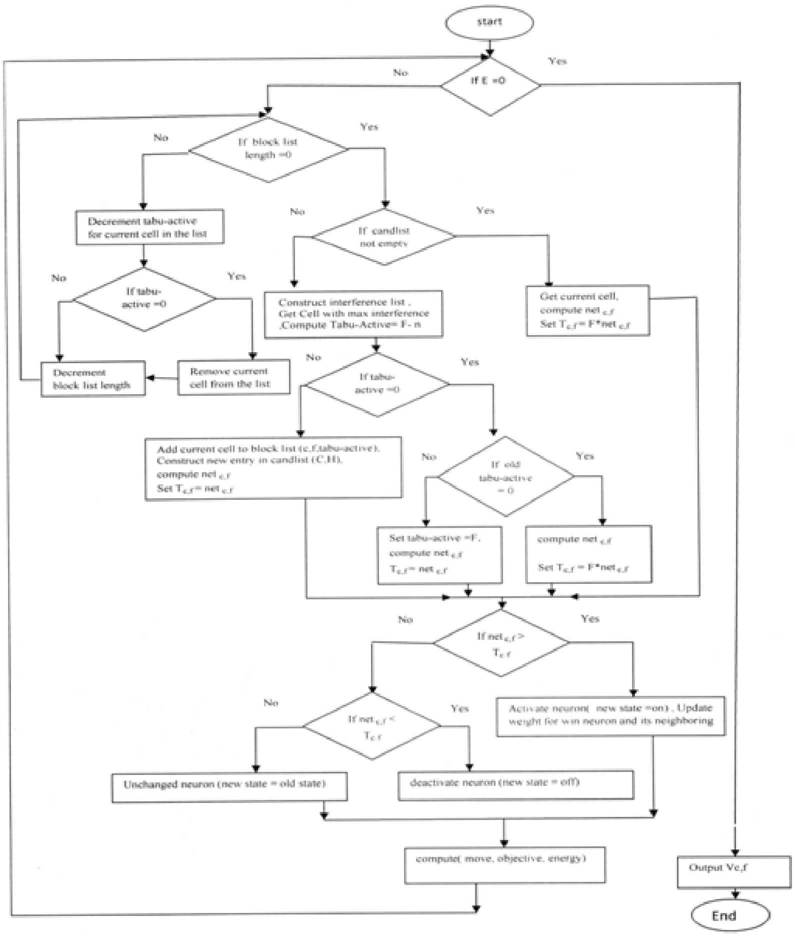

Fig. 2. Flowchart of proposed algorithm.

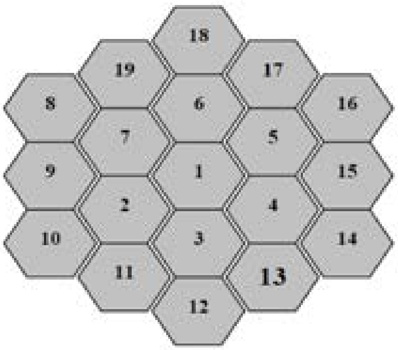

Fig. 3. Cellular area.

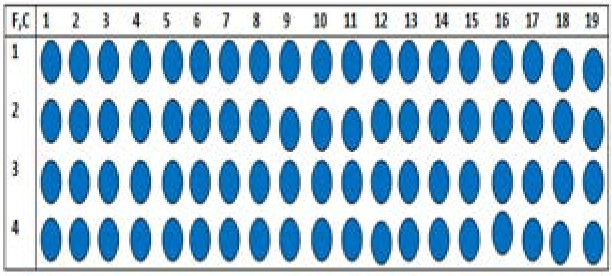

Fig. 4. HNN model for cellular area of 19 cells and 4 frequencies.

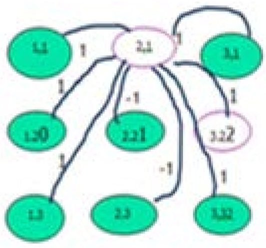

Fig. 5. Part of HNN model consisting of 3 cells and 3 frequencies.

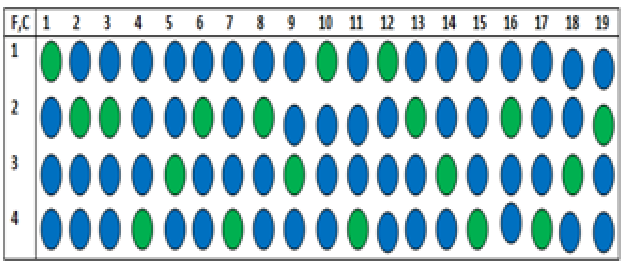

Fig. 6. Initial solution, objective =12, E= -3.5.

Tables 1 and 2 show how the research problem is solved using the proposed algorithm. It summarizes two different cases for the problem. The first case, when there is available frequency in frequency set to be used among the selected interference cell and its neighbouring cells, this case is solved in two steps, at first step, cell detection and deactivation is done and at the second step, cell activation is implemented. According to the algorithm flowchart in Fig. 2, this process is demonstrated in first and second iteration respectively in the table. At first iteration, the set of all interference cells and its number of interference is constructed as shown in Colum 1, then the cell with maximum interference number is selected which is cell (3,2), the tabu-active is computed and its equal to 1 (column 5), this means that the cell will be blocked (deactivated) for one iteration (column 6). At the same time a candidate item is added with new available frequency from frequency set which is 3 and the formed pair is (3,3) Colum 3. Finally, the energy is computed to check the stopping condition besides new move and new objective value columns (8, 9, 10) respectively. The resulted solution is shown in Fig. 7. In this figure the deactivated neuron is marked with red colour and the candidate neuron is marked with yellow circle. In the second iteration, the given item in the candidate list is selected and activated in column 6. The new solution is shown in Fig. 6. In the second case when there is no available frequency, the algorithm simply blocks the given cell for a number of iteration equal to the maximum number of interference. And there is no candidate item computation, as shown in 5th iteration in the table as shown in Fig. 7. In this figure cell at locations (4, 4) is marked with red circle to indicate that it is unchanged. The algorithm continue working for 7 iterations until find the required solution with energy = 0, Fig. 8.

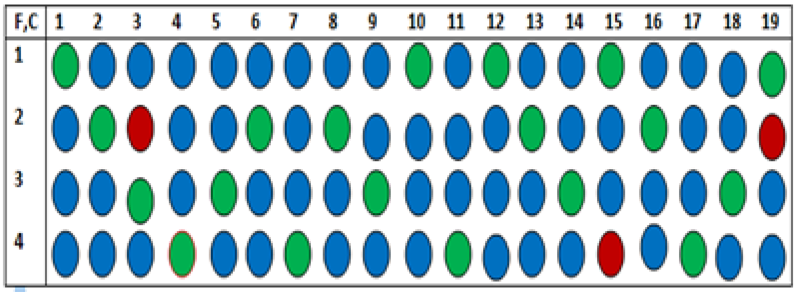

Fig. 7. Result solution after 5 Iterations.

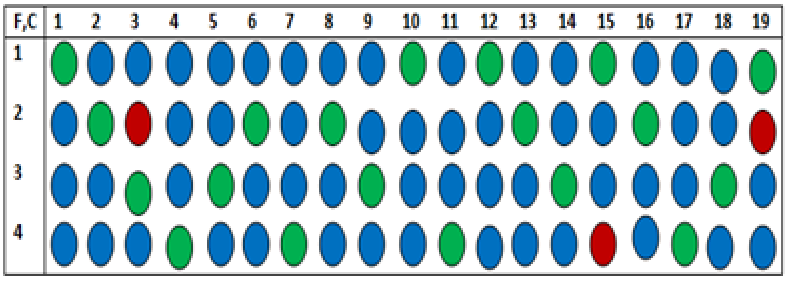

Fig. 8. Final solution in the HNN model after 7 iterations.

Table 1. Summary of HNN-TS implementation.

epoch	**Set of interference** (cell, No. of interference)	**Candidate list** (cell, H)	**Selected neuron** (cell, freq.)	**Tabu-active**	**Tabu tenure**	
					Block (c,f,tabu)	**Active (c, H),** (state = On)
1	(3,2), (4,1), (6,1), (15,1), (19,2)	(3,3)	(3,2)	1	(3,2,1)	-
2	(4,1), (6,1), (15,1), (19,2)	-	(3,3)	0	-	(3,3)
3	(4,1), (6,1), (15,1), (19,2)	(19,1)	(19,2)	1	(19,2,1)	-
4	((4,1), (6,1), (15,1)	-	(19,1)	0	-	(19,1)
5	(4,1), (15,1)	-	(4,4)	4	(4,4,4)	-
6	(15,1)	(15,1)	(15,4)	4	(4,4,3), (15,4,4)	-
7	-	-	(15,1)	-	(4,4,2), (15,4,3)	(15,1)

Table 2. Summary of final results.

epoch	**Objective value**	**Move value** Diff(oldobj, newobj)	**Energy value**
1	-	12	-3.5
2	14	2	-2.5
3	14	2	-2.5
4	16	2	-1.5
5	16	2	-1
6	16	2	-0.5
7	19	3	0

6. Conclusion

In this paper a hybrid algorithm was proposed based on the Hopfield neural network and tabu search, the hybridization is an embedded type, where the short term memory and tabu restriction of candidate list is used is used to control the neuron in Hopfield network. The proposed algorithm is used to assign frequency in cellular network. An experimental result shows that the algorithm can find optimal solution for a given initial solution after 7 iterations.

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