A New Approach on Co-ordinate based Routing Protocol for Mobile Networks

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***Abstract*—A new dynamic routing protocol (CSTR) for mobile networks is proposed in this paper. The rules for mapping between cell number and corresponding co-ordinates are discussed. The routing protocol has been formulated with the help of a tree structure generated *inter-alia*. All possible routing paths could also be enumerated in a simple manner. This method is simpler than other techniques reported so far. The simulation study confirms routing path analysis for destination nodes.**

Keywords-co-ordinate; routing; tree; mobile network;

I. INTRODUCTION

In the current era, rapid growth of cellular telephony is coupled with a need for improved and efficient allocation strategies. An effective call selection procedure is also needed at the same time. Call Admission Control (CAC) is such a strategy used to give permission to limited number of users for using the network during congestion. The rest of the users are not allotted at any slot during that period [2]. Consequently, Quality of Service (QoS) can be ascertained only for the admitted users. It is therefore necessary to consider two near-contradictory requirements – allocating resources as well as ensuring Quality of Service (QoS) when all users are trying to make a request at the same time.

It is known that in mobile cellular networks nodes communicate with each other using multi-hop links. This structure is stationary because there are base stations in every cell. Each node in the network has call forwarding capability to other nodes. Till date, various routing strategies have been designed to address the problem of finding routing path coupled with efficient congestion control technique. A new dynamic pricing scheme called as Priority based Tree Generation for mobile networks (PTGM) has been proposed in [1]. In the said paper, an efficient call scheduling procedure has been proposed. The unique path sequence for each call requesting cell was also determined.

A new co-ordinate based dynamic routing protocol (CSTR) for mobile networks is being proposed in this paper. The cellular structure described in [1] by two of the authors has been mapped into Cartesian co-ordinate system, with the mobile terminal (MT) placed at the origin. The call requesting cells have to service its requests to other cells through MT which, in effect, acts as a switching center in this protocol. This protocol has been formulated with the help of a tree structure. The cells rejected in [1] are also included in this new structure. All possible routing paths for a particular destination node are obtained by applying a search technique. The simulated result of performance analysis for the system is also shown.

The rest of this paper is organized as follows. In section II, the proposed model is discussed alongwith associated mapping rules. We present algorithms for the derived system model in section III. The algorithm is analyzed with diagrams and tables in section IV. The simulation results and performance analysis are discussed in section V.

II. CO-ORDINATE BASED SYSTEM REPRESENTATION OF THE PROPOSED MODEL

The cellular structure of the mobile network described in [1] is shown in Fig. 1(a) below for completeness. Without loss of generality, the terminal MT is taken to be positionally static in a hexagonal cell during any particular time period of study. Users' requests to neighboring cells are serviced through MT.

A. Mapping rules of cell number into corresponding co-ordinates system

Although each cell in the cellular structure can communicate with other six cells in its environment, it is proposed that the system will consider call forwarding capability to only the three adjacent cells of upper radius. The reason behind this is that - those three excluded cells lie either on the lower radius or on the same radius. Hence, rejected calls for those excluded cells are being serviced by other cells in its lower radius. For example in Fig. 1(a), cell number C_{23} forwards calls to C_{33}, C_{34} and also C_{35}. The cell numbers C_{22}, C_{12} and C_{24} are excluded for the reason stated above. It is evident that this exclusion, in no way, will affect the efficiency of call routing.

In the new model proposed herein (fig. 1(b)), MT is denoted by (0, 0) and each other cell is having a coordinate of the form (x, y). The cells covered by a radius r (transmission covering range in [4]) of MT are mapped as (x, y+1), (x+1,y+1) and (x+1,y) such that x+1≤ r and y+1≤ r. For example, $C_{13,}$ C_{12} and C_{11} cell numbers of r=1 in [1] are mapped into (1, 0), (1, 1) and (0, 1) respectively.

Therefore, cellular structure of mobile networks depicted in [1] could be mapped into a co-ordinate based system as shown in Fig. 1(b).

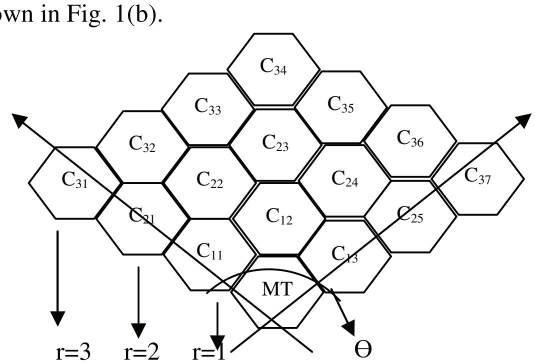

Figure 1(a). Structure used in [1].

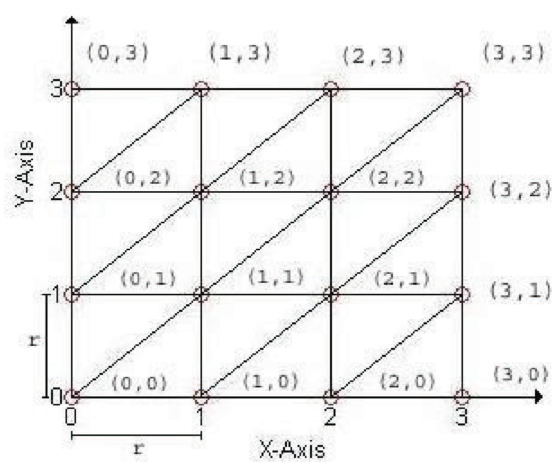

Figure 1(b). Representation of the proposed model used here.

III. CO-ORDINATE BASED SEARCH TREE GENERATION WITH DETERMINATION OF ROUTING PATHS

A new algorithm for Search Tree Generation and Determination of Routing Paths (CSTR) is proposed in this paper. We could overcome the limitations of [3] - that Grid based technique could not prescribe a methodology for finding the paths. The advantages claimed in our work are:

(i) all possible routing paths could be enumerated by this model, and,

(ii) experimental results, i.e., simulation results obtained also establish the results on routing path lengths proposed by us.

This algorithm (CSTR) works in two basic steps:

Step (i) **Search tree generation with call forwarding constraint:**

This tree has been generated from the root MT (0, 0) with the help of a look-up table. The nodes of the subsequent levels are constructed according to the mapping rules defined in section II A. This table is represented by a square matrix T of dimension (r+1). Each element T [a, b] denotes the address of the corresponding cell. For example, if we consider cell number C_{32}, T [1, 3] contains the address of the cell C_{32} that bears the co-ordinate (1, 3). The use of look-up table reduces the need of re-computation of already visited nodes during tree generation. The tree is generated by recursive calls of the Generate function. The co-ordinates of MT (*x=0 and y=0*) and the radius *r* is passed as the initial parameter. This procedure is described by the following algorithm.

Algorithm:

```
T[r+1,r+1] ;  /*  look-up table */
Start with MT (x, y), where x=0 and y=0;
Generate (x, y, radius (r))
begin
        if ( x || y > r)
                make the children node == null;
                then  return;
        else
                address = T[x,y+1];
                if (address!=null)
                then link parent with address;
                     return;
                else
                     T[x, y+1] = address of (x, y+1);
                      Generate(x, y+1,r);
                endif
                address = T[x+1,y+1];
                if (address!=null)
                then link parent with address;
                     return;
                else
                     T[x+1, y+1]= address of (x+1,y+1);
                      Generate(x+1, y+1, r);
                endif
                address =T[x+1,y];
                if (address!=null)
                then link parent with address;
                     return;
```

```
                else
                        T[x+1,y]= address of (x+1,y);
                         Generate (x+1,y,r);
                endif

        endif
end
```

Step (ii): **Finding all possible routing paths through searching:**

Initially, the queue (Q) contains only the root of the tree and the path length is initialized to 0. Now, a search technique is applied through subsequent levels of the generated tree to obtain all possible routing paths. The path length for each of the node in the tree is recorded until the queue is empty. For example, the search result shows routing paths for (2, 2) in a system of order 3 as (0, 0) → (0, 1) → (0, 1) → (0, 2) → (1, 2) → (2, 2), (0, 6) → (1, 1) → (2, 2) etc. The algorithm described below is effectively BFS technique and it works in linear time- it is evident from the algorithm itself.

Algorithm:

```
Search ( );
begin
        initialize queue Q with root;
        path_length=0;
        do {
                path_length++;
                N = Q[1];  /* First element of queue */
                record the path_length for each children of  N;
                put all the children in the queue;
                remove the first element of the Q;
           } while ( Q != empty)
end
```

IV PERFORMANCE ANALYSIS

The proposed model is analyzed with r=2 for simplicity, however it is applicable for any value of r within the transmission range [4] of MT. The following tree structure has been generated by executing the algorithm presented in section III. Table I shows all possible routing paths for a particular destination of r = 2.

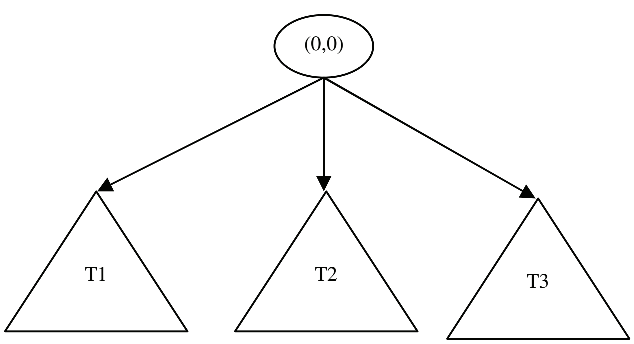

Figure 2(a). Tree structure for r = 2 with sub trees T1, T2 and T3.

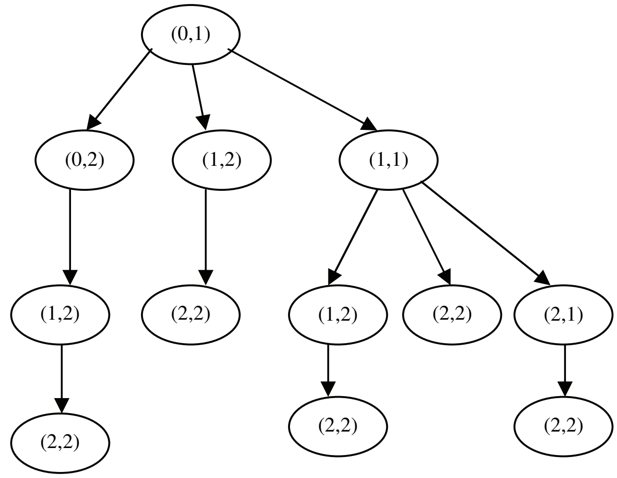

Figure 2(b). Subtree T1.

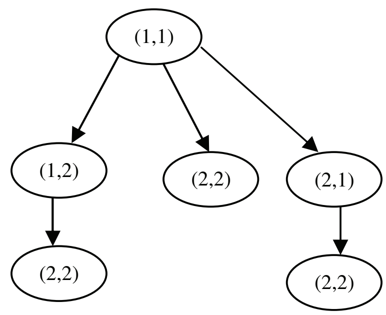

Figure 2(c). Subtree T2.

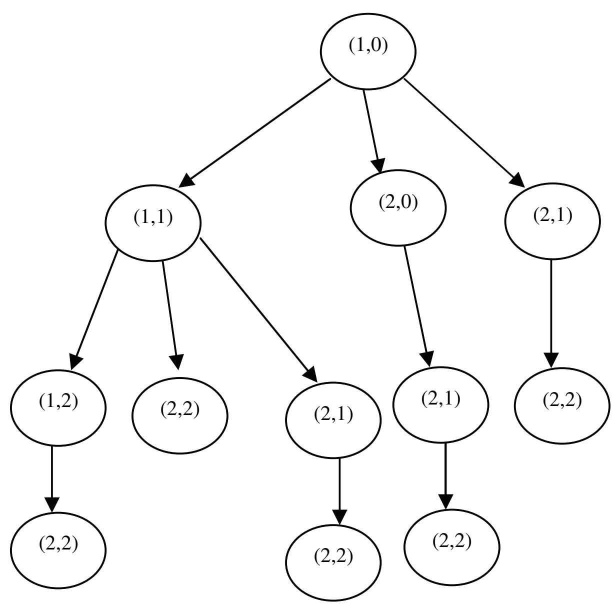

Figure 2(d). Subtree T3.

TABLE I. POSSIBLE ROUTING PATHS FOR DESTINATION (2,2)

Destination	Possible Routing paths
(2,2)	(0,0) → (0,1) → (0,2) → (1,2) → (2,2)
	(0,0) → (0,1) → (1,2) → (2,2)
	(0,0) → (0,1) → (1,1) → (1,2) → (2,2)
	(0,0) → (0,1) → (1,1) → (2,2)
	(0,0) → (0,1) → (1,1) → (2,1) → (2,2)
	(0,0) → (1,1) → (1,2) → (2,2)
	(0,0) → (1,1) → (2,2)
	(0,0) → (1,1) → (2,1) → (2,2)
	(0,0) → (1,0) → (1,1) → (1,2) → (2,2)
	(0,0) → (1,0) → (1,1) → (2,2)
	(0,0) → (1,0) → (1,1) → (2,1) → (2,2)
	(0,0) → (1,0) → (2,0) → (2,1) → (2,2)
	(0,0) → (1,0) → (2,1) → (2,2)

The routing path lengths are calculated from the generated tree structure in Fig.2 (a), Fig.2(b), Fig.2(c) and Fig.2(d). The frequency of occurrence of different path lengths have been found, e.g., considering the destination node (2, 2), the path lengths of 2, 3 and 4 have occurred 1, 6 and 6 times respectively. This process is repeated for all the destination nodes.

Now, standard statistical approach has been applied to show the significance of performance analysis. We have computed weighted mean of path length for different paths using frequency of occurrence as weights. For example, the node (2, 2) has weighted mean path length 3.38 - the corresponding path lengths are 2, 3 and 4 and the respective frequency values are 1, 6 and 6.

V. EXPERIMENTAL RESULTS

We have simulated our proposed model with MATLAB 7.6. Here, this result shows the variation of different path lengths for all destinations upto radius r = 3.

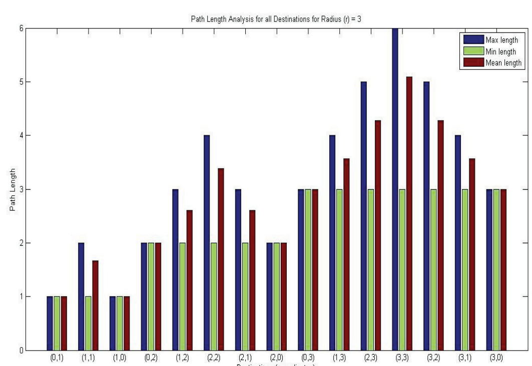

Figure 3. Path length analysis for all destinations.

VI. CONCLUSIONS

The procedure for construction of routing tree structure described in this work does not require re-computation of already computed subtrees, thereby computational cost is reduced to a large extent. At the same time, this model has been enhanced with the inclusion of the rejected calls thereby increasing the flexibility of dynamic call routing. Further study on extending this model for construction of routing tables is in progress.

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