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Integrated Planning and Capacity Management of Survivable DS-CDMA Networks*

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Abstract -*In this paper, we jointly investigate both planning and survivability problems for DS-CDMA networks, which is modeled as mathematical optimization formulation in terms of deploying cost minimization. We apply Lagrangean relaxation as a solution approach. Based on computational experiments, proposed algorithm is calculated with much more improvements than other primal heuristic. This paper concludes that survivability is a time-consuming and expensive factor. For more efficient, it is suggested that in the stage of network planning, the planning of normal condition (without considering failure states) is appropriate. A new model considering survivability and performance management can be developed when it is needed.*

Keywords: DS-CDMA, Lagrangean relaxation, mathematical programming, network survivability, network planning, capacity management.

1 Introduction

Even thoght the system planning for the GSM has reached nearly perfect results [1] [2]. Issues for network planning consist of allocation for mobile telephone switching offices (MTSO), base stations, backbone topology, and system configuration in terms of set up costs. Routing problem in network planning stage is also considered. Since backbone topology is a key factor in the routing problem, we jointly consider the backbone topology of the network and the routing path for each O-D (origination-destination) pair. However, less research focuses on the planning of CDMA-based communication networks, in which the system capacity is bounded by interferences which comprise of inter-cellular, intra-cellular interferences, and background noises [3] [4]. Based upon the analysis [5], the capacity limit of DS-CDMA is uplink connection. Reliable and survivable environment is another important issue in provisioning uninterrupted services [1] [6]. When any base station fails, it should dynamically re-allocate resources to provide adequate services. In system operators' point of view, the major disbursals are just the cost of building the wireless communication network. A sound network design will save a lot of money and also will fulfill some system requirements [1] [2].

This paper investigates the planning and capacity management problem of DS-CDMA network under survivability constraint. The problem is deciding the suitable positions of communication devices, network topology, and base station power control, etc. A number of assumptions are given, 1) the interference situation of each base station is under general condition; 2) the same frequency band is reused in every cell; 3) the reverse link is perfectly separated from the forward link; 4) the only uplink connection is considered; 5) every mobile user is under perfect reverse link power control; 6) multi-path fading and mobility are not considered; 7) only voice traffic is considered. The remainder of this paper is organized as follows. In Section 2, the problem of network planning and capacity management of survivable DS-CDMA is formulated as a mathematical model. Section 3 presents a solution approach to the problem. In Section 4, heuristics are developed to calculate good primal feasible solutions. Section 5 illustrates the computational experiments. Finally, Section 6 concludes this paper.

2 Problem Formulation of Network Planning and Capacity Management

The following is the problem formulation of the optimization problem [7]. A legend of the notation used in the proposed mathematical formulation is given in Table 1.

$$Z_{IP} = \min \sum_{j\in B} \Delta_j^B h_j + \sum_{l\in L} \Delta_l^L(c_l) + \Delta^W(w_i) \qquad \text{(IP)}$$

subject to:

$$\left(\frac{E_b}{N_{total}}\right)_{req} \le \frac{\frac{S}{N_0} a_j^e + (1-a_j^e)V}{1+\frac{1}{G_i}\alpha\frac{S}{N_0}(\hat{c}_j^e-1)a_j^e + \frac{1}{G_i}\alpha\frac{S}{N_0}\sum_{\substack{j'\in B\\ j'\neq j}}\left(\frac{r_{j'}^e/2}{Max(D_{lj'}-r_{j'}^e/2,\varpi)}\right)^\tau \hat{c}_{j'}^e a_{j'}^e} \quad \forall j\in B, e\in E \ (1)$$

$$\sum_{l\in L_5}\sum_{o\in O}\sum_{p\in P_o} k_o x_p^e \delta_{pl}\phi_{lj} \le g_j^e \quad \forall j\in B, e\in E \ (2)$$

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$$\theta(g_j^e, \beta_j^e) \le \hat{c}_j^e a_j^e \qquad \forall j \in B, e \in E \quad (3)$$

$$A^e \le \frac{\sum_{o \in O} \sum_{p \in P_o} k_o x_p^e}{\sum_{o \in O} k_o} \qquad \forall e \in E \quad (4)$$

$$D_{jt} z_{jt}^e \le r_j^e \mu_{jt}^e \qquad \forall j \in B, t \in T, e \in E \quad (5)$$

$$0 \le r_j^e \le R_j \qquad \forall j \in B, e \in E, r_j \in Y_j \quad (6)$$

$$\sum_{p \in P_o} x_p^e \le 1 \qquad \forall o \in O, e \in E \quad (7)$$

$$\sum_{j \in B} z_{jt}^e = 1 \qquad \forall t \in T, e \in E \quad (8)$$

$$\hat{c}_j^e \le M \qquad \forall j \in B, e \in E \quad (9)$$

$$\sum_{o \in O} \sum_{p \in P_o} k_o x_p^e \delta_{pl} \le \varepsilon(c_l, \sigma_l^e) \qquad \forall l \in L - \{L_5\}, e \in E \quad (10)$$

$$\sum_{o \in O} \sum_{p \in P_o} x_p^e \delta_{pl} \phi_{lj} \rho_{lt} \le z_{jt}^e \quad \forall j \in B, t \in T, l \in L_5, e \in E \quad (11)$$

$$G_i = \frac{w_i}{K_R} \qquad \forall w_i \in W \quad (12)$$

$$a_j^e \le h_j \qquad \forall j \in B, e \in E \quad (13)$$

$$x_p^e = 0 \text{ or } 1 \qquad \forall o \in O, p \in P_O, e \in E \quad (14)$$

$$z_{jt}^e = 0 \text{ or } 1 \qquad \forall j \in B, t \in T, e \in E \quad (15)$$

$$h_j = 0 \text{ or } 1 \qquad \forall j \in B \quad (16)$$

$$a_j^e = 0 \text{ or } 1 \qquad \forall j \in B, e \in E \quad (17)$$

$$c_l \in Q_1 \qquad \forall l \in L_1 \quad (18)$$

$$c_l \in Q_2 \qquad \forall l \in L_2 \quad (19)$$

$$c_l \in Q_3 \qquad \forall l \in L_3 \quad (20)$$

$$c_l \in Q_4 \qquad \forall l \in L_4 \quad (21)$$

The objective function is to minimize the total cost of the following items: (a) the first term means the fixed cost of base station j, including installation, operation, maintenance and equipment costs; (b) the second term means the cost of links, including connections among MTSO's and their slave base stations, and the cost related with MTSO; (c) the third term means the spectrum licensing cost. These items are the major costs involved in configuring a cellular network. Constraint (1) is to ensure that every connection in any base station is serviced with the required QoS. Be more generic, we don't consider the multi-user detection here. Aggregate flow and channel constraints can not be exceeded for each base station by (2) and (3), respectively. Constraint (4) requires that the coverage ratio in every system state is fulfilled. Constraint (5) guarantees that any base station only serve mobile users that are in its coverage area. Constraint (6) is to ensure that the transmission radius of each base station ranges from 0 to R_j. Constraint (7) ensures that each O-D pair would be transmitted at most on one path, because the system would not have enough capacity to provide services on some failure state e. Constraint (8) requires that each mobile user can be homed to only one base station. Constraint (9) is to ensure that the number of users who can be active at the same time in a base station would not exceed upper bound. Capacity constraint of link l is expressed in (10). Constraint (11) is to guarantee that if a base station does not provide service to a mobile user, the link between them cannot be selected as a part of routing path. Constraint (12) is processing gain formula. Constraint (13) ensures that if a base station is not installed, it cannot be active. Constraints (14)-(17) and (18)-(21) are integer property of the decision variables and sets constraints, respectively.

3 Problem Solution

3.1 Lagrangean relaxation approach

By using the Lagrangean relaxation approach [8][9], we transform the primal problem (IP) into the following Lagrangean relaxation problem (LR) where constraints (1)-(5), (10) and (11) are relaxed.

Lagrangean relaxation problem (LR):

$$Z_D\left(v_{jei}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7\right) = \min \sum_{j \in B} \Delta_j^B h_j + \sum_{l \in L} \Delta_l^L(c_l) + \Delta^W(w_i)$$
$$+ \sum_{j \in B} \sum_{e \in E} v_{je}^1 \left(\left(\frac{E_b}{N_{total}}\right)_{req} + \left(\frac{E_b}{N_{total}}\right)_{req} \frac{1}{G_i} \alpha \frac{S}{N_0} ((\hat{c}_j^e - 1) a_j^e \right.$$
$$\left. + \sum_{\substack{j' \in B \\ j' \ne j}} \left(\frac{r_{j'}^e/2}{Max((D_{jj'}^e - r_{j'}^e/2), \varpi)}\right)^{\tau} \hat{c}_{j'}^e a_{j'}^e) - \frac{S}{N_0} a_j^e - (1 - a_j^e) V_j^e) \right)$$
$$+ \sum_{j \in B} \sum_{e \in E} v_{je}^2 \left(\sum_{l \in L_5} \sum_{o \in O} \sum_{p \in P_o} k_o x_p^e \delta_{pl} \phi_{lj} - g_j^e \right) + \sum_{j \in B} \sum_{e \in E} v_{je}^3 \left(\theta(g_j^e, \beta_j^e) - \hat{c}_j^e a_j^e \right)$$
$$+ \sum_{e \in E} v_e^4 \left(A^e - \frac{\sum_{o \in O} \sum_{p \in P_o} k_o x_p^e}{\sum_{o \in O} k_o} \right) + \sum_{t \in T} \sum_{j \in B} \sum_{e \in E} v_{jte}^5 \left(D_{jt} z_{jt}^e - r_j^e \mu_{jt}^e \right)$$
$$+ \sum_{l \in L - L_5} \sum_{e \in E} v_{le}^6 \left(\sum_{o \in O} \sum_{p \in P_o} k_o x_p^e \delta_{pl} - \varepsilon(c_l, \sigma_l^e) \right) + \sum_{l \in L_5} \sum_{t \in T} \sum_{j \in B} \sum_{e \in E} v_{jtle}^7 \left(\sum_{o \in O} \sum_{p \in P_o} x_p^e \delta_{pl} \phi_{lj} \rho_{lt} - z_{jt}^e \right)$$

subject to: (6)-(9), (12)-(21).

where v_{je}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7 are Lagrange multipliers. To solve (LR), it can be decomposed into the following five independent and easily solvable subproblems

Subproblem 1: (related to decision variables $\hat{c}_j^e$, h_j, a_j^e, r_j^e and w_i)

$$= \min \sum_{j \in B} \left\{ \Delta_j^B h_j + \sum_{e \in E} \left[a_j^e \left(((\frac{E_b}{N_{total}})_{req} \frac{1}{G_i} \alpha \frac{S}{N_0}) \right. \right. \right.$$

$$(g_j^e v_{je}^1 - v_{je}^1 + \sum_{\substack{j' \in B \\ j' \neq j}} v_{j'e}^1 (\frac{r_j^e/2}{Max(D_{j'j}^e - r_j^e/2, \varpi)})^\tau c_j^e) - v_{je}^1 \frac{S}{N_0} + v_{je}^1 V_j^e -$$

$$\left. \left. \left. + ((\frac{E_b}{N_{total}})_{req} - V_j^e) v_{je}^1 - r_j^e \sum_{t \in T} v_{jte}^5 \mu_{jt}^e \right] \right\} + \Delta^W(w_i) \quad \text{(SUB 1)}$$

subject to: (6), (9), (12), (13), (17), and

$$LB \le \hat{c}_j^e \le UB \qquad \forall j \in B, e \in E \qquad (22)$$

Base on past experience, we intend to find the lower bound and upper bound of $\hat{c}_j^e$ to improve the solution efficiency of the subproblem, and the gap between the dual solution and primal feasible solution, then constraint (22) is added. The number of mobile users that are covered by the active base stations is just the UB if it is smaller than M. Also, we can assume that all of the base stations are active but one, the number of mobile users that are not covered by active base stations and can be covered by the inactive base stations is just the LB. Then, we can decompose (SUB1) into $|B|$ independent subproblems. Furthermore, for each subproblem, we decompose it into $|E|$ subproblems.

Table 1. Description of notation

Notation	Description	Notation	Description
G_i	The processing gain in the bandwidth state i	W	The set of total bandwidth
K_R	Data bit rate	E_b	The energy BS received
N_0	The background noise	N_{total}	Total noise
α	Voice activity	R_j	Upper bound of radius of base station j
Y_j	The set of radius of base station j	ϖ	A small number
$\theta(g_j^e, \beta_j^e)$	Minimum number of channels for traffic demand g_j^e and the call blocking probability shall not exceed β_j^e	$\varepsilon(c_l, \sigma_l^e)$	Maximum traffic (in Erlang) supported by c_l trunks so that the call blocking probability shall not exceed σ_l^e
μ_{jt}	Indicator function which is 1 if mobile user t can be served by base station j and 0 otherwise	S	The power that a base station receives from the mobile user that is homing to it with perfect power control
B	The set of candidate location for a base station	T	The set of mobile users
E	The set of network states[1]	σ_l^e	Call blocking probability of link l required by users
O	The set of OD pairs	A^e	Acceptable coverage ratio on network state e
ρ_{lt}	Indicator function which is 1 if mobile user t is one end of link l	δ_{pl}	Indicator function which is 1 if link l belongs to path p and 0 otherwise
$\Delta_l^L(c_l)$	Cost function of link l with capacity c_l	Δ_j^B	Cost function of base station j
$\Delta^W(w_i)$	Spectrum w licensing cost	ϕ_{lj}	Indicator function which is 1 if base station j is one end of link l
M	Upper bound on number of users that can be handled by a base station	P_o	The set of paths which can support the requirement of OD pair o
V_j^e	An arbitrarily large number.	τ	Attenuation factor
h_j	Decision variable which is 1 if base station j is decided to build and 0 otherwise	r_j^e	Decision variable of transmission radius of base station j at network state e
a_j^e	Decision variable which is 1 if base station j is decided to be activated at network state e and 0 otherwise	$\hat{c}_j^e$	Decision variable of number of users who can be active at the same time in the base station j at network state e
z_{jt}^e	Decision variable which is 1 if mobile user t is serviced by base station j and 0 otherwise at network state e	β_j^e	Call blocking probability of base station j at state e required by users
k_o	User demand of O-D pair o (in Erlang)	$D_{jj'}$	Distance between base station j and j'
D_{jt}	Distance between base station j and mobile user t	x_p^e	Routing decision variable which is 1 if path p is selected at network state e.
g_j^e	Decision variable of aggregate flow in base station j on network state e (in Erlang)	c_l	Decision variable of capacity assigned for link l
L_1	The set of links which is between two MTSO	w_i	The total bandwidth in the bandwidth state i
L_2	The set of links which is between an MTSO and other systems	L_3	The set of links which is between an MTSO and other ISPs
L_4	The set of links which is between a base station and an MTSO	L_5	The set of links which is between a mobile user and a base station

[1] In this paper, we only consider the failing possibility of some base stations. One of the states is that all network components are working.

Subproblem 2 : (related to decision variable z_{jt}^e)

$$\min \sum_{t\in T}\sum_{j\in B}\sum_{e\in E} v_{jte}^5 D_{jt} z_{jt}^e - \sum_{l\in L_5}\sum_{t\in T}\sum_{j\in B}\sum_{e\in E} v_{jtle}^7 z_{jt}^e \quad \text{(SUB 2)}$$

subject to: (8), (15), and

$$\sum_{j\in B}\sum_{s\in S} z_{jst}^e = 1, \text{ if A[e]} = 1 \qquad \forall t\in T, e\in E \qquad (23)$$

Like (SUB 1), adding a redundant constraint (23) to improve the dual solution's quality. It means that we must find a base station to serve each mobile user under the condition that the coverage ratio equals 1. To rewrite (SUB 2), we can get

$$\sum_{t\in T}\sum_{j\in B}\sum_{e\in E} v_{jte}^5 D_{jt} z_{jt}^e - \sum_{l\in L_5}\sum_{t\in T}\sum_{j\in B}\sum_{e\in E} v_{jtle}^7 z_{jt}^e = \sum_{t\in T}\sum_{j\in B}\sum_{e\in E} z_{jt}^e (v_{jte}^5 D_{jt} - \sum_{l\in L_5} v_{jtle}^7)$$

Subproblem 3: (related to decision variable x_p)

$$\min \sum_{j\in B}\sum_{e\in E} v_{je}^2 \sum_{l\in L_5}\sum_{o\in O}\sum_{p\in P_o} k_o x_p^e \delta_{pl}\phi_{lj} + \sum_{e\in E} v_e^4 (A^e - \frac{\sum_{o\in O}\sum_{p\in P_o} k_o x_p^e}{\sum_{o\in O} k_o}) + \sum_{l\in L-L_5}\sum_{e\in E} v_{le}^6 \sum_{o\in O}\sum_{p\in P_o} k_o x_p^e \delta_{pl}$$
$$+ \sum_{l\in L_5}\sum_{t\in T}\sum_{j\in B}\sum_{e\in E} v_{jtle}^7 \sum_{o\in O}\sum_{p\in P_o} x_p^e \delta_{pl}\phi_{lj}\rho_{lt} \qquad \text{(SUB 3)}$$

subject to: (7) (14) and $\sum_{p\in P_o} x_p^e = 1, \text{if A[e]} = 1, \forall o\in O, e\in E$ (24).

A redundant constraint (24) is also added to improve the dual solution's quality. We must find a route for each OD-pair under the condition that the coverage ratio equals 1.To rewrite (SUB 3), we get

$$\sum_{e\in E}\sum_{o\in O}\sum_{p\in P_o} x_p^e \left[\sum_{l\in L_5}\sum_{j\in B} (v_{je}^2 k_o \delta_{pl}\phi_{lj} + \sum_{t\in T} v_{jtle}^7 \delta_{pl}\phi_{lj}\rho_{lt}) + \sum_{l\in L-L_5} v_{le}^6 k_o \delta_{pl} - \frac{v_e^4 k_o}{\sum_{o\in O} k_o} \right] + \sum_{e\in E} v_e^4 A^e$$

Subproblem 4: (related to decision variable c_l)

$$\min \sum_{l\in L-L_5} \Delta_l^L(c_l) - \sum_{l\in L-L_5}\sum_{e\in E} v_{le}^6 \varepsilon(c_l, \sigma_l^e) \qquad \text{(SUB 4)}$$

subject to: (18)-(21).

Because the value of c_l is limited and discrete, we can decompose this into $|L|$ subproblems. To get the optimum solution, we must exhaustively search for all possible c_l.

Subproblem 5: (related to decision variable g_j)

$$\min - \sum_{j\in B}\sum_{e\in E} v_{je}^2 g_j^e + \sum_{j\in B}\sum_{e\in E} v_{je}^3 \theta(g_j^e, \beta_j^e) \qquad \text{(SUB 5)}$$

subject to: $\theta(g_j^e, \beta_j^e) \le M \qquad \forall j\in B, e\in E.$ (25)

Since the value of $\theta(g_j^e, \beta_j^e)$ is an integer and is limited, constraints (3) and (9) imply constraint (25). (SUB5) can be decomposed into $|E|\times|B|$ subproblems. To get an optimal solution, we also exhaustively search for all possible $\theta(g_j^e, \beta_j^e)$.

3.2 Duality of planning and capacity management problem

By the weak Lagrangean duality theorem [8] [9], for any $(v_{je}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7) \ge 0$, $Z_D(v_{je}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7)$ is a lower bound on Z_{IP}. The following dual problem (D) is then constructed to calculate the tightest lower bound.

$$Z_D = \max Z_D\left(v_{je}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7 \right) \qquad \text{(D)}$$

subject to: $v_{je}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7 \ge 0.$

Based on the subgradient method [9], let g be a subgradient of $Z_D\left(v_{je}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7 \right)$. Then, in iteration k of the subgradient optimization procedure, the multiplier vector $\pi = \left(v_{je}^1, v_{je}^2, v_{je}^3, v_e^4, v_{jte}^5, v_{le}^6, v_{jtle}^7 \right)$ is updated by $\pi^{k+1} = \pi^k + t^k g^k$. The step size t^k is determined by $t^k = \delta\left(Z_{IP}^h - Z_D(\pi_k)/\|g^k\|^2 \right)$. Z_{IP}^h is the primal objective function value for a heuristic solution. If the decision variables satisfy the relaxed constraints, then a primal feasible solution is also calculated. Otherwise, those infeasible primal solutions should be modified to obtain primal feasible solutions.

4 Getting Primal Feasible Solutions

To get primal feasible solutions, we divide the network planning problem into two parts: (1) the mobile users homing subproblem and base station configuration subproblem, in which the base station is built or not and it should be active or not in every error state; (2) the backbone network topology design subproblem and capacity assignment subproblem.

4.1 Heuristics for homing and base station configuration subproblem

We try to solve the homing subproblem and the base station configuration subproblem. Considering a network design problem with a single component failure state, it makes decisions in the initialization stage. For example, for each mobile user, we pre-calculate number of base stations that covers the user. If a mobile user covered only by "two" base stations, build these two base stations. We continue the solving process with the value of decision variable z_{jte} of each mobile user. With the values of z_{jte}, we determine the approximate aggregate traffic of each base station, then we use approximate aggregate traffic to process the following LR algorithm.

[*Algorithm LR*]

Step 0. In each failure state, we arrange the built base stations in descending order of the approximate aggregate traffic.

Step 1. Starting at the base station with the heaviest loading, turn it on in this failure state with the maximum power radius. In the meantime, turn off the base stations violating QoS constraint.

Step 2. Granting to all mobile users, which are in the coverage of current base stations, but not assigned yet.

Step 3. Considering the other built base stations that have not been turned off with steps 1 and 2.

Step 4. Rearrange the base stations that have not been built yet in descending order of the approximate aggregate traffic.

Step 5. Build the base station that is the heaviest loading and turn it on with the maximum power radius in this failure state. In the meanwhile, we turn off the base stations violating QoS constraint.

Step 6. Assign all mobile users, they are in the coverage of current base station and are not assigned yet, to this base station.

Step 7. Repeat steps 4, 5, and 6 until all mobile users have homed to a base station that is built and active in this failure state. If the program gets into an infinite loop and a few mobile users are left, homing them to the base station that has the shortest distance between them.

Step 8. Rehome the mobile users that are not homed to a nearest active base station.

Step 9. For each base station, we find the maximum distance between the base station and its slave mobile users. Take this value to fit the degree of radius.

Step 10. For each base station, calculate the actually aggregate traffic and assign enough capacity.

Step 11. Check the QoS constraint (1). If violates QoS, give up this iteration.

4.2 Heuristics for topology design and capacity assignment subproblem

In this part, we intend to consider $\sum_{e \in E} v_{le}^{f}$ and its length for each link as its weight. The minimum cost spanning tree algorithm is used to select enough L_1 links to build a tree for routing. For each base station j, we choose the L_4 link, which has the minimum cost, as its candidate link, then calculating the routing path for all OD-pairs on each scenario. According to the aggregate traffic of each link, we assign proper capacity to it under the call blocking rate constraint. Repeat the above processes and consider all network states to get several values of each link. We choose the maximum volume of capacity of each link, which is calculated on each network state, as our primal solution.

5 Computational Experiments

The parameters referring to previous works of Lin [2], Um [4], Lee [6], and Wu [8] are listed in Table 2. Table 3 specifies a number of experimental scenarios. All experiments are coded in Java and running on a dual Pentium III 1G MHz PC running Microsoft Windows 2000 Advance Server with 2GB DRAM. In order to prove the efficiency of proposed heuristics, a simple algorithm (denote SA) cited from [7] is implemented. Figure 1 illustrates that LR is calculated with more cost reduction than SA from 5% to 46%. Generally, the more cost is to be spent for the cases of both the more traffic is loading, Figure 2, and the more number of base station is planned, Figure 3. CPU analysis running up to 1000 iterations is listed in Table 4. Survivability cases 1-3 calculated totally with about 1-1.5 hours, while cases A, B, and C only consumed around 3, 13, and 20 minutes. It is more time-consuming if we jointly consider network survivability and network planning. Also, increasing cost is unavoidable for considering survivablity issue, Figure 4, it takes around more 36.194% expenses to guarantee survivability. For more efficient, it is suggested that in the stage of network planning, the only normal condition (without considering failure states) is appropriate. A new model jointly considering survivability and performance management can be developed when it is needed.

6 Conclusions

In this paper, we formulate the planning and capacity management problem of survivable DS-CDMA networks as a mathematical model. It considers both non-regular size cell and non-uniform traffic demand. In terms of performance evaluation, Lagrangean relaxation based solution has more significant improvement than other algorithms. Be more generic, downlink capacity constraint must be taken into account. Three-dimensional geographical informaion, e.g. the height of antenna, is also a considerable issue. Furthermore, integrating sectorization that is a popu lar technique to enhance capacity for wireless communication systems to the DS-CDMA planning would be a robust work. Finally, we will use proposed model to fit the other traffic demands.

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Table 4. Comparison of computation times (in second)

Problem	Case					
	1	2	3	A	B	C
SUB 1	30	30	30	1	16	16
SUB 2	300	300	300	16	30	47
SUB 3	700	700	700	47	100	140
SUB 4	1	1	1	1	1	1
SUB 5	1	1	1	1	1	1
Subgradient	3300	3370	3200	235	600	890
Primal	16	16	24	1	16	16

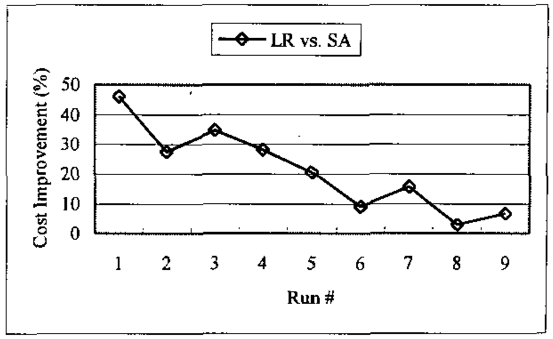

Figure 1. Cost reduction of algorithm LR on SA

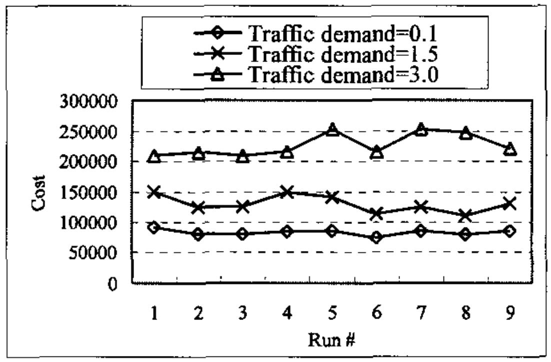

Figure 2. Cost comparision with respective to traffics

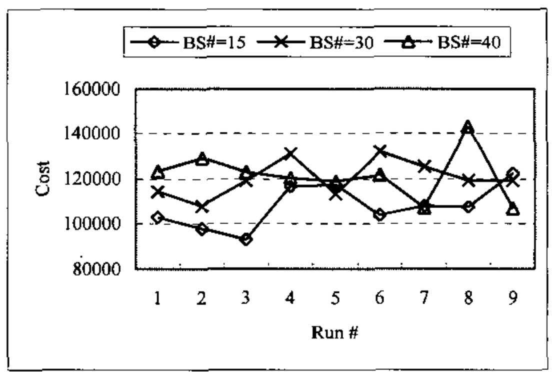

Figure 3. Cost comparision with respective to BS #.

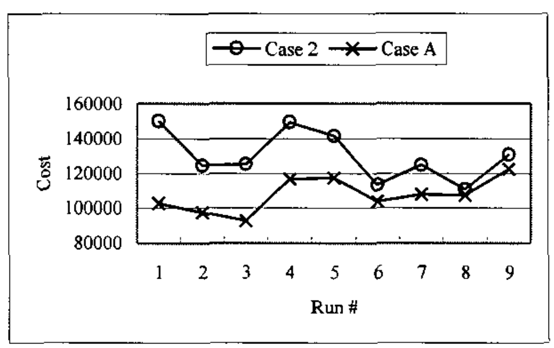

Figure 4. Cost comparision with survivability (case 2) and without survivability (case A).