Chapter 4
An Evolutionary Approach to Velocity and Traffic Sensitive Call Admission Control

The chapter proposes a new approach to call admission control in a mobile cellular network using an evolutionary algorithm. Existing algorithms on call admission control either ignore both variation in traffic conditions or velocity of mobile devices, or at most consider one of them. This chapter overcomes the above problems jointly by formulating call admission control as a constrained optimization problem, where the primary objective is to minimize the call drop under dynamic condition of the mobile stations, satisfying the constraints to maximize the channel assignment and minimize the dynamic traffic load in the network. The constrained objective function has been minimized using an evolutionary algorithm. Experimental results and computer simulations envisage that the proposed algorithm outperforms most of the existing approaches on call admission control, considering either of the two issues addressed above.

4.1 Introduction

Call Admission Control (CAC) refers to an interesting decision-making problem of efficient call management in a mobile cellular network. The primary objective of this problem is to serve as many calls as possible, and prevent dropping of calls in progress [1-3]. Additionally, an efficient call management system also aims to assign appropriate channels to the incoming/handoff calls, so that the necessary soft constraints for channel assignment are maintained [1-8].

Typically, soft constraints include co-channel, co-site, and adjacent channel constraints, all of which need to be satisfied to serve the secondary objective. In the current literature, Quality of Service (QoS) is often used to measure the quality of CAC with an attempt to maximize call assignment and soft handoff, satisfying the soft constraints. The higher the QoS, the better the CAC.

This chapter provides a novel approach to formulate the CAC as a complex decision-making problem with an objective to optimize service of calls in a dynamic environment under the fluctuation of load and motion of the mobile station. The formulation involves construction of an objective function with constraints, and has been solved using an evolutionary algorithm. Experiments have extensively been undertaken to minimize call drops.

S. Ghosh and A. Konar: CAC in a Mobile Cellular Network, SCI 437, pp. 129–152.
springerlink.com © Springer-Verlag Berlin Heidelberg 2013

4.1.1 Review

Limited works on CAC employing genetic algorithm (GA) has appeared in the existing literature. One of the initial works utilises a local policy, where the cells are square (and not hexagonal) in shape and the call arrival rate follows Poisson distribution in a Markov model [1]. The performance of the system depends only on the linear combination of call dropping and the call blocking probability. The policy is said to be local since a base station only gets the information of its four neighbours. Here a two parent two offspring GA is used. Clique packing technique is used to take care of the channel assignment problem implicitly [1]. The process is terminated when the policy improvement appears to stagnate.

In the year 2000 [7, 8] the authors proposed a scheme, where the system is defined in terms of *m* classes of users in each cell. A user in class *i* would require b_i amount of bandwidth. The goal was to maximize $\sum x_i b_i$ for candidate solutions x_i , where the handoff and blocking probability have a given upper bound. Both semi Markov decision process and GA are used. Here also the process is local one considering the call acceptance of a single cell.

In 2004 one more CAC scheme was proposed for General packet radio service (*GPRS*) using GA [6]. Here the GPRS architecture was of given special emphasis. The CAC module is almost the same as the one described in [7]. But the fitness function is different as it is the product of QoS factor and length of the queue of the class and inverse of the square root of frequency. The advantage of this method over the previous one described in is the usage of GPRS technology and its architecture [6].

4.1.2 The Problem

CAC systems are mainly used to take decisions whether a call should be serviced, blocked or dropped by a Base Station (BS), and if serviced, it identifies the channel to be assigned to that call. At the time of taking such decision, the interference is considered the only factor in most of the current literature [1 - 48].

Existing literatures presented above, concentrates on specific aspects of the call admission control problem. A few of these considers rectangular cells and the near neighbour and hence ignores the entirety of the network, while the rest considers only the hand off and call drop due to insufficient channels. Unfortunately, most of the above literatures consider the mobile stations either static or moving very slowly in the small area with very low traffic load. The mobility factor comprising speed and direction of movement has been ignored in these works. The overall network load is also ignored and hence the handoff policies used have a partial effect on the network. Most of the above schemes are localized to a single cell. Hence the channel reuse is also not done efficiently.

In this chapter, we propose a scheme that takes a more wide view of the call admission control problem. We consider our cells to be hexagonal so as to easily track the movement of Mobile Stations (MS) in the neighbourhood cells. Instead of considering a single cell scenario we have taken a small network to implement the algorithm to incorporate the intercellular communication efficiently. The decision of acceptance or rejection of a call dose not only depend on the feasibility and availability of the channel but also on the speed at which the MS moves and its direction of movement. Its geographical location with respect to the base station also has a significant importance. Moreover the traffic density on a cell is also considered to be a determining factor.

The reuses of the channels also make the approach more effective. The algorithm proposed in the chapter is based on all the factors mentioned above which more perfectly handles the real world situation.

There are certain parameters to measure the efficiency of such a system. One important parameter is the number of call drop that shows the number of unwanted call disconnection in the system and should be as low as possible. The other one would be the call block where the new call attempts are rejected by the network due to the insufficiency of the free channels. The number of assignable channels that helps in increasing the efficiency of the system is another important parameter considered here.

In this chapter, we propose a scheme, which takes into account the motion aspect of the mobile station as well, besides considering all the necessary objectives of CAC. We here use three parameters: i) speed, ii) direction, and iii) distance of the MS from the nearest base station to model the motion of the mobile station. The above three parameters play an important role at the time of soft handoff of a call from one cell to other. The importance can be explained with the help of Fig. 4.1, where the central cell has six neighbours.

The MS in such a cell while in service may move in various directions with different speed. If it moves toward cell 5 or 6 directly then the channel for handoff will be searched in those cells. When it moves slowly along the common boundary of cell 5 and 6, the cell with base station nearer to the current location of MS is considered. Again, if the above movement takes place with a very high speed, then the call may be dropped due to high interference. Suppose it moves towards cell 2 very slowly, then there may not be a requirement for a soft handoff at all since it may never cross the existing cell boundary.

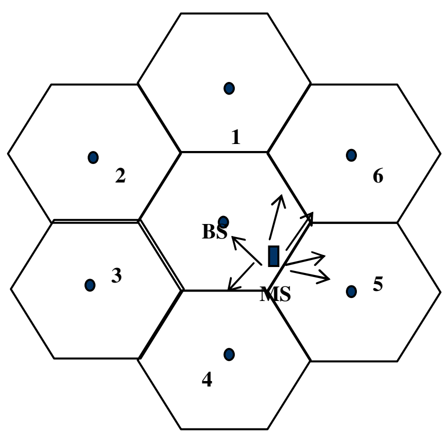

Fig. 4.1 Illustrating the need to consider speed in a given mobile cellular network.

Hence, we aim at developing an optimal set of assignment, which will address of the quality of service, and the velocity aspect of the scheme.

4.1.3 The Approach

The problem of call admission can be reconstructed as an optimization problem with given constraints. As such a fuzzy approach would not be appropriate in that case. Graph colouring problem and others are not suitable since there are some resources that are shared by all the cells and hence using a unique colour to represent a cell is difficult. Hence the natural option was to take a GA approach.

Assigning a call to a channel is done using the electromagnetic compatibility constraints. In general, there are three types of constraints [3]:

- ***Co-channel Constraint*** **(CCC):** The same channel cannot be simultaneously allocated to a pair of cells unless there is a minimum geographical separation between them.
- ***Adjacent Channel Constraint*** **(ACC):** Adjacent channels cannot be assigned to a pair of cells unless there is a minimum distance between them.
- ***Co-site Constraint*** **(CSC):** A pair of channels can be employed in the same cell only if there is a minimum separation in frequency between them.

These constrain are said to be the soft constrains of channel assignment and are used as the feasibility constrain for call admission control. Call admission control involves decision-making regarding assignment of channels to incoming calls or dropping calls in service, besides serving handoff calls, if feasible. To arrive at such decision, certain factors should be taken into consideration.

When a new call arrives, the feasibility condition for call assignment is checked using the soft constraints and the decision about call assignment/blocking is taken.

When a MS starts moving with a call in service the scenario changes. Then the feasibility condition only is not adequate to prevent call dropping. The speed and direction of movement of MS along with the distance of MS from the neighbouring BS play a major role in granting call services to soft-handoff since the crossover of cells triggers a soft-handoff.

The previous works remained silent on the mobility aspect of the MS and its location from the nearest base station. Traffic change in cells because of variation in incoming calls is a common phenomenon, but unnoticed in most of the literature while addressing the call admission control problem. Traffic change, however is not only influenced by the arrival of new calls, but is pronounced also by the mobility of the existing calls. Special emphasis is thus given on traffic changes and mobility aspect to address the call admission control problem in this chapter.

Most of the works on CAC using GA concentrates on the decision-making about the calls in a single cell. The traffic loads in most of the cases are considered to be static in nature. But all the cells with all the channels are going through the same process and hence the network is changing dynamically. Considering only one cell and its neighbours with the consideration that conditions of those neighbours are static also makes the system limited in effect. If the whole network is considered, then the solution becomes more applicable and robust.

In this chapter we have considered the case of dynamically changing cells of the entire network. We have considered dynamically changing demand of the channels as well as random movement of each MS with varying speed. In this context we see that the call drop due is minimized considerably and soft handoff is achieved effectively. The call service is almost consistent with the change in demand.

The proposed system thus is more sensitive to the continuously changing demands of the real world and the changing location of the MS. With this the QoS is also taken care of using the soft constraints for interference. This approach is a holistic one as all the cells of the network is considered. Hence it is a new way of looking into the CAC problem, which caters better in a real world situation.

4.2 Formulation

Here we have attempted to handle the calls with their mobility factor. A caller may be in motion when a call is generated or while being serviced. Depending on the speed of the MS and the direction in which they are moving, there may be a need to reassign the call to a different channel of a different cell. To explain such situation we start with defining the primitives.

4.2.1 Definitions

We consider a system of M hexagonal cells present in the network and each of them has N number of frequency channels. In CAC we need to find out the best allocation of calls in different cells. So we need to know about the current status of allocation, which is usually represented by an allocation matrix. In this chapter, we plan to select the appropriate allocation matrix online, so as to satisfy given objective function and systems constraints to be introduced later. The formal definition of allocation matrix is given here for convenience.

Definition 1: Let $[f_{m,i}]$, $\forall i \in M, m \in N$, be a binary matrix describing allocation of channels in given cells, where

$$F = [f_{m,i}] = \begin{cases} 1, & \textit{if } m^{th} \textit{ channel is allocated to serve a call in the } i^{th} \textit{ cell} \\ 0, & \textit{if the } m^{th} \textit{ channel in the } i^{th} \textit{ cell is free.} \end{cases}$$

Example 4.2.1: An example of a 4x3 allocation matrix where there are 4 cells and 3 channels is given as

$$\begin{array}{cc} & \textit{channel} \rightarrow \\ \textit{Cell} \downarrow & \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \end{array}$$

This implies that the 2nd channel of the 1st cell is serving a call and rest of the channels are free.

The knowledge of calls assigned to channels in any cell is a very important to measure the feasibility of assigning the new calls satisfying the soft constraints.

Definition 2: Let *assignment matrix* $A=[a_{m,i}], \forall i \in M, m \in N$, be a matrix describing the assignment of calls to the channels of a cell, where

$$a_{m,i} = p, \quad \textit{where p is the number of channel assigned to the } m^{th} \textit{ call in cell i}$$

Example 4.2.2: Let there be 10 calls in the network with 4 cells and 3 channels. Then

$$\begin{array}{c} calls \rightarrow \\ Cell \downarrow \begin{bmatrix} 1 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 3 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 2 & 0 \\ 0 & 2 & 0 & 0 & 0 & 1 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 3 & 0 & 0 & 0 \end{bmatrix} \end{array}$$

We can see that the 1st call is served by the 1st channel of the 1st cell, the 2nd call by the 2nd channel of 3rd cell, 3rd call by the 1st channel of 2nd cell and so on.

While allocating the calls to the channels we should maintain the QoS in terms soft constraints. The soft constrains ensure that the new call assignment do not have any interference with the existing calls assignment in the neighbouring cells or in the same cell. In this chapter, we measure the QoS as a function of three important network attributes: feasibility, hotness (the measure of load) and motion of the MS. The feasibility of channel assignment is often expressed as linear combination of allocation and compatibility matrices. A formal definition of compatibility matrix is given here.

Definition 3: The *compatibility matrix* C gives a measure of satisfaction of the soft constraints, attempted to minimize co-channel, co-site and the adjacency-channel interference, whose non-diagonal and diagonal elements are expressed by

$$C_{j,k} = \textit{minimum channel seperation required for a call assignment in cell j when there are calls assigned in cell k, and}$$

$$C_{i,i} = \min\textit{imum channel seperation required to assign a call in cell i when there are other channels assigned in the same cell.}$$

Speed of the MS is a very important aspect of the CAC since it affects the soft handoff and the call drop process.

Example 4.2.3: A compatibility matrix in a four cell network is given as

$$\begin{bmatrix} 4 & 3 & 2 & 0 \\ 3 & 4 & 3 & 2 \\ 2 & 3 & 4 & 3 \\ 0 & 2 & 3 & 4 \end{bmatrix} \quad \begin{aligned} &where,\ C_{i,i} = 4 \\ &and\ \ C_{i,j} \in \{0\ to\ 3\} \end{aligned}$$

Definition 4: Speed $V = [v_{p,i}]$ in the present context refer to rate of position changing of a MS busy with a call utilizing a channel p in cell i.

Example 3.2.4:

$$\begin{aligned} &v_{p,i} = 0 && \textit{when the MS is static} \\ &0 < v_{p,i} \le 60 && \textit{when inside the city} \\ &v_{p,i} > 60 && \textit{in highways} \end{aligned}$$

Distance of a MS from the BS is also an important aspect as it takes part in the soft handoff process.

Definition 5: Distance of MS j from the BS i $\forall i \in M$ is denoted as $Dis = [dist_{i,j}]$

Example 3.2.5: $dist_{i,j} = d$ (Fig. 4.2)

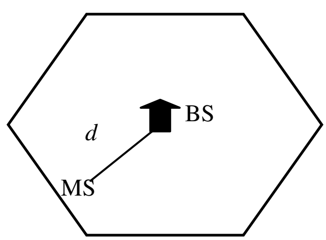

Fig. 4.2 Measurement of d

Hotness is another major factor while deciding about a call assignment to a channel. It is named hotness since it shows how many calls are coming to a particulate cell i.e. how hot and happening the cell is. If the number of incoming calls becomes very high the limited resource of the system will not be able to handle the incoming calls and thus subsequent new calls will be blocked.

Definition 6: Hotness of a cell i is defined as the number of incoming calls per unit time and is denoted as $H = [h_i]$

Example 3.2.6: Hotness in a 4-cell scenario where maximum number of incoming calls is 10 can be given as

$$H = [h_i] = \begin{bmatrix} 2 & 10 & 8 & 5 \end{bmatrix}$$

The angle of motion of MS with respect to the BS shows the direction in which the MS is moving and hence the search for cells with free channels becomes easier. Hence it is also an important factor in CAC.

Definition 7: Angle of motion is the angle made by the direction of motion of a MS p with respect to the BS i and is denoted by $Delt = [\delta_{p,i}]$, and is illustrated in Fig.4.3.

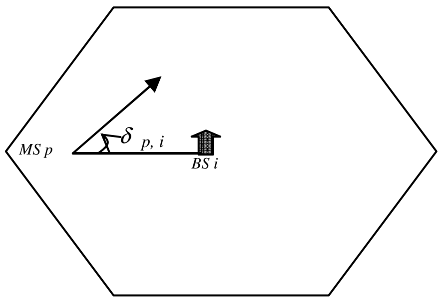

Fig. 4.3 Angle of Motion

Call duration is useful for finding out the calls going for a very long time. At the time of high congestion, these calls are dropped to free the channels for reuse.

4.2.2 Formulation

Let the time taken by each call in a given channel p, of each cell i is denoted by $T_{p,i.}$ If $v_{p,i}$ be the speed with which an MS is moving in any direction, then, its velocity along that direction is $v_{p,i} \cos \delta_{p,i}$. Again if $dist_{p,j}$ be the distance traversed by the MS in time $\Delta T_{p,i}$ then average probability of capturing that MS is denoted as P_{CMS} and is given by

$$P_{CMS} = \sum_p \frac{\left(v_{p,i} \cos \delta_{p,i}\right) \Delta T_{p,i}}{dist_{p,j}} \tag{4.1}$$

An increase in the value of the above expression is created by a high range of velocity, which gives very little time to search a new channel and to go for a soft hand off (SHO). Hence it should be minimized.

The difference between the two calls in the two different channels should be at a minimum distance to avoid the interference described as soft constrains above. The feasibility of assignment of calls in a cell i can be checked by satisfying inequality (4.*2a*) [1], [3]. In (4.*2a*) the left hand side of the inequality suggest the distance between two channels of which one assign m^{th} call in i^{th} cell and the other assign n^{th} call in j^{th} cell. The right hand side of the inequality gives the minimum channel separation required to assign calls in both the cells ***i*** and ***j***. The condition demands that the channel separation should satisfy the bare minimum value obtained from compatibility matrix and is said to be feasibility condition and denoted by Feas.

$$\sum_m \sum_n (\sum_i (|a_{m,i} - a_{n,j}|)) < \sum_i C_{i,j} \tag{4.2a}$$

$$\Rightarrow \mathrm{Feas}^j = \sum_m \sum_n (\sum_i (|a_{m,i} - a_{n,j}| - C_{i,j})) < 0 \tag{4.2b}$$

It follows from the last inequality that smaller the value of the left hand side, lesser is the interference and thus better is the quality of service of the call assigned to the channel.

The traffic load in a cell is an important issue to determine the possible admission of incoming calls in a given cell. Traffic load in the cell i may be expressed as the ratio of incoming calls and the total free channels of the cell. We define a metric to measure the traffic load in a given cell i, denoted as Load and is given by

$$Load = \frac{h_i}{\sum_m (1 - f_{m,i})} \tag{4.3}$$

Hence the traffic load is the more if the number of incoming calls exceeds considerably than the free cells in the system and starts affecting the overall system performance. Hence this is also to be minimized.

We now construct an objective function, the minimization of which yields a possible solution to the call admission problem. Since expressions (4.1), (4.2b) and (4.3) all need to be minimized, a minimization of their linear combination offers an objective that jointly satisfies all the three basic objectives. The overall objective function is given by

$$Z_{Candidate} = P_{CMS} + Feas + Load$$

$$= \sum_i \left(\sum_p \frac{(v_{p,i} \cos\delta_{p,i})\Delta T_{p,i}}{dist_{p,i}} + \sum_m \sum_n (\sum_j (|a_{m,i} - a_{n,j}| - C_{i,j})) + \frac{h_i}{\sum_m (1 - f_{m,i})} \right) \tag{4.4}$$

The lower the value of the function better is the performance of CAC system. Here we also define the difference of fitness ΔZ as

$$\Delta Z = Z_{offspring} - Z_{parent} \tag{4.5}$$

4.3 Proposed Algorithm

We have used the traditional concept of GA for the call admission control system. Here we have considered the call assignment in the network as the parent population and used crossover and mutation to generate the offspring population. Since it is considered on the total network the chromosomes are two dimensional in nature with rows representing cells and columns representing columns. With the generation of offspring we calculate the cost of both parents and offspring and retain the fittest. The algorithm is described below with the abbreviations.

M**, N**	Total number of channel and cell;
ITE	Total number of iteration;
L	Long call interval;
ε	Very small number;
s	Size of population;
V	Speed as given in definition 4
H	Hotness as given in definition 6
A	Assignment matrix as given in definition 2
C	Compatibility matrix as given in definition 3
Delt	Angle of motion as given in definition 7
Dist	Distance as given in definition 5.
P	$\{p^j\}$ = Initial population.
C-Pool	Parent Pool.
O-Pool	Offspring Pool
Z	fitness for a candidate

Algorithm:

CALL_Adm(A,C;Z)
BEGIN
FOR (j=0 ; j<s; j++)
Initial *(A, C;* p^j*) ;*
END FOR.
P=$\{p^j\}$*;*
FOR (i =0;i<ITE; i++)
Do

Selection *(A, C, P; C-Pool);*
Crossover *(C-Pool; O-Pool);*
Mutation *(O-Pool; O-Pool);*
FOR (j=0; j<s; j++)
Fit *(A, C, Dist, Delt , V, H, C-Pool ;* Z_{Pool} *) ;*
Fit *(A, C, Dist, Delt , V, H, O-Pool ;* Z_{Pool}*) ;*
IF ($\Delta Z_f^j > 0$*)*
Update C- Pool as $p^j = f^j$;
END IF.
END FOR.

($T_{x,i,j}$)++;

$IF\left(T_{x,\ i,j} > L\right)$

Drop_call *(x, i, j ,O-Pool; O-Pool);*

END IF;

IF ($\Delta Z_f^{\,j} < \varepsilon$)

BREAK;

END IF;

WHILE (CONDITION 2a)

END FOR;

END.

Initialization:

In this chapter, we consider the solutions as the assignment of calls to channels of all the cells in the network. Hence we have each solution as a *M x N* vector F (assignment) such that

$$F = \left\{f_{m,i}\right\} = \left\{\begin{array}{l} 1 \text{ when } m^{th} \text{ channel in } i^{th} \text{ cell is in service} \\ 0 \text{ otherwise} \end{array}\right\},$$

where F satisfy the soft constraints.

We have considered a pool of *p* such vectors of assignment as a parent population all of which satisfies the soft constraints.

Initial (A, C; p^j):

BEGIN.

$FOR\ \left(i = 0; i < N; i++\right)$

$FOR\left(m = 0; m < M; m++\right)$

$IF\ \left(|\, a_{m,i} - a_{n,j}\, | < C_{i,j}\right)$

$$f_{m,i} = \left\{\begin{array}{l} 1 \text{ when } m^{th} \text{ channel in } i^{th} \text{ cell is in service} \\ 0 \text{ otherwise} \end{array}\right\},$$

END IF.

END FOR.

END FOR.

$Construct\ \ p^j = F = \left[f_{m,i}\right]$

Return p^j.

END.

Example 3.3.1: We consider a network with 3 cells and 4 channels. Then the parent matrix, obeying the compatibility constraints, may look like the following p^j where a '1' represents a channel in a cell is assigned to a call and a '0' represents a free channel.

$$p^j = F = [f_{m,i}] = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \text{ where, M=3 and N=4.}$$

Selection:

A roulette wheel with slots sized according to feasibility is used for selection process. We construct such a roulette wheel as follows

- First we calculate the feasibility value for a parent p^j using condition (2b) denoted as $feas^j$.
- Then we calculate the total feasibility of all parents $\sum_{j=0}^{s-1} feas^j$.
- Now we calculate the probability of selection of a parent p^j as $\Pr ob_{p^j} = \frac{feas^j}{\sum_{j=0}^{s-1} feas^j}$.
- Now we calculate the cumulative probability $CP_i = \sum_{j=0}^{i} \Pr ob_{p^j}$.
- The selection process is based on spinning the roulette wheel s times; each time we select a single chromosome for a new population in the following way:
  - Generate a random (floating) number r in the range [0; 1],
  - If $r < CP_1$ then select the 1st chromosome (p^1);
  - Otherwise select the ith chromosome p^i (2< i < s) if $PROB_{i-1} < r < PROB_i$.

This way we can choose the parents who have higher feasibility of getting new calls in the population. The pseudo code for selection is given below.

Selection (A, C, P; C-Pool):

Let x be an integer.
BEGIN.

$$Feas^j = \sum_m \sum_n (\sum_i (| a_{m,i} - a_{n,j} | - C_{i,j}))$$

Fsum= 0;

FOR (j=0 ; j< s ; j++)
Fsum = Fsum + Feas ^{j};
END FOR;

$$\Pr ob_{p^j} = \frac{feas^j}{\sum_{j=0}^{s-1} feas^j}$$

CP_i =0.
FOR (j = 0 ; j< i ; j++)

$$CP_i = \sum_{j=0}^{i} \Pr ob_{p^j}$$

END FOR.
r = Random (float in [0, 1]).

IF(r < CP_0) then x=0;

ELSE

FOR (i=1; i < s ; i ++)

IF ($PROB_{i-1} < r < PROB_i$)
x= i;
Pool = Pool U {p ^{x}};
BREAK;
END IF.
END FOR.
END IF.
Return C-Pool;
END.

Crossover:

We use the C-Pool generated by the selection procedure for crossover. We consider two random chromosomes from the C-Pool to crossover. We consider a one-point crossover and generate a random position *(r, c)* at which the crossover takes place to produce two offspring.

Let $p_{m,l}^x$ and $p_{m,l}^y$ be two parents taking part in crossover. After crossover the offspring are kept in O-Pull.

The pseudo code of crossover is given as:

Crossover (C-Pool; O-Pool):
BEGIN.
FOR(ps=0; ps < SizeOf (C-Pool) ; ps ++)

```
    // Taking chromosomes for cross over
x = Random (number < SizeOf ( C-Pool));
y = Random (number < SizeOf ( C-Pool) &&  ≠x);
// Deciding position of cross over
r = Random (number < m);
c= Random (number < l);
FOR( i= 0; i < r; i++)
FOR (j =0; j < c; j++)
```

$f^{x}_{j,i} = p^{x}_{j,i}$

$f^{y}_{j,i} = p^{y}_{j,i}$

```
END FOR.
    END FOR.
FOR ( i= r ; i < m; i++)
        FOR (j =c; j < l; j++)
```

$f^{x}_{j,i} = p^{y}_{j,i}$

$f^{y}_{j,i} = p^{x}_{j,i}$

```
    END FOR.
    END FOR.
        Update O-Pool;
 END FOR.
END.
```

Example 3.3.2: Let the parents have 3 cells and 4 channels and the crossover point is randomly chosen as 3rd row 3rd column.

i.e $r_{max} = 4$ and $c_{max} = 3$ and

$$p^1 = \begin{matrix} 0 & \boxed{1 \quad 0} \\ 0 & \boxed{0 \quad 0} \\ 1 & 0 \quad 0 \\ 0 & 0 \quad 1 \end{matrix} \qquad p^2 = \begin{matrix} 1 & \boxed{0 \quad 0} \\ 0 & \boxed{0 \quad 1} \\ 0 & 0 \quad 0 \\ 0 & 1 \quad 0 \end{matrix}$$

Then after crossover at r = 3 and c =3 the offspring become

$$f^1 = \begin{matrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{matrix} \quad \text{and} \quad f^2 = \begin{matrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{matrix}$$

Mutation:

We consider the random call hang-up in the system and express this phenomenon as mutation. Suppose in a given cell r, a call served with channel c is disconnected by the caller. Then following the definition of allocation matrix F, we understand that the element $f_{ml} = 0$ for m= r and l=c, after disconnection of the call.

$$\text{i.e. } f_{m,l} = 0, \quad where \quad m = r, l = c$$

We have considered minimum two such hang-ups in the network. Accordingly random positions are generated where mutation is done as described above.

Mutation (O-Pool; O-Pool):

BEGIN.
FOR (i=0; i < Size Of (O-Pool); i++)
r = Random (number < m);
c= Random (number < l);
$f_{r,c} = 0,$
END FOR
Update O-Pool;
END.

Example 3.3.3: Let there be mutation at the positions (1,2) and (4,3) for the parents with 4 cells and 3 channels
i.e, $r_{max} = 4$ and $c_{max} = 3$ and

$$f = \begin{matrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{matrix}$$

Now, r1= 1, c1=2, and r2 = 4, c2 = 3. Hence after mutation the offspring will become

$$f = \begin{matrix} 0 & \boxed{0} & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & \boxed{0} \end{matrix}$$

Fitness check :

This is the part where we calculate the fitness of the new offspring and there parents using the equation (4) where all the other values are known.

Fit *(A, C, Dist, Delt , V, H, Pool,; Z_{pool}) :*
BEGIN.
WHILE(! EOF(O-Pool)

FOR (p=0 ; p <N; p++)

$$P^{i}_{CMS} = \sum_{p} \frac{(v_{p,i} \cos \delta_{p,i}) \Delta T_{p,i}}{dist_{p,i}} .$$

END FOR.

FOR (m=0 ; m <N; m++)

FOR (n=0 ; n <N && m ≠ n ; n++)

FOR (j=0 ; j <M; j++)

$$Feas^{i} = \sum_{m} \sum_{n} (\sum_{j} (| a_{m,i} - a_{n,j} | - C_{i,j}))$$

END FOR

END FOR.

END FOR.

FOR (m=0 ; m <N; m++)

$$Load^{i} \frac{h_i}{\sum_{m} (1 - f_{m,i})}$$

END FOR.

$$Z_{Pool} = \sum_{i} P^{i}{}_{CMS} + Feas^{i} + Load^{i}$$

RETURN(Z_{Pool}).

END WHILE

END.

<u>Call Drop:</u> this is where the call is forcefully terminated due to the time constraint.

Drop_call *(x, i, O-Pool; O-Pool)*

BEGIN

$$f^{x}_{i,j} = 0;$$

END

4.4 Experiments and Simulation

In this experiment we have considered the following assumptions:

- The network has 21 hexagonal cells and 7 channels(Fig 4.4)
- The value of
  - Co-channel distance is 2
  - Adjacency channel distance is 3
  - Co-site distance is
- The number of incoming calls lays in the range 0 to 150 and changes dynamically.

- Initial population size was taken as 20.
- The velocity change was from 0 to 120 km/hr.
- The distance between two base stations is 2 km and remains unchanged.
- The calls are considered long if they go on more than 30 minutes.
- The direction of the MS, its distance from the base station and velocity changes dynamically.

The algorithm stated above is executed using the given fitness function. The initial conditions and necessary changes of the dynamic network are enforced obeying the above stated assumptions. The results obtained are shown an explained below. Fig.4.5 depicts the fitness values with respect to the increasing demand. In the initial stage when the demand is low the fitness starts with a low value and further goes down. Hence more and more channel start getting assigned.

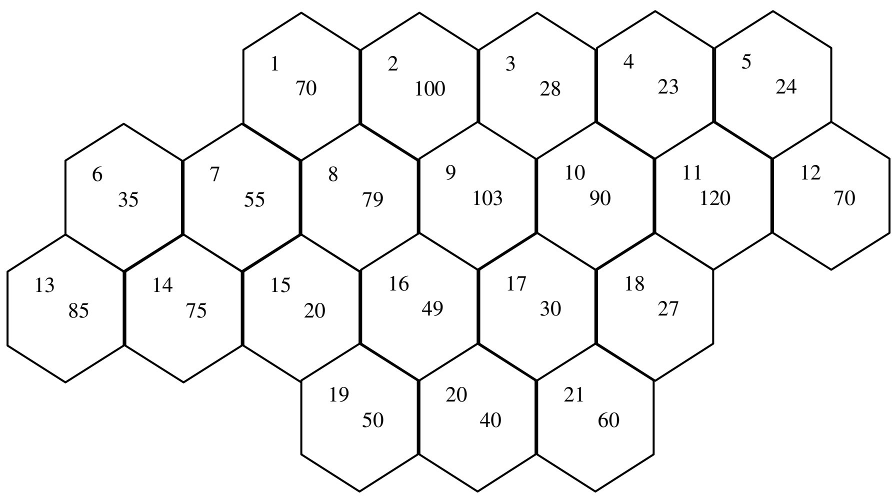

Fig. 4.4 Network of 21 cells

Initially the fitness starts decreasing as channels starts getting assigned to the calls. The fitness goes down after shooting up to a highest peak. This is due to a strong congestion in the system due to the insufficiency of the free channels in the network. This situation is resolved by dropping calls which are in service for long intervals. Again the fitness goes down and calls get assigned to channels. The in-between fluctuations in fitness values are due to the change in velocity as well as the distance of MS from BS. But as traffic load increases, the system is not able to handle the situation due to in sufficient free channels.

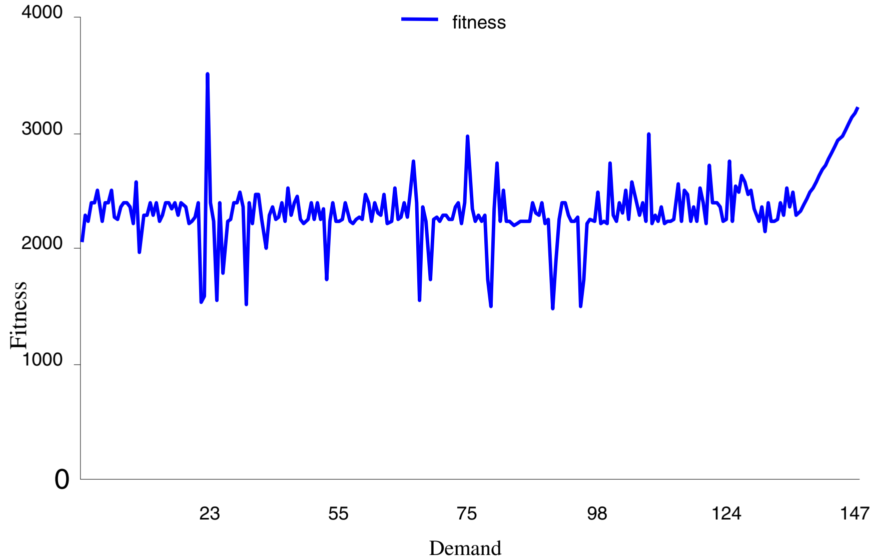

Fig. 4.5 Changing Fitness vs. Demand

Fig. 4.6 shows both the change in demand and assignment versus generation of the evolutionary process. It is evident from the figures that assignment of calls goes up when demand is medium to low but goes down when demand goes up.

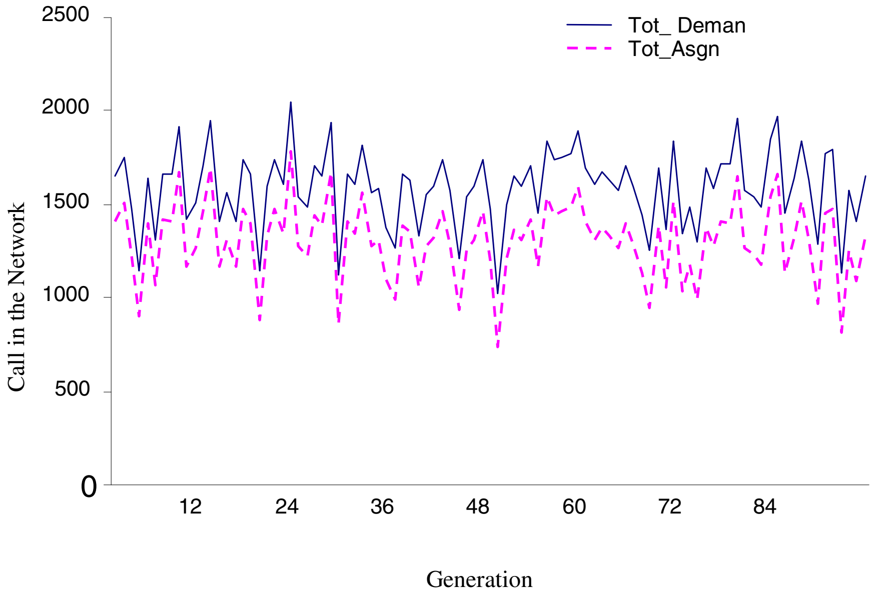

Fig. 4.6 Call Assignment with changing demand over generations

Again after a bulk of call assignment the number of available channels decrease and then new calls get blocked. This happens due to the high level of congestion and insufficient channels. After a while some calls end naturally and the channels are again free. So call assignment rate again increases.

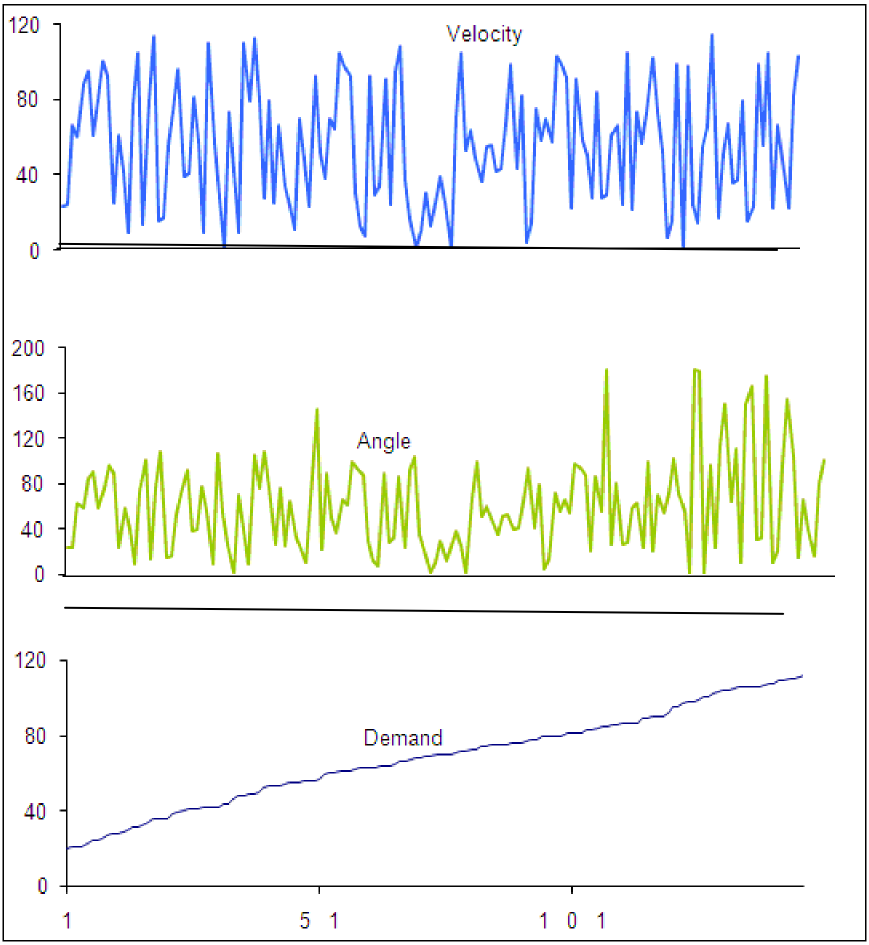

Fig. 4.7 Change in fitness due to change in the parameters

Fig. 4.7 shows the change in different parameters of the dynamic network with respect to increasing demand. We have here a randomly changing velocity and directions of calls in each channel. We calculate the fitness of assignment in such changing system with an increasing demand.

It is seen that whenever the velocity as well as the angle changes sharply the fitness function increases sharply even though the demand is not very high. Again when the angle changes sharply again there is a rise of fitness value. Again it is evident from Fig. 4.7 that fitness value goes down for slower speed and smaller change in direction. But if the congestion level is very high i.e. incoming calls is plenty in number then fitness value rises and stays flat.

This happens due to the insufficiency of free channels even though the long calls are terminated and some calls end naturally by releasing some channels free in the network. A flood of in coming calls can create congestion, which cannot be handled as long as resources are not increased.

In the present context of call admission control, the measure of efficiency (*MOE*) is defined as the ratio between the number of calls serviced and the number of incoming calls in the network. Fig. 4.8 provides the effect of increasing call demand on the efficiency.

Fig. 4.8 indicates that the call management system performs well in terms of assigning calls to free channels, even when call demand is increasing. The initial part of the graph is decreasing in nature. This is due to the fact that initially, after a certain number of call assignments, most of the channels become occupied.

At that point new calls are rejected. Then after a while, as proposed by our algorithm long time calls are retrieved and this procedure recurs after a fixed interval of time. Hence after this period call drop are minimized. And hence the MOE becomes more of less smooth.

At the end when the number of incoming calls increases excessively that the system cannot cope up with the given resources, the measure of MOE drops down.

$$MOE = \frac{\text{No. of call serviced}}{\text{No. of incomming calls}} \quad (0 \leq \text{MOE} \leq 1)$$

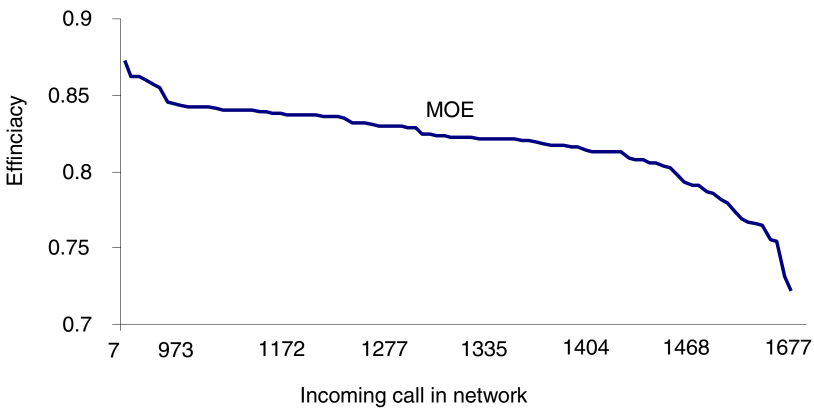

Fig. 4.8 Measure of Efficiency

4.5 Conclusion

In this chapter various aspects of call admission control is considered to obtain a more realistic solution. Here the call admission control problem is divided into three parts. The first we represent the probability of capturing a specific MS in a given network. This probability depends on the velocity and direction of the mobile station as well as its distance from the BS.

Next we represent the feasibility of acceptance of a call by a channel. Here we take care of the interference that may occur in the network. Finally we represent the traffic load that is responsible for optimising load in a system. All three modules combined together the system for the call admission control problem introduced above. Most of the works in this field do not consider all the aspects mentioned above together in a single system but have worked on any one of the aspects at a time.

The methodology of CAC presented here performs better in networks with dynamic parameter settings, such as hotness and feasibility and the load as well. Further, the proposed scheme considers direction and speed of the MS, and the distance of the MS from the BS. The performance of the proposed scheme is compared with existing results on CAC with varying load, and the results are appealing. It is evident from the experimental results that the proposed technique is capable of serving more calls than the other methods, and it can reuse more number of channels than the same by other methods.

The system realised above is a centralized system, where all the calculation and decision making is done by the centralized call admission system and is then broadcasted to all the cells in the network. It is better to use a distributed system, which may perform faster. In such system some of the information should be shared by broadcasting them. The main hurdles in using a fully distributed system are the communication bottleneck. This can, however, be relieved by considering a partly central and partly distributed realization. The trade-off in this case is important to determine which part should remain centralized, and which one to be realized in a distributed manner, so that communication among the system modules is minimized.

References

1. Wang, L., Arunkumaar, S., Gu, W.: Genetic algorithms for optimal channel assignment inmobile communications. In: Proceedings of the 9th International Conference on Neural Information Processing ICONIP 2002, vol. 3, pp. 1221–1225 (November 2002)
2. Hou, J., Fang, Y.: Mobility-based call admission control schemes for wireless mobile networks. Wirel. Commun. Mob. Comput. 1, 269–282 (2001)
3. Sakar, S., Sivarajan, K.N.: Channel assignment algorithms satisfyingm cochannel and adjacent channel reuse constraints in cellular mobile networks. IEEE Trans. Veh. Technol. 51(5), 954–967 (2002)

4. Wang, S.-L., Hou, Y.-B., Huang, J.-H., Huang, Z.-Q.: Adaptive Call Admission Control Based on Enhanced Genetic Algorithm in Wireless/Mobile Network. In: Proceedings of the 18th IEEE International Conference on Tools with Artificial Intelligence (2006)
5. Chen, H., Cheng, C.-C., Yeh, H.-H.: Guard-Channel-Based Incremental and Dynamic Optimization on Call Admission Control for Next-Generation QoS-Aware Heterogeneous Systems. IEEE Transaction on Vehicular Technology 57(5) (September 2008)
6. Thilakawardana, S., Tafazolli, R.: Efficient Call Admission Control and SchedulingTechnique for GPRS Using Genetic Algorithms. Mobile Communications Research Group, Centre for Communications Systems Research, CCSR (2004)
7. Kang, S.H., Sung, D.K.: A CAC Scheme Based on Real-Time Cell Loss Estimation for ATM Multiplexers. IEEE Transaction on Communication 48(2) (February 2000)
8. Xiao, Y., Chen, C.L.P., Wang, Y.: A Near Optimal Call Admission Control With Genetic Algorithm For Multimedia Services In Wireless/Mobile Networks. In: IEEE Nat. Aero. Elec. Conf., pp. 787–792 (October 2000)
9. Deb, K.: Multi-Objective Optimization using Evolutionary Algorithms. John Wiley, London (2001)
10. Nuaymi, L., Godlewski, P., Mihailescu, C.: Call Admission Control Algorithm for Cellular CDMA Systems based on Best Achievable Performance. In: Proc. IEEE Vehic. Tech. Conf. (VT 2000- Spring), Tokyo, vol. 1, pp. 375–379 (2000)
11. Jeon, W., Jeong, D.: Call Admission Control for Mobile Multimedia Communications with Traffic Asymmetry between Uplink and Downlink. IEEE Trans. Vehic. Tech. 50(1), 59–66 (2001)
12. Koo, I., Bahng, S., Kim, K.: Resource reservation in call admission control schemes for CDMA systems with nonuniform traffic distribution among cells. In: Proc. IEEE Veh. Technol. Conf., vol. 1, pp. 438–441 (2003)
13. Tugcu, T., Ersoy, C.: Application of a realistic mobility model to call admissions in DS-CDMA cellular systems. In: Proc. IEEE Veh. Technol. Conf., vol. 2, pp. 1047–1051 (2001)
14. Badia, L., Zorzi, M., Gazzini, A.: On the impact of user mobility on call admission control in WCDMA systems. In: Proc. IEEE Veh. Technol. Conf., vol. 1, pp. 121–126 (September 2002)
15. Ahmed, M.H.: Memorial Call Admission Control In Wireless Networks: A Comprehensive Survey. IEEE Communication Surveys 7(1) (2005)
16. Tian, X., Ji, C.: Bounding the Performance of Dynamic Channel Allocation with QoS Provisioning for Distributed Admission Control in Wireless Networks. IEEE Trans. Vehic Tech. 50(2), 388–397 (2001)
17. Haung, Y., Ho, J.: Distributed Call Admission Control for a Heterogeneous PCS Network Computer. IEEE Trans. Comp. 5(12), 1400–1409 (2002)
18. Islam, M.M., Murshed, M., Dooley, L.S.: A directionally based bandwidth reservation scheme for call admission control. In: 5th International Conference on Computer and Information Technology (ICCIT 2002), Dhaka, Bangladesh, December 26-28 (2002)
19. Wong, D., Lim, T.J.: Soft handoffs in CDMA mobile systems. IEEE Personal Communications Magazine 4(6), 6–17 (1997)
20. Ye, J., Shen, X., Mark, J.W.: Call Admission Control in Wideband CDMA Cellular Networks by Using Fuzzy Logic. IEEE Transactions on Mobile Computing 4(2) (March/April 2005)

21. Chen, Y.-H., Chang, C.-J., Shen, S.: Outage-based fuzzy call admission controller with multi-user detection for WCDMA systems. IEE Proc. Commun. 152(5) (October 2005)
22. Chung-Ju, Chang, L.-C., Kuo, Y.-S., Chen, S.S.: Neural Fuzzy Call Admission and Rate Controller for WCDMA Cellular Systems Providing Multirate Services. In: IWCMC 2006, Vancouver, British Columbia, Canada, July 3–6 (2006)
23. Malarkkan, S., Ravichandran, V.C.: Performance analysis of call admission control in WCDMA System with Adaptive Multi Class Traffic based on Fuzzy Logic. IJCSNS International Journal of Computer Science and Network Security 6(11) (November 2006)
24. Yoshida, T., Watanabe, M., Nishida, S.: Channel prediction for OFDMA using mixtures of experts. International Journal of Knowledge-Based and Intelligent Engineering Systems 10(3), 193–200 (2006)
25. Moura, A.I., Ribeiro, C.H.C., Costa, A.H.R.: WBLS: A signal presence-based Wi-Fi localisation system for mobile devices in smart environments. International Journal of Knowledge-Based and Intelligent Engineering Systems 13(1), 5–18 (2009)
26. Liu, Z., Zarki, M.E.: SIR-Based Call Admission Control for DSCDMA Cellular System. IEEE J. Selected Areas of Comm. 12, 638–644 (1994)
27. Evans, J.S., Everitt, D.: Effective Bandwidth-Based Admission Control for Multiservice CDMA Cellular Networks. IEEE Trans. Vehicular Technology 48, 36–46 (1999)
28. Chang, C., Shen, S., Lin, J., Ren, F.: Intelligent Call Admission Control for Differentiated QoS Provisioning in Wide Band CDMA Cellular System. In: Proc. IEEE Vehicular Technology Conf. (VTC 2000), pp. 1057–1063 (2000)
29. Comaniciu, C., Mandayam, N., Famolari, D., Agrawal, P.: QoS Guarantees for Third Generation (3G) CDMA Systems Via Admission and Flow Control. In: Proc. IEEE Vehicular Technology Conf. (VTC 2000), pp. 249–256 (2000)
30. Bambos, N., Chen, S.C., Pottie, G.J.: Channel Access Algorithms with Active Link Protection for Wireless Communication Networks with Power Control. IEEE/ACM Trans. Networking 8, 583–597 (2000)
31. Andersin, M., Rosberg, Z., Zander, J.: Soft and Safe Admission Control in Cellular Networks. IEEE/ACM Trans. Networking 5, 255–265 (1997)
32. Ho, C.-J., Copeland, J.A., Lea, C.-T., Stüber, G.L.: On Call Admission Control in DS/CDMA Cellular Networks. IEEE Trans. Vehicular Technology 50, 1328–1343 (2001)
33. Fang, Y., Zhang, Y.: Call Admission Control Schemes and Performance Analysis in Wireless Mobile Networks. IEEE Trans. Vehicular Technology 51, 371–382 (2002)
34. Wu, S., Wong, K.Y.M., Li, B.: A Dynamic Call Admission Policy with Precision QoS Guarantee Using Stochastic Control for Mobile Wireless Networks. IEEE/ACM Trans. Networking 10, 257–271 (2002)
35. Fang, Y., Chlamtac, I.: Teletraffic Analysis and Mobility Modelling of PCS Networks. IEEE Trans. Comm. 47, 1062–1072 (1999)
36. Naghshineh, M., Schwartz, M.: Distributed Call Admission Control in Mobile/Wireless Networks. IEEE J. Select. Areas Comm. 14, 711–717 (1996)
37. Dziong, Z., Jia, M., Mermelstein, P.: Adaptive Traffic Admission for Integrated Services in CDMA Wireless-Access Networks. IEEE J. Seleced Areas of Comm. 14, 1737–1747 (1996)
38. Klir, G.J., Yuan, B.: Fuzzy Sets and Fuzzy Logic: Theory and Applications. Prentice-Hall (1995)
39. Wang, L.X.: A Course in Fuzzy Systems and Control. Prentice Hall (1997)

40. Rappaport, T.S.: Wireless Communications: Principles and Practice. Prentice Hall (1996)
41. Viterbi, A.J., Viterbi, A.M., Gilhousen, K.S., Zehavi, E.: Soft Handoff Extends CDMA Cell Coverage and Increase Reverse Link Capacity. IEEE J. Selected Areas of Comm. 12, 1281–1288 (1994)
42. Braae, M., Rutherford, D.A.: Fuzzy Relations in a Control Setting. Kybernetes 7, 185–188 (1978)
43. Del Re, E., Frantacci, R., Giambene, G.: Handover and Dynamic Channel Allocation Techniques in Mobile Cellular Networks. IEEE Trans. Vehicular Technology 44, 229–237 (1995)
44. Liu, T., Bahl, P., Chlamtac, I.: Mobility Modelling, Location Tracking, and Trajectory Prediction in Wireless ATM Networks. IEEE J. Selected Areas Comm. 16, 922–936 (1998)
45. Guerin, R.A.: Channel Occupancy Time Distribution in a Cellular Radio System. IEEE Trans. Vehicular Technology 36, 89–99 (1987)
46. Seskar, I., Maric, S., Holtzman, J., Wasserman, J.: Rate of Location Area Updates in Cellular Systems. In: Proc. IEEE Vehicular Technology Conc. (VTC 1992), pp. 694–697 (1992)
47. Nanda, S.: Teletraffic Models for Urban and Suburban Microcells: Cell Sizes and Handoff Rates. IEEE Trans. Vehicular Technology 42, 673–682 (1993)
48. Varshney, U., Jain, R.: Issues in emerging 4G wireless networks. IEEE Computer 34(6), 94–96 (2001)