Effective Cell Size Scheme in Multi-hop Cellular Networks†

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Abstract – **In 3G-based multi-hop cellular networks (MCNs), the cell size affects the cell capacity and the network reachability, which in turn affect the total demand of source nodes that can be served or the system throughput. Improper cell size assignment greatly affects the performance of the networks. To address the cell size issue, we recently proposed the Optimal Cell Size (OCS) scheme to find optimal cell sizes to maximize the system throughput for a 3G TDD W-CDMA MCN. Although OCS provides an optimal cell size solution, it is computationally expensive. In this paper, we propose a heuristic cell size scheme, called Small Cell Size First (SCSF), which is more efficient and provides good results in terms of throughput compared to the optimal solutions provided by OCS. SCSF outperforms the fixed small cell size (SCS) multi-hop case when the network is sparse and the large cell size single-hop case regardless of the network density.**

Keywords - multi-hop cellular networks; TDD; CDMA; cellular networks; optimal algorithm; heuristic; cell size; throughput

I. INTRODUCTION

In a cellular system, the cell coverage is basically the communication range of the base station (BS) or the cell size. The cell capacity is usually measured by number of admitted calls or maximum supportable data rate in the cell. In third generation (3G) cellular systems, wideband code division multiple access (W-CDMA) technology is used. Because of the interference-limited [3] characteristic of the technology, a large cell has small capacity whereas a small cell has large capacity. During the planning stage, if a large coverage is required, a small interference margin [3], which corresponds to a low cell capacity, is allocated so that more radiated power of a mobile node or the BS can be allocated for the propagation loss [3] for a large coverage. If a large cell capacity is required, a large interference margin is allocated to allow a high capacity whereas the margin for propagation loss is reduced which corresponds to a small cell. In this case, more BSs are required for coverage. Obviously, such a static approach either cannot cope with the dynamic nature of users in 3G or is costly.

In MCNs [1, 2, 5, 8, 9], mobile nodes may communicate with the BS through one or more intermediate nodes. Therefore, the coverage not only depends on the cell size but also the availability of mobile nodes for relaying. To achieve high cell capacity without sacrificing the coverage or network reachability, some MCN proposals, e.g. ad hoc cellular relay architecture (A-Cell) [8], assume a small cell size and a dense network. A small cell allows high cell capacity whereas a dense network provides sufficient relaying nodes for relaying signals. However, in practice, a dense network may not always be the case. When the network is sparse, the performance of MCN could be greatly degraded. This is because distant mobile nodes may not find relaying paths to reach the BS to use the available capacity. If a large cell size is set, more nodes can reach the BS, but the resulting cell capacity may not meet the demands. Again, a static cell size strategy cannot cope with the dynamic nature of a MCN environment. The cell size issue in MCNs has not been addressed until we recently proposed the Optimal Cell Size (OCS) scheme [11]. OCS is formulated as an Integer Linear Program. The task of OCS is to find the optimal cell sizes that maximize the system throughput for a 3G time division duplex (TDD) W-CDMA MCNs. Although OCS provides optimal cell size solutions, like most optimized scheme, OCS is computationally expensive and may not suitable for large real-time problems. In this paper, we propose a heuristic cell size scheme, called Small Cell Size First (SCSF), which is more efficient than OCS. The running time of SCSF is $O(m \log m)$ where m is the number of BSs that the source node can reach through multi-hop relaying. Simulation results show that SCSF achieves on average 71% throughput performance of OCS. SCSF also outperforms the fixed small cell size case when the network is sparse and the large cell size single-hop case regardless of the network density.

In the next section, we discuss the cell size in MCNs. In Section III, we introduce the SCSF scheme. In Section IV, we describe the simulation model and discuss the results.

II. CELL SIZE

In this section, we describe the network model, discuss the concept of optimal cell size in a single-cell and a multi-cell MCN environment, and provide the definition of the cell size problem.

A. Network Model

Fig. 1a illustrates the network model of a typical single-cell TDD W-CDMA or CDMA MCN environment. In the figure, a connection (call or session or traffic flow) in a source node is represented by a virtual point called source point s_i. Each source point s_i is assigned exactly one channel with a demand of traffic $\mu(s_i)$. Each source node may have several source points; each supports a different connection for a different service. A connection is relayed by relaying points r_j in relaying nodes on a relaying path. A relay node may have several relaying points for relaying different connections. To communicate with a source point s_i, the BS only needs to communicate with the last-hop node on the relaying path of the source point. For example, nodes A, B, and D are last-hop nodes. A source node can be a relaying node and a last-hop node itself (see node B). The BS is connected to the radio network controller [3] in a 3G system.

In the model, all mobile nodes are assumed to use a fixed short transmission range except the last-hop nodes, e.g., nodes A, B, and D. The last-hop nodes can communicate at a flexible

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range as large as the BS range. Using a fixed instead of a flexible transmission range for general mobile nodes helps simplify the relay architecture whereas using short transmission range helps reduce transmission power and, hence, the interference. Directional antennas are assumed to help increase channel reuse and reduce interference among nodes.

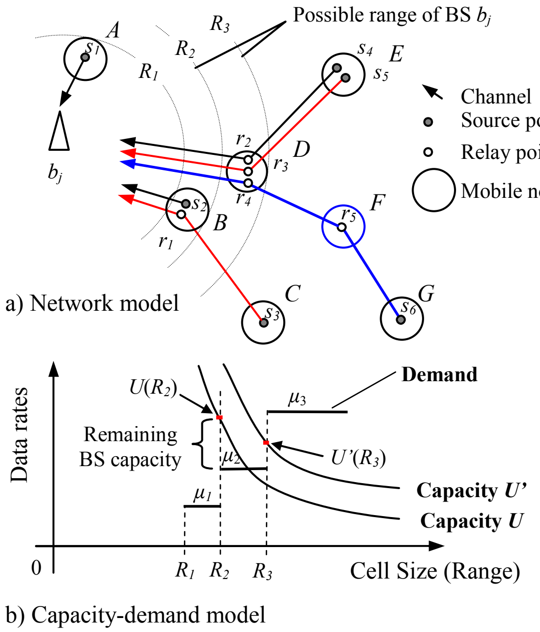

Figure 1. Network model and Capacity-demand model

B. Optimal Cell Size - Single-Cell Case

Fig. 1b shows the Capacity-demand model [9] that we recently introduced for explaining the concept of optimal cell size. The *capacity* represents the cell capacity of the CDMA technology and is a decreasing function over the cell size. The *demand* represents the total data rate requested by the source nodes and is an increasing step function over the cell size.

In the figure, there are three demand values (μ_1, μ_2, and μ_3) plotted as three line segments; each value represents the cumulated demand of the source nodes having their last-hop nodes within the corresponding communication range (cell size) of the BS. For example, $\mu_1 = \mu(s_1)$ *and* $\mu_2 = \mu(s_1) + \mu(s_2) + \mu(s_3)$. The two capacity functions, U and U', represent two typical optimal cell size cases.

For case 1, the curve of the capacity function U intersects with the demand segment μ_2 which is the total demand originated from source nodes *A*, *B* and *C*. The demand of node *C* is relayed through node *B* to the BS. The optimal cell size is at range R_2 because, at this range, the demand that can be served is maximized and equal to μ_2 and the remaining capacity ($U(R_2)$ - μ_2) for future calls is also maximized.

For case 2, the curve of the capacity function U' is in-between the demand segments μ_2 and μ_3. In this case, if the total demands that can be served by the capacity corresponding to the range R_3 is more than μ_2, then R_3 is the optimal cell size; otherwise, the optimal cell size is at R_2. This problem is special case of knapsack problem [4, 11] which is NP-hard.

C. Optimal Cell Size - Multi-Cell Case

In a multi-cell MCN environment, the task of finding the optimal cell sizes not only requires the computation of the cell sizes, but also involves the selection of a BS among several possible BSs for a connection (source point) of a source node. The decision is dependent on the availability of relaying paths (each path ends at a different neighboring BS), the locations of the last-hop nodes of the paths, the cell sizes, and the corresponding cell capacities. For example, in Fig. 2, connection s_7 requested by node *I* can be assigned to BS b_2 or b_3. Assigning the connection to b_3 gives a lower overall system capacity compared to that of assigning it to b_2 because the cell size of b_3 needs to be larger to cover the last-hop node *J* of the relaying path for the connection in node *I*. Assume that a source point has one path per each BS. The distance between the last-hop node of the path and the BS is an important input parameter for determining the optimal cell size.

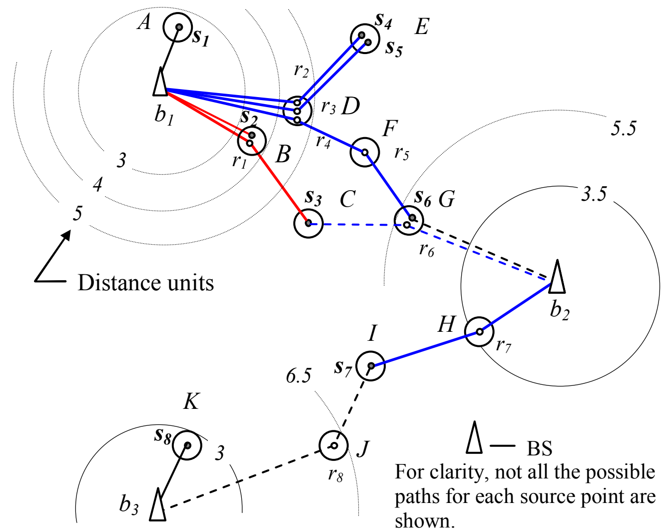

Figure 2. Cell size in a multi-cell environment

As mentioned earlier, BS only needs to communicate with the last-hop node on a relaying path for a source point s_i. In other words, to determine whether or not a source point can reach the BS, we just need to know the distance of the last-hop node of the relaying path for the source point from the BS. Assume a routing protocol provides a set of relaying paths for each source point for each BS, the topology in Fig. 2 can be translated into three sets of relaying paths; each set of paths ends at a different BS. From these paths we can construct a bipartite distance graph G (V_h, E) for each BS where V_h is the set of vertices $\{v(s_1), v(s_2), . . . , v(s_m)\}$representing the last-hop relaying points towards the BSs and E is the set of edges connecting a vertex in V_h to a BS. Each edge is weighted by the distance $d(v(s_i), b_j)$ of the last-hop relaying node having the last-hop relaying point $v(s_i)$ on the path reaching the BS b_j. If no relaying path is found for a source point for a BS, the distance of that source point to that BS is set to infinite (∞). Fig. 3 shows the distance graph for the BS b_1 for the scenario in Fig. 2. For example, for s_3 in Fig. 3, $v(s_3) = r_1$ and $d(v(s_3), b_1) = d(r_1, b_1) = d_3 = 4$.

To define the set of cell ranges (cell sizes), let $R(b_j)$ be the set of communication ranges $\{R_1, R_2, . . ., R_n\}$ of BS b_j in non-decreasing order where R_n represents the distance between the BS and the last-hop node of the relaying path for a source point s_i to the BS. The ranges can be obtained based on the distance graph G. For example, in Fig. 3, the set of the ranges for BS b_1 is {3, 4, 5} where the number represents the units of distance. Note that the set of ranges can also be a set of predetermined

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values, e.g., {1, 2, 3, 4, 5, 6, 7}, depending on the standard and/or configuration of the system in practice.

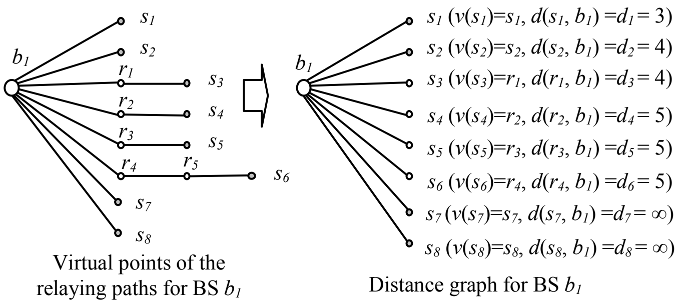

Figure 3. Distance graph for base station b_1

D. Problem Definition

Based on the optimal cell size concepts, the cell size problem is defined as follows.

Given a set of BSs, a set of relaying paths of all source nodes to the BSs, and a cell capacity function, the task is to find the optimal cell sizes to maximize the system throughput. Each source node has one or more traffic demands and each relaying path goes to a different BS,

As mentioned earlier, the problem is special case of knapsack problem [4, 11] which is NP-hard. We recently, formulated the problem as an Integer Linear Programming problem, the OCS [11] scheme. The idea of OCS is to maximize the total demand that can be served which gives the system throughput. Although OCS provides an optimal solution for cell size, like most optimized scheme, it is computationally expensive and may not be suitable for large real-time problems. In this case, a heuristic which provides good results compared to the optimal solution provided by OCS is more suitable.

III. Small Cell Size First (SCSF)

In this section, we propose a heuristic cell size scheme, called Small Cell Size First (SCSF) to solve the cell size problem in a TDD W-CDMA MCN.

SCSF is a greedy algorithm. The idea of SCSF to choose a relaying path of a source point such that the required communication range (cell size) of the BS is the smallest, i.e., the distance of the last-hop node of the chosen path from the BS is the shortest and the BS have enough remaining cell capacity to meet the demand of the source point. In this case, the cell or system capacity of a MCN is maximized. Fig. 4 illustrates the SCSF algorithm.

Note that SCSF is not a power control scheme and once SCSF computed the cell sizes, an effective power control mechanism is assumed to maintain the cell sizes until the traffic pattern or network topology is changed. The change triggers the cell size computation and adjustment process.

Steps of the SCSF algorithm

In Step 1, when a new call arrives, input the demand (data-rate) μ of a new call request.

In Step 2, a set of n relaying paths of the call, each path goes to a different BS, is assumed to be provided by a routing algorithm.

In Step 3, the distance of the last-hop node of each path from its corresponding BS is computed and stored with its BS as an entry on a list. We call the distance, last-hop distance.

Input: the demand of a new call, the relaying paths for the call to the BSs, and the capacity function of the BSs.
Output: the target BS for the call and the range of the BS.

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1. Input the demand μ of a new call.
2. Input n relaying paths for the call.
3. Compute and store the last-hop distance of each path on a list.
4. Sort the list based on the last-hop distances in an ascending order.

5. Loop through the list,
6.      If last-hop distance <= current cell range of the corresponding BS,
7.          If the remaining capacity is enough to meet the demand μ,
                The current cell range is the target cell range for the call.
                The BS is the target BS for the call.
                Done and break the loop.
            Endif.
        Else
8.          Find a minimum larger cell range that covers the last-hop node.
9.          If the remaining capacity of the range is enough for the demand μ,
                The larger cell range is the target cell range for the call.
                The BS is the target BS for the call.
                Done and break the loop.
            Endif.
        Endif.
10. End Loop (i.e., Repeat Step 6 for the next entry on the list)
11. If not Done,
        The call is blocked (i.e., not enough capacity for the call)
    Endif.
```

Definitions:

- **Last-hop node** is a node nearest to the BS on a path.
- **Last-hop distance** is the distance of a last-hop node on a path from its corresponding BS.
- **Target cell range** is the communication range of the target BS.
- **Target BS** is the BS to which the new call is proposed to connect.

Figure 4. The SCSF Algorithm

In Step 4, the list is sorted in an ascending order according to the values of the last-hop distances. Thus, the last-hop distance of the entry at the head of the list is the shortest. The BS of that entry requires the shortest communication range (smallest cell size) to cover the last-hop node of that call, i.e., the shortest communication range for the call (source node) to reach the BS. The BS is a potential target BS (cell) for the call.

In Step 5, the entry starting from the head (first entry) of the list, i.e., the first entry, is checked to see if the BS can be the target BS or if the BS has enough capacity to meet the demand.

In Step 6, the last-hop distance of the entry is checked. If it is less than or equal to the current communication range of the corresponding BS, continue with Step 7; otherwise, go to Step 8.

In Step 7, the remaining capacity of the BS is checked. If the remaining capacity is enough to meet the demand μ of the call, the current cell range of the BS is the target cell range, the BS is the target BS for the call and the iteration of the loop is finished; otherwise, go to Step 10, i.e., repeat Step 6 for the next entry on the list.

In Step 8, as the last-hop distance of the entry is greater than the current communication range (cell size) of the BS, a larger cell range that covers the last-hop node of the relaying path needs to be found.

In Step 9, if a larger but minimum cell range to cover the last-hop node is found and the remaining cell capacity of the BS at that range is enough to meet the demand μ of call, the range

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is the target cell range and the BS is the target BS. The iteration of the loop is finished.

In Step 10, if no target BS is found (i.e., not Done) and the iteration of the list is not exhausted, repeat Step 6 to try the next entry on the sorted list.

In Step 11, after the iteration is finished, if no Target BS is found (i.e., not Done), the call is blocked.

Illustration of SCSF algorithm

SCSF is executed at the radio network controller [3] of a 3G system. The controller connects to the BSs which collect the information of the mobile nodes. We use the topology and traffic pattern in Figure 5 to illustrate the SCSF algorithm. In the figure, assume that the connections for node *A*, *B*, *E*, *G*, *I*, and *K* are established. Assume a new call request s_3 is placed at node *C* with a demand μ and three relaying paths for the call to the three BSs (b_1, b_2, b_3) are C-B-b_1, C-G-b_2, and C-b_3 respectively. The last-hop distances of the paths to their corresponding BSs are $d(r_1, b_1) = 4$, $d(r_6, b_2) = 5.5$, and $d(s_3, b_3) = \infty$, where r_1, r_6, and s_3 are the last-hop nodes (points) on the relaying paths for the source point s_3. Note that, as mentioned in Section II.A, mobile node uses short range only to communicate with other mobile node. Thus, node *K* cannot relay signals for node *C* as node *K* is outside of the communication range of node *C*. The last-hop distances of the paths are stored on a list which is then sorted in an ascending order based on the value of the distances. The sorted list becomes $\{(4, s_3, b_1), (5.5, s_3, b_2), (\infty, s_3, b_3)\}$.

The first potential target BS for the call is b_1 because b_1 requires the smallest cell range (4 units of distance) to cover the last-hop node *B* of the path for the call. Since the last-hop distance of the path is 4 units which is smaller than the current cell range (5 units of distance) of b_1, the current cell range is a potential target cell range for the call. If the remaining capacity of b_1 of the current range is enough to meet the demand of the call, then b_1 is chosen as the target BS and the current cell range of b_1 is the target cell range; otherwise, the BS with the next shortest last-hop distance on the list will be the potential target BS. In this case, b_2 is the next potential target BS. Since the current cell range of b_2 is smaller than the last-hop distance of the last hop node *G* of the path to b_2, a larger cell range (5.5 units of distance) is required to cover the last-hop node *G* of the path. If the remaining capacity (the capacity at range 5.5 minus the used capacity for existing connections) is larger than the demand of the call, then b_2 is the target BS and the target range is 5.5 units of distance. If not, b_3 which is the next entry on the list will be the potential target BS. Since the last-hop distance of the path for the call to b_3 is ∞, i.e., unreachable, there is no target BS in this case.

Complexity Analysis

As we mentioned earlier, OCS is an Integer Program. Since there is no known polynomial time algorithm for Integer Programming in the worst case, any polynomial time algorithm for solving the cell size problem is more efficient than the OCS in the worst case.

For the SCSF algorithm, when a new call request of a source node is placed, several possible relaying paths for the source node are provided by a routing protocol. Each of the paths goes to a different BS. Only the last-hop distances of the paths are needed for the cell size computation. The last-hop distances are sorted in an ascending order and the capacity of the BS starting from the head of the list is checked. The sorting requires $O(m \log m)$ time where m is the number of BSs and the checking requires $O(m)$ time. Thus, the time complexity of SCSF is $O(m \log m)$ plus $O(m)$ which is $O(m \log m)$. Thus, SCSF is more efficient than OCS in the worst case to compute the cell sizes.

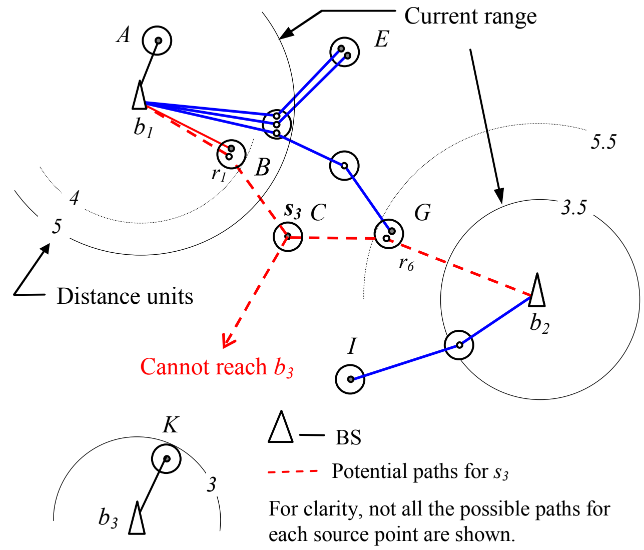

Figure 5. An example to illustrate the SCSF algorithm

IV. PERFORMANCE EVALUATION

In this section, we study the performance of SCSF with respect to OCS, a multi-hop small cell size (SCS) case and a general single-hop large cell size (LCS) case by using simulations. Note that there is no other existing cell size scheme for comparison. The settings of SCS are the same as the settings of OCS and SCSF except that the cell size of SCS is small and fixed whereas OCS and SCSF have adjustable cell size.

A. Simulation Model and Parameters

The simulation model is a 3-Cell model (see Fig. 6). Each cell has 25 source nodes. The number of relaying nodes of each cell varies from 0 to 160 in increments of 40. The source nodes and relaying nodes are uniformly distributed over a circular area with a radius of 1.1 km centered at each BS. The role of source node and relaying node are separated so that the case of no mobile nodes willing to relay signals can be captured.

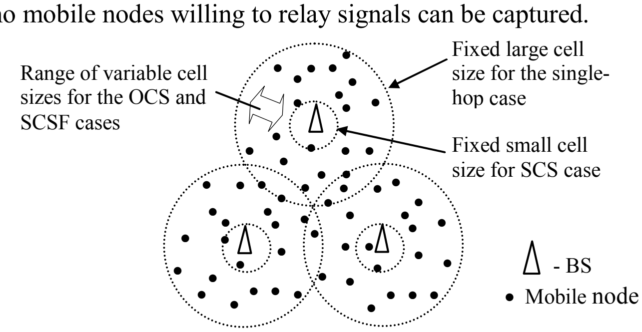

Figure 6. 3-Cell model

In this model, we vary the number of relaying nodes to model different nodal densities, traffic patterns and network topologies. Table I shows the simulation parameters. The cell ranges for the SCS and single-hop LCS cases are 250m and 1.1 km, respectively. For SCSF and OCS, the cell size ranges from 250m to 1.1 km. The capacities corresponding to ranges are

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shown in Table II. The values in the table are obtained by using the capacity function $U(R)$ that we approximated by using curve fitting based on the sample data of uplink ranges with respect to the uplink capacity (data rates) in a suburban area for W-CDMA network in [3]. The sample data is shown in Table III. The capacity function $U(R) = 245.56R^4 - 2717.13R^3 + 11245.43R^2 - 20736.4R + 14511.99$, where $U(R)$ is the cell capacity in terms of data-rates (kbps) and R is the transmission range of the BS. As the cell range R increases, the capacity $U(R)$ of the cell decreases. We scale down the capacity values by a factor of 9.5 to reduce the simulation time. Since our interest is in the relative throughput gain of SCSF as compared to that of OCS and SCS, the absolute value of cell capacity is less significant in this case. For the SCSF, OCS and SCS cases, the communication range of the mobile nodes is fixed at 250m with a capacity of 1035 kbps except the last-hop nodes which have flexible communication ranges as large as the ranges of the BS. For data transmission, each transmission frame is 10ms long and consists of 15 time-slots according to the TDD WCDMA standard [3]. Each time-slot can be assigned at most 5 codes and each code corresponds to a data rate of 13.8 kbps [3]. Each call uses three slots and one code per slot at a constant bit rate. The duration of each call is 5 minutes. The maximum number of hops is set to 7 to avoid excessive delay. Each mobile node is equipped with a directional antenna with a 45^o beam angle to increase the spatial reuse. The duration for the simulation is 5 minutes. The simulation is modeled with OPNET Modeler 10.0A [7]. The optimization package used is MOSEK version 5 [6].

The OPNET Modeler is used to generate the network topology. The distance graph for the BSs is computed using the Euclidean shortest paths as relaying paths. For the OCS case, the distance graph is input to MOSEK to compute the optimal cell sizes and the connection assignment of each source point. The optimal cell sizes and connection assignments are transferred back to OPNET for the simulation to obtain the throughput and the other performance metrics. For the SCSF case, the computation of cell size using MOSEK is not required.

In this simulation, our focus is to quantify the relative throughput among SCSF, OCS, SCS and the single-hop LCS case. We assume the mobile nodes to be static (or with limited mobility) so that the results will not be affected by the effectiveness of routing. High mobility may cause frequent disconnections and may require updating of the paths by routing and the cell sizes by SCSF and OCS. This increases the control overhead, but does not affect the approximate optimality of SCSF to the optimal solutions. We assume a heuristic channel assignment scheme from [10] for channel assignment. A channel is represented by a time-slot and code pair. We assume perfect power control so that the cell capacity function remains unchanged during the simulation. We also assume perfect physical medium, and sufficient battery capacity of mobile nodes for relaying signals.

TABLE I. SIMULATIONS PARAMETERS

	OCS/SCSF	SCS	Single-hop LCS
BS or last-hop nodal range	250 ~1100 m	250 m	1100 m
Nodal range	250 m		1100 m
Number of slots/ frame	15		
Data rate per code	13.8 kbps		
Call request rates	0.5 calls/min.		
Call holding time	5 min.		
Max. hop count	7		
Antenna	directional antenna with beam angle 45^o		
Simulation duration	5 min.		

TABLE II. CAPACITY CORRESPONDING TO THE CELL RANGE

Range (m)	250	390	560	780	1100
Capacity (kbps)	1035	828	621	414	207
Capacity (codes/ slot)	5	4	3	2	1

TABLE III. UPLINK RANGE VERSUS CAPACITY

Range (km)	1.1	1.4	1.75	2.25	2.7	3.1
Capacity (kbps)	2048	1024	384	144	64	32

B. Performance Metrics

We use the following metrics to evaluate the performance of SCSF, OCS, SCS, and the single-hop LCS case.

Cell throughput – the number of packets per second received at all BSs. ***Call acceptance ratio*** (*AR*) – the ratio between the number of accepted calls and the total number of calls. High throughput and/or high call acceptance ratio represents a good choice of cell size that provides a good balance between the cell capacity and the network reachability to achieve high demands being served.

Cell size – the communication range of the BS. Large cell size increases the network reachability, but reduces the cell capacity and vice versa.

Packet delay - the time required for a packet sent from the source node to reach the BS. Low packet delay represents the effectiveness of the channel assignment scheme.

C. Simulation Results

In Figures 7, 8, and 9, we observe that when the number of relaying nodes is zero, the SCSF, OCS and SCS cases are reduced to a single-hop case. For the SCS case, many source nodes cannot reach the BS to use the available cell capacity because the cell size is small (low network reachability). Therefore, the cell (or BS) throughput and the call acceptance ratio (*AR*) are low. For the single-hop LCS case, although the cell size is large (high network reachability), the cell capacity is too small to meet the demand. Thus, the throughput and the *AR* are also low. For the OCS case, the size of each cell is adjusted to an optimal value to maximize the demands that can be served. The throughput is the highest and the average cell size of the OCS case is 731m. The single-hop LCS case has higher throughput and *AR* than that of SCS because it has a better combination of coverage and capacity than that of SCS. The throughput of the SCSF case is higher than that of the SCS and the single-hop LCS cases because SCSF uses better cell sizes to accommodate more demand.

As the number of relaying nodes increases, more source nodes can reach the BS through multi-hop relaying. Thus, the throughput and *AR* of all the multi-hop cases (SCSF/OCS/SCS) increase. For the SCSF and OCS cases, the cell sizes are adjusted to a smaller value to achieve a higher capacity to meet the increased reachable demand. Thus, the throughput of the SCSF and OCS cases is higher than that of the SCS case. OCS has the highest throughput because OCS uses the optimal cell sizes.

When the number of relaying nodes is 120 or more, the network reachability is no longer an issue, but the capacity is because most source nodes can reach the BSs through relaying and the total demand is higher. OCS uses the same (smallest) cell size as that of SCS to achieve maximum capacity to serve the demands. Thus, OCS and SCS achieve their highest throughput. The throughput of SCSF also increases, but the average increase is lower than that of the OCS and SCS cases because, in some cases, the cell size of the SCSF case could be dominated by some source nodes which require a larger cell size (small cell capacity) to cover them such that SCSF could not have the smallest cell size for achieving the highest cell capacity to meet the demands.

In Fig. 10, although the packet delay of SCSF, OCS and SCS cases is higher than that of the single-hop LCS case because multi-hopping is involved, the delay is still considered to be low in a multi-hop environment. This is due to the effectiveness of the channel assignment scheme. Fig. 11 shows the delay-throughput characteristic of SCSF, OCS and SCS which follows a general trend in multi-hopping situation.

SCSF on average achieves 71% of the performance of OCS in terms of throughput. SCSF also achieves 168% higher throughput than that of the SCS case when the network is sparse and 144% higher throughput than that of the single-hop LCS case regardless of the network density.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we propose a heuristic cell size scheme, called Small Cell Size First (SCSF) for a TDD W-CDMA MCN. SCSF computes the cell sizes which provide a good balance between cellular capacity and coverage to achieve high system throughput. SCSF is more efficient than OCS in solving large real-time cell size decision problems. Simulation results show that SCSF on average achieves 71% throughput performance of OCS, i.e., SCSF provides good results compared to the optimal solutions provided by OCS. SCSF also outperforms SCS when the network is sparse and the single-hop large cell size case regardless of the network density.

Power control is important to maintain the cell size and the cell capacity on which the cell size schemes are based. A topic for future work would be the development of an effective power control scheme for MCNs.

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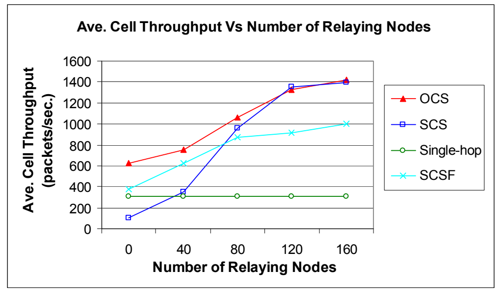

Figure 7. Cell Throughput

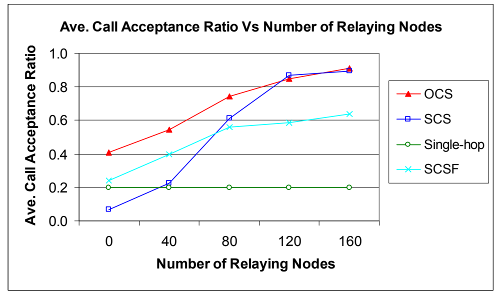

Figure 8. Call Acceptance Ratio

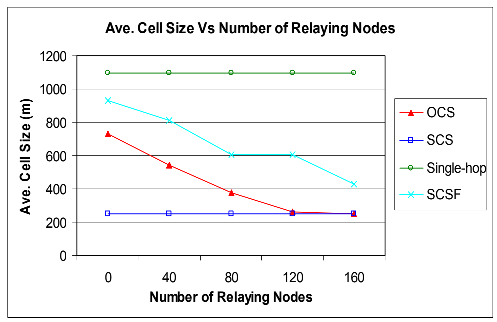

Figure 9. Cell Size

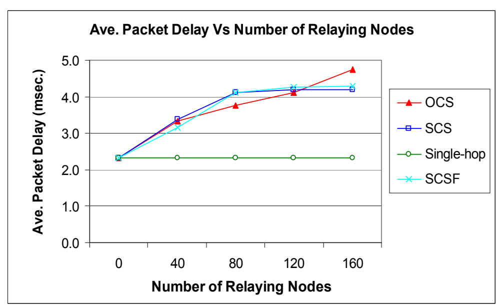

Figure 10. Packet Delay

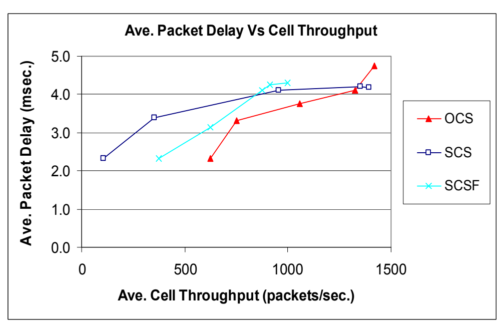

Figure 11. Packet Delay Versus Cell Throughput

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