Coordinate Based Directed Routing Protocol

Subarno Banerjee, Supriya Roy, and P. K. Guha Thakurta

***Abstract*—In this paper, we propose a new Coordinate mapping scheme for the Cellular Wireless Network. We introduce the idea of Directed Routing and design a Routing Protocol for the proposed system. The protocol selects the optimal path considering both Path length and Congestion. The performance of the model is evaluated based on theoretical consolidations and simulations. A QoS model is realised.**

***Index Terms*—Cellular network structure, directed routing, mobile communication, optimal path, routing tree.**

I. Introduction

Recent progress in wireless communication technology addresses a variety of challenges like efficient call routing, enhancing user experience with good scheduling algorithms, delay reduction, congestion control, energy efficiency, channel allocation, adapting to traffic and usage patterns, security and authentication issues. Among several fundamental limitations of mobile communication are bandwidth, power and channel capacity. In recent times, there has been an increasing motivation to switch from the wired networks to wireless networks due to its ease of access. With increasing number of mobile subscribers day to day, there is an ever increasing need of adapting the mobile communication systems. A major challenge for the network designers is to develop efficient call scheduling and routing techniques for the increasing traffic and to reduce congestion at the same time thus maintain the Quality of Service.

A tree based routing path generation approach was adopted in Priority based Tree Generation (PTGM) for mobile networks [1]. The call requests were given priority based on cell location and orientation with respect to a fixed mobile terminal (MT). The work was further extended in CSTR [2] where a suitable coordinate mapping for the cellular network structure was introduced. Still the model used the old priority assignment factors as in PTGM. The scheduling scheme proposed in PTGM, though observed to comply with QoS requirements, had serious drawbacks. It was not able to handle multiple call requests originating from the same cell. The priority assignment was unfair and leaded to isolation of cells located at a particular orientation with respect to the MT. Thus call requests originating from those low priority cells were handled inefficiently. A call was always forwarded to a non-adjacent cell thus leading to more propagation delay and distortion. The mapping used in CSTR was a direct polar to coordinate transformation and was not valid for the entire 360^{o} cellular structure. The model could not be generalized. A call was necessarily routed via a Message Switching Centre, i.e. Mobile Terminal (MT). A call originating from any cell was first routed to the MT and then routed to the destination cell. Basically this approach reduced to a simpler routing strategy that always generated a path from a cell to MT. However, this approach was primitive and always resulted in a longer indirect path.

In this paper, we present a generic coordinate representation for the cellular network structure. We introduce the concept of directed routing wherein call requests are always forwarded to adjacent cells leading closer to the destination. The routing technique generates all possible paths within a range of path lengths and selects the best path considering path length and congestion. The problems associated with PTGM and CSTR are also eliminated in this work. The model is capable of handling multiple call requests from the same cell. Propagation delay and distortion [3] is also minimized by forwarding calls to adjacent cells only. Also, there are no biased priority factors and this makes the proposed routing scheme fairly meaningful. We also consolidate the performance of the model in terms of average path lengths generated by the protocol and the variation of congestion probability with distance.

Paper Outline

The paper is organized as follows. In section II, an overview of the model is presented with emphasis on the proposed Routing Protocol. The Coordinate mapping and other parameters required to support the model are also defined. The idea of Directed Routing is described and summarized with different algorithms. In section III, we analyze the performance of the model in terms of path length and congestion. In section IV, we conclude with a short discussion on the advantages and possible expansion of the proposed model.

II. Proposed Model

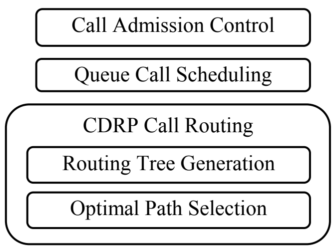

Fig. 1. Modules of the Proposed Model

In this model, new call requests are admitted under a CAC policy and queued for scheduling. Once a call is scheduled, the routing tree is generated for the source destination cells of the scheduled call request. The optimal path is then selected

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and the call request is serviced by routing through the selected path. The functionality of the proposed model is divided in the following modules as shown in Fig. 1.

We adopt the conventional CAC [4] and the Queue Call Scheduling with ageing techniques. In this paper, we emphasize on the newly proposed CDRP routing technique.

A. The Coordinate Cellular Mesh

We present a new coordinate representation, as shown in Fig. 2, for the cellular network structure where the cells are identified in two alternating layers with a mutual offset. These layers extend symmetrically in all directions to form an infinite cellular matrix.

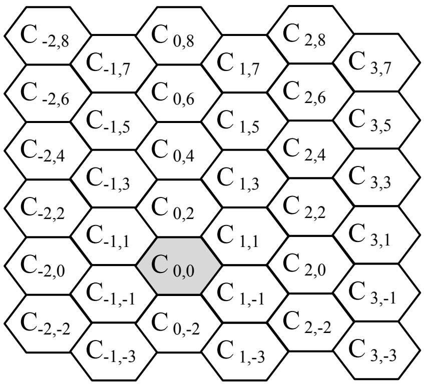

Fig. 2. The Coordinate cellular mesh.

For any cell $C_{(x,y)}$, the six adjacent cells are given by the set $\{ C_{(x,y+2)}, C_{(x,y-2)}, C_{(x+1,y+1)}, C_{(x+1,y-1)}, C_{(x-1,y+1)}, C_{(x-1,y-1)} \}$.

B. Cell Data Structure

Each cell is required to store the following three parameters:

1) *Relative Location*: Each cell stores two indices (x,y) that indicates the relative location of that cell with respect to a suitably chosen reference cell ($C_{0,0}$). We propose to select that cell as the reference cell which is statistically known to be the most frequent call initiator.
2) *Capacity*: It is the maximum number of calls that a cell can forward at a particular time.

These two parameters are static to the model i.e. they do not vary during the operation of the system.

3) *Congestion*: It is the total number of calls that are being forwarded via the cell at a particular time. This parameter is dynamic to the model and varies upon call admission and call end.

C. Routing Tree Generation

We devise a routing protocol which is capable of generating directed paths between any two cells. The algorithm is such that it always forwards a call towards the actual destination i.e. to the adjacent cells that lead closer to or to an equal distance from the destination. This algorithm is repeated for each cell that receives a call forward request until the destination cell is reached.

We define distance between two cells $C_{(x1,y1)}$, $C_{(x2,y2)}$ *as* $\partial(C_{(x1,y1)}, C_{(x2,y2)}) = |x2-x1| + |y2-y1|$.

For a Source ($C_{(-1,5)}$) – Destination ($C_{(3,1)}$) pair, we compute ∂(Source, Destination) and then select those adjacent cells for which distance from destination is lesser, or if no such cell is found, then equal.

$C_{(-1,5)}$	$\partial = 8$
$C_{(-1,7)}$	10
$C_{(-2,6)}$	10
$C_{(-2,4)}$	8
$C_{(-1,3)}$	6
$C_{(0,4)}$	6
$C_{(0,6)}$	8

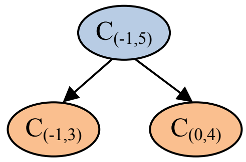

Fig. 3(a). Call forwarding.

The first selected cell $C_{(-1,3)}$ becomes the next source and the algorithm continues recursively until it finds ∂=0.

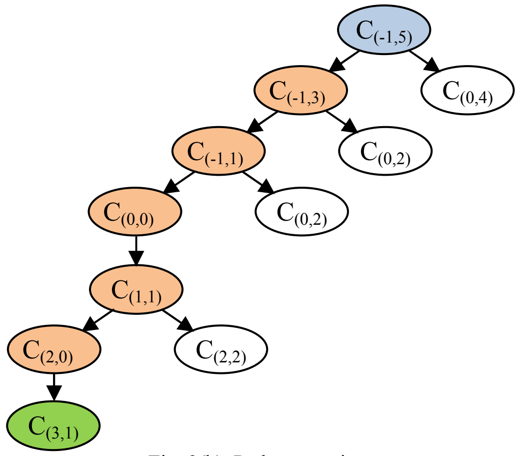

Fig. 3(b). Path generation.

Then we go to the previous incomplete level and continue with the algorithm to generate the complete Routing tree.

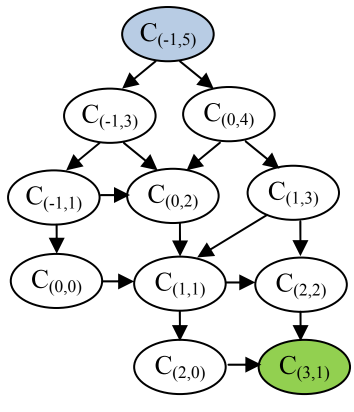

Fig. 3(c). Routing tree generation

The above procedure for Routing Tree generation is summarized in Algorithm I. The algorithm is recursive in nature.

D. Optimal Path Selection

We define Availability of a cell as,

$$\text{Availability} = \text{Capacity} - \text{Congestion}$$

We traverse the Routing Tree. Each traversal to the leaf node gives a possible path. For each possible path we sum the Availability of each participating cell of that path. We discard a path if any participating cell in the path has Zero Availability. It simply means that the cell is fully congested to its capacity and can no longer forward new calls. Finally we select the Optimal Path maximizing the Availability and minimizing the Path Length. As we route the call through the above selected path, we increment the congestion values for each participating cell. Similarly the congestion values are decremented upon call end.

ALGORITHM I: ROUTING TREE GENERATION

```
Input: Source C(a,b), Destination C(p,q)
Output: Routing Tree from C(a,b) to C(p,q)
Method:
directed_call_forward(C(x,y))
{
    create node for C(x,y) and make it the current parent node
    d=∂ (C(x,y), C(p,q))
    for each adjacent cell C(i,j) of C(x,y)
        if (∂ (C(i,j), C(p,q)) < d) then
            create a node for C(i,j) and make it a
            child of the current parent node
            directed_call_forward(C(i,j))
            count++
        end if
    end for
    if(count=0) then
        for each adjacent cell C(i,j) of C(x,y)
          if (∂ (C(i,j), C(p,q)) = d) then
            create a node for C(i,j) and make it
            a child of the current parent node
            directed_call_forward(C(i,j))
            count++
          end if
        end for
    end if
}
```

ALGORITHM II: OPTIMAL PATH SELECTION

```
Input: Routing tree for a Source C(a,b) – Destination C(p,q) pair
Output: Optimal path minimizing Path length and Congestion
Method:
get_optimal_path( )
{
   for each traversal of the Routing tree from the source to the destination
       define a new path P in the list of paths L
       for each node 'a' in P
          Increment Path length(P) by 1
          Compute Availability(a) = Capacity(a) – Congestion(a)
          if Availability(a) = 0
             reject path P
          else
             increment Availability(P) by Availability(a)
          end if
       end for
   end for
   Sort L on increasing Path length and then decreasing Availability
   Return the first path in L
}
```

III. PERFORMANCE ANALYSIS

The number of possible paths considered by CDRP for call routing for a particular distance ∂ is between 1 and 2∂. The number of possible paths increases significantly with distance. The path length is bounded between ∂ and 2∂.

There are 2∂ cells at a distance ∂. ∂-1 cells are at a path length 2∂. The remaining ∂+1 cells have their path lengths in the sequence:

$$\partial + 2\sum_{i=1}^{\frac{\partial}{2}-1}(\partial - i)$$

The average path length is given by:

$$\bar{l} = 1 + \tfrac{\partial-1}{4} + \tfrac{1}{\partial}\sum_{i=1}^{\frac{\partial}{2}-1}(\partial - i) \qquad (1)$$

The average path length, shown by the middle curve in Fig. 4, is an almost linear function of ∂ and it falls closer to $\frac{\partial}{2}$ with increase in ∂.

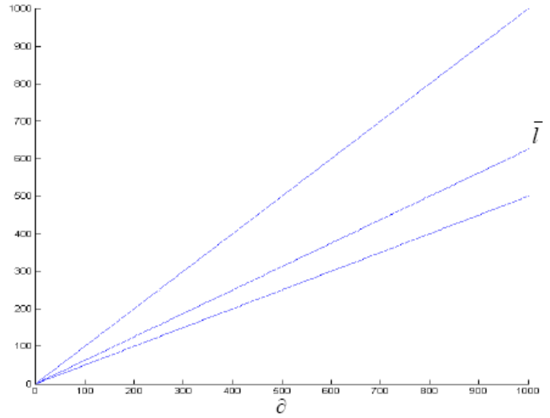

Fig. 4. Variation of average path length.

To analyse the dynamic effect of congestion, we define the probability of a cell being congested as:

$$p_{congested} = \frac{u}{C};\ u = \text{Network usage},\ C = \text{Capacity} \qquad (2)$$

Average probability of a path being congested for a particular value of distance ∂ is given by:

$$P(\partial) = \left[p_{congested}\right]^{\bar{l}(\partial)} \qquad (3)$$

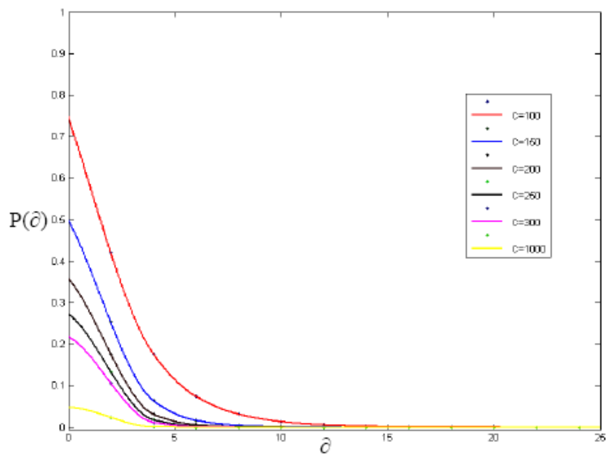

Fig. 5. Variation of congestion probability

The probability of finding a congestion free path increases rapidly with distance. This is justified by the obvious fact of increasing number of options in terms of available paths with increase in distance. Also, this probability increases with increase in capacity for a particular distance. With a larger capacity, a router can forward more number of calls before getting congested.

Although increase in distance means increase in average path length, distortion and delay in propagation is reduced by forwarding the calls to adjacent cells only. Thus QoS is maintained.

IV. Conclusion

The CDRP routing strategy reduces the problem of call routing to a simple and straightforward approach. The idea of directed routing proposed in this paper proves to be very efficient in terms of congestion and path length. Also, calls are forwarded to adjacent cells thus reducing propagation delay and distortion. Thus, a QoS model has been established.

Though the idea is in a rudimentary stage, it lays a foundation for the development of a decentralized call routing systems, eliminating the need of high capacity Mobile Switching Centers.

We are currently extending the model for supporting priority distribution based on geographical factors and history of traffic.

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