A NEW DYNAMIC SINGLE-ROW ROUTING FOR CHANNEL ASSIGNMENTS

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Abstract

One of the graph theoretic approaches of channel assignment for cellular networks is routing a pair of nodes arranged in a single-row axis called single-row routing problem. The network with nodes representing caller and receiver is to be transformed into a single-row network efficiently is proposed. The connected graph derived from the base network is presented using incidence matrix. The rows and columns of the matrix represent the ordered list of zones and ordered list of nets respectively for the Single-row network. By successive row-interchange of the matrix, maximum number of nodes adjacent to each other can be placed with minimum distance. The proposed method with the support of ESSR bySalleh in [2], only increases the speed of convergence to the optimal ordering of nets but also find the minimum value of energy function, street congestion and the number of doglegs. The comparative analysis between the traditional method and the proposed method is also discussed.

Keywords: *Single-row routing; ESSR; street congestion; doglegs; incidence matrix*.

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1. INTRODUCTION

In recent years, there has been a tremendous growth in the demand for wireless cellular networks. The cellular principle partitions a geographical area into cells where each cell has a base station and a number of mobile terminals (e.g. mobile phones). A group of base stations are connected to the Mobile Switching Center (MSC). The MSC monitors all the mobile users inside or outside the cells of its own network via the base stations. Users communicate each other by obtaining conflict-free channels from MSC. The cells denoted as c_i for i = 1, 2...n, in a network are generally regular hexagon in shape as proposed by R.Mathar in [10] and by V. H. MacDonald in [11].

Most of the engineering and science problems are presented based on graph.To solve channel assignment problem for cellular networks, the graph which represents the problem is transformed into single-row network (S). Due to the frequent change in the shape of the graph, channel assignment is performed in the network using a routing method known as dynamic single-row routing.

In this model, a set of m evenly-spaced pins (terminals or vias), p_i for 1, 2...m, arranged horizontally from left to right in a single horizontal row called *single-row axis.* Each path joining the pair of pins is called a *net*. The problem is to construct $m/2$ nets $L=\{N_k\}$, for $k = 1,2,\ldots m/2$, formed from the horizontal intervals (b_k,e_k) on the node axis, where pins b_k and e_k are the extremities of the intervals. Each of the net is formed from a pair of pins through non-intersecting vertical and horizontal line segments drawn only in the direction from left to right. Physically, each net in the single-row provides a conductor path for its pins to communicate. The area above and below the node axis are called the *upper street* and *lower street* respectively. Thus,

$$Q = \max (Q_u, Q_l) \qquad (1)$$

where, Q, Q_u and Q_l are overall, upper and lower street congestions respectively. The net crossing on the node axis, called a *dogleg* or inter-street crossing. The objective of single-row routing is to minimize both street congestion (Q) and number of doglegs (D). S.Salleh et al. in [2] proposed a model called ESSR (*Enhanced Simulated annealing technique for Single-row Routing*) where the energy functions is directly proportional to the absolute sum of the height of segments of the tracks:

$$\text{Energy, E} = \sum_{k=1}^{m/2} \sum_{j=1}^{m_k} \left| h_{k,j} \right| \qquad (2)$$

In equation (2), $h_{k,j}$ is the height of segment j in the net k , while m_k is the number of segments in the net k. ESSR finds optimal results in terms of both street congestion and number of doglegs. The energy for the given net list is formulated as a function of the street congestion (Q) and number of doglegs (D), or $E= f(Q, D)$. The basics of simulated annealing approach are to find the optimal result in terms of both minimum street congestion and number of doglegs through a series of iterative steps. In this approach a list of nets L is formed according to their positions from top to bottom. The list of nets generated initially is treated as L_0 and start the process with initial high temperature. The initial value of energy function E_0 is also recorded. The temperature is then lowered gradually, where at the same time, the position of a set of nets in the list are swapped. The new energy is recorded and its difference from the old energy known as ∂E determines whether the new list is accepted or rejected. The new list is accepted if $\partial E \leq 0$. If $\partial E > 0$ then the new list is accepted only if its Boltzmann probability given by $P(\partial E) = e^{-\partial E/T}$ is greater than some threshold value, ϵ. This annealing step is repeated until the energy becomes minimum and that no further improvement is observed after several iterations. The new list corresponding to this minimum energy is then the solution to the problem, and this list produces the desired least-congested routing.

The rest of this paper is organized as follows. Section 2 presents preliminaries, in which related works and the motivations for our method are discussed? The details of the proposed method and algorithms are discussed in section 3. Section 4 analyses the proposed method through experiment using open software Scilab-5.4.1. And finally, the paper is concluded in section 5 with future direction.

2. PRILIMINARIES

Considering all the callers and receivers belonging to the same network, the problem is to assign *n* channels to the *m* telephone calls at a discrete time *t*. Each call requires two channels, one for the caller and another for the receiver. In order to assign the channels on real-time basis to the caller and the receiver, the network needs to be transformed into single-row network. The methodology is that initially a connected graph is to be formed from the given network. Then the graph is transformed into a single-row network. Many researchers have studied on the transformation of single-row networks from various types graphs for the purpose of the design of circuits in VLSI as proposed by Johar et al in [9]. In [1], Salleh et al. proposed a model for transforming the connected graph into its single-row, in which, the graph is partitioned into several disjoint cliques using the Hopfield neural network. Then the corresponding interval graph is generated with matching nodes in the single-row axis. Finally, they applied ESSR technique to obtain its least congested single-row routing. Salleh et al. in [2] proposed ESSR model, where local minimum converges to the global minimum in faster. Norazia et al. in [3] proposed a new technique based on graph clustering by using *k*-means algorithm. The ESSR was used to obtain the optimum single-row network and also could minimize the inter-street crossing (doglegs). Loh et al. in [6] implemented spanning tree model for this problem. Salleh et al. in [4] proposed a technique for transforming complete graph into its single-row representation and also applied the single-row routing in the channel assignment problem for wireless cellular network system. Salleh and Sarmin in [5] studied the real-time simulation of channel assignment in wireless cellular network using single-row routing techniques.

The model proposed by Salleh et al. in [5] motivates to transform the given connected graph into single-row network using incidence matrix in order to find local optimal solution subject to minimizing the value of energy function, street congestions and number of doglegs in the problem of dynamic single-row routing. By arranging all the adjacent vertices as near as possible, the energy value of the nets for the single-row network could be diminished to zero. However, most of the previous works in the single-row routing problem have implemented the technique of spanning tree or clique finding to transform the connected graph into single-row network. By using incidence matrix for the connected graph, it is easier to arrange the adjacent vertices (zones) nearest to each other by interchanging the appropriate rows. This continues till the number of two consecutive 1's in the columns of the matrix is at least (*v-1*), where *v* is the number of vertices (zones) of the graph (network S). So that the energy value produced by the nets formed by the nearest adjacent zones could be zero. In this way the ordering of the zones as well as the ordering of nets for the single-row network can be obtained in polynomial time. Since the proper ordering of zones directly affect the speed of convergence to the optimal solution, therefore instead of selecting the initial list of nets either in random or sequential as proposed by Kuh et al. in [2] and by Loh et al. in [9], the initial list is selected from the proposed model can expedite the speed of convergence to the optimal solution than the models proposed earlier. The intervals for the single-row network obtained in this process are now mapped to the nets by one-to-one correspond. The nets made up of horizontal and vertical line segments in unidirectional i.e., is from left to right without crossing each other.

3. SINGLE-ROW ROUTING NETWORK

In the first step the base network showing the requests for channels by the communicating users is considered. In the second step the above network is converted into a connected graph known as *G*. The given graph is now represented as an incidence matrix with n-rows and m-columns in the third step. The ordering of rows is based on the ordering of degrees of the vertices of the graph G. That is, if $deg(v_1) \leq deg(v_2) \ldots \leq deg(v_n)$, then the first row will contain v_1, second row will contain v_2 and so on. The elements of incidence matrix *M* of graph *G* is defined as,

$$a_{i,j} = \begin{cases} 1, \, if\ j-th\ edge\ incidence\ with\ i-th\ vertex \\ 0, \, Otherwise \end{cases} \quad (3)$$

In fourth step, interchange two appropriate rows in each iteration until the number of two consecutive 1's in the columns of the matrix is at least (*v-1*). In fifth step, form the intervals by correct mapping of 1's from the final matrix into the pins of the single-row axis. Then these intervals are converted into nets in which each net contains two pins at either ends. The ordering of zones for the single-row network is now same as the ordering of rows of the final incidence matrix M_f. From the matrix M_f, the initial net list is found which is known as L_0. By applying ESSR for the routing in single-row network, it is found that the value of energy function, street congestion and the number of doglegs are minimum. Thus the list of nets generated in this way is optimal.

Algorithm 1:(Formation of zone orders and intervals)

```
for each column j
for each rows i
if a_i,j==1
if a_i+1,j ≠ 1
for r = i+2 to n
if a_r,j==1
interchange a_i+1,j with a_r,j
endif
endfor
endif
endif
endfor
one=count number of pairs of 1's
if one=number rows-1
return M_f and exit;
endfor
ordered_zones = ordered list of rows
ordered_intervals= ordered list of columns
```

Algorithm 2: (Formation of the nets)

```
for each row i
for each column j
if a_ij >0 then
N=N+1; // N initialized to 0
a_ij= N
endif
endfor
endfor
//Joinning two pins
for each row i
for each column j
if a_ij>0 then
P=a_ij
a_ij=-1;
endif
endfor
if a_ij >0 then
Q=a_ij;a_ij=-1;
Join(p,q) // net joining pin p to q
break;
endif
endfor
for each i=1 to row-2
//row is number of rows of M_f
for each column j =1 to col
//col is number of column of M_f
if a_ij>0 then
S= a_ij
A_ij=-1;
for each k=i+2 to row
for each j=1 to col
if a_kj>0 then
T=a_ij
a_ij=-1;
Join(S,T) //joining  pins S and T
break;
endif
endfor
endfor
endif
endfor
endfor
```

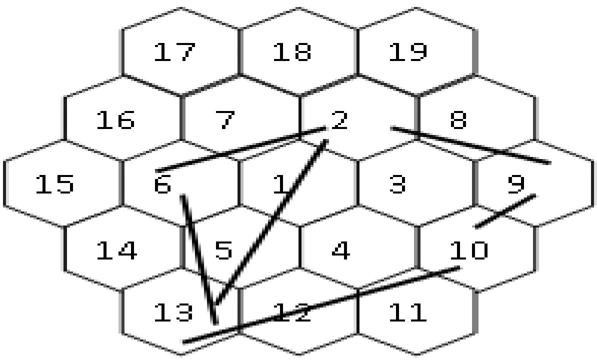

Fig -1: Base Network

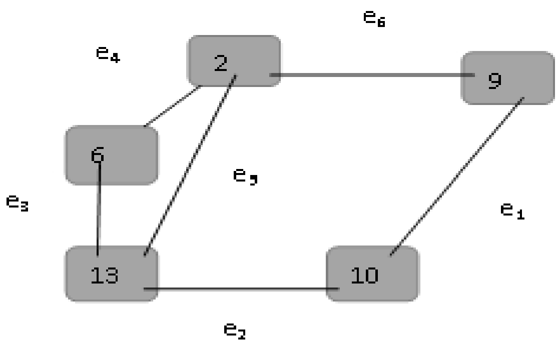

Fig -2: Connected graph of Base Network

As an illustration figure 1, shows a base network. Figure 2 represents the connected graph *G* corresponding to the given base network. The vertices in this graph are known as the cells from which the requests for channels are generated and the edges are communication paths among callers and receivers. Since the vertices of the graph *G* also correspond to the zones of the single-row network *S*, therefore they are marked by enclosing it with a shaded box. The graph in figure 2 is now represented by the incidence matrix *M* with 5- rows and 6- columns. Since the degree sequence of vertices is deg (6) ≤ deg (9) ≤ deg (10) ≤ deg (13) ≤ deg (2), the rows of the matrix are arranged as 6, 9, 10, 13 and 2. The columns are arranged with edges in a sequential order i.e. e_1, e_2, e_3, e_4, e_5 and e_6.

Using algorithm 1, the final matrix M_f is derived from the given matrix *M* by swapping two appropriate rows in successive iteration. Thus the matrix M_f is found with at least four pairs of consecutive 1's in the columns. From the matrix M_f, five rows representing vertices correspond to zones z_i ($i=1, 2, 3, 4, 5$) for single-row network. In this case, the ordering of zones is denoted as (6, 13, 10, 9, and 2). In single-row network S, since $\sum_{i=1}^{n} d_i = 12$, where d_i is the degree of the vertex v_i , the number of pins to be used is 12. The pins are also known as the terminals used by S. These 12 pins, generate 6 intervals that are denoted by $I(c_k, r_k)$ for $1 \le k \le 12$ from the matrix M_f. Each of the intervals made up of two pins is marked by two end points known as caller (c_k) and receiver (r_k). After forming a single-row network from the base network, a routing technique is applied to create an unique path between a pair of pins. The paths obtained in this way are known as nets. Each of e_j*'s* of the matrix M_f are called intervals represented by $I_i(c_k, r_k)$, for $1 \le i \le 6$ and $1 \le k \le 12$ is constructed only from left to right direction. For example, in this case, $I_1(1,11)$, $I_2(2,3,)$, $I_3(4,12)$, $I_4(5,6)$, $I_5(7,8)$ and $I_6(9,10)$ are the intervals as presented in the figure 3.

In figure 3, the ordered zones are 6, 13, 10, 9 and 2, where each of the zone controls two or more pins (terminals). Now using algorithm 2, the initial order list of nets is found. In this case, the initial list of the nets N_i, for $1 \le i \le 6$, as shown in the figure 4. Let the initial net list is given by, L_0= $\{N_2(2,3), N_4(5,6), N_5(7,8), N_6(9,10), N_1(1,11), N_3(4,12)\}$.

Using the equation 1 and 2, the energy function, minimum street congestion and the number of doglegs are calculated as $E = 5$, $Q = 2$ and $D = 2$ respectively. To improve this solution the method ESSR as proposed by Salleh et al. in [2] is implemented. The optimal ordering of nets using ESSR is presented in the figure 5. The corresponding minimum energy function, minimum street congestion and number of doglegs from the figure 4 for this illustration are given by $E = 2$, $Q = 1$ and $D = 0$, with the corresponding ordered zones <6, 13, 10, 9, 2>. The final net list is denoted as L_f = $\{N_2(2,3), N_3(4,12), N_4(5,6), N_5(7,8), N_6(9,10), N_1(1,11)\}$, whose realization for single-row network is given in Fig.6.

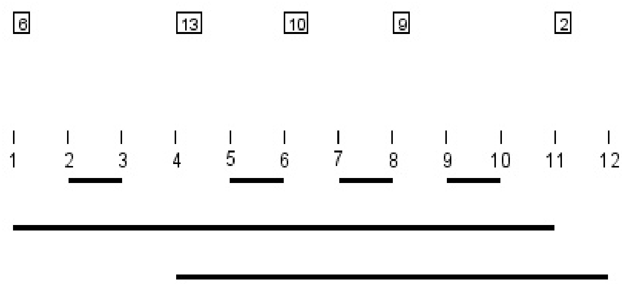

Fig -3 Initial order zones of single-row network

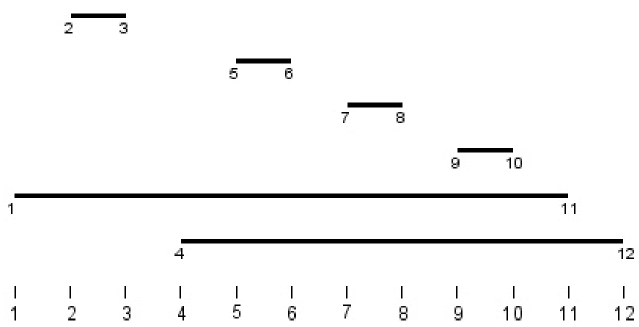

Fig -4. Initial list of nets

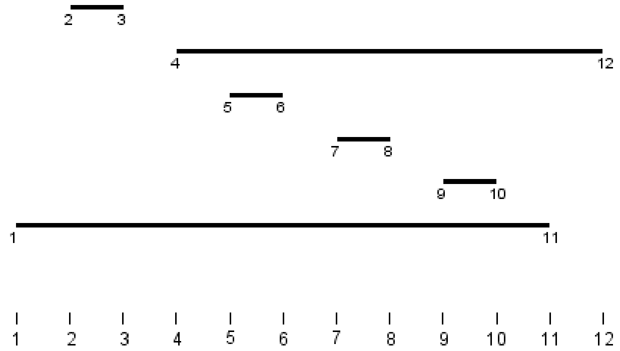

Fig -5. Optimal Ordering of Nets

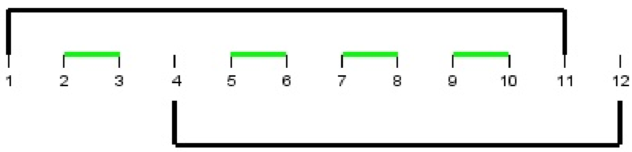

Fig -6. Realization of optimal paths

4. ANALYSIS AND EXPERIMENTAL RESULTS

Most of the traditional works for transformation of single-row network are based on the implementation of maximal cliques finding problem. In general maximal clique problem is NP-complete as suggested by Panos M. Pardalos et al. in [8]. The running time to find all the maximal cliques of connected graph of n vertices is $O(3^{n/3})$ as derived by Etsuji Tomita et al. in [7]. Where as representing the graph in incidence matrix and applying finite number of swap operations on its rows, transformation problem takes polynomial time. However, incidence matrix, which is the alternative to a connected graph, is highly used for the design of electrical circuits. The method proposed by us is more beter than the others based on their initial as well as optimal values of energy function, street congestion and the number of doglegs respectively. The Table 1 shows the comparative results between traditional method and the proposed method. The bar graph given in figure (7, 8, 9) below showing the comparison between energy values, number of doglegs and street congestions of the figure 1 in this paper based on the traditional and proposed method. We have implemented proposed algorithms in Scilab 5.4.1 software for the formation of optimal ordering of zones and ordered list of nets.

Table 1 : Comparative Analysis

Graph	Initial Solution						Optimal Solution					
	Traditional Method			Proposed Method			Traditional Method			Proposed Method		
	E	Q	D	E	Q	D	E	Q	D	E	Q	D
Fig.1	9	3	3	5	2	2	7	2	2	2	1	0
Fig 1[3]	3	2	0	1	1	0	2	1	0	1	1	0

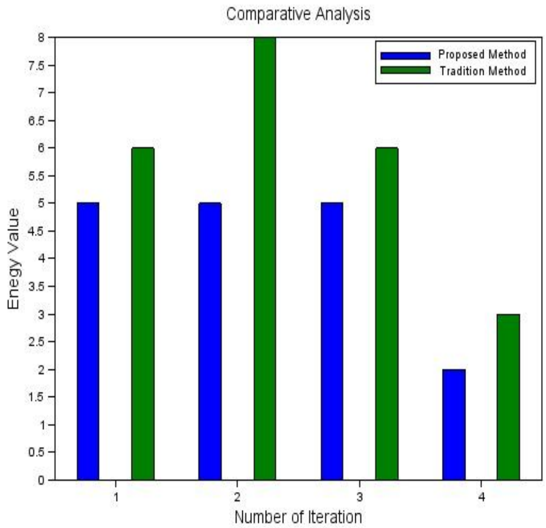

Fig -7 Comparative analysis of energy value of Fig.1

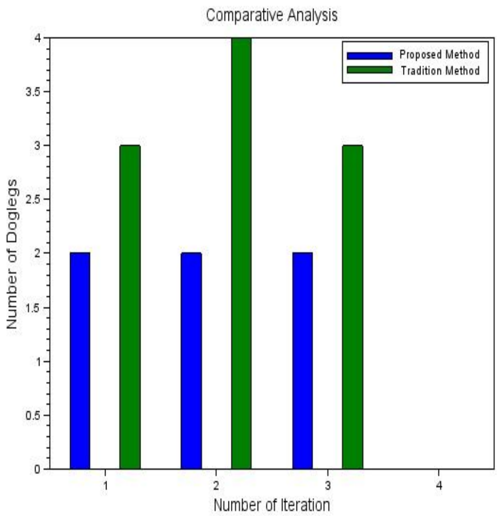

Fig -8 Comparative Analysis of Number of Doglegs of Fig.1

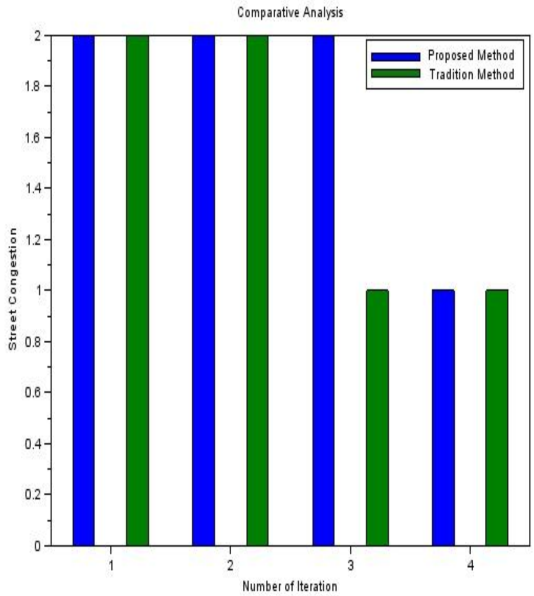

Fig - 9 Comparative Analysis of Street Congestion of Fig -1

5. CONCLUSIONS

The proposed method for optimal solution for the ordered list of nets and at the same time with minimum value of energy function, street congestion and number of doglegs are derived by the support of ESSR in [2]. From the graphs of comparative analysis between traditional and proposed methods, we concluded that the initial list of nets based on our method results a better optimal solution in comparison to the tradition method. We will consider the same problem when the communicating users belong to the same cell of the same network for future scope. We will also try to find the rate of convergence to find the optimal solution.

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